

## THE CELLULOSE GAP (THE FUTURE OF CELLULOSE FIBRES)

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**Within the next two decades the world population will grow by 1.4 billion and is moving up the food chain. By 2030 we will have an additional demand for food of 43 %. On the other hand arable land is limited and the cropland area per person will shrink. This situation will result in a food crisis.**

**Also the demand for textile fibres (natural as well as man-made) will increase by 84 %. But in the future cotton production will be stagnant because of the limited availability of arable land.**

**The experience shows that approximately one third of textile fibres have to be cellulosic fibres because of certain properties like absorbency and moisture management. This will result in a disproportionately high demand for man-made cellulosic fibres in the coming years.**

**The substitution of cotton by man-made cellulose fibres is also a contribution to the environmental protection.**

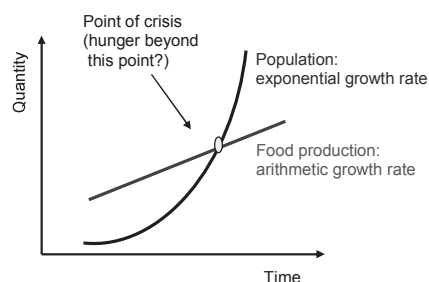
**Keywords:** *Population growth, arable land, food crisis, textile fibres, cotton, man-made cellulose fibres*

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### Introduction

Thomas Robert Malthus, an English economist (\*1766, †1834), in opposition to the popular view in 18<sup>th</sup> century Europe that saw society as improving and in principle as perfectible, wrote in his “Essay on the Principle of Population” about the increase or decrease of population in response to various factors:

The increase of population is necessarily limited by the means of subsistence. Population growth therefore generally expands in times and in regions of plenty until the size of the population relative to the primary resources causes distress. But “Population, when unchecked, increases in a geometrical ratio, but subsistence increases only in an arithmetical ratio“ (see Figure 1). As a result, population sooner or later gets checked by famine, wars and disease [1].



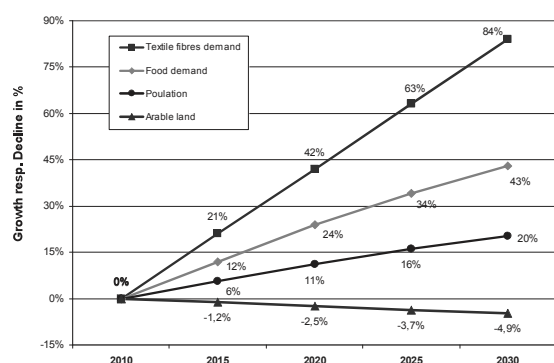
**Figure 1.** Th. R. Malthus: Principle of Population.

This publication roused a storm of controversy.

What Malthus failed to foresee was the astonishing development of transport and colonisation which took place in the 19<sup>th</sup> century and which increased the area from which foodstuffs and raw materials could be drawn enormously.

With the advent of the progressive agribusiness (“Post-war Green Revolution”), the use of synthetic

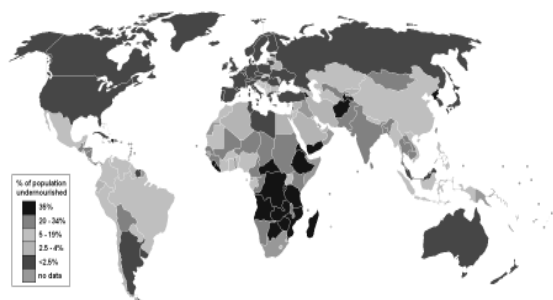
fertilisers, pesticides, state-of-the-art irrigation systems and today's genetic engineering were the driving forces for the exponential growth of the food production. Today, 200 years later, we are again confronted with the comeback of the "Malthusians Misery". The world population growth is outpacing the growth of food supply and the number of malnourished people is growing again. The following diagram (see Figure 2) shows the problems which we will face in the near future: the population is growing by 20% over the next two decades, at the same time we need more food and textile fibres, but arable land is decreasing [2].



**Figure 2.** Development of the world population, the need for food and textile fibres and the availability of arable land.

In 1996, when the world leaders attended the World Food Summit in Rome, they committed themselves to halve the number of undernourished people by 2015 (see Figure 3).

Today, the number has already risen to more than a billion undernourished people compared to 825 million in 1996 [3].



**Figure 3.** Percentage of Population affected by Undernutrition by Country [4].  
With the current growth rate of

78.6 million persons p.a. (respectively 215,000 per day) the population will continue to grow from today 6.9 to 8.3 billion by 2030 [5]. This means that combined with the impact of rising incomes and urbanisation, the food demand will roughly double in the next 50 years. The agricultural production and yields, however, will stagnate. Since several years now the global food security situation has worsened and continues to represent a serious threat for humanity!

### Availability of Arable Land and Food

Approximately 17.3 mill km<sup>2</sup> (11.6 %) of the earth's 149 mill km<sup>2</sup> of land are cultivated. This includes 15.8 mill km<sup>2</sup> ( $\hat{=}$  10.6 %) arable land, which is land cultivated for crops that are replanted after each harvest like all sorts of grains, sugar or cotton. It further includes 1.5 mill km<sup>2</sup> ( $\hat{=}$  1.0 %) permanent crop land, which is land cultivated for crops that are not replanted after each harvest like citrus, coffee or rubber. The remaining 132 mill km<sup>2</sup> include permanent pastures, forests, barren land and built-on areas [6]. About 1 % of the total arable land (10 to 20 million hectares) is currently being lost per year; urbanisation alone is responsible for about 3 - 4 million hectares [7].

The combined development of population growth and shrinking arable land means that compared to 1960, where approximately 4,400 m<sup>2</sup> of arable land per capita was available worldwide, only 30 years later, in 1990, it was merely 2,700 m<sup>2</sup> per capita, and in 2025 it most probably will only be 1,700 m<sup>2</sup> per capita [8].

It seems obvious that more arable land would be necessary to secure food production.

Historically, one of the successful ways out of this dilemma was to increase food production by an enhancement of the yield per area without expanding the area of arable land itself.

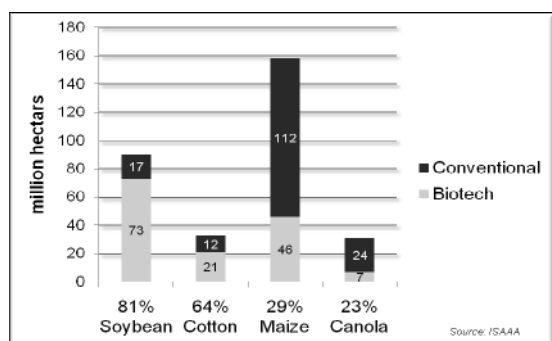
However, the intensification of production requires a much higher input of inorganic fertilisers and pesticides as well as a

substantial improvement of the irrigation systems. Ironically, all these efforts decrease the yields in the long run. The agricultural land is constantly losing fertility.

The inputs of synthetic fertilisers and pesticides can be reduced or avoided with an ecological cultivation, the yields, however, will be much lower.

The only practical method to reduce the input of pesticides and to increase the yield at the same time is the use of genetically modified crops. Genetic engineering is analogous to nuclear energy: nobody loves it, but both will be absolutely necessary for the environment!

Several of the important crops are already genetically engineered: 81 % of the soybeans, 64 % of the cotton, 29 % of the maize and 23 % of canola (variety of rapeseed) grown are genetically modified (see Figure 4).



**Figure 4.** Global Adoption of Principal Biotech Crops 2010 – in million ha [9].

Over the last years, the area planted with gene-modified crops is growing by 10 million hectares p.a. and has reached 148 million hectares in 2010.

The benefits are immediate and obvious: Higher yields, less need for pesticides, fewer crop losses and more attractive products. Genetic engineering offers faster crop adaptation as well as a more biological rather than a chemical approach to yield increases.

People in the area of the “Fertile Crescent” have been domesticating wild plants more than 10,000 years ago, by artificial selection. Our ancestors made a fateful choice to domesticate annual and not

perennial plants. The reason was that the artificial selection could be done year by year. Today, all the grains but also cotton are annual plants. Perennial plants would have some advantages (e.g. deeper roots, less soil erosion).

Maybe it’s provocative, but

*“Selective breeding is nothing else than genetically modifying. And genetic engineering is in other words the shortening of the evolution.”*

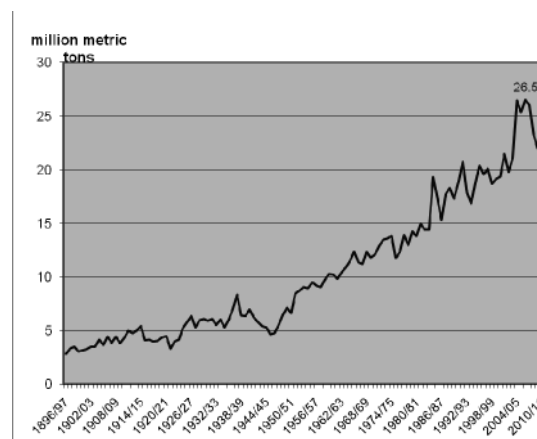
Refusing genetic engineering makes the food problem even more daunting.

### Conclusions

- We will have a desperate shortage of fertile farmland in the near future.
- Arable land on which non-food crops are growing today has to be used more and more for food crops.
- Food crops should be used for feeding people, not for animal feed or bio-fuels.

### Cotton: Production, Planted Areas & Yield

Over the last 60 years cotton production has continuously increased (see Figure 5).



**Figure 5.** Cotton Production 1896-2010 [10].

The area on which cotton was grown fluctuated between 29 and 36 million hectares. At an average this is only about 2 % of the worlds arable land but the percentage in those climatic regions where cotton can be grown is of course much

higher.

During the last years the cotton growing area shrunk from 35.7 to 30.6 hectares (in 2010/11, the area was increasing because of the extreme high cotton price) and it will certainly continue to shrink further in the future. Many cotton growing countries are highly populated with a tremendous need to increase food production. The area for food has to be expanded. More and more farmers decide to cultivate plants that contribute to nutrition which brings higher and primarily safer incomes.

In the US, in China and in Europe cotton farmers receive huge amounts of subsidies (e.g. in 2009/10: 5.3 billion US-\$) [11].

In addition, there is a continuous land loss by soil degradation (desertification, salinization etc.) reducing the overall arable land available.

Cotton Year	Production	mill. tons
2009/10	ICAC preliminary (May 2011)	22.00
2010/11	ICAC projection (May 2011)	24.80

Year	Area mill. ha (assumption)	Yield kg/ha (assumption)	Theoretical maximum production mill. tons
2015	31.0	850	26.35
2020	30.0	875	26.25
2025	29.0	900	26.10
2030	28.0	925	25.90

Figure 6. Assumption of Cotton Production for the next two Decades [12].

As a consequence, there will be less land available for cotton production. Projections indicate (see Figure 6) that the cotton planted area will drop to approximately 28.0 million hectares until 2030. Within the same period, because of an intensified cultivation of genetically modified cotton, the yield (actual: close to 800 kg/ha) however will continue to increase for the next two decades and will reach a level of about 925 kg/ha in 2030. The loss of cotton planted areas can partly be compensated. But still the overall cotton production in the foreseeable future will decrease: based on the above assumptions the maximum possible production at that time will be about 26 million metric tons of cotton per year!

### Textile Consumption

Income and population growth are the major factors driving increases in textile consumption.

The world population will increase by 1.4 billion people during the next 20 years (see Figure 7).

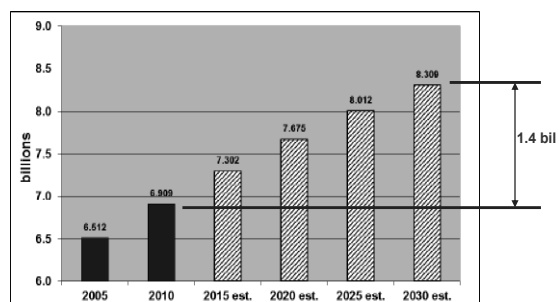


Figure 7. Growth of the Population 2005–2030 [13].

The per capita fibre consumption, more or less in parallel with the income, has grown at an average rate of 1.8 % per annum over the last 10 years (see Figure 8).

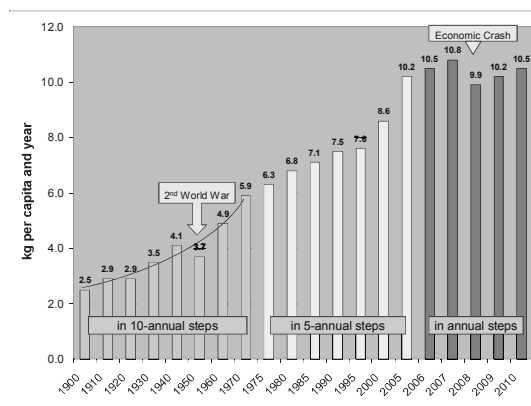
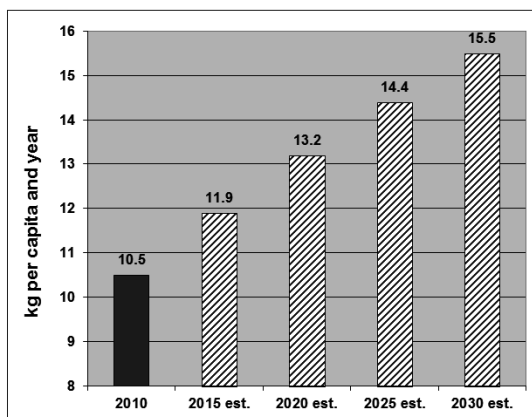


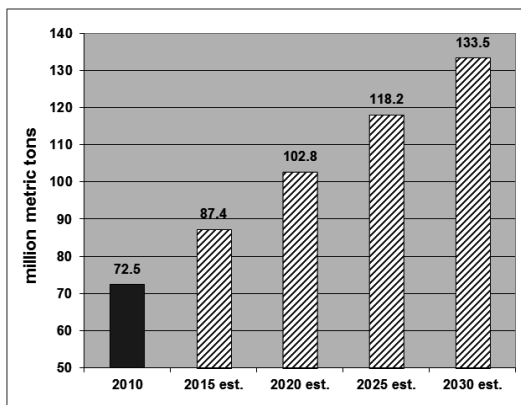
Figure 8. Fibre Consumption per Capita (1900 – 2010) [14].

It is projected to grow by 2.5 % p.a. in the coming 5 years and thereafter to decline to about 1.5 % in the following years (see Figure 9).



**Figure 9.** Per Capita Textile Fibres Consumption 2010 – 2030 [15].

Both, the population growth and the growth of the per capita textile consumption resulted in a continuous, substantial increase of the overall fibre consumption. It has reached 72.5 million tons in 2010 and is projected to grow with an average growth rate of 3.1 % p.a. to a level of 133.5 million tons in 2030 (see Figure 10).



**Figure 10.** Textile Fibres Consumption 2010–2030 [16].

### Cellulosic and Synthetic Fibres

The physiological performance of cellulose fibres - cotton or man-made - is unmatched by any other man-made fibre. They are *hydrophilic* and stand for absorbency and breathability. These inherent physiological fibre properties are ideal for the *moisture\_management*. The fibres can absorb sufficient moisture, which they then release into the surrounding air. This function ensures an adequate temperature balance on the skin, especially where textiles touch the skin.

Different to petroleum-based synthetic fibres (Polyester, Polyamide, Polypropylene, Polyacrylonitrile and others) cellulosic fibres are ideal in all fields of application where moisture management and physiological performance are of high importance, whether this is in the textile and garment industry for woven and knitted fabrics or in nonwovens or industrial products.

For several decades the growing fibre demand was mainly covered by synthetic fibres (see Figure 11). They entered the fast growing applications with a lower importance of properties typical for cellulose.

Year	Wool	Cotton	Manmade cellulosic fibres	Synthetic fibres	Total	%-age of cellulosic fibres
Historical Data						
1900	0.7	3.2	0.0	0.0	3.9	82.1
1920	0.8	4.6	0.0	0.0	5.4	85.2
1940	1.1	6.9	1.1	0.0	9.1	87.9
1960	1.5	10.1	2.7	0.7	15.0	85.3
1980	1.6	13.8	3.5	10.8	29.7	58.2
2000	1.4	18.9	2.8	28.4	51.5	42.1
2005	1.2	24.8	3.3	37.0	66.3	42.4
2010	1.2	21.8	4.2	45.3	72.5	35.9
Future (assumption)						
2015 est.	1.2	26.4*	6.2	53.6	87.4	37.2
2020 est.	1.2	26.3*	10.3	65.0	102.8	35.6
2025 est.	1.2	26.1*	14.8	76.1	118.2	34.6
2030 est.	1.2	25.9*	19.0	87.4	133.5	33.6

\* Possible peak production

**Figure 11.** Historical and Future Development of Fibre and Filament Consumption [17].

While still growing in absolute terms until the beginning of this millennium, the share of cellulosic fibres continuously dropped. However, in the recent decade the cellulosic fibre supply, because of the limitations to increase the cotton production, also in absolute terms, could no longer meet the growing demand.

Already from 2006/07 onwards the cotton demand outweighed the supply (see Figure 12) and presently the global cotton inventories are on the lowest level in 14 years.

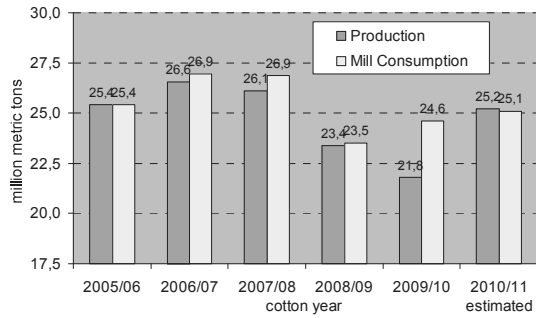


Figure 12. World Cotton Production and Consumption [18].

As a consequence, cotton prices during the last two years have risen strongly (more than 300 %) (see Figure 13) and it can be expected that they will even out on a high price level with the stagnation or the decline of the production.

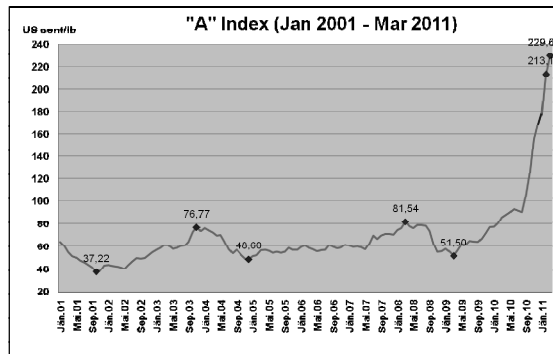


Figure 13. "A" Index (Nov 2008 – Oct 2010) [19].

The FAO Food Price Index shows a similar trend. Food prices are also exploding (see Figure 14).



Figure 14. "FAO Food Price Index" (1990 – 2010) [20].

### Cellulosic fibre gap

Based on the pattern of required fibre properties in different applications it can be projected that cellulosic fibres – natural and man-made - in the future will still make 33 to 37 % of the fibre demand (see Figure 15 and 16).

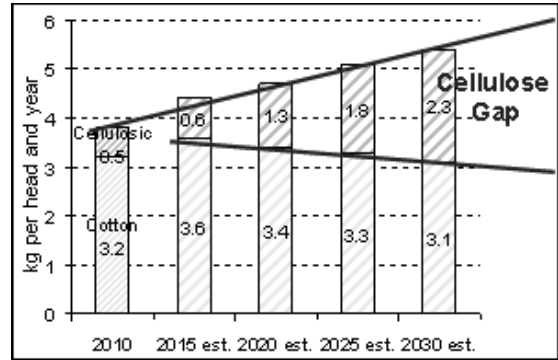


Figure 15. Per capita consumption of cellulosic fibres (in kg per head and year) 2010-2030(est) [21].

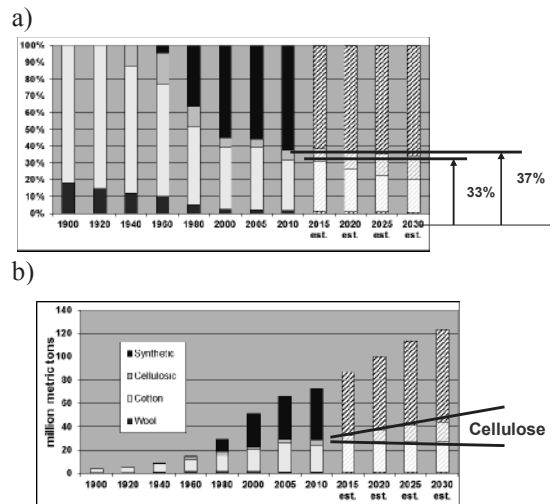


Figure 16. Consumption of different fibres 1900 – 2030: a) in % of total consumption and b) in mill. tons [22].

The annual per capita consumption of cellulosic fibres will increase from presently 3.7 kg to 5.4 kg in 2030. However, due to the limitations to increase the production, it will only be possible to cover 3.1 kg of this demand with cotton.

The only way to fill the resulting cellulosic fibre gap (see Figure 16) and to secure supplies is to increase capacities for man-made cellulosic fibre production.

This process has already started with significant investments in recent years.

Man-made cellulosic fibres are an ideal

substitute for cotton (see Figure 17)!

	Vis- cose	Vis- cose- Blends	Lyocell	Lyocell - Blends	Modal	Modal- Blends
<b>Woven and knitted fabrics:</b>						
<b>Apparel:</b>						
Underwear			√	√√	√√	
Knits	√	√	√	√		√
Bottom weights		√	√	√√		√
Active wear				√√		
Socks				√√	√√	
Shirts / Blouses			√	√√		
<b>Home textiles:</b>						
Bed linen			√	√√		
Towels				√	√√	
Filling				√		
<b>Nonwovens:</b>						
Cleaning rags	√	√		√		
Sanitary articles	√	√		√		
Baby wipes		√		√√		

**Figure 17.** Man-made Cellulosic Fibres as a Substitute for Cotton.

Companies which are mainly using cotton today will have to add man-made cellulosic fibres to their production programme.

To a large extent they can be tailored and accordingly be selected to the application. With Viscose, Lyocell, Modal, Acetate, Cupro, Triacetate, etc. several types of man-made cellulosic fibres are on the market.

**Sustainability**

The sustainability of products and processes is a complex, but in view of the future extremely important topic. Dimensions that need to be considered in an assessment are the relevance to the ecology (effect to the environment), the economy (value generation) and the social responsibility (enhancing the quality of life).

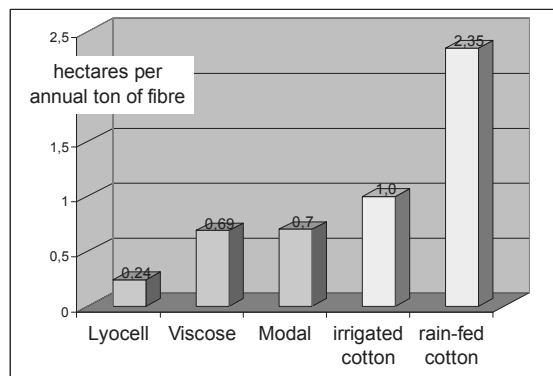
In comparing the sustainability of cotton with the sustainability of man-made cellulosic fibres, the main differences result from the way of cultivation (e.g. the use of scarce agricultural land, synthetic

fertilisers and pesticides), from manipulation of the genom and the water consumption.

Today, 70 % of the cotton is already genetically modified and approximately 1 % is “organic cotton”.

The implications of the scarcity of prime fertile agricultural land, good for food production in densely populated developing countries have been addressed already.

Compared to cotton cultivation man-made cellulosic fibres are based on wood, which is grown in forests on marginal land. Without the need to use synthetic fertilisers or pesticides and without the need for irrigation, the yield of cellulose fibres from Central European beech forests and from fast-growing eucalyptus is much higher (see Figure 18). Life cycle analyses show that man-made cellulosic fibres have a much smaller carbon footprint compared to cotton.



**Figure 18.** Land needed for the production of various cellulosic fibres [23].

Only 45 % of the cotton grows based on natural rains. Cotton production based on irrigation requires 15 to 35 times more water than cellulose fibre production based on wood pulp (see Figure 19). The water either is provided by flood or furrow irrigation (97 %), mobile irrigation (2 %) or drip irrigation (1 %).

The sustainability implication of water utilisation will substantially grow in the future. Today, already approximately one third of the world population suffers from water shortage. Until 2025, this share is likely to expand to two thirds! Several studies addressing this problem concluded

that “Water will become the oil of the future!”

Cotton already has caused the virtual disappearance of the Aral Sea, formerly the 4<sup>th</sup> biggest freshwater sea on earth. This environmental disaster, in a time-span of only three decades, resulted from excessive use of the inflowing rivers for cotton irrigation.

In spite of being a natural fibre, cotton in comparison to man-made cellulosic fibres – like Viscose, Lyocell or Modal – is not

sustainable at all (see Figure 20).

The natural origin of man-made cellulosic fibres from the renewable resource wood contributes to a sustainable future.

Fibres with prefixes as “eco-”, “bio-”, “natural-” and “organic-” are not always sustainable. For example water consumption is not a criterion for the certification as organic cotton. This proves that even “bio” is not necessarily “eco” as well.

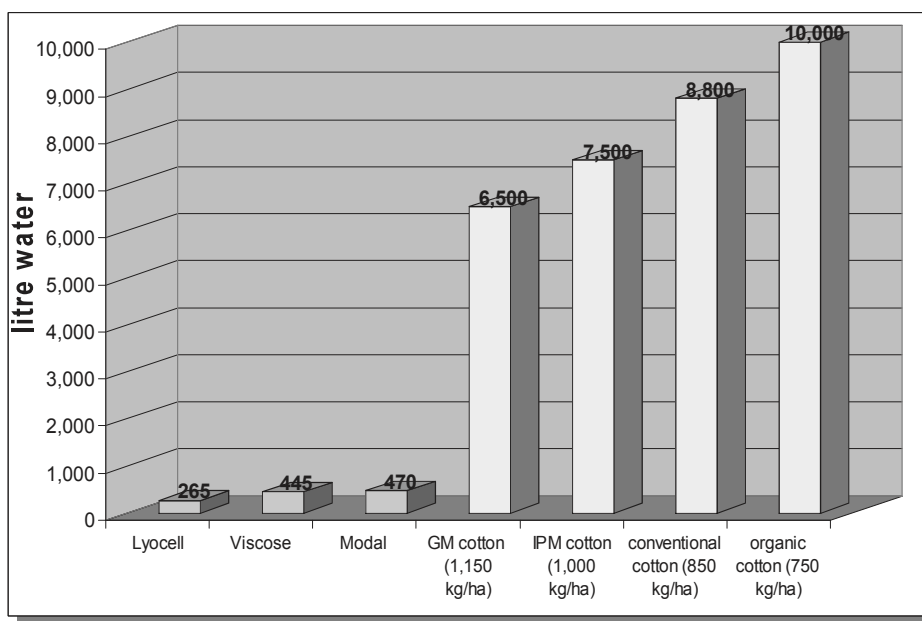
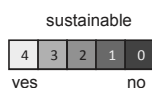


Figure 19. Water requirement for one kg of fibres [24].

		Man-made Cellulose Fibres				Cotton							
		Lenzing Viscose Austria	Lyocell (Tencel)	Lenzing Modal	Lenzing Viscose Asia	Gen-modified 70%		Organic 1%		IPM 10%		Conventional 20%	
Environmental impacts	Use of pesticides (+ human impact)	no	no	no	no	little		no		high		huge	
	Manure, fertilizer	no	very little	no	no	synthetic fertilizer (little)		only natural manure		synthetic fertilizer (high)		synthetic fertilizer (very high)	
	Soil degradation, depletion, ecotoxicity, acidification, eutrophication, etc												
Resources	Cumulative energy demand												
	Land use, yield	forest land	forest land	forest land	forest land	agricultural land 110 -120%		agricultural land 70 - 80%		agricultural land 80 - 90%		agricultural land 100%	
	Water consumption (incl. process + irrigation water)	rain-fed	rain-fed	rain-fed	rain-fed	rain-fed	irrig.	rain-fed	irrig.	rain-fed	irrig.	rain-fed	irrig.
Fibre quality		good	good	good	good	good		reduced		good		good	
Sustainability Points		26	24	24	21	22	20	21	17	16	13	14	11
Ranking		1	2	2	5	4	7	5	8	9	11	10	12



30 - 50% higher fibre price

rain-fed cotton <40% irrigated cotton >60%

Figure 20. Sustainability Ranking of Cellulosic Fibres [25].

## Final Conclusions

1. The demand for textile fibres together with the increasing world population and the per capita fibre consumption will continue to grow.
2. The production of natural fibres will remain constant or shrink. The growth of total fibre consumption therefore can only be covered by man-made fibres.
3. Certain properties of cellulosic fibres (Cotton, Viscose, Lyocell, Modal and others), especially their physiological performance, cannot be substituted by petroleum-based synthetics (Polyester, Polyamide, Polypropylene, Polyacrylonitrile and others).
4. Cellulosic fibres – natural and man-made - therefore also in the future will make up 33 – 37 % of the fibre market. Companies which are mainly using cotton today will have to add man-made cellulose fibres to their production programme.
5. Man-made cellulose fibres are extremely sustainable fibres. In comparison to cotton they have some important assets (see Figure 20):
  - No arable land is necessary. The trees (eucalyptus and beech) for the pulp production are growing in forests or on marginal land,
  - less water consumption,
  - no input of pesticides and fertilizers.
6. Man-made cellulose fibres are really ecological fibres: The substitution of cotton by man-made cellulose fibres is an important step in order to protect our environment.

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