

CONSTRAINTS TO FIBER PRODUCTION¹

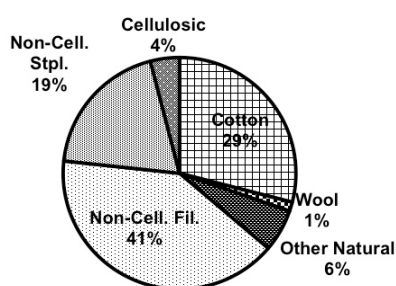
T. Townsend

International Cotton Advisory Committee, Washington DC, USA

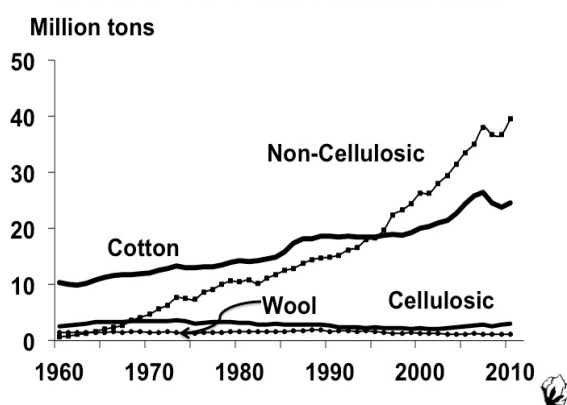
OVERVIEW

Relatively strong economic recovery in calendar 2010 supported strong demand for textile products, and world apparel fiber mill use rose to approximately 74 million metric tons. Non-apparel natural fibers such as flax, hemp, jute, abaca, and coir add another 4 million tons of fiber use to the total, and minor synthetic fibers such as aramid and carbon fibers add another 2 million tons, bringing total world fiber use in 2010 to about 80 million tons². Further growth to a little more than 75 million tons of apparel fiber and 81 million tons for all fibers is estimated to have occurred during 2011³.

World Fiber Production



WORLD FIBER PRODUCTION



Consumption of natural fibers totaled 31 million tons in 2011, and cotton accounted for 25 million tons, wool about 1.3 million tons, flax about 800,000 tons, silk about 100,000 tons, and jute and all the hard fibers equaled another 4 million tons. Natural fibers account for 36% of total fiber use, and cotton alone accounted for 29%. In the 1960s, cotton represented about two-thirds of world apparel fiber mill use. By the 1980s, cotton's share had fallen to about half, and while the downward trend abated between 2000 and 2006 because of low cotton prices, the downward slide in market share for cotton has accelerated with the rise in cotton prices since 2008.

In 2011, chemical fibers accounted for 64% of total fiber use, with non-cellulosic fibers, primarily polyester staple and filament, accounting for 60% of the total and cellulosic fibers accounting for 4%. Since the 1960s when world fiber use was approximately one-fourth of the current level, almost all the growth in consumption has occurred with polyester and cotton, especially polyester. While there have been

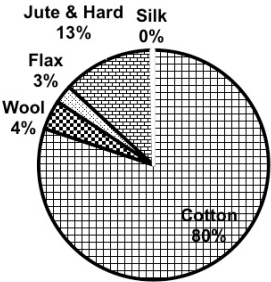
¹Presentation before the International Cotton Conference Bremen 2012, March 21-24, 2012.

²The Fiber Year Consulting, The Fiber Year 2011, May 2011.

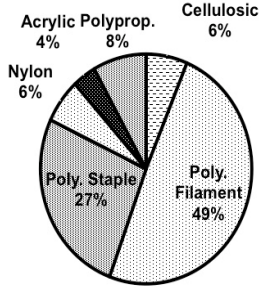
³ ICAC Secretariat.

year-to-year fluctuations in demand for all fibers, consumption of wool, other natural fibers such as silk and flax, and non-cellulosic fibers such as nylon, about 3 million tons, and acrylic, about 2 million tons, have either been relatively flat or declining. Therefore, in any discussion of competition and compatibility among fibers, the focus is most commonly on cotton and polyester. There has been growth in cellulosic staple fibers (rayon or viscose) over the last two decades, from two million tons in the early 1990s to more than 3 million tons now. Some of the growth in cellulosic staple fiber production has been offset by a decline in cellulosic filament production.

World Natural Fiber Production



World Chemical Fiber Production



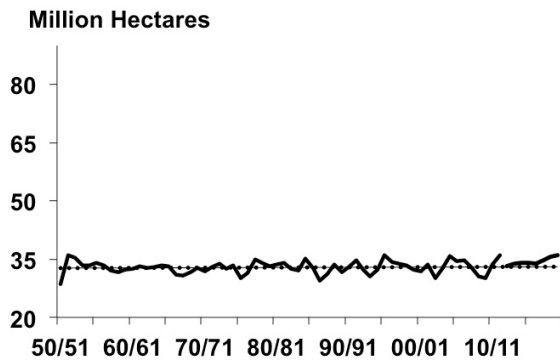
Natural Fibers

Cotton Production: The Role of Technology

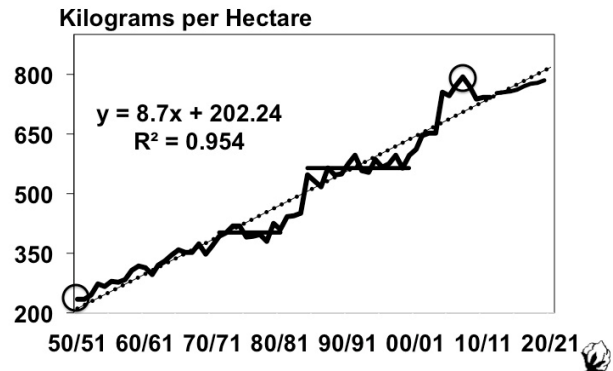
The world cotton industry experienced dramatic changes over the last six decades. Production nearly quadrupled, rising from 7 million tons in 1950/51 to a record of 27 million tons in 2004/05. The average annual rate of growth in world production over the last six decades was 2.5%, or about 290,000 tons.

Growth in cotton production was steady during the 1950s and 1960s but slowed during the 1970s because of slower world economic growth and limited gains in cotton yields. World cotton production exploded from 14 million tons in the early 1980s to 19 million tons in 1984/85, as political change in China, higher prices, and the widespread use of better seed varieties and better methods of plant protection against pests led to increased yields. World production climbed to a record of nearly 21 million tons in 1991/92 but leveled off during the 1990s. With the commercial use of biotech cotton varieties beginning in 1996 and the expansion of cotton areas in Francophone Africa, Australia, central Brazil, northwestern China, and Turkey, world production reached 27 million tons in 2004/05 and remained nearly as high during the following three seasons. Production declined during the recession to 22 million tons in 2009/10, still well above the pre-2004/05 level. Production rose to nearly 25 million tons last season and is estimated at 27 million tons in 2011/12.

WORLD COTTON AREA



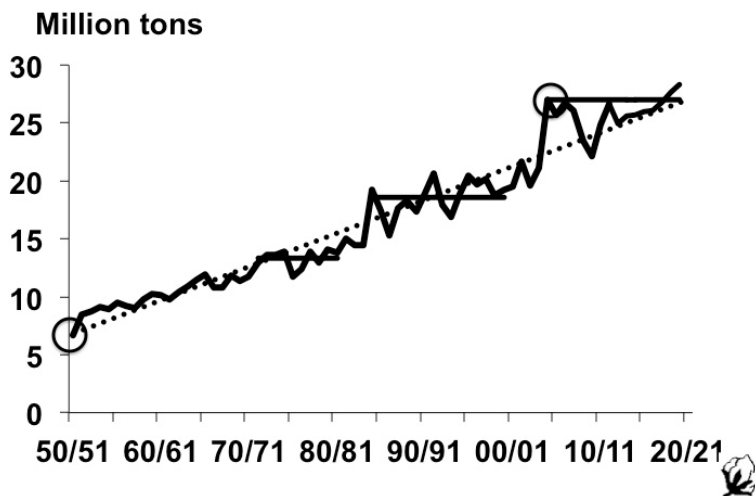
WORLD COTTON YIELDS



World area dedicated to cotton has fluctuated since the 1950s between 28 million hectares and 36 million hectares, with an average of 33 million hectares. While there have been dramatic reductions in cotton area in some regions since the 1950s, particularly in the United States, Central Asia, northern Brazil and North Africa, there have been offsetting increases in Francophone Africa, China, India and Pakistan. With total area showing no tendency to rise, all growth in world cotton production since the 1950s came from improved yields linked to improved technologies.

The world yield has trended higher since the 1950s, with periods of slow growth alternating with periods of rapid growth. The world cotton yield in the early 1950s was 230 kilograms of lint per hectare. Yields rose steadily at an average rate of more than 2% per year during the 1950s and 1960s, and then more slowly from the mid-1970s until the mid-1980s. During the 1980s the world cotton yield rose dramatically and reached a record of nearly 600 kilograms per hectare in 1991/92. However, yields stagnated during the 1990s due to problems associated with diseases, resistance to insecticides, and the disruption of production in the former Soviet Union. Yields began rising again in the late 1990s with improvements in seed varieties and the use of biotech varieties, and the world yield in 2007/08 reached a record 793 kilograms per hectare. The world yield in 2009/10 and 2010/11 was lower at about 740 kilograms per hectare, and the world yield this season is estimated only a few kilograms higher. The average rate of increase between 1950/51 and 2010/11 was 9 kilograms per hectare per year.

WORLD COTTON PRODUCTION



Projection of World Cotton Production to 2020

World cotton area is expected to continue varying from year to year, as it always has, between 29 and 36 million hectares. Due to increased competition with food and fuel crops and tighter water constraints, cotton prices will have to be higher than they were in the 2000s to maintain cotton area within this range.

The extraordinary increases in yields observed in cotton production over the 2000's, averaging almost 4% annually, will likely not continue in the near future. Since the 1950s, cotton yields have experienced periods of slow growth during periods of technology consolidation, alternating with periods of rapid growth during periods of new-technology adoption. Yields seem to have entered a period of slow growth since 2005/06, as the rate of expansion in biotech cotton area has slowed. As in the past, new technologies will trigger new periods of rapid growth in cotton yields. However, it is impossible to forecast when such advances will take place, and many of the new advances in technologies will focus on optimizing the use of inputs such as water, fertilizers, and pesticides rather than focusing on increased yields. The world cotton yield is expected to grow by an annual average rate of less than 1% this decade, reaching 780 kilograms per hectare by 2019/20.

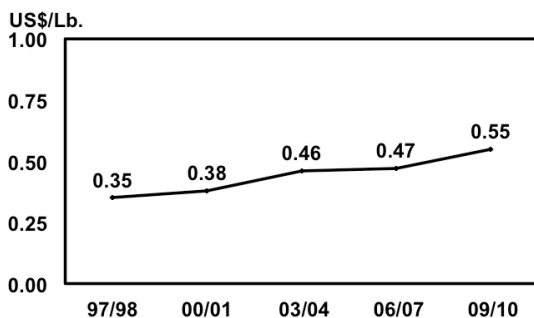
For eight years between 1970/71 and 1978/79, world cotton production was essentially flat at about 13 million tons. For a sixteen-year period from 1984/85 to 1999/2000, world production was again flat at about 19 million tons. Current expectations for area and yield suggest that world production is again in a period of technology consolidation during which production will not rise much. World production in 2019/20 is projected at 28.5 million tons, compared with the estimate for this season of 27 million tons.

Cotton Production: Rising Production Costs

The ICAC Secretariat surveys the cost of cotton production around the world every three years; the most recent survey was completed in 2010 with data for 2009/10. Thirty-four countries representing nearly 89% of world cotton area participated in the 2010 survey. Differences in production systems, the lack of data on opportunity costs for labor provided by farmers themselves, estimating unit costs of inputs which vary during a season, and a lack of data on fixed costs for land and machinery are some of the difficulties in making valid estimates. Nevertheless, within broad ranges, estimates can be made.

In 2009/10, the world average net cost of production (net cost equals the total cost excluding land rent and after deducting the value of cotton seed) of one pound of cotton lint was 55 cents per pound. The estimated world average net cost of cotton production increased from 35 cents per pound of lint in 1997/98 to 38 cents in 2000/01, to 46 cents in 2003/04 and 47 cents in 2006/07. The 17% increase in the average net cost of cotton production from 2006/07 to 2009/10 coincided with a period of no growth in the world cotton yield and rising prices of inputs, including fertilizer, insecticides and labor. With yields unlikely to rise substantially, costs per pound of production are likely to keep rising this decade.

Net Cost of Lint Production - World



Net Cost of Lint/Lb. by Region (US\$)

N. America	= 0.87
Australia	= 0.64
Asia	= 0.52
West Africa	= 0.52
S. America	= 0.49
Africa (Other)	= 0.41
World	= 0.55

The average net cost of production varies substantially by region. The highest-cost cotton-producing region in the world in 2009/10 was North America, 87 cents per pound, and the reported net cost of production in Australia was also above the world average, 64 cents. The reported average costs in Asia, including China, India and Pakistan, and West Africa were essentially at the world average, while production costs in South America are below the world average because of rising yields in Brazil, and the lowest costs of production reported were in Southern and Eastern Africa.

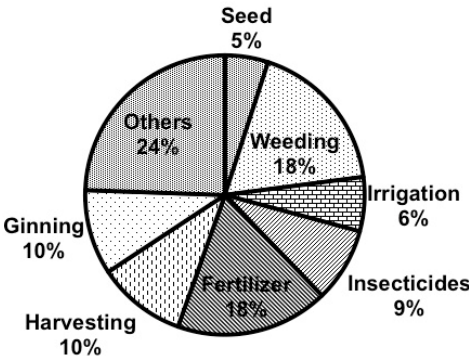
The two biggest components of the average net cost of production of cotton in 2009/10 were weeding, which is often labor intensive, and fertilizer, which is capital intensive. Harvesting and ginning together account for one-fourth of the total net cost of production; insecticides, irrigation and planting seeds together account for one-fourth of production costs.

At price levels for cotton that are competitive with polyester, land and labor are the major constraints to growth in cotton production. Ample supplies of fallow arable land exist in the world, especially in South America and East Africa where costs of production are lowest. However, substantial investments and changes in governance in each region are necessary to bring such land into productive use.

Agricultural labor is becoming scarcer as economies develop, and labor-intensive agronomic practices such as weeding and harvesting are being replaced with technology. The most common form of biotechnology in cotton is insect resistance, and many countries are experimenting with herbicide tolerant varieties. The use of mechanical harvesting is expanding, and one-fourth of cotton in Xinjiang in Western China is now harvested with pickers. Argentina has developed a small, pull-behind cotton stripper for use by smallholders, and both picker and stripper technologies are being extended to more countries. Nevertheless, given likely levels of prices for cotton, labor availability will restrict production increases.

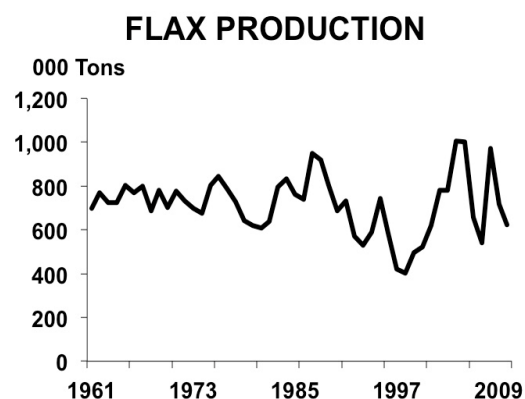
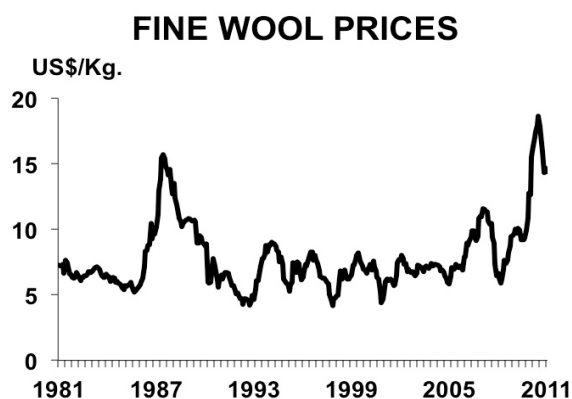
Accordingly, at expected price levels, and given expected developments in agricultural technology and adoption, cotton production growth will be constrained by a lack of land and labor resources.

Cost Structure - World 2009/10



Wool: an Elegant Fiber

As of 2010, wool, the other major natural apparel fiber, accounted for about 1% of world fiber use, or 1.13 million tons, down from 10% or 1.5 million tons in the 1960s. As of December 2011, fine wool on the Australian Wool Exchange averaged US\$14.39 per kilogram or \$6.53 per pound. There have been some gains in wool production per hectare since the 1960s, but animal husbandry is inherently complicated, resulting in high production costs relative to polyester and cotton. With world wool production trending lower, wool is not forecast to gain market share at the



expense of cotton or chemical fibers. Wool has suffered from shifts in fashion toward more casual appearances and preferences among consumers for easy-care products. The wool industry is working to expand machine-washable wool products so as to expand the range of product choices available. Fiber blends involving wool are possible, but most wool products, including suits and carpets, are 100% wool reflecting the unique, elegant, properties of wool.

Other Natural Fibers

World mill use of flax, used to produce linen, ranged between 400,000 tons and one million tons between 1960 and 2010; flax production in 2010 was 622,000 tons. There has been no trend increase or decrease in flax production since the 1960s. Producer prices for flax were between US\$5 and US\$6 per kilogram in Russia and Ukraine in 2009. Mill delivered costs of linen would be substantially higher, making linen uncompetitive for common applications.

World production of silk is about 100,000 tons, according to the International Sericultural Commission in Lyon, France. As of January 2012, raw silk in China was quoted at more than US\$6 per kilogram or \$2.70 per pound. Blends involving silk are becoming available to consumers, but with world production of just 100,000 tons, opportunities are limited.

World production of jute, kenaf and allied fibers was 3.1 million tons in 2010/11 according to the International Jute Study Group (IJSJG). World production of sisal, henequen, and other similar fibers in 2010 was 272,000 tons. Production of abaca was 70,000 tons, and production of coir was 653,000 tons. Thus hard fiber production totaled 4.1 million tons. These fibers are used in coarse applications such as roping, bags and mats and are not included by the ICAC in apparel fiber statistics.

Chemical Fibers

Polyester production: Capital Intensive

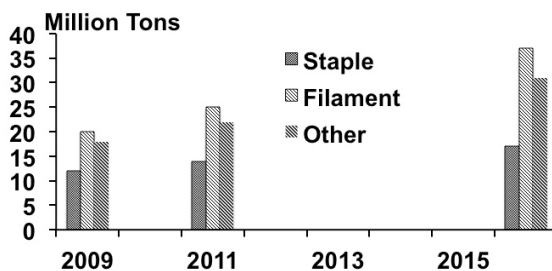
A barrel of crude oil generally yields 93% liquid petroleum products, and the entire petrochemical industry is based on the remaining 7%. Beginning with crude oil, refiners produce aromatics and olefins. From the aromatics stream, benzene, toluene and xylenes are produced. Paraxylene is produced from xylene and is used to make Purified Terephthalic Acid (PTA).

Ethylene is generally produced from oil, but in North America a significant portion comes from natural gas, and Mono Ethylene Glycol (MEG) is produced from ethylene.

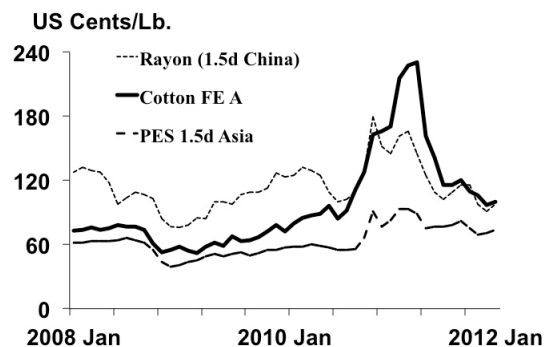
PTA and MEG are combined to make any kind of polyester, whether it is fiber, resin, film or anything else.

According to the PCI Consulting Group, with which the ICAC Secretariat exchanges information on fiber production, PTA production will rise from 47 million metric tons in 2011 to 69 million tons by 2016, with PTA production capacity expected to rise from 52.5 million tons in 2011 to 100 million tons by 2016. Global MEG capacity is also expanding, and world MEG capacity is forecast by PCI to expand from 28 million tons in 2011 to 36 million by 2016. It takes 0.86 kilograms of PTA plus 0.345 kilograms of MEG to produce one kilogram of polyester. Therefore, the growth in polyester raw material capacity would enable the production of a maximum of approximately 100 million tons of polyester by 2016; PTA and MEG are used for nothing else.

World Polyester Production



FIBER PRICES



Polyester has numerous uses, and according to PCI, world polyester production in 2011 was approximately 61 million tons, of which about 14 million was used for staple fiber production, 25 million was used for filament production and roughly 22 million tons were used for PET Resin, film, polymer and other uses. By 2016, polyester production is forecast at about 85 million tons, of which staple and filament production will account for nearly 54 million tons, or about two-thirds of total polyester production.

According to an expert with PCI⁴, over the long run there should not be any polyester production constraints as there are sufficient new raw material capacities coming on stream, primarily in the Far East. However, in the short-term there may be some bottlenecks to polyester growth as new paraxylene (PX) and MEG capacity is lagging the projected growth in polyester production, and any short-term supply disruptions could cause availability issues. Exclusive of raw material availability, polyester expansion requires extensive capital investments, both in dollars and an educated employment pool, neither of which seem to be a constraint in the Far East for the foreseeable future.

PTA must be shipped in powdered form and is relatively expensive to transport, and so there is limited deep sea trade in PTA except for the Far East. MEG is easier to transport because it is traded in liquid form and is inert; therefore, there is a very robust trade flow among regions.

New polyester plants are in the 200,000 to 250,000 metric tons per year capacity range and generally use a continuous polymerization process of mixing PTA and MEG to make fiber. The costs of construction are estimated in the \$150 million range for a new 250,000-ton polyester staple plant. Operating costs (energy, labor, sales, overhead) for polyester staple production are in the 15 -18 cents per pound range depending on capacity utilization rates. Raw materials, PTA and MEG, cost about 70 cents a pound of fiber currently, meaning that raw materials are at least three-fourths of total production costs. Total production costs are estimated at 85 cents to 90 cents per pound of fiber. In China, total costs may be about a dime lower in the 80 cents per pound range for polyester staple fiber as they receive raw material discounts.

Cellulosic Fibers: Growth in Staple Fiber Production

Cellulosic fibers, known commonly as viscose or rayon, are made mostly from Dissolving Wood Pulp (DWP), although if relative prices are attractive, cotton linters are also used. China is the largest producer of DWP, and investments in both DWP production and cellulosic fiber production are continuing. Estimates for 2012 indicate that world cellulosic fiber production was running at only 70% capacity, indicating substantial room for increased production, even without additional investment⁵. There are no realistic physical constraints to the production of wood pulp, especially with ongoing breeding efforts resulting in purpose-designed trees such as the loblolly pine in the United States that is grown specifically to supply the wood and paper products industries.

Since 2008, the differential between prices of DWP and rayon or viscose, an indicator of the cost of conversion of DWP to cellulosic fiber, ranged between 35 and 60 cents per pound, two to three times the cost of conversion of feedstock to polyester fiber. Accordingly, cellulosic prices are generally above those of polyester and cotton. However, during 2010 and 2011 when cotton prices rose to more than \$2 per pound, this was not the case. Given the properties of the two fibers, cotton and

⁴ Michael Bermish, Senior Consultant, PCI, Xylenes and Polyesters, Ltd.

⁵ Alasdair Carmichael, PCI Consulting Group.

cellulosics can be substitutes and complements in different apparel and home furnishing applications.

Nylon: A Technical Fiber

Two types of nylon are produced around the world, nylon 6 in Asia and Europe and Nylon 6.6 in the U.S. and Europe. About 70% of world use is nylon 6. Almost all nylon is filament. Nylon is more expensive than polyester, but it is much stronger, it packs well, and it is highly resistant to heat. Consequently, all airbags are made of nylon, and nylon is finding its way into many technical applications, including automotive products. The precursor chemicals refined from oil and natural gas that are used to make nylon are abundant; the only constraint to increased nylon production are economic alternatives. Because nylon is used increasingly in technical applications requiring specific fiber characteristics, the likelihood of fiber blends involving nylon is small.

Acrylic and Polypropylene

Demand for acrylic fiber has been weakening for decades because costs tend to be higher than for polyester without compensating technical advantages. Acrylic is produced exclusively as staple fiber from petroleum and natural gas feed stocks. There are no realistic constraints to production.

Polypropylene is the cheapest of all the major fibers and is used in low-cost, coarse applications. Polypropylene is lightweight relative to strength and has zero absorbency. Produced as a filament fiber from oil, polypropylene's primary advantage is cost.

Summary

Polyester will capture the lion's share of growth in fiber production and use during this decade. Growth in production of cotton and the other natural fibers is limited by constraints to land and labor and, at least for the time being, a pause in the commercialization of new production technologies. In contrast, there are no effective resource constraints to limit growth in production of non-cellulosic fibers. Production of cellulosic fibers is also trending higher but from a comparatively small base. Nylon, acrylic, polypropylene, wool, flax, silk and other natural fibers are likely to experience little or no growth.

WORLD FIBER PRODUCTION

Million tons

