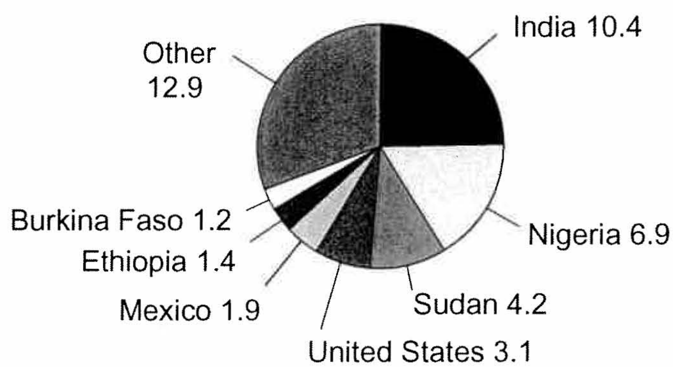
Sorghum *Sorghum*

Production	
Area Under Cultivation	42.0 million ha
Global Production	58.0 million MT
Average Productivity	1,381 kg/ha
Producer Price	$90 per MT
Producer Production Value	$5,222 million
International Trade	
Share of World Production	13%
Exports	7.7 million MT
Average Price	$98 per MT
Value	$754 million
Principal Producing Countries/Blocs (by weight)	United States, India, Nigeria, Mexico, Argentina, China, Sudan, Australia
Principal Exporting Countries/Blocs	United States, Argentina, France , Sudan
Principal Importing Countries/Blocs	Mexico, Japan, Spain, Israel, Italy, Chile
Major Environmental Impacts	Habitat conversion Soil erosion and degradation Agrochemical use Poisoning in herbivorous animals Fire hazards
Potential to Improve	Fair BMPs are known and reduce input use and runoff in developed countries New varieties reduce soil degradation Many producers are poor and not well integrated into the market or extension systems Pests are a major problem for poor farmers

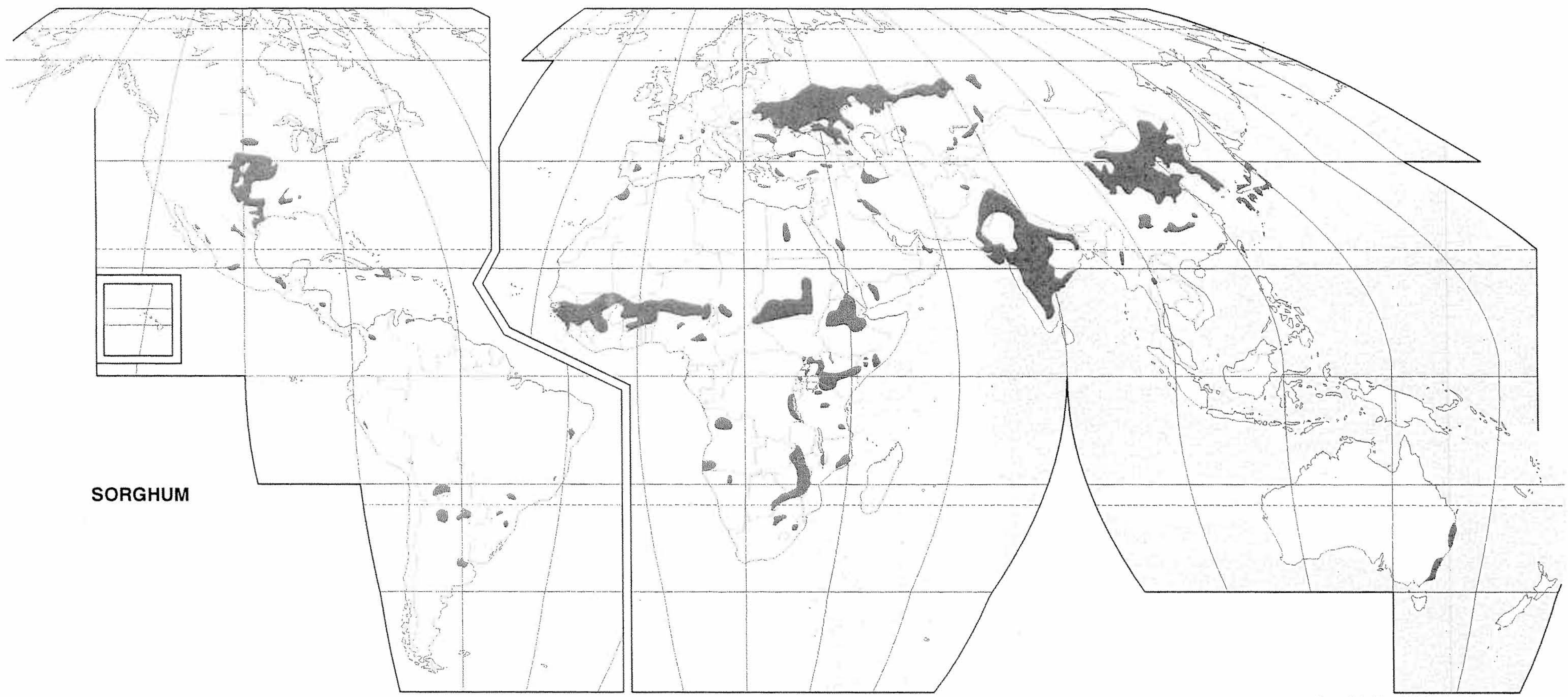
Source: FAO 2002. All data for 2000.

Sorghum

Area in Production (MMha)



SORGHUM



Main areas of production

Chapter 19

Sorghum

Overview

Sorghum is a grass in the same family as corn and sugarcane. It was domesticated about 5,000 years ago, and nearly all of its genetic material comes from varieties that were originally cultivated in Africa. Today, sorghum is a food staple in many parts of Africa and Asia. One of the main advantages of sorghum is that it is very drought tolerant. Along with millet, it is planted by African farmers in dry and marginal areas as a hedge against famine.

Just as corn, cocoa, rubber, potatoes, and other crops were taken from the Americas to Europe, Africa, and Asia, sorghum was brought to the colonies from Africa. It is thought that it was brought from Africa to the Caribbean, where it was grown to feed slaves (DeWalt and Barkin 1987). It subsequently spread to Central, South, and North America. By the nineteenth century, sorghum was grown over much of the Great Plains as a drought-tolerant animal feed.

At the beginning of the twentieth century, the U.S. Department of Agriculture and the Texas Agricultural Experiment Station were working together in Chillicothe, Texas, to introduce and test different varieties of sorghum. During this period researchers bred and selected new lines of sorghum that were higher yielding, mechanically harvestable, resistant to disease, and adapted to a wider range of climatic conditions (DeWalt and Barkin 1987). In the 1960s and 1970s the DeKalb Seed Company began to develop lines of high-yield sorghum. They intended for Great Plains farmers to adopt these lines when the climate changed, or when the aquifers that they were using to irrigate corn dried up. That has not yet happened; instead, the new varieties were exported to much of Central and South America, Africa, and Asia.

Producing Countries

Sorghum is cultivated to produce grain and silage. The United States, India, Nigeria, Mexico, Argentina, China, and Sudan are the largest producers of sorghum grain. This grain is used both for human food and for animal feed. From 1999 to 2001 the United States produced 20 to 25 percent of all sorghum grain globally. The top seven sorghum grain producers account for 77 percent of global production (see Table 19.1) (FAO 2002).

Table 19.1 Sorghum Production and Cultivation by Country, 2000

Country	Production (MT)	Area Cultivated (ha)
United States	11,951,910	3,126,630
India	8,862,700	10,397,900
Nigeria	7,711,000	6,885,000
Mexico	5,842,308	1,899,201
Argentina	3,350,513	723,600
China	2,608,456	894,860
Sudan	2,488,000	4,194,960
Australia	2,115,912	622,267
Ethiopia	1,548,720	1,359,190
Burkina Faso	1,016,275	1,225,223
Egypt	941,188	162,597
Brazil	779,608	523,970
Tanzania	664,200	638,700
Venezuela	581,526	286,697
World	57,964,600	41,964,377

Source: FAO 2002. All data for 2000.

In other countries, especially in Asia, sorghum is produced primarily for silage. India is the largest producer of sorghum that is cut green for silage. It is used for feeding livestock, especially cows. In other countries, the grain is harvested and the stalks are fed to livestock.

The total area under production for sorghum in any given country is a function of whether the land is used for grain or fodder, as well as the overall efficiency of the production methods employed. Production efficiency, in turn, depends on general productivity, climatic and soil conditions, and whether the crop is grown in polyculture or monoculture systems.

India, with nearly 25 percent of the global land devoted to sorghum, leads all producers in area under cultivation. Nigeria, Sudan, the United States, Mexico, Ethiopia, and Burkina Faso also devote considerable land to the crop. In fact, these seven sorghum producers account for nearly 70 percent of the global area under sorghum cultivation. Many countries devote at least a quarter of their agricultural land to sorghum, and Niger devotes at least 50 percent, as shown in Table 19.2.

Table 19.2 Percentage of Agricultural Land Devoted to Sorghum Production, 1994

50 Percent or More	25–49 Percent	10–24 Percent
Mauritania	Botswana	Chad
Niger	Burkina Faso	El Salvador
Somalia	Eritrea	Ghana
	Mali	Haiti
	Sudan	Lesotho
	Tanzania	Mozambique
	Yemen	Nigeria

Source: FAO 1996.

In 2000 only 13 percent of all sorghum grain was exported. The United States accounted for more than 80 percent of all exports and exported some 55 percent of all domestic production, as shown in Table 19.3. Only France exported a larger proportion of total production.

Table 19.3 Sorghum Export Statistics, 2000

Country	Export (MT)	Percentage of Crop Exported
United States	6,577,186	55.0
Argentina	770,324	23.0
France	229,006	61.6
Sudan	105,318	4.2
China	16,760	0.6
Australia	10,732	0.5
Italy	6,325	2.9
Venezuela	2,986	0.5
Nigeria	2,476	0.03
Burkina Faso	1,525	0.1
World	7,669,185	13.2

Source: FAO 2002.

Consuming Countries

Sorghum is consumed by people in most of the developing countries that produce it. Per-capita consumption of sorghum is highest in Africa, especially in Burkina Faso, Ethiopia, Mali, Niger, Nigeria, Sudan, and Tanzania. In India, sorghum is mostly used as animal fodder, with the exception of rural parts of Maharashtra where the grain is used as a food staple.

Sorghum grain is also used as animal feed in many countries, and nearly all international trade in sorghum is for animal feed. This is true in the United States, Mexico, Brazil, Japan, South Korea, and some European countries. In Europe, sorghum is mostly fed to poultry and pigs, but some is used for cattle as well

Mexico is the main importer of sorghum grain, followed by Japan. Together, they accounted for just over 85 percent of global imports in 2000 (FAO 2002). Globally, most exported grain is used as animal feed.

Production Systems

Sorghum is grown widely both for food and animal feed. Roughly 90 percent of the land planted to sorghum globally is in developing countries, mainly in Africa and Asia, where more than 70 percent of the crop is used for food. Most of the areas planted to sorghum are lands that are marginal for agriculture, i.e. they are subject to low and irregular rainfall and drought.

Broadly speaking, there are two different production systems. Intensive, commercialized production is concentrated mainly in the developed world and parts of Latin America and the Caribbean. Most of this production is used for animal feed. This production is characterized by monocrop cultivation and the use of hybrid seeds, fertilizer, and improved water management technologies. Commercial sorghum is fully mechanized. Seeds are planted in rows, and the plants are cultivated by machine or, in the case of no-till production, sprayed with herbicides. The crop is harvested by machine. Yields average about 3 to 5 metric tons per hectare. While this type of commercial production amounts to less than 15 percent of the area planted to sorghum, it produces more than 40 percent of global output. Furthermore, about 40 percent of this commercial production is traded on international feed markets (FAO and ICRISAT 1996).

Most of the sorghum produced around the world, however, is produced for subsistence or local food markets. For many households the goal is to produce enough sorghum to feed themselves, and depending on the year, many fail to achieve this goal. The production systems are extensive and characterized by few inputs. Most of the seeds are planted by hand, sown either by broadcasting the seeds or planting them in hills. Most subsistence and small-scale production of sorghum is in polyculture systems. The impacts of weed and insect pests are diminished by growing the plant in association with other crops. In some instances, improved seed varieties are being planted (especially in Asia), but for the most part these systems are far less intensive than those used for commercial production. Improved seeds are seen as a relatively cheap investment with a good chance of improving overall production. But for most cash-poor subsistence producers and small farmers, investments in other inputs compete directly with those for schooling or health care, both of which are seen as having higher potential returns on investment. Consequently, the use of fertilizer is limited, and very few producers have adopted moisture conservation techniques. As a consequence, yields average only 0.5 to 1.0 metric tons per hectare in most areas (FAO and ICRISAT 1996).

In Africa and Asia, land holdings are small, and farmers have little equipment to use in production. While cultivation techniques on these small farms are relatively simple and generally follow traditional practices, there is an increased use of chemical inputs and mechanization. Some larger farms (as in Zimbabwe) are mechanized and more productive. In general, however, implements tend to be for hand use or are used with animal power. Only the larger farms use tractors and tractor-drawn equipment. Because sorghum is drought resistant, it tends to be cultivated mostly under rainfed conditions with little or no irrigation. Low prices for sorghum also tend to discourage capital-intensive inputs such as irrigation. In Sudan, for example, 90 percent of the crop is grown under rainfed conditions. In most of India, where sorghum is cultivated as a silage crop to be cut and fed to dairy cows, it is also produced in traditional ways with few purchased inputs.

Whether grown commercially or for subsistence, sorghum production is limited by the same factors: birds, insects, diseases, weeds, and drought. Nearly 150 insect pests attack sorghum. In addition, sorghum is a host for more than 100 plant pathogens, including fungi, bacteria, viruses, and nematodes. The most serious diseases are grain mold, anthracnose, ergot (honeydew disease), root and stalk rots, and downy mildew. Striga is the most common weed, globally, and it has wiped out production in some areas.

From research undertaken in different parts of the world, it is clear that sorghum can produce more than 10 metric tons per hectare under ideal conditions (ICRISAT 2000). At this time, subsistence producers achieve, on average, only 5 to 10 percent of that amount. Higher yields will most likely be achieved through improved production practices rather than through increased or improved inputs. If sorghum is to achieve its potential contribution to improving food supplies and reducing poverty in marginal rural areas, the factors limiting its production in different circumstances must be identified and overcome.

Unfortunately, production trends appear to be headed in the opposite direction. In many poorer regions of the world, sustainability of sorghum is becoming an issue of great concern. Fallow periods are being shortened and more marginal lands are being brought into production. Marginal lands, often farmed by poorer producers, are cultivated with little or no fertilizer and few improved soil management techniques. As a consequence, soil degradation is increasing (FAO and ICRISAT 1996).

There are some noteworthy historical trends in sorghum production. The area planted to sorghum worldwide gradually increased from 1900 to 1985, when area planted (50 million ha) and total production (77.5 million MT) both peaked (FAO 2002). Production increases during that period, however, did not keep pace with population growth. This was probably due to the availability of other cereals as well as the replacement of manual labor first with draft animals and then with machines. Also, sorghum hybrids were not developed as quickly as those for corn. Even so, sorghum was well adapted to meet the basic food and animal feed needs in some areas of the world.

The introduction of sorghum hybrids, in conjunction with the genetic gains made in the poultry industry, made sorghum an increasingly attractive alternative to more expensive cereals such as corn and soybeans used for animal feed. Also, sorghum required fewer inputs than other cereal grains. While sorghum production for human food has been declining, much of the increased production has been aimed at poultry and, subsequently, pork feed. By the year 2000 more than 41.7 million hectares globally were planted to sorghum (FAO 2002).

Sorghum production in the United States mirrors this trend. From the late nineteenth century until the 1930s, the area planted to sorghum declined. This was probably due to increased efficiency of production with tractors, rather than a declining demand for sorghum. During this period considerable sorghum was also cut green for silage and to make molasses. By 1950 only 4 million hectares were planted to sorghum. The area under production peaked again in the 1960s and 1970s and then began to decline. The declines in U.S. area cultivated appear to have occurred for a number of reasons. Hybrids proved to be far more productive than traditional varieties, and when fertilizers and other chemicals were thrown in production increased even more. These factors reduced the need for larger areas planted to maintain or increase total production. The single most important technological change in sorghum cultivation since the 1950s and 1960s has been the development and use of hybrid seeds. Hybrids are now used widely throughout the world. As a result, productivity and uniformity in maturity and grain quality have increased. Hybrids have also encouraged mechanization and increased the use of fertilizers and other purchased inputs. In India hybrids are planted on about 55 percent of the total area. Yields on those areas have doubled over the past thirty years (FAO and ICRISAT 1996).

Most cultivated sorghum belongs to the species *Sorghum bicolor.* This species has more than five different races. Information regarding the specific varieties produced is difficult to obtain. The major races and the distribution of their cultivation is as follows:

- Bicolor: Most African, Asian, and American countries
- Guinea: African savannas and South Asia
- Caudatum: Northwest Nigeria, Chad, Sudan, Ethiopia, and Uganda
- Kafir: Southern Africa and northern Nigeria
- Durra: Sudan and India

There are several constraints that have affected productivity of sorghum. Most are related to production and include poor seedling vigor, damage from birds and other pests, harvest inefficiency, and lack of access to improved seeds, fertilizers, and pesticides (especially in developing countries). Once the crop is harvested, there are other problems. These include post-harvest losses, storage complications, difficulties in marketing the produce, and fluctuations in demand based on availability and price of other cereal substitutes for food or animal feed.

Other factors have limited sorghum production in the United States. For example, comparable increases in productivity of corn and soybeans have allowed both to remain competitive with sorghum in the market. The water shortages that were expected to affect corn production in the western Midwest and Great Plains were offset by the development of more drought-resistant corn varieties and by the use of artisanal water from aquifers for hub irrigation systems. Finally, U.S. government policies that had allowed and even encouraged marginal land to be planted to grain sorghum were ended in favor of taking that land out of production and putting it into the Conservation Reserve Program (CRP). Thus, farmers were paid not to plant marginal and highly erodible land, and some of that land was not fit to grow much besides sorghum.

This has not been the case in every country, however. The adoption of sorghum both for food and feed in Mexico has been striking, particularly for a country where corn has been the staple for thousands of years. The hybrid sorghum, developed in the 1950s, was rapidly adopted by farmers. Sorghum was more productive than corn, and required less labor. By 1982 sorghum provided 74 percent of the raw material used in animal feed in Mexico (*Boletín Interno*, 29 September 1982, as cited in DeWalt and Barkin 1987). The net profit per hectare from sorghum was more than 4.5 times that from corn in 1983 (DeWalt and Barkin 1987).

However, as the Mexican and U.S. economies have become more integrated through the North American Free Trade Agreement (NAFTA), U.S. agricultural policies have had a greater impact on production in Mexico. In particular, U.S. subsidies for corn and other feed grains have affected prices in Mexico. Similarly, beef, pork, and poultry prices in the United States also influence prices in Mexico. This has dampened the profits from crops like sorghum, and farmers have begun to switch to higher-value, more labor-intensive agricultural products where they might have an advantage in the U.S. market.

Processing

Sorghum is processed for human consumption to use either directly in food or in the production of beverages. In processing for food items, sorghum is either boiled and eaten, or ground into flour to be used as an ingredient in other foods. A number of traditional foods are made from sorghum in the areas where it has become a food staple. These foods include fermented and unfermented breads, stiff porridge, thin porridge, and steamed foods. Sorghum flour is used in various baked products such as hearth and flat breads, cakes, muffins, cookies, biscuits, tortillas, etc. Sorghum flour can be used as a substitute for any other whole-grain flour. In Southeast Asia and Nigeria, sorghum flour is used to make noodles, pasta, and related products. In Botswana sorghum is processed to make weaning foods.

Sorghum is also used in the production of alcoholic and nonalcoholic beverages. Nonalcoholic beverages and dried malt extracts are produced from sorghum in Nigeria. Instant beer powder, ground malt, beer, and rice-product substitutes are made in South Africa. Sorghum-based beer and malt are also made in Mexico. Sorghum wine is produced in China and Taiwan.

Sorghum varieties that have higher sugar content in the stalks, known as sweet sorghum (as opposed to grain sorghum), are used as sugarcane substitutes. In the southern United States, the juice that is extracted from the stalks of sweet sorghum is used to make sorghum syrup, a substitute for maple syrup and blackstrap molasses.

Sorghum is also processed for use in livestock feed and for pet food. It is a major ingredient in chicken, pig, and cattle feeds throughout the Americas. In most cases the grain is pelleted or hammered in specialized mills. This material is then mixed with other feed ingredients depending on the species that is being fed and its age.

There are a few industrial uses of sorghum as well. Specially processed sorghum flour or meal (e.g. partially decorticated and acid-modified) is used as a low-cost adhesive. Similar sorghum-based materials are used in the manufacture of wallboard, as binding materials for fillers, and ore-refining materials. Sorghum is also used to make petroleum substitutes (U.S. Grains Council 2001). In the United States, Kansas and Nebraska are the leaders in the production of ethanol from sorghum.

Substitutes

Millet, corn, rice, wheat and other cereals, and soybeans are the principle substitutes for sorghum in food as well as in animal feed. Pearl millet is the main alternative to sorghum in many parts of the world because it has similar climate and soil requirements. In fact, when drought is expected, many farmers plant millet because that crop matures more quickly and requires less water than sorghum. Corn is another alternative crop to sorghum. In parts of Africa, corn is grown for human consumption. However, in most parts of the world corn and sorghum are produced for animal feed, particularly for poultry. Sorghum is more drought-tolerant than corn.

In many countries that do not have specific production or price policies for sorghum, its production is affected by such policies for corn, rice, wheat, or other cereals. With the liberalization of cereal and grain markets in many countries, prices have tended to vary between different parts of a country as well as throughout the year. These variations will affect farmers' willingness to plant sorghum as well as other crops (FAO and ICRISAT 1996).

Market Chain

In most Asian and African countries sorghum has traditionally been a subsistence crop, with only small volumes entering a more formal market chain. As a consequence, markets are poorly developed. In most countries where sorghum is a food crop, markets tend to be local and regional with much of the product consumed within a very short distance of the producer.

Increasingly, however, sorghum is bought and sold commercially. These transactions tend to be dominated by people with sufficient capital to hold the product after harvest in order to sell it later in the year. Initially this occurs mostly in rural markets near areas of production or between neighboring households. Marketing channels between producers and the major urban centers are poorly developed but are becoming better organized. The factors that limit the development of more efficient markets within the African subsistence-oriented production sectors, for example, include the overall limited and/or variable trade volumes due to scattered and irregular supplies and the large distances and high transportation costs to get the sorghum to domestic markets. Such markets exhibit huge price fluctuations that result from short-term imbalances between supply and demand that peak during harvest. In addition, there are no specific price or production policies to promote stable markets, especially in Africa and Asia.

Because sorghum is an important food crop in many countries, more formal marketing arrangements have been effective in some parts of the world. For instance, the Sorghum Board of South Africa handles 60 percent of the crop each year. The Board ensures stability of supply and maintains its status as buyer of last resort. In practice, the Board has become the primary buyer rather than letting the grain enter the private sector, which traditionally buys sorghum from producers at low prices, holds the crop for a few months, and then charges much higher prices to consumers.

In other parts of the world where sorghum is produced primarily for animal feed, the market chain is similar to those for soybeans and for other grains such as corn, wheat, and rice. In general, livestock producers do not produce sorghum. As a consequence, there is still considerable space for sorghum buyers and traders. In fact, larger-scale producers of sorghum for animal feed are fully integrated into well functioning markets. Most developed country producers sell all their production into such markets. In some instances, farmers feed the grain they produce to their own animals, which they later sell, but increasingly feeding is undertaken by another, specialized set of producers. The sorghum market faces another important challenge—the grain industry today is a global market filled with intense competition among a variety of potential sources of animal feed that are increasingly evaluated in terms of their energy and overall dietary content as well as their price, availability, and storage life. So far, it has not been demonstrated that sorghum has a higher feed value than other feed grains.

The market infrastructure in Asia is relatively well developed for both human and animal consumption of sorghum. This is especially the case in areas with high population density such as India and China.

In Australia, the sorghum industry has undergone a major change with regard to its main traditional market, Japan. The changes in Australia probably anticipate similar changes in other surplus grain producing countries. Demand has shifted away from exporting grain to the more traditional international markets (such as Japan) toward keeping it on the more dynamic and expanding Australian domestic markets. At this time Australia is using sorghum as an animal feed to produce meat for sale on international markets. In short, the country is adding value to its grain, in the form of meat, rather than selling it directly to other countries where it is fed to animals. As shipping basic grains and disposing of animal waste from intensive feeding operations in many developed countries become more expensive, this trend of meat exports is likely to continue. This is especially likely if the European Union relaxes its policies that protect its own livestock producers.

Market Trends

World production of sorghum increased 40 percent from 1961 to 2000. International trade has increased by 83 percent, from 4.2 million metric tons to 7.7 million metric tons over the same forty years. Prices, on the other hand, have decreased 59 percent since 1961. From 1961 to 2000 average yields have increased 54.7 percent per hectare.

World sorghum production is projected to grow at 1.2 percent per year to about 74 million tons in the year 2005. This notwithstanding, population growth will outpace production increases, particularly in countries where sorghum is a vital food security crop. Food sorghum consumption will grow by about 15 percent by 2005, driven by a 39 percent increase in demand in Africa. By contrast, food utilization of sorghum in Asia is expected to drop by 8 percent, a continuation of the current trend. Other grains will be substituted for sorghum as human food, while sorghum production destined for animal feed will continue to increase.

Several other factors also affect sorghum market trends. For example, futures and options, transportation and logistics, farm policies, and private insurance continue to change the marketing and overall management of sorghum. Increasingly, issues such as identity-preserved hybrids and contract production will continue to add to producers' marketing options and strategies. Ultimately, the key to marketing sorghum depends on market supply and demand and information about the two.

Improvements in transportation and market infrastructure as well as more basic information are required in many parts of the world to encourage more intensified sorghum production. Broadening sorghum markets so that it can substitute for other grains in more global markets could also encourage production and increase returns to producers by reducing their dependence on local markets. Developing supplies of high-producing new varieties would help producers increase yields over time, as would improved input markets to ensure that agrochemicals are more readily available, cheaper, and more efficiently used.

Environmental Impacts of Production

The primary environmental problems from sorghum production arise, ironically, from its unique plant characteristics. Sorghum is a drought-tolerant crop. Breeding has made it even more so. As a consequence, production is expanding into more marginal areas. In addition, the sorghum plant has certain chemical defenses that can poison animals or water supplies if the crop or effluent from it is mishandled. Other environmental problems from sorghum production include habitat conversion and habitat degradation, soil erosion and degradation, use of agrochemicals, and fire hazards.

Habitat Conversion and Degradation

The cultivation of sorghum poses severe threats to the integrity of many ecoregions around the world, including some of the most fragile. Because of its ability to survive and produce with less water and poorer soils than most other commodities, sorghum is grown on some of the world's most delicate land. In the Rift Valley of Eastern Africa, for example, land is increasingly being converted to crops such as sorghum, millet, and irrigated rice. These are now the most cultivated crops in Malawi. Habitat conversion for cultivation drastically changes the composition of the local flora and fauna. The farming activities of rural people throughout this region are destroying and fragmenting large areas of natural habitat. This is the most important conservation issue in the area and sorghum is right in the middle of it.

In Asia and Africa, the long-term, continuous cultivation of sorghum leads to the infestation of fields by striga, a parasitic weed. Heavy infestations by this weed can leave the land unfit for cultivation. Striga can lead to declining soil fertility, and more importantly it can become so invasive that it strangles sorghum plants and makes farming unviable. In short, the areas with greatest infestations are abandoned (FAO and ICRISAT 1996).

One of the ways to reduce the impacts of striga is to plow and plant very early in the planting season before rains have started and the weed has become established. If planting is delayed for any reason, then striga becomes established and production will be severely affected. In the early 1980s, Ethiopian troops attacked peasants in the northern part of the country with the intent to disrupt food production. Their tactic delayed planting and striga became established in the fields. This was one of the major causes of the famine of 1984–85 (Clay, Holcomb and Niggli 1985).

Soil Erosion and Degradation

Sorghum causes erosion on slopes as shallow as 4 degrees (Buxton, Anderson and Hallam 1997), and produces more erosion than most other cultivated crops (Thurman 1996).

The high potential for soil erosion tends to restrict sorghum production to soils with little slope. When grown for silage, most sorghum foliage is removed from the field when harvested. Soil is then at greater risk for water and wind erosion. In addition, nitrogen leaching from the soil can occur from the time sorghum is harvested until the next crop is planted and established. This can be a period of more than six months in areas with pronounced dry seasons or winters.

When grown as a grain, these issues are present, but not as pronounced. Sorghum produces considerable foliage, which if left in the field, acts as an effective mulch, especially if chopped at harvest. No-till practices can also reduce the impact of sorghum production on soil erosion while increasing soil health. Meyer et al. (1999) found that on research erosion plots, no-till practices reduced soil erosion for sorghum by more than 80 percent.

As a result of population pressures in most African countries, fallow periods are being shortened and more marginal lands are being brought into cultivation. These marginal lands are farmed with little or no fertilizer, and the cultivation methods used (e.g.

planting rows without regard to incline) can be a major cause of soil degradation. In addition, changes in climate such as lower rainfall levels and higher temperatures lead to periodic drought, which makes cultivation riskier. These factors force farmers in parts of Africa to adopt inappropriate production practices. The net result is production practices that are unsustainable in the long term coupled with declining productivity in the short term (FAO and ICRISAT 1996).

Farmers have long observed that sorghum is "hard" on the soil. Grain sorghum is a soil-depleting crop because its fibrous root system is deep (relative to other crops such as corn or millet) and extensive; it fills the rhizosphere and uses up the nutrients present in the soil (Ross and Webster 1970). Still, these are precisely the characteristics that make the plant drought-resistant and able to tolerate marginal soil.

Use of Agrochemical Inputs

One of the main environmental impacts from commercial sorghum production is the use of agrochemical inputs. Sorghum is one of the most chemically dependent of all agricultural crops (Thurman 1996). Many types of fertilizers and pesticides are used in sorghum cultivation and storage, but since most storage occurs off-farm, only the impacts related to cultivation are discussed below.

On the cultivation side, a number of pesticides are commonly used on sorghum, including organophosphates such as chlorpyrifos, dimethoate, and malathion. Carbamates like carbaryl and carbofuran are increasingly used as well, and are highly toxic. Pyrethroids are also used and this is important because these substances are extremely toxic to fish and other aquatic life. Lindane is the only organochlorine that is used; it is registered for use as a seed treatment in sorghum. Fungicides are also used in sorghum fields as foliar sprays and for seed treatment. Mancozeb, a fungicide that is commonly used, is toxic to fish. Birds, insects, mammals, and reptiles are exposed to these agrochemicals.

Small grains such as wheat and sorghum provide food and cover for many wildlife species. Wildlife is directly exposed to pesticides when they eat plants or seeds with chemical residues or when they swallow the pesticide granules or water that is contaminated by them. They are exposed indirectly when they eat insects or other animals exposed to or killed by pesticides. Pesticides washed by rain into streams, ponds, or other wetlands can harm aquatic animals (Rollins et al. 1997).

Herbicides are used to control weeds both in and adjacent to sorghum fields. Globally, atrazine is the most commonly used herbicide in sorghum cultivation, alone or in combination with other pre-plant herbicides like alachlor, metolachlor, 2,4-D, dimethenamid, paraquat, etc. The greatest risk to wildlife from herbicides is the effect they can have on wildlife habitat, as wildlife rely on the trees, brush, grass, and weeds in and near fields for food and cover (Rollins et al. 1997).

The application of fertilizers and other chemicals can also affect soil microorganisms and hence soil fertility. Heterotrophic bacteria (those responsible for converting dead plant material into organic matter) in surface soil are several times more abundant in unfertilized soil than in fertilized soil(Barber and Matocha 1994).

Poisoning Animals

Defensive chemicals produced by the sorghum plant itself can be toxic to domestic animals and wildlife. The sorghum plant can be toxic to herbivores if it is eaten prior to flowering. Sorghum, sorghum hybrids, and related plants contain high levels of prussic acid (hydrogen cyanide). Prussic acid poisoning can occur when livestock is pastured on sorghum or when wild herbivores eat sorghum by mistake or during periods when other food is scarce. These characteristics are common with grain sorghum as well as related plants, including Sudan grass, sorghum-Sudan grass hybrids, Johnson grass, and sweet sorghum. The presence of naturally occurring polyphenol chemicals in the sorghum plant, especially in varieties with purple undercoats, has also been found to affect the health of wild birds.

Fire Hazards

A wild species of sorghum, *Sorghum halepense*, has been known to create a fire hazard in natural ecosystems. The biomass yield of grain sorghum is quite high. It has been measured at about 35 metric tons per hectare in southern Europe. This biomass is often burned by farmers and can be a fire threat at that time.

Sorghum Silage Effluent

Effluent from sorghum silage has a very high biological oxygen demand (BOD). If this effluent is allowed to enter natural watercourses, it can reduce oxygen levels so dramatically that it can kill many freshwater organisms. Thus, effluent from sorghum silage is an environmental hazard when allowed to enter a watercourse.

Better Management Practices

There are a number of strategies by which sorghum farmers can reduce the environmental impacts of production. Several are similar to those that have been discussed for other crops, including building the soil, reducing pesticide use, treating effluent, and developing systems of carbon payments.

It is possible both to reduce the impacts of sorghum cultivation on the environment and to benefit producers financially, but it requires good planning and proper execution. In general, the adoption of better practices can reduce the impact of sorghum production by maintaining productivity on existing lands indefinitely and reducing runoff and pollution. Several different, complementary practices can help to reduce the impacts.

Build the Soil

The use of cover crops and crop rotation help build and maintain the soil. The introduction of organic matter and green manure build and maintain productivity. In addition, these same treatments reduce the already-low fertilizer and water needs of sorghum as the organic matter binds more effectively with the nutrients and water available naturally.

Sorghum production reduces soil vitality through the direct exposure of soil to sunlight during preparation for planting and the period of time it takes the crop to form a canopy over the soil. No-till sorghum or interplanting sorghum with cover crops has been found to decrease runoff more than other cultivation methods (Meyer et al. 1999). This approach can reduce soil erosion by more than 80 percent and decrease runoff by at least 10 percent.

Soil erosion from wind and water is one of the most obvious impacts of sorghum production. In many parts of the world the better management practices are basic. Producers should not plant up and down the hillsides. Rather, they should plant horizontally, running rows perpendicular to the slope. Similarly, if wind tends to come from one direction, then rows should be planted perpendicular to the direction of the wind so that the tall rows act as miniature wind breaks.

Another BMP to reduce soil degradation is continuous farming. This refers to crops that are grown in sequence within a year, in contrast to crop rotation that occurs over a number of years. Farmers in many parts of the world are finding that planting an off-season ground cover (especially a legume), even if it does not provide a marketable crop, improves subsequent yields of other crops. The more biomass produced by the ground cover, the higher the subsequent yields.

Soil erosion can also be reduced by chopping and leaving large amounts of crop residue from grain sorghum on the field after the harvest. If the residue is mulched, this is an even more effective way to control soil erosion (McCarthy, Pfost and Currence 1993). Sorghum crop residue benefits the soil by assisting moisture retention. This, in turn, maintains beneficial organisms near the surface of the soil that assist with the recycling of nutrients into forms that are available to plants.

In the United States, a continuous cropping system of winter wheat-fallow-grain sorghum-fallow has been shown to conserve soil and water resources (Getachew, Unger and Jones 1997). Annual plants such as sorghum, corn, and millet can make effective vegetation barriers if they are in place during critical erosion periods (James and Croissant 1994). Planting a sorghum crop in the summer-autumn period can also help to prevent soil erosion. An additional benefit of this sequence planting is that sorghum provides food for wildlife during a period of scarcity. On the Great Plains in the United States, producers often plant sorghum to attract wildlife, which then also attracts either ecotourists or hunters (Rollins, Fuchs and Winn 1997). Using this system, ranchers can generate up to 25 to 50 percent of their total income from the sale of hunting permits

(Greg Simmods, personal communication). Since this has gone on for many years, it appears that the hunting off-take levels must be reasonably sustainable.

Reduce Pesticide Use

Another increasingly important set of impacts from sorghum cultivation are problems related to the indiscriminate and often unnecessary use of pesticides and herbicides during production. Most of these impacts can be prevented, or at the very least reduced, by the judicious use of agrochemicals. Using such chemicals to address specific problems, rather than prophylactically or indiscriminately, will not only reduce the environmental impacts, but will also make the producers more financially viable. In addition, it will make them less dependent on chemical solutions for addressing production problems.

For example, there are effective measures for addressing the problem of the striga weed pest. As mentioned above, early planting tends to reduce the impacts of striga. Deeper plowing tends to reduce its impacts as well. Maintaining ground cover and seeding at optimal times also help to reduce the impact of the weed. If carried out over a number of years, these approaches can help to reduce or even eliminate striga. Recently, newer varieties of sorghum have been introduced that are more resistant to striga infestation, thus preventing degradation of the soil that occurs when striga takes over a field.

Develop Payments for Carbon Sequestration

With biomass production of up to 35 metric tons per hectare per year, sorghum has tremendous potential to increase biomass within crop rotation and no-till management systems. Such dense biomass residue also has the potential to act as a carbon sink. This can increase the organic matter in the soil, thereby increasing productivity while reducing chemical and water requirements of subsequent crops. In addition, it could potentially be the source of carbon sequestration payments for farmers.

Manage Silage to Avoid Toxicity

Improved feed management can reduce the risk to animals of poisoning. Cutting silage at the appropriate growth stage and feeding appropriate amounts to livestock can prevent prussic acid or cyanide poisoning in animals.

Treat Effluent from Silage

The effluent from sorghum silage should not be allowed to enter water bodies. It is a very effective soil additive and should be reintroduced to fields unless that is not feasible financially. Many silage storage facilities, however, would permit producers to capture liquid as it builds up or drains from silos or other silage storage facilities and return it to the fields in liquid form. If the material will drain into water systems then it needs to be treated first. This can be accomplished simply through containment until the organic matter decomposes, reducing BOD. This process can be accelerated through inoculation with effective microorganisms. All these treatments would reduce or prevent environmental effluent problems.

Outlook

Sorghum is one of the five main food grains of the world. To date, most of the attention on the crop has focused on increasing its acceptability and availability as a feed grain. However, much of the information collected during these efforts could also be used to improve sorghum production for subsistence and small-scale farmers. For such producers, sorghum production has not come close to achieving its potential as a food crop. If sorghum could be produced consistently and as close to its known production potential as corn, rice, or soybeans, the result would be to increase food and income to some of the most marginalized people on Earth. In addition, intensifying production in areas already cultivated could take pressure off of some of the most marginal, drier, tropical habitats in Africa and Asia.

Also in its favor, the sorghum plant produces more biomass per hectare than any other cultivated cereal grain. This means that no-till or conservation tillage sorghum, without burning, can build organic matter in soil faster than almost any other food crop. It also means that if markets ever develop for carbon sequestration for agricultural crops, sorghum (probably along with corn) would be one of the most interesting to consider.

However, it is not clear that sorghum, if left to conventional international markets alone to determine its fate, will be sufficiently interesting as an animal feed. While it has considerable production gains that can still be achieved, and while it does well in drier climates (which may become more common in the future), it is not clear that sorghum is as nutritious or as palatable to animals as other animal feeds. Also, to achieve its potential, sorghum will require considerable expenditures in research and development, and it is not clear who would fund it.

Resources

Web Resources

www.fhsu.edu/agriculture/sorghumwebsites.htm
www.manage.gov.in/managelib/agrinet/dblinks.htm
www.hort.purdue.edu/newcrop/nexus/Sorghum_nex.html
intsormil.org/iclinks.htm
www.sorghumgrowers.com/

Contacts Within the WWF Network

No one within the WWF network has been identified as working on this commodity. Please contact Jason Clay at WWF-US (jason.clay@wwfus.org) for suggestions of contacts outside the network.

References

Barber, K. L. and J. E. Matocha. 1994. Rotational cropping sequence and fertilization effects on soil microbial populations. *International Sorghum and Millet Newsletter,* 35(126).

Buxton, D. R., I. C. Anderson, and A. Hallam. 1997. *Performance of sweet and forage sorghum grown in monoculture, double-cropped with winter rye, or in rotation with soybean and maize.* Agricultural Research Service. Washington, D.C.: U.S. Department of Agriculture.

Clay, J.W., B. K. Holcomb, and P. Niggli. 1985. *Politics and the Ethiopian famine 1984–85.* Cambridge, MA: Cultural Survival.

DeWalt, B. R. and D. Barkin. 1987. Seeds of change: The effects of hybrid sorghum and agricultural modernization in Mexico. In H. R. Bernard and P. Pelto, eds. *Technology and social change*. Second Edition. Prospect Heights, IL: Waveland Press.

FAO (Food and Agriculture Organization of the United Nations). 1996. *Production yearbook 1995. Vol. 49.* FAO Statistical Series No. 130. Rome: UN Food and Agriculture Organization.

——. 2002. *FAOSTAT statistics database.* Rome: UN Food and Agriculture Organization. Available at http://apps.fao.org.

FAO and ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1996. *A joint study. The world sorghum and millet economies: Facts, trends, and outlook.* Rome: UN Food and Agriculture Organization. 21–22.

Getachew A., P. W. Unger, and O. R. Jones. 1997. Tillage and cropping system effects on selected conditions of a soil cropped to grain sorghum for twelve years. *Communications in Soil Science and Plant Analysis,* 28(1/2):63–71.

Holmes, P. A. 1992. *The marketing of grain sorghum in Australia. AIAS Occasional Publication.* 68:375–380. Melbourne, Australia: Australian Institute of Agricultural Science.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 2000. *Genetic Resources and Enhancement Program annual report*. Patancheru, India: ICRISAT.

James, T. A. and R. L. Croissant. 1994. Controlling soil erosion from wind. *Crops Online Fact Sheet No. 0.518*. Fort Collins, CO: Colorado State University Co-operative Extension. Available at http://www.ext.colostate.edu/pubs/crops/00518.pdf .

Maiti, R. K. 1996. *Sorghum science.* New Delhi, India: Oxford and IBH Publishing Co.

McCarthy, J. R., D. L. Pfost, and H. D. Currence. 1993. *Conservation tillage and residue management to reduce soil erosion.* Agricultural publication G1650. Columbia, MO: MU Extension, University of Missouri-Columbia. Available at http://muextension.missouri.edu/explore/agguides/agengin/g01650.htm

Meyer, L., S. Dabney, C. Murphree, W. Harmon, and E. Grissinger. 1999. Crop production systems to control erosion and reduce runoff from upland silty soils. *Transactions of the ASAE* (American Society of Agricultural Engineers). 42(6) Nov/Dec: 645–652.

Rollins, D., T. W. Fuchs, and J. Winn. 1997. *Reducing pesticide risks to wildlife in small grains and sorghum.* Texas Agricultural Extension Service. College Station, TX: The Texas A&M University.

Ross, W. M. and O. J. Webster. 1970. *Culture and use of grain sorghum*. USDA/ARS Agriculture Handbook 385. Washington, D.C.: U.S. Department of Agriculture.

Runge, C. F. 1994. *The grains sector and the environment: Basic issues and implications for trade.* Rome: UN Food and Agriculture Organization. November 1. 49 pages.

Skinner, P. R. 1996. Sorghum marketing and utilization in South Africa. In *Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, Gaborone, Botswana, 25–29 July 1994.* Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics. 315–319.

——. 1997. Maryland grain sorghum hybrid performance trials. Unpublished.

——. 1998. Agronomy mimeo 20. In C. W. Smith and R. A. Frederiksen, eds. *Sorghum: Origin, history, technology, and production*. New York: John Wiley and Sons, Inc.

Thurman, W. N. 1996. *Assessing the environmental impact of farm policies.* AEI Book Summary. American Enterprise Institute for Public Policy Research. Available at www.aei.org/bs/bs6793.htm. Washington, D.C.: AEI.

UNCTAD (United Nations Commission for Trade and Development). 1994. *Handbook of international trade and development statistics, 1993*. Geneva, Switzerland: UNCTAD.

U.S. Grains Council. 2001. *Value enhanced grains*. Washington, DC: U.S. Grains Council. Available at http://www.vegrains.org.