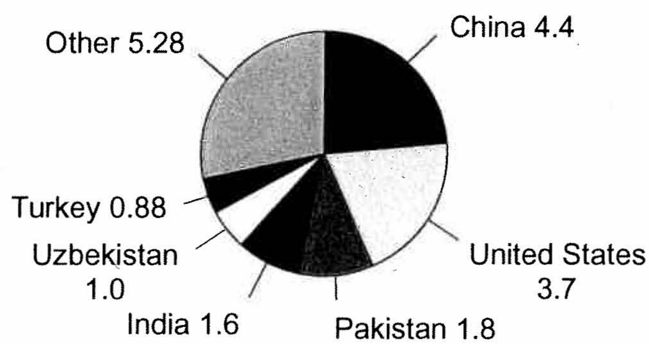
Cotton *Gossypium hirsutum*

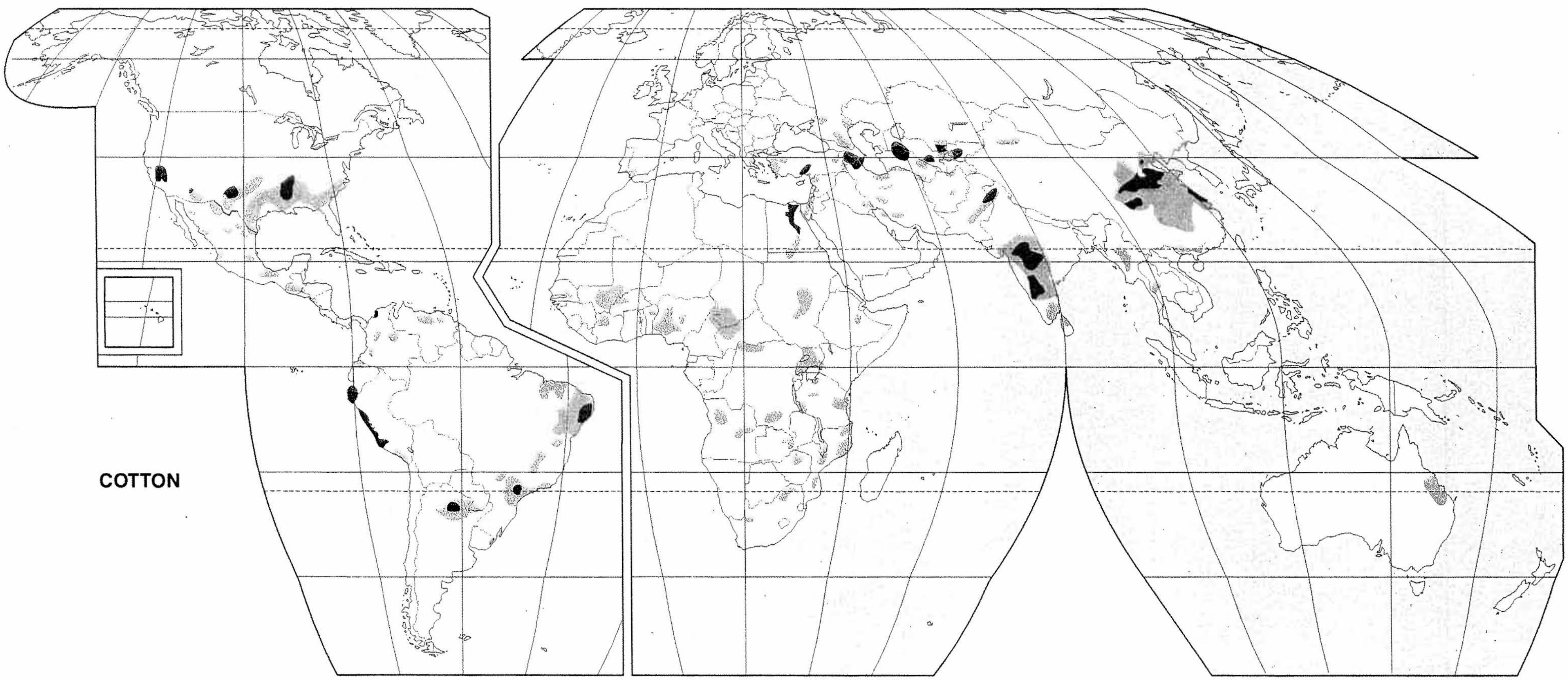
Production	
Area Under Production	32.7 million ha
Global Production	54.6 million MT (Seed) 19.1 million MT (Lint)
Average Productivity	1,670 kg of seed/ha 584 kg of lint/ha
Producer Price	$616 per MT
Producer Production Value	$33,644 million
International Trade	
Share of World Production	26%
Exports	7,663 million MT
Average Price	$1,020 per MT
Value	$7,818 million
Principal Producing Countries/Blocs (by weight)	China, United States, Pakistan, India, Uzbekistan, Turkey
Principal Exporting Countries/Blocs (of cotton lint)	Uzbekistan, Australia, United States, China, Greece
Principal Importing Countries/Blocs (of cotton lint)	Turkey, Indonesia, Mexico, Thailand,
Major Environmental Impacts	Habitat conversion Soil erosion and degradation Agrochemical use Water use and contamination
Potential to Improve	Poor Organic cotton exists but does not address water and some other sustainability issues BMPs have been identified, but reducing overall water and toxic chemical use will be difficult Genetic modification offers potential to reduce some impacts, but may raise others if transgenics are introduced

Source: FAO 2002. All data for 2000.

Total Cotton Lint Production (Million MT)



COTTON



Chapter 12

Cotton

Overview

The use of cotton has been dated to 3000 B.C. The word cotton is derived from the Arabic *qutton* or *kutn*, meaning the plant found in conquered lands, which refers to Alexander the Great's conquest of India. Cotton requires 180 frost-free days per crop. As a result, it is produced between 36 degrees south latitude and 46 degrees north latitude in tropical and subtropical climates.

Cotton achieved true "commodity" status in 1753 when Carolina cotton was listed on the London exchange. By 1861 cotton had become the single most important crop traded in the world, and more than 80 percent of it was grown in the southern United States. The surge in demand for cotton came from the industrial revolution, in particular from the expansion of the textile industry and the change from wool to cotton.

In the past, several annual and perennial varieties of cotton were grown. Each was adapted to different growing conditions and produced cotton of different length fibers and natural colors. Over time the trend has been to breed whiter cotton with more and longer fiber. Most perennial, or tree, species of cotton have been abandoned because they cannot be produced or picked by machine, even though their long fiber is highly sought after. More recently, some producers have begun to revive cotton varieties that have natural colors other than white to eliminate the dying process. Others have begun to produce organic cotton. Neither of these trends represents a significant share of either local or global markets.

Cotton is the largest money-making nonfood crop produced in the world. Its production and processing provide some or all of the cash income of over 250 million people worldwide, and employ almost 7 percent of all labor in developing countries. Nearly all activities associated with cotton production, processing, and manufacturing are becoming more concentrated in the hands of fewer companies and fewer countries. Cotton textiles constitute approximately half of all textiles (Banuri 1999).

Producing Countries

Cotton is grown on farms in more than 100 countries. India (8.6 million hectares), the United States (5.3 million hectares), China (4.0 million hectares), Pakistan (2.9 million hectares), and Uzbekistan (1.4 million hectares) lead all countries with 68 percent of the world's total area planted to cotton. In 2000 the world production of cotton was 19.1 million metric tons of lint (FAO 2002).

Approximately 2.5 percent of the world's arable land is used to grow cotton (Banuri 1999). The amount of total acreage devoted to the crop has changed little since the 1930s, but overall production has tripled and there have been significant shifts in where the production takes place (Soth 1999). For example, in the United States overall declines in area planted during the past seventy years were offset by increases in production.

Globally, yields averaged 1,670 kilograms of seed or 584 kilograms of lint per hectare in 2000. The most efficient cotton producers were Israel (which led all producers with average yields of 3,827 kg/ha) followed by Syria, Mexico, and Spain, each of which produced at about double the global average per hectare. The major producers of cotton by weight (not area) are China, the United States, Pakistan, India, Uzbekistan, and Turkey (FAO 2002). About two-thirds of all cotton is now produced in less-developed countries, with China the biggest producer by far. In the 1980s, several African countries increased their production of cotton. For several of these, cotton ranks in the top two exports by value, as shown in Table 12.1. World exports of cotton lint are dominated by Uzbekistan, Australia, the United States, China, and Greece (FAO 2002).

Table 12.1 Cotton's Ranking of Total Exports by Value for Selected Countries, 1990–91

Leading Export	Second Largest Export	Third Largest Export
Benin	Sudan	Central African Republic
Burkina Faso	Togo	Egypt (fiber, yarn)
Chad	Zambia	Madagascar
Mali	Zimbabwe	Paraguay
Pakistan (yarn, cotton, fabric)		Syria
Uzbekistan		Tajikistan

Source: UNCTAD 1994.

Consuming Countries

Nearly two-thirds of all raw cotton production is used in domestic manufacturing. The remainder is exported. Globally, the main cotton-consuming countries are China, the United States, India, Pakistan, and the European Union. Global imports are dominated by Turkey, Indonesia, Mexico, Thailand, and China. In each of these countries, cotton is used primarily for textile manufacturing.

Cotton consumption in developed countries had declined to approximately 35 percent of overall fiber consumption by the early 1980s. After that point, cotton began to be seen as a nonsynthetic, comfortable, natural alternative to many other fibers. Within ten years, cotton had increased again to nearly half of all fiber consumption in developed countries. Conversely, as cotton use increased in developed countries, its percentage of total fiber use in less-developed countries began to decline. At the same time, less-developed countries began to produce more of the world's cotton, thread, and cloth for export.

Most producers of raw cotton now undertake value-added processing to increase the overall value of the crop. That trend is reflected in the fact that the ten largest cotton-producing countries consumed 50 percent of the global cotton output in 1986 and 77 percent of an even larger volume in 1996 (FAO 1977, as cited in IISD/WWF 1997 and Banuri 1999). Thus, they "consume" the raw cotton by manufacturing it to thread or even cloth for export.

Production Systems

Cotton takes about six months to reach maturity. It is planted in rows about 1 meter apart. Planting, weeding, and even harvesting are increasingly undertaken by machine. Fertilizers are applied regularly. In addition, a number of different pesticides are used both as preventative measures and to treat specific pest infestations.

During the growing season, cotton produces flowers that turn into green seedpods, or bolls. Fibrous seed hairs grow in the boll and surround the seeds. The fibers are from 2 to 5 centimeters long. The fibers can be picked by hand or by machine; today most are picked by machine. Once picked, the fibers are passed through a ginning machine to eliminate the seeds. They are then spun into yarn and dyed and woven to create different fabrics.

During the past century, cotton production has shifted from a labor-intensive industry to a capital-intensive one as machinery and chemical inputs have been substituted for labor. This has even occurred in developing countries. Even so, in countries like Pakistan, most cotton is still grown on small farms of less than 1 hectare.

Most of the increase in productivity has resulted from genetic improvements and green revolution technologies. The overall goal of genetic modification is to improve the basic characteristics of the plant. Through selective breeding programs, cotton now has enhanced fiber strength and fiber length, and a broader geographic range of production. Genetic work on cotton has also focused on insect- and disease-resistant varieties. For example, work is being undertaken to change the shape and size of leaves that provide the nutrients for insects. Researchers are also attempting to increase the speed at which cotton ripens to limit the plant's vulnerability to insects and other pests as well as its overall water and input requirements. This work also extends the range over which cotton can be produced profitably.

Finally, through gene splicing, breeders are introducing insect-repellent genes into plants such as cotton (Banuri 1999). Recently, at least two transgenic varieties of Bt (Bacillus thuringiensis) cotton have been developed. These cotton varieties, produced in both the U.S. and China, produce low levels of insecticides that deter specific insect pests that attack cotton. Other varieties of cotton are being developed that are fungicide-, herbicide- and pesticide-tolerant. Because pesticide applications are targeted to address specific pests, such varieties are intended to reduce overall pesticide use. Transgenic Bt cotton now accounts for most cotton acreage in the United States and, globally, genetically modified cotton is one of the more widely planted genetically modified organisms (GMOs) at this time (Osgood 2002). The environmental impacts, positive or negative, of GMO cotton are not yet well understood. However, one of the concerns about Bt cotton is that it produces and releases low levels of pesticides which may create resistance much the same way overuse of antibiotics does.

Cotton requires a substantial amount of water during the growing cycle. However, it is also very sensitive to rain (either rain that is excessive or that occurs when the cotton bolls are maturing) and humidity, which can encourage diseases. Consequently, most cotton is produced in more arid lands where humidity is not an issue and where water can be provided by irrigation as needed. Cotton is irrigated on 53 percent of all land where it is cultivated. More importantly, 73 percent of all cotton is produced on irrigated land.

To reduce insect infestation and to maintain soil nutrients, cotton is often rotated with other crops. If cotton is grown continuously on the same land, pest populations build up and agrochemicals must be used to control them. Cotton plants are susceptible to a large variety of pests and diseases that can lead to stunted growth, poor color, lower yields, and even the death of the plant. Cotton's main insect pests are bollworms, budworms, leaf worms, and weevils. Traditional pest control methods were labor-intensive and included hand-picking pests, intercropping, crop rotation, and burning infected residues. Over the last 100 years, most of these methods have been abandoned in favor of chemical pesticides (Banuri 1999). The value of pesticide use in cotton alone is estimated at U.S.$2–3 billion annually. This is a significant proportion of production costs and is close to 10 percent of the annual value of the crop (Murray 1994, as cited in Banuri 1999).

Processing

Cotton has several uses. In addition to the longer fiber that is used for thread and textiles, shorter cotton fibers (or lint) are used for cotton balls, teabags, paper, or stuffing for sofas. The seed, which is 60 percent of the harvest by weight but only 10 to 25 percent of the value, is pressed to extract the oil. Cottonseed oil is used as vegetable oil and in margarine and other foods. The solid remainder is called cottonseed cake and is used for cattle feed. Cottonseed, cottonseed oil, and cottonseed cake production are dominated by China, the United States, the former USSR, and India (FAO 2002).

A wide range of cotton products are exported from most cotton-producing countries. These range from cotton lint to other manufactured items. Table 12.2 outlines the cotton exports from Pakistan, the world's fifth largest cotton producer.

Table 12.2 Exports of Cotton and Cotton Products from Pakistan, 1995–96

Item	Value (billions of rupees*)	Percentage of Total Production
Cotton lint	19.44	13.2
Cotton waste	0.17	0.1
Cotton yarn	54.05	36.8
Cotton cloth	43.28	29.5
Specialty items	2.14	1.5
Garments	27.64	18.8
Total cotton sector	146.73	100.0
Total exports	294.74	

Source: Banuri 1999.
*In 1995, U.S.$1 equaled approximately 34.3 Pakistan rupees.

Cotton has one of the greatest environmental impacts of all agricultural commodities during its processing. The water and energy requirements during the processing and manufacturing of cotton textiles are tremendous. It can take up to 200 liters of water to produce, dye and finish one kilogram of textiles (EPA 1996, as cited in Center for Design 2001). Globally, the textile industry is estimated to use 378 billion liters (100 billion gallons) of water each year. While these figures include all types of textiles, nearly half of all textiles are cotton and it is safe, therefore, to conclude that cotton uses a significant amount of water. Wastewater from textile production is often difficult to treat as it contains high concentrations of color, BOD, total organic carbon, dissolved solids and high content of toxic metals (e.g. chromium, copper, cobalt, lead, zinc, etc.) (Parekh 2003). An estimated 10 to 15 percent of 700,000 metric tons of dye is released globally each year in the effluent. In the United States, each surveyed textile factory in 1989 produced an average of 1,100 metric tons of solid waste each year (American Manufacturers Institute 1989, as cited in PPRIC 2003) with annual estimates for the industry in excess of one million metric tons of solid waste each year. The industry also uses a tremendous amount of energy. One textile processing plant in Bulgaria uses 4,800 metric tons per year of heavy fuel oil and 7,300 MWh per year of electricity (Galatex 2003).

The manufacture of cotton textiles also has tremendous impacts through the use and flushing of dyes. It has been said, for example, that you can see what the next year's trends in clothing colors will be by looking at Hong Kong's harbor. Wastewater from dying can vary in chemical composition, making treatment difficult. In fact, one of the reasons the dying industry has largely moved out of the United States and Europe is because of these countries' stricter regulations for wastewater treatment.

Substitutes

Prior to 1750, more than three quarters of all textiles were made of wool, about a fifth were made from flax, and the rest, just 4 percent in the year 1700, were made of cotton. Over the next century and a half, cotton came to dominate textiles globally, accounting for more than 85 percent of world fiber consumption by 1900. By 1999, it was the source of 48 percent of global textile production (Soth 1999).

The importance of cotton has declined during this century because of the increasing production and trade of cotton substitutes. Today cotton is around 48 percent of worldwide fiber use, while synthetics make up about 45 percent. The other fiber commodities include flax and wool as well as fibers derived from oil or wood pulp. For a number of uses these alternate fibers are good substitutes for cotton. Even so, overall fiber consumption is increasing and the production and use of cotton is increasing as well.

Market Chain

The cotton market chain can be divided into three different areas of activities—production, processing, and marketing. Each of the three areas is dominated by different players. Production tends to be controlled, albeit increasingly ineffectively, by government. In many countries the government controls research, extension, input supply (both what is allowed and its availability in some countries), and credit. Of course in some countries, like the United States, government subsidies are also important. On the other end of the market chain, apparel manufacture is controlled by the large retail chains that buy the clothes, representing a classic buyer-driven commodity chain. In the middle of the chain, however, thread, yarn and cloth manufacture are undertaken by a wide range of players that are not well organized or controlled either by the private sector or by government. Companies involved in yarn production, through manufacturers' associations, could lobby to influence government policies, but government does not comprehensively address this segment of the market chain in many countries.

Information about the market chain for cotton is hard to obtain. However, it appears that fifteen major trading companies dominate the market. These privately held companies are estimated to control between 85 and 90 percent of internationally traded cotton. There is a general suspicion that they use their influence on trade and price policies in ways that are detrimental to growers. For example, traders have been charged with using their control of traded cotton to convince mills not to buy directly from growers but rather to buy from established merchants (Morris 1991).

There is great variation in production even in a single country, as an analysis of the market chain in Pakistan illustrates. In that country, for example, there is a great deal of variation in size of production units; formality of the contractual connections between producers, processors, and the rest of the market; the nature of competition; and underlying cultural and governance systems. There are 1.3 million cotton farms, of which roughly half are smaller than 2 hectares (Banuri 1999). A vast majority of cotton farms are operated as family farms by owners or tenants with limited literacy and access to technology. The main determinant of technological change is the government, through its rather ineffective extension services.

At the other extreme are large-scale textile processors and small-scale garment manufacturers, both influenced directly and indirectly by international corporations that are clearly part of a much more formal and organized market chain. In the middle, in Pakistan, are large-scale spinning units and small-scale, informal weaving units. The latter number in the tens of thousands, mostly operating as family enterprises, with virtually no governance (Banuri 1999).

Market Trends

Between 1961 and 2000 global cotton production increased by 100 percent while trade increased by only 33 percent. This implies a relative increase in the use of domestic cotton in producer countries for value-added production at the local level. During the same period, prices for raw cotton declined by 58.9 percent (FAO 2002).

One of the biggest and most influential players in the cotton market is China. In 1998 China single-handedly exacerbated already falling prices by putting more than 200,000 metric tons of cotton on the market. The country's stated goal was to buy 2 million metric tons of soybeans. The government's ultimate goal appears to have been to redirect producers away from cotton acreage and toward grains, food crops, and soybeans. Through this conscious market manipulation, more than 600,000 hectares were transferred from cotton to the production of other crops. Over three growing seasons,the total land planted to cotton declined by 13 percent. However, when China's stocks have worked their way through the textile industry, there is likely to be an increase in cotton prices, which will stimulate production in other countries.

The clear signals that should be sent by such events are often clouded in the reality of cotton trading. For example, trading is complicated in developing countries where a large number of traders serve as intermediaries between producers and processors. It is not in traders' interest to be candid and give producers complete or up-to-date information about potential increases in cotton prices.

The cotton market was affected in the late 1990s by three different and unrelated international financial crises: those in Southeast Asia, Russia, and Brazil. The Southeast Asian financial crisis had perhaps the largest impact on cotton markets. In 1998–99, Thai cotton spinners reduced their purchases by 35 percent, Taiwan cut its purchases by 15 percent, the Philippines by 10 percent, and Indonesia by 40 percent. In the end, Indonesia's cotton demand fell by 23 percent to 350,000 metric tons. Due to the uncertainty of economic recovery and the high cost of working capital, most Asian companies were unwilling to hold large stocks of cotton. Just-in-time delivery became the norm. Only top-of-the-line cottons were purchased on a longer-term basis (UNCTAD 1999).

The financial crisis in Russia also had a big impact on global cotton markets. In a matter of months, demand decreased from 200,000 metric tons to 75,000 metric tons. This in turn freed up 125,000 metric tons of cotton from Central Asia for the international market, which further depressed prices (UNCTAD 1999).

Finally, the Brazilian crisis brought the already depressed cotton market to its knees. The response in Brazil was a little different. The overall level of imports remained the same in weight and volume, but the grade and quality of cotton purchased deteriorated. Furthermore, Brazilian textile makers shifted their purchases to countries that are known to produce cheaper, inferior cotton (UNCTAD 1999).

These events raised spot prices for cotton above New York futures prices. Most manufacturers were only buying what they needed at the time or to fill orders that were in hand. Nothing was being done on speculation. The expectation was that prices would fall even further, so buyers were reluctant to enter the market. Ironically, even though manufacturers had less working capital, their expenditures for cotton went up when there should have been more cotton on the market. The increase in prices did not go to the producer, however. Instead it went to those buyers and distributors in developed countries who had access to working capital and who could hold product until it was needed. This situation lasted for most of the 1997–98 season (UNCTAD 1999).

There is another major factor that could affect the price of cotton globally and, consequently, where cotton is produced. The issue of concern to most people in the cotton industry is the strength of the Chinese currency. If the Chinese yuan is devalued, millions of spools of cotton yarn held in China would then become competitive on the global market. This would tend to push the price down. At that time, those holding higher-valued inventories would suddenly find their position eroded. This would push prices even lower. These factors could quickly cause prices paid to producers to plummet.

Agricultural policies also have an impact on cotton production and global market trends. In some countries, cotton is a strategic crop (a crop that is deemed to be extremely important to a country's security, e.g. in the USSR where cottonseed oil was important for lubricating weapons). In others, agricultural policy is beginning to shift away from cotton and towards food production. These later shifts have led to declines in overall cotton production. Elsewhere, increasing water scarcity and tighter regulations of water management have reduced the availability of water for irrigated cotton production. As a consequence, some cotton producers may now be more interested in improved or more efficient water management systems for cotton. This could stimulate the identification and adoption of better management practices, but it is also likely to result in higher-priced cotton.

Declining commodity prices, increased energy costs, and uncertain economic conditions in many parts of the world have contributed to overall stagnation of cotton prices and consequently of production. For example, the real costs of irrigation projects have doubled in the last twenty-five years. One estimate suggests that in the 1980s alone real costs for irrigation rose between 70 percent and 116 percent (Serageldin 1996, as cited in Dinar 1998). Any technological changes that reduce the cost of irrigation or increase production from it, however, could make cotton and other irrigated crops more competitive. This would tend to expand irrigated areas as well as their environmental impacts. If anything, the increasing scarcity of freshwater on a global scale is likely to make producers invest in higher-priced, more efficient management in order to stay in business at all.

Environmental Impacts of Production

While habitat conversion is a problem associated with cotton production, the most important production impacts are the use of agrochemicals (especially pesticides) and water. The quality of soil and water and the impact on biodiversity in and downstream from the fields are also major concerns. Finally, because of the high use of pesticides there are a number of human health concerns, both for farm workers and for nearby and downstream populations.

On the processing and manufacturing side, the use of industrial chemicals is of concern, especially those associated with dyeing textiles and finishing clothes. These chemicals affect not only the environment but also workers in the processing and apparel industries. Of particular concern is the use of carcinogenic dyes and chemicals, especially azo dyes.

At the producer level, the main environmental impacts from cotton production in order of importance include use of agrochemicals, water use, soil erosion and degradation, freshwater contamination, and habitat conversion and the associated loss of biodiversity. Each is discussed separately below.

Use of Agrochemicals

When produced with conventional agricultural practices, cotton generally requires the use of substantial amounts of fertilizers and pesticides. Globally, cotton accounts for 11 percent of all pesticides used each year, even though the area of production is only 2.4 percent of the world's arable land. With regard to the subset of insecticides, cotton producers use 25 percent of all insecticides used each year. In developing countries, estimates suggest that half of the total pesticides used on all crops are applied to cotton. Forty-six insecticides and acaricides (compounds used to control mites and ticks) comprise 90 percent of the total volume of all pesticides used on cotton. Five of these are classified as extremely hazardous, eight as highly hazardous, and twenty are moderately hazardous (Soth 1999).

The use of pesticides poses health risks to workers; to organisms in the soil; to migratory species such as insects, birds, and mammals; and to downstream freshwater species. Research on the cause of fish deaths in the United States showed that pesticides, even used with the proper application, harm freshwater ecosystems. Endosulfan is a pesticide that is classified as highly toxic. In August 1995 endosulfan-contaminated runoff from cotton fields in Alabama resulted in the death of more than 240,000 fish along a 25-kilometer stretch of river (PANUPS 1996). In another instance, gulls in Texas were killed 3 miles from cotton fields where parathion was sprayed when they ate insects that had been poisoned. Studies have estimated the human impact from pesticides used on cotton to be as high as 20,000 people killed and 3 million poisoned every year (IISD/WWF 1997). In addition to direct contamination in fields, people are also affected through water runoff, drift of sprayed mist, the use of empty pesticide containers for other purposes, and inadequate or illegal disposal of expired or unused pesticides (Banuri 1999).

The shift to chemical control of pests is relatively new, beginning after World War II. In the United States, for example, in 1950 cotton pests were controlled by agricultural management and tillage practices. Pest cycles were taken into consideration before planting and at harvesting. Crop rotations were used to avoid insect infestations. Planting in lower densities also allowed producers to reduce the impact of pests.

From the 1950s on, however, pesticides were seen as a cheaper alternative to the use of labor and machinery. By the late 1990s in California, an average of 9.1 kilograms (20 pounds) of pesticides (active ingredients only) were used each year per hectare of cotton production. This rate of usage has not changed in the past decade. The most acutely toxic pesticide registered by the U.S. Environmental Protection Agency is aldicarb (sold under the trade name Temik), which is frequently used on cotton. In fact, 85 to 95 percent of all aldicarb used in the United States is used on cotton. Aldicarb has been detected in the groundwater in sixteen states (Monsanto 1999). Pesticides make up by far the largest share of the agrochemicals used on cotton, as shown in Table 12.3. Herbicides make up about a quarter of all agrochemicals used, and fungicides a relatively small amount.

Table 12.3 Pesticides Used in U.S. Cotton Cultivation, 1994

Pesticide	Share (%)
Insecticides	67
Herbicides	22
Fungicides	5
Others	6

Source: Woodburn 1995.

In many parts of the world the use of chemicals in cotton production is an even more recent phenomenon, but one rapidly increasing in scope. In Pakistan, for example, the Ministry of Food and Agriculture estimated in 1983 that only 5 to 10 percent of the cotton-growing area in the Punjab was treated with pesticides, but by 1991 this had increased to 95 to 98 percent of the total area (Banuri 1999).

Over time, farmers who use pesticides discover the "treadmill" effect: ever-higher doses are required to control pest populations because of the development of resistance in pests and the elimination of natural pest predators. The elimination of beneficial insects and predators means that farmers cannot afford to step off the treadmill because of anticipated crop losses. The increasing use of pesticides means higher costs and reduction of net income to farmers.

Pesticides used on cotton (and other crops) must constantly be changed due to the increase in resistance of the various pests. For example, almost 500 insects and mites have developed resistance to specific insecticides. Similarly, 48 weed species have become resistant to one or more herbicides. More than 100 plant pathogens are resistant to fungicides, and two nematodes are also showing marked resistance (NAS 1986, as cited in Allen 1994). Repeated applications of DDT to control bollworm have caused whitefly and aphid populations to increase in almost all cotton-producing countries (Vaissayre 2001).

Destruction of cotton crops by pesticide-resistant pests caused yields in the Sudan to fall by 80 percent over the past several decades from 3,250 kilograms per hectare to 500 kilograms per hectare (Allen 1994). In northeastern Mexico, the resistance of tobacco budworms (a secondary pest that emerged from efforts to eradicate the boll weevil) devastated the cotton industry and reduced crop acreage from 300,000 hectares in the 1960s to 500 hectares in 1970.

Pesticides are indiscriminate. For every targeted organism that is killed, many more beneficial ones also perish. Pesticides not only affect the flora and fauna in the fields being planted to cotton, they also are carried by water to wetlands and rivers and ultimately the ocean. Many modern pesticides are particularly toxic to water-dwelling insects, plankton, crustaceans, and fish. A number are persistent, behaving like DDT in reaching ever-higher levels as larger organisms eat smaller organisms (bioaccumulation). Moreover, over time pesticides become less effective, so larger volumes or stronger pesticides are used, increasing even further the damage to other nontarget organisms.

Water Use

Cotton uses a tremendous amount of water both to produce and process. Cotton production requires 550 to 950 liters per square meter of area planted. Put another way, 7,000 to 29,000 liters of water are required for each kilogram of cotton produced (Soth 1999). Some estimates indicate that it is the largest user of water among all agricultural commodities. Estimates indicate that cotton represents more than half of the irrigated agricultural land in the world. Cotton production and processing are also a major source of pollution of fresh water (Soth 1999).

In many cotton-producing areas, surface waters are diverted to irrigate cotton. Most cotton irrigation systems rely on traditional flooding techniques. Fresh water is taken from its source (e.g. river, lake, reservoir, or underground) and transported via a series of ever-smaller, open canals to the area to be irrigated. Freshwater losses occur through evaporation, seepage, and inefficient water management. Globally, irrigation efficiency of all types is lower than 40 percent (Gleick 1993). This means that 60 percent of the water used in irrigation never makes it to the targeted plant. The continuous cultivation of cotton in the Aral Sea basin of Uzbekistan has caused a tremendous decrease in the surface area of the sea—it has shrunk by almost half. The reason is that two of the rivers that formerly fed the Aral Sea (the Amu Darya River and Syr Darya River) were diverted for cotton production. Once the world's fourth largest lake, the Aral Sea formerly harbored many fish; today there are few. In addition, some twenty of its twenty-four native fish species are now extinct there, including the sturgeon that produced world-famous caviar. In China's Yellow River valley, where cotton is grown under both irrigated and rain-fed conditions, a shortage of irrigation water due to falling water tables has also been reported (Gillham 1995).

Table 12.4 identifies the main activites associated with cotton production that affect freshwater ecosystems and biodiversity. These include runoff from fields, drainage, pesticide application, water withdrawal for irrigation, extensive irrigation, dam construction, and land reclamation. While these activities result in a range of impacts from eutrophication and pollution to loss of soil and other biodiversity, Table 12.4 illustrates how the different impacts are related to specific activities and will need to be addressed through those activities.

Table 12.4 Impacts of Cotton on Freshwater Ecosystems and Biodiversity

Mechanism	Pollutant/Change	Impact
Runoff from fields	Fertilizer	Eutrophication and pollution
	Pesticides	Loss of soil organisms and other biodiversity
	Sediments	Suspended solids and pollution
Drainage	Saline drainage water	Salinization of ground and surface water
	Contaminated drainage water	Pollution of ground and surface water sources with agrochemicals
Application of pesticides	Insecticides, fungicides, and herbicides	Wildlife mortality and bioaccumulation
	Spray drift from aerial applications	Contamination of adjacent areas
	Leakage of equipment	Contamination of ground and surface water
Water withdrawal for irrigation	Depletion of groundwater reserves	Lowering of water table, ponds, streams, etc.
Extensive irrigation	Waterlogging	Rising water tables
	Saline and/or contaminated drainage water	Salinization of soils
Dam construction for irrigation	Disruption of natural cycles of water flow, changes in water table	Habitat destruction for organisms that depend on seasonal changes in stream and river levels
Land Reclamation	Clearing existing vegetation	Habitat destruction, with associated loss of biodiversity

Source: Soth 1999.

Groundwater depletion is another environmental problem associated with cotton cultivation. In many areas groundwater is pumped to irrigate cotton. In essence this water is mined from underground reserves. In ossified aquifers, which are aquifers with solid caps that do not allow the water to be replenished from surface runoff, water is a nonrenewable resource. Even in other types of aquifers, groundwater systems can take hundreds or even thousands of years to be refilled once they have been drained.

According to a recent World Wildlife Fund report on cotton (Soth 1999), the impact of cotton on total freshwater supplies is probably much greater than the irrigation data shows. Even with irrigated cotton, some 60 percent of water demand is provided by rainfall (Klohn 1998). The total global freshwater demand for cotton production is between 50 and 210 cubic kilometers per year. This is between 1 percent and 6 percent of total global freshwater withdrawal (Soth 1999).

Soil Erosion and Degradation

Soil quality is severely degraded by cotton cultivation. Even though the global area devoted to cotton cultivation has remained constant for the past seventy years, cotton production has "used up" many areas, leading to their abandonment, and expanded into new areas. Soil depletion and degradation is the leading cause of the globally moving cotton production frontier. However, as with many crops, there are no global estimates of the extent of land degradation and abandonment that has resulted historically from cotton production.

Cotton farmers in the last half-century sought not only to transform the ecological system, but to eliminate some forms of biodiversity, such as certain insects, altogether through the use of pesticides. The result of this strategy was high mortality of birds and downstream aquatic organisms. In addition, it caused a severe reduction in soil quality and fertility through the impact of the constant and increasing use of pesticides on soil microorganisms (Banuri 1999). These organisms give soil its vibrancy. They are essential to processing organic material and making it available, once again, to plants. Without such organisms, soil becomes little more than a growth medium to which producers must add all the necessary nutrients required by cotton.

Salinization from irrigated cotton production also causes the degradation and eventual abandonment of productive land. One estimate indicates that in six leading cotton-producing countries, between 12 and 36 percent of the currently irrigated area is already damaged through salinization (Dinar 1998). Investigations in Australia concluded that irrigated cotton production can lead to a chain of events that cause soil salinization. Irrigation runoff into groundwater results in rising water tables and eventually the establishment of shallow water tables. The rising water table dissolves salts present in the soil and carries these to the surface. In dry climates this leads to the salinization of soils as water is pulled up through the soil to the surface where it evaporates, leaving behind salts (Zilberman 1998). As soil salinity increases, productivity decreases until crops can no longer be grown.

In regions where evaporation exceeds both rainfall and the fresh water provided through irrigation, salinization is inevitable. Salt buildup happens most rapidly on soils that are poorly drained. Half of the irrigated land in Uzbekistan has lost productivity due to salinization. Pakistan and Brazil report similar problems (Gillham 1995). Even if cotton production were to cease, it is unlikely that native local plant communities would be able to recolonize soils that have been contaminated with high levels of salt.

Freshwater Contamination

Runoff from cotton fields contaminates rivers, lakes, and wetlands with suspended solids, pesticides, fertilizers, and salts. These pollutants can affect biodiversity directly due to their toxicity, or indirectly through long-term accumulation.

Underground aquifers can also be contaminated with chemicals, pesticides, or salts from cotton production. This draws into question any potential future uses of the water.

Habitat Conversion

Much of the land used to cultivate cotton has been in production for generations. This is true of areas in China, the United States, Egypt, Pakistan, India, and Brazil. However, other areas have been converted rather recently. The Pacific coastal plain from Mexico to Panama, for example, was converted from natural cover and slash-and-burn/fallow cultivation systems to permanent agriculture after 1950. By the late 1970s a million acres of Central American cotton fields were producing over a million bales of cotton annually, making it the third largest cotton-producing region after North America and the former Soviet Union. Virtually all the hardwood forests there were destroyed as were coastal savannas, evergreen forests, and coastal mangrove swamps. Only 2 percent of the original forests in the Central American cotton-production areas remain. As a result of labor concerns in the 1970s and declining yields (even with increased chemical inputs) in the 1980s, much of this area was converted from cotton production to pasture and beef production.

Cotton can indirectly cause the conversion of habitat as well. For example, the construction of dams to create reservoirs for irrigation water supplies can destroy considerable areas of riverine habitat and the species it supports as well as migratory species within river systems. In addition, the mechanization of cotton production, and its subsequent abandonment, in Central America displaced considerable numbers of landless laborers who then moved into highland, forested areas where they cleared land to produce subsistence crops.

Better Management Practices

The current production of cotton is not only environmentally unsustainable, it undermines the necessary conditions for future cotton production. A tremendous amount of work will be required to bring cotton production into line with even minimally acceptable environmental standards. The strategy then must be to focus on reducing the most significant impacts. Toward this end, the overall goal of a conservation strategy for cotton should be to promote the sustainable production and use of cotton by minimizing the impacts of overall water withdrawal as well as pollution of freshwater ecosystems from cotton production (Soth 1999). Measuring the impact on freshwater ecosystems could serve as a useful evaluation for the adoption of better practices. For example, impacts on freshwater will be reduced if less water is taken from rivers during key times, if fewer agrochemicals are used (because of more effective targeting), and if less soil is lost from erosion.

In order to evaluate improvements, it is important to have specific, measurable targets both for the environmental impacts of production and the percentage of cotton that is produced using improved techniques. Some of the techniques will be the application of advanced irrigation technology and the use of more ecologically sound growing methods, such as organic farming or integrated pest management (IPM).

For farmers, the interest in sustainable cotton is direct. They stand to save water resources, maintain soil quality, maintain present and future incomes, and reduce health problems. It is also quite likely that they will actually save money by reducing expenditures for pesticides and other inputs.

For the rest of the cotton market chain, there is also direct interest in sustainable cotton production. Every business that buys and uses cotton—from yarn makers to weavers, textile manufacturers, and retail clothing stores—has an interest in a stable, sustainable supply of cotton.

The issue, then, is how to promote more sustainable cotton production within the overall constraints of the current regulatory structure as well as the overall cotton market chain. Producers in different parts of the world do not have to comply with the same regulations and consequently have different production costs. Furthermore, any additional regulatory changes in one country could put those producers at a disadvantage vis-à-vis unregulated producers in other countries. Changes to make production more sustainable also cost money in up-front investments. In addition, individual actors in a production chain respond to changing incentive structures which are often linked to overall governance. In the absence of effective governance, transition costs will be inequitably distributed and will vary for the different players in the market chain (e.g. they will not be the same for producers as for manufacturers, etc.). With cotton, the higher costs of the transition to sustainability appear to fall disproportionately on the producers and manufacturers. However, the benefits are more likely to accrue to mass retailers who have a comparative advantage (in labeling, packaging, advertising, and possibly even certification) in creating and taking advantage of consumer interest, but relatively few actual costs in changing production systems and reducing impacts on the ground (Banuri 1999).

Switching to production systems that reduce environmental impacts will be impossible without the development of clean technologies. Alternative technologies exist for processing and are in the experimental stage of production, for example new technologies and management practices for organic and "green" cotton production. While technologies exist at the conceptual stage that have been implemented with specific producers (at least for IPM), the dissemination and application has not yet been undertaken, so the full range of feasible options are not yet identified (Banuri 1999).

Banuri (1999) suggests that any feasible program to encourage sustainable cotton production must intervene in the existing governance systems. These systems need either to be strengthened to facilitate the transition or to be transformed through investments and environmentally based investment screens, technical assistance, environmental certification programs or buyer screens, or government regulatory programs based upon better management practices. Whenever possible, these different approaches should be structured to send the same or complementary signals to the market chain so that they reinforce each other and increase the likelihood of success for each.

Most initiatives to reduce the environmental impacts of cotton production are not producer-neutral (they do not affect all producers equally). They will all tend to favor those participants with the strongest, most dominant positions in the market chain. This includes those who have adopted more modern production approaches; who operate at a relatively large scale; who have preferential access to credit, technology, and/or government resources; who have a near monopoly over a portion of the market chain; or who are able to take their profits first from the consumer dollar (Banuri 1999).

Encourage Organic Production

Organic methods produce cotton without the use of synthetic fertilizers and pesticides. Instead they depend on natural processes to increase yields and disease resistance, partly through enhancing soil quality. Organic production is also the only internationally recognized, independently assessed certification or label for cotton production (Banuri 1999). By 1993 organic production was estimated at between 6,000 and 8,000 metric tons, or less than .04 percent of total global output for cotton. Some 75 percent of all production was in the United States.

Many, but not all, of the main environmental problems from cotton production could be addressed by switching to organic production. Organic standards for cotton have already been established and are available for review. However, organic standards do not set limits on the water that can be used to grow the crop, and this is the main problem with current cotton production. The water issue must be addressed to make organic cotton sustainable. In addition, while synthetic chemicals are not allowed in organic production, naturally occurring ones are. What this means is that a number of pesticides that include copper are allowed, even though they are toxic to soil organisms and other non-target species.

There is also some evidence that organic cotton might not produce the volume of product that is desired for a wide range of reasons. In the United States, for example, interest in organic and naturally colored cotton in the late 1980s and early 1990s stimulated the establishment of whole new companies, product lines, and the on-farm certification of several producers. In the end, after several years of stable or in some cases increasing production levels, production began to decline (even with crop rotation) and prices increased dramatically. At this time it is not clear why these declines occurred or what it would take to correct them.

In the United States, keeping organic cotton production segregated was not a major problem at the farm level or even when the cotton was sold. However, keeping the cotton segregated throughout the different processing activities from ginning to spinning and weaving operations proved to be very difficult and expensive. All non-organic cotton had to be cleaned out of the operations. Because of the huge scale required to make these operations competitive within a global economy, it would be very costly and time-consuming to clean them out between runs of cotton that need to be segregated. There simply was not sufficient organic cotton to keep separate processing facilities in operation. As a consequence, the cost of spinning and weaving organic cotton was much more expensive than conventional cotton, and most manufacturers wanted nothing to do with it.

Even though organic cotton sales have declined, it appears that there is still consumer interest in the product. Such production can be encouraged through the purchasing policies of manufacturers and retailers that wish to be proactive; they can decide to give preference to organic cotton, and pay a premium for it, or only purchase organic products. Raw cotton is a tiny percentage of the cost of cotton textiles. Costs could be kept down by targeting producers in less-developed countries where labor can be substituted for chemicals. Smaller spinning and weaving operations could be dedicated to organic cotton as production grows. Cutting-edge companies with high mark-ups might be willing to work on this approach, but it is doubtful. It is much more likely that interest in organic cotton will only grow considerably if a really large company decides to make a commitment to organic cotton that would stimulate the market accordingly.

Reduce Water Use

In general, improved irrigation systems and water management could reduce water losses to 15 percent or less from current levels of 60 percent on average (Ait Kadi 1993, as cited in Kirda 1999). In Israel, for example, water shortages have led to the development of very efficient drip-irrigation systems. In such production systems, the total water used to produce a kilogram of cotton is far less than the 7,000 to 29,000 liters of water required to produce a kilogram of cotton with conventional means. Furthermore, drip irrigation systems produce the highest cotton yields of any cotton production systems in the world. Today, however, only 0.7 percent of irrigated areas globally use drip technology because of its high costs (Soth 1999).

Improved cultivation techniques also reduce water use. For example, conservation tillage reduces overall water use because crop residues are left on top of the soil, allowing them to act as water-conserving mulch. In Brazil a number of producers report that corn is grown in rotation with cotton and other crops because it provides more mulch. Similarly, pasture grasses are planted at the same time as corn, between the rows, to provide more biomass that will act as mulch and through their root systems help to build up the organic matter in the soil. Careful crop rotations reduce the need for pesticides and fungicides in addition to reducing water use.

Promote Integrated Pest Management

Integrated pest management (IPM) for cotton builds on practices that farmers have used for centuries. These include adopting varieties that are resistant to pests, altering the time of sowing and harvest to minimize exposure to pests, cultivating to reduce weeds, and removing crop residues. Pesticide use can be reduced by carefully monitoring pest levels and by targeting applications. The least toxic pesticide is chosen whenever possible; botanical pesticides such as neem and various tobacco extracts are also used. IPM reduces pests to "economically manageable" levels rather than aiming for complete eradication. Cultural practices such as crop rotation and intercropping are used to help keep down pest populations. Physical controls such as hand-killing pests and using pheromones to trap pests are also employed when possible so that fewer toxic chemicals are needed (Banuri 1999). IPM, however, does allow the use of standard chemical controls when necessary.

One study in India found that IPM resulted in higher cotton yields and a 28 percent decline of unit costs (Kishor 1992, as cited in de Vries 1995 and Banuri 1999). In short, using IPM for cotton has been found to be economically and environmentally beneficial. An added benefit is that IPM generates more employment. Still, most studies about the impacts for cotton are qualitative rather than quantitative, and few long-term studies have been undertaken. Applications of IPM for cotton have not worked on a broader scale (Banuri 1999), but there has also been little systematic attempt to apply the research on IPM that has been undertaken to date.

Rework Subsidies to Promote Conservation

Current U.S. price-support subsidies for cotton production account for as much as half of the income the 25,000 American cotton growers receive for their crop. This program insures that American cotton growers receive $0.70 per pound for their cotton, when the world price is only $0.40. Such subsidies have a direct impact on cotton production throughout the world. At the very least, they squeeze producers in countries that cannot subsidize production (or at least cannot subsidize it as much), forcing them to cut corners. Thus, U.S. government subsidies are matched by environmental subsidies in many less developed countries where producers are forced to cut corners to reduce their costs in order to compete with subsidized cotton production.

While subsidies may be inevitable, they should be used to achieve concrete conservation results. They could be used, for example, to retire the least productive lands or to require the adoption and use of improved practices, such as more efficient irrigation. They could also be used to wean producers from the use of the most toxic chemicals and reduce chemical use over time by subsidizing a switch to integrated pest management.

In a carrot-and-stick approach, policies could be developed to address pollution, toxic chemical use, water use and effluent issues. "Pollution taxes" could complement the subsidy approach described above while helping governments address the nonpoint-source pollution (the cumulative impact of cotton production in a region with many producers) caused by cotton and other forms of agricultural production. These types of policies would tend to push cotton producers and those who work with them to identify, refine, and adopt better management practices such as those described in this section.

Outlook

Humans need fiber for clothing and other products. Other sources of plant-based fiber such as hemp, sisal, flax, and wood pulp do not at this time appear to be viable alternatives to cotton, either in terms of the quantity of material that could be produced or the overall environmental impact of production. Likewise, synthetic fibers do not appear to be viable alternatives, as their production (mostly from petrochemicals) also raises serious environmental issues.

Cotton seems to be unavoidable. However, no matter what the advertisers say, there is nothing “natural” about cotton. It uses too much water, too many pesticides, and produces too much pollution. The environmental impacts of cotton production must be reduced. The question is how. Producers have little slack, since most of the profits from cotton are not made at the producer end. However, one place to start may be with the fact that many of the ways to improve cotton production are more labor-intensive. Therefore, one of the best ways to start making cotton more sustainable is to eliminate subsidies and market barriers; this would promote production in those countries where labor costs are low enough to make possible the adoption of labor-intensive practices.

Another way to reduce cotton’s impact significantly would be to begin to charge for pollution. Cotton production is one of the biggest sources of agricultural pollution, as it is the largest user of toxic chemicals in agriculture. Pollution is the Achilles heel of the industry. However, cotton interests are entrenched in both developed and less-developed countries; it was cotton and rice interests in California that ultimately created the political momentum to push through the U.S. farm bill in 2000. This will be one of the more difficult industries to change.

Resources

Web Resources

www.cottonaustralia.com.au/
www.cottonworld.com.au
www.pan-uk.org/Cotton/cotindex.htm
www.icac.org
www.cotton.pi.csiro.au
www.cotton.org
www.cottoninc.com
www.panda.org/resources/publications/water/cotton/impact_long.pdf
www.panda.org/about_wwf/what_we_do/freshwater/what_we_do/business_agriculture/cotton/cotton_impact_introduction.cfm

Additional resources can be obtained by searching on "cotton" on the WWF International Intranet:
http://intranet.panda.org/documents/index.cfm

Contacts Within the WWF Network

Noel Ainsworth, WWF-Australia (nainsworth@wwf.org.au)
Rob Cairns, WWF-UK (robcairns72@hotmail.com)
Michelle Handley, WWF-Australia (mhandley@wwf.org.au)
Richard Holland, WWF-Netherlands (rholland@wwf.nl)
Hammad Naqi Khan, WWF-Pakistan (hnaqi@wwf.org.pk)
Nazir Mehmood, WWF-Pakistan (nmehmood@wwf.org.pk)
Olga Pereladova, WWF Russia Program Office (opereladova@wwf.ru)
Richard Perkins, WWF-UK (rperkins@wwf.org.uk)
Andrew Rouse, WWF-Australia (arouse@wwf.org.au)
Nicole Santer-Nemeth, WWF-Switzerland (nicole.santer@wwf.ch)
Walter Wagner, WWF-Switzerland (walter.wagner@wwf.ch)

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