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Fact Sheet on Production Efficiency and Energy Usage in Cotton Production

Produced by

The Expert Panel on Social, Environmental and Economic Performance of Cotton Production (SEEP)

Production Efficiency & Energy Usage

Focal Countries: Global.

1. Definition / Description of the issue

Production Efficiency -- Scope of the issue:
The challenge to the agricultural community is to meet the food and fibre requirements of a rapidly growing population with limited availability of natural resources, specifically land, water and energy. Traditionally, the focus for improving production efficiency has been to either reduce the amount of resources required per unit of production or to increase production capacity using the same amount of resources. Ideally the cotton industry will seek to achieve both to meet future food and fibre requirements, that is, increase production with reduced resources. Numerous examples of this ideal exist today: conserving water by replacing surface irrigation with low pressure sprinklers or drip systems; reducing applied chemicals by replacement of insecticides with integrated pest management (IPM) strategies, Bt transgenic cotton varieties, and area-wide pest management; conserving energy by replacing mechanical weed control with herbicides and conservation tillage; and saving fertilizer resources by switching from uniform to variable rate applications. All of these practices have increased production while reducing inputs. As about two-thirds of world cotton is produced by smallholders in developing countries with very few inputs, a third approach should also be considered: To Increase the use of applied resources to increase production efficiency on such farms.

Production Efficiency and cotton production:
Agriculture accounts for 70-75% of the current human consumption of water (Wallace 2000; WBCSD. 2008). Global cotton production consumes 3% of the total volume of water used for global crop production (Figure 3.), and in 2007 cotton was grown on 2.3% of the world's arable land (Figure 1.), making cotton production's water use proportionate to land use. Cotton supplies 36% of the world's demand for textile fibres (Figure 2.) and despite a steep rise in demand over the last 40 years, cotton's global land requirements have remained essentially unchanged (Meyer et al., 2008).

During this same time period, the area of global agricultural land has grown by 10%, but in per capita terms, agricultural land area has been in decline (WBCSD 2008). This trend is expected to continue as land is increasingly limited and the world population is growing. For example, grain-producing land per capita in 2030 is projected to be just 0.08 hectares (0.2 acres) or just one-third of what was available in 1950 (UNFPA 2001). Although cotton land has been projected to increase by a modest amount in the future (UNEP 2009) a similar trend would be expected as the world's population growth out paces this increase.

By 2050, the human population is projected to increase to about 9 billion (FAO 2006; U.S. Census Bureau 2009), and this increased population density, coupled with changes in dietary habits in developing countries, is expected to put tremendous pressure on agricultural land usage, and water and energy resources. Cotton will be competing for these resources with food crops and other non-food crops such as those used to produce biofuels. Yet, a synergy between cotton and food crops has been observed with smallholders in Sub-Saharan African countries where cotton growers are producing at least as much food as non-cotton growers (Raymond & Fok. 1994).

Figure 1. World land usage by agricultural crops. (FAOSTAT, 2007)

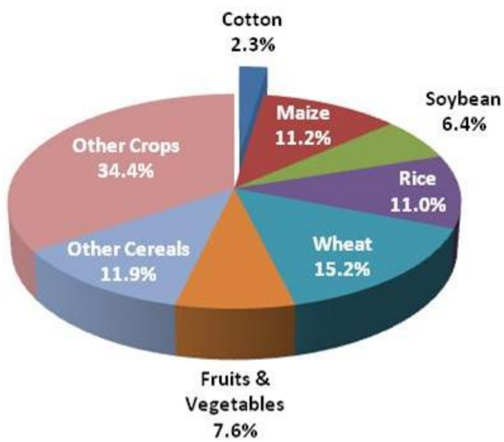


Figure 2. World fiber demand (National Cotton Council of America, 2007)

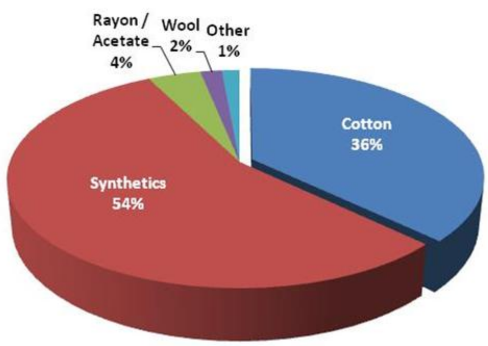


Figure 3. Volume of water (all sources) used globally for various crops for production at the field level. Total agricultural use is 6,390 Gm^3 per year (Hoekstra & Chapagain, 2007)

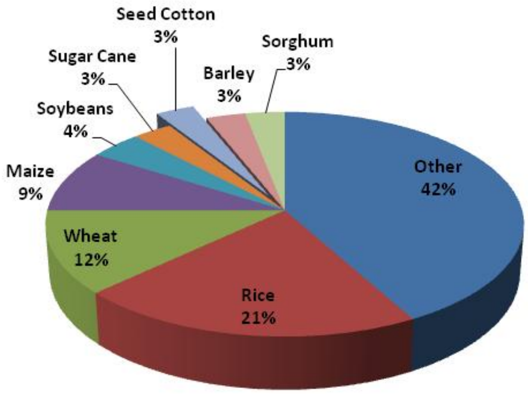
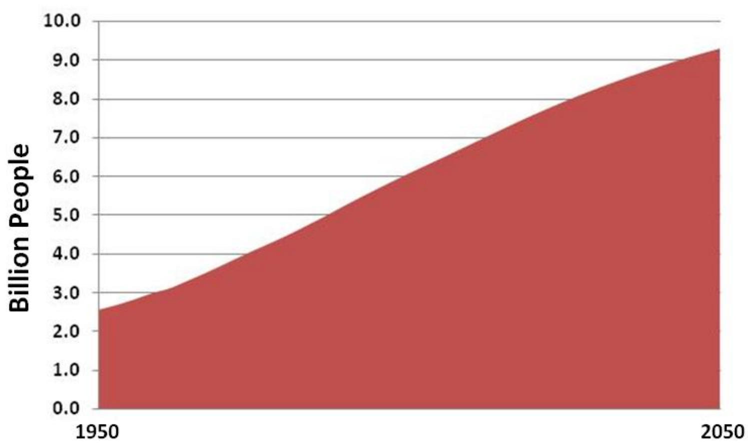


Figure 4. Estimated increase in the world's population (U.S. Census Bureau, 2009)



2. Range of data

Production Efficiency - Land:

The past half century has witnessed a steady increase in the efficiency of land use (expressed as the amount of fiber produced on one hectare of land) for cotton production. Cotton yields have doubled since 1965 while harvested hectares have remained relatively constant (Figure 5) resulting in a 50% decrease in the amount of land required to produce a kilogram of fibre (Figure 6) (Meyer 2008).

Figure 5. World cotton land use and yield 1965 – 2008. (Meyer 2008)

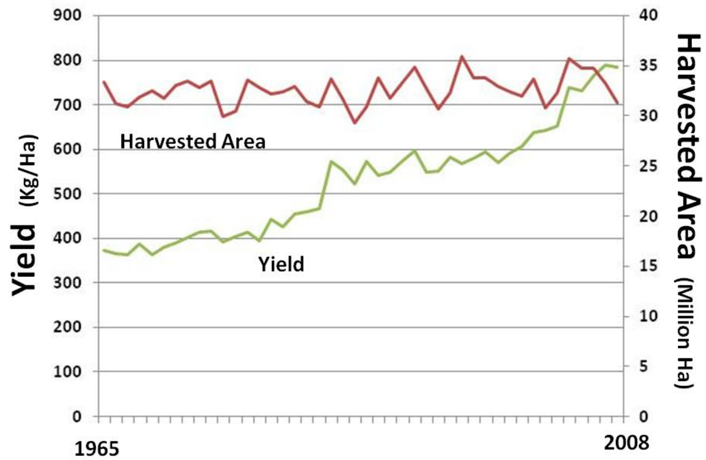
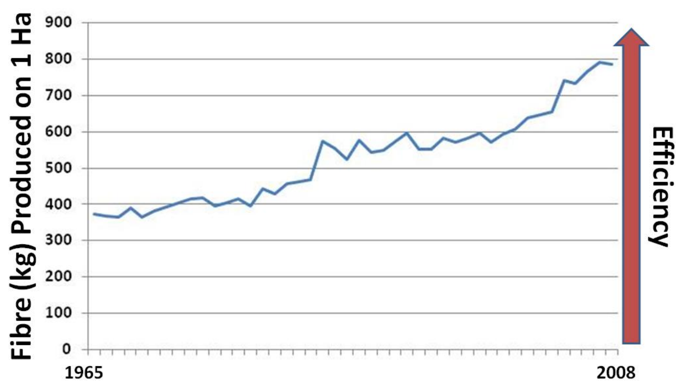


Figure 6. Land Use Efficiency (LUE) for cotton. (Meyer, 2008).



Worldwide, this trend toward greater land use efficiency has been seen in crops other than cotton. This is clearly seen in data presented by the World Bank (2009) where the roles of yield growth and growth in area planted are examined as factors in annual production growth between 1965 and 2008. In comparison to rice, maize, soybeans, and wheat, cotton closely rivals wheat in making the greatest advances over this extended time period (Figure 7). However, for the period 2000-2008, as compared to 1965-1999, where the other commodities have either made relatively small gains (maize) or declined (wheat, rice, and soybeans) in productivity, cotton made dramatic increases (Figure 8). The authors of the World Bank study attributed accelerated gains to the greater use of transgenic varieties in most of the crops but for cotton, increases in basic germplasm and better production efficiency, among other things, that have also been contributing factors. In contrast, in Sub-Saharan African countries, from the mid-1980s to 2005, the growth of cotton production resulted exclusively from area growth by smallholding producers. Since then, cotton production has been stagnating, at best.

Figure 7. Contribution to average annual increase in production, 1965-2008 (World Bank, 2009)[1]

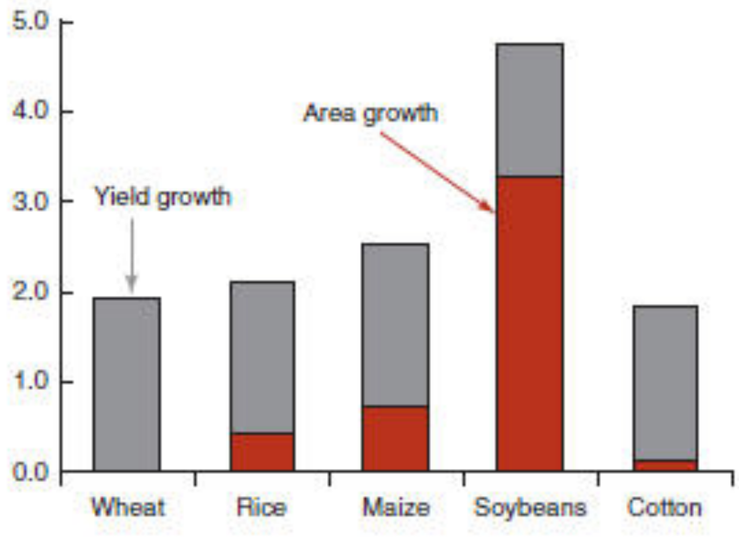
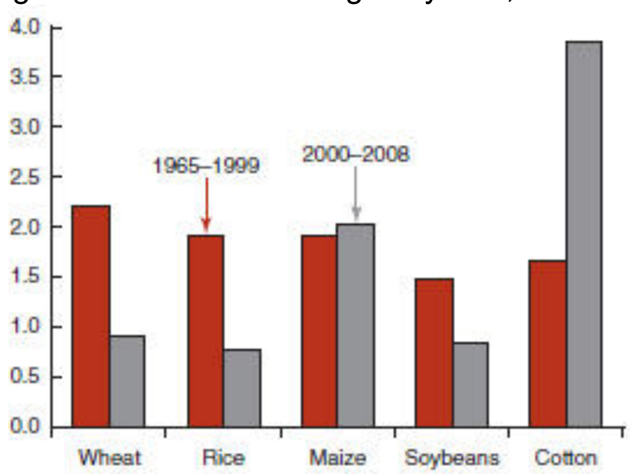


Figure 8. Annual % change in yields, 1965-99, 2000-08 (World Bank,2009)[2]



Production Efficiency - Water:

Water Use Efficiency (WUE) expressed as kilograms of output (fibre or seed cotton) per cubic metre of water for cotton production has also improved. Zwart and Bastiaanssen (2004) updated the global WUE values for wheat, rice, cotton and maize that were previously reported by FAO in 1979 (Doorenbos, J., and A.H. Kassam, 1979). Their research was based on published research post 1979 and, for cotton, data was obtained from nine countries on five continents. The WUE values for all crops had improved over what had been reported in 1979 (Table 1.). The authors attributed some of the variability in

[1] Source: World Bank calculations based on USDA data.
[2] Source: World Bank calculations based on USDA data.

the WUE for cotton and the other crops (shown by large ranges in values) to differences in climate, irrigation water management, and soil management.

Table 1. Water Use Efficiency (WUE) for various crops

Crop	FAO (1979) WUE Range (Kg/m^3)	Zwart & Bastiaanssen (2004) WUE Range (Kg/m^3)	Zwart & Bastiaanssen (2004) WUE Mean (Kg/m^3)
Wheat	0.8 – 1.0	0.6 – 1.7	1.09
Rice	0.7 – 1.1	0.6 – 1.6	1.09
Seed Cotton	0.4 – 0.6	0.4 – 1.0	0.65
Cotton Lint	0.1 – 0.2	0.1 – 0.3	0.23
Maize	0.8 – 1.6	1.1 – 2.7	1.80

Production Efficiency - Energy:

Matlock et al. (2008) quantified the energy required by cotton production over a range of global cotton production practices. Energy efficiency [expressed as the amount of fibre produced per one Megajoule[3] (MJ)] for cotton ranged from a high of 0.071 Kg fibre/MJ of energy in the South-eastern United States to a low of 0.016 Kg fibre/MJ energy for non-mechanized farms in South America (Table 2). The authors attributed the high amount of variability in the production systems studied to differences in yields and the use of irrigation

In addition to estimating total energy requirements, Matlock et al. (2009) also looked at the energy contained in the cottonseed produced and found that six of the ten regional production scenarios could be at least energy neutral to energy positive (i.e., there is more energy in the seed than energy needed to produce the crop, even when accounting for losses in converting the seed to energy). The authors also point out that this is a conservative estimate, as they did not attempt to include any crop products such as gin waste or cotton stalks in their energy calculations.

[3] The joule is a derived unit of energy or work. It is equal to the energy expended in applying a force of one newton through a distance of one metre or in passing an electric current of one ampere through a resistance of one ohm for one second.

Table 2. Energy Use Efficiency (EUE) for various global cotton production systems.

Region	Production Description			Mean Cotton Fibre (Kg/MJ)	Mean Seed Cotton (Kg/MJ)
	Production Strategy	Irrigation	Fertilizer		
USA East	Mechanized	None	High	0.071	0.176
USA West	Mechanized	High	High	0.028	0.071
South America*	Mechanized	Medium	Medium	0.016	0.041
	Non-Mechanized	Medium	Medium	0.008	0.021
Australia	Mechanized	High	High	0.048	0.121
Mediterranean	Mechanized	Medium	High	0.044	0.110
	Non-Mechanized	Medium	Low	0.058	0.145
Asia	Mechanized	High	High	0.031	0.077
	Non-Mechanized	Medium	Medium	0.040	0.100
Africa*	Non-Mechanized	High	None	0.009	0.022
* There are high levels of uncertainty in the estimates for the non-mechanized production systems of South America and Africa due to lack of data.					

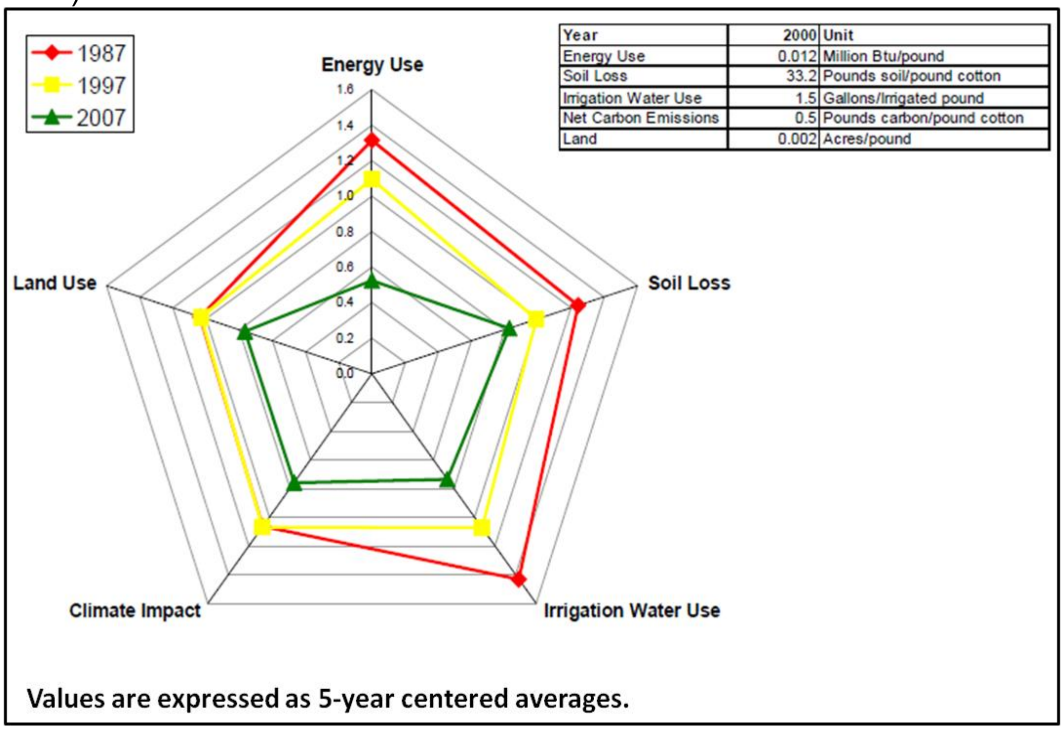
In 2009, three studies were conducted in the United States to determine the embodied energy in cotton production across all systems. A comparison of the results is presented in Table 3.

Table 3. Energy Use Efficiency (EUE) for cotton production in the United States.

Research Study	Mean Cotton Fibre (Kg/MJ)	Mean Seed Cotton (Kg/MJ)
Nelson et al. (2009)	0.057	0.142
Matlock et al. (2009)	0.040	0.101
Keystone (2009)	0.072	0.181

In addition to an evaluation of the embodied energy in cotton production, Keystone (2009) also is developing metrics to measure the environmental outcomes of agriculture in the United States. National, publicly-available data on cotton, maize, soybeans and wheat are being used to measure outcomes for five environmental indicators: land use, soil loss, irrigation water use, energy use and climate impact (greenhouse gas emissions). This is an on-going process, but the first report was published in 2009 on data from 1987 – 2007. Results for cotton given in Figure 9 show the improvements that were made over the 20 years of the study, especially in regard to energy and irrigation water use and soil loss.

Figure 9. Cotton Efficiency Indicators (Per Unit of Output, Index 2000 = 1) (Keystone, 2009)



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