WWF

BACKGROUND PAPER

THE IMPACT OF COTTON ON FRESH WATER RESOURCES AND ECOSYSTEMS

A PRELIMINARY SYNTHESIS

May 1999

This report was prepared for WWF by Jens Soth, Environmental Protection Encouragement Agency, Hamburg (Germany), and Christian Grasser and Romina Salerno, Kiefer & Partners AG, Management Consultants for Energy and Environment, Zurich (Switzerland). Toxicity data on cotton pesticides (Appendix 4) were compiled by Philipp Thalmann, Kueng-Biotech and Environment, Bern, Switzerland, and added to the report in April 2000.

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FOREWORD AND SCOPE OF THE REPORT

Current situation

freshwater – a future challenge

Many people are aware, that global freshwater withdrawals increase rapidly and that there might be a freshwater crisis awaiting future generations if not action is taken. But there are also qualitative aspects in the freshwater discussion: water is more and more polluted. Access and availability of safe and clean water to meet basic needs for a growing population is one of the big challenges on the global political agenda.

ecological freshwater crisis

Another important factor in the freshwater discussion is less known: the ecological freshwater crisis. 25% of the freshwater ecosystems have been degraded or lost in the 25 years from 1970 to 1995. This alarming rate in the decline of freshwater biodiversity and habitats is a clear and direct challenge to conservation. Existing international efforts to conserve freshwater ecosystems need to be further increased.

new and integrated strategies

But new strategies are required as well. Approaches which integrate ecological requirements and essential human needs must be strengthen. Opportunities for co-ordinated management of the conservation community with the water resources development community, policy makers, partners in the relevant sectors from farmers to business and industry should be identified. Effective cooperate actions for freshwater conservation need to be developed.

cotton and freshwater

The WWF international is currently assessing the potential of cotton and freshwater as a possible starting point for new opportunities for the freshwater programme and the Living Waters Campaign. Agriculture is the sector which presents the single greatest threat to the conservation of freshwater habitats and biodiversity. Cotton is a crop of global importance and is a strong symbol to demonstrate the human pressure on freshwater resources and ecosystems. Cotton addresses to people in cotton consuming countries as well as to cotton producing countries. In Latin America, Africa and Asia, cotton is one of the most important cash crops for smallholders in many countries. Cotton links freshwater issues with a tangible product of daily use and offers good and attractive communication tools. It has the potential to reach new target audiences outside the conservation scene with an effective message on global freshwater issues. These are some reasons, why Cotton could be a good model crop to promote a change towards a more sustainable water management and new partnerships.

Aim and scope of this draft report

basic facts and figures

This draft report provides basic facts and figures on cotton and freshwater. However, the report can only be seen as a first sketch of the size and nature of the issue. It is a preliminary synthesis of existing scientific data. No recommendations or strategies are proposed in this paper.

limitations

Due to a lack of data for several issues, the fact report has it‘s clear limitations. For example, a detailed analysis of impacts on specific catchments in cotton growing areas was not possible at this point of the study due to the lack of available data on a regional scale. Crop specific agricultural data are hardly accessible. Only little data of ground water pollution by pesticides (witch are not crop specific) do exist. Although it can be assumed that cotton pesticides have severe effects on wildlife, little information could be accessed where investigations proofed clear links of documented fish or bird kills due to pesticides to a specific crop.

cotton and the destruction of freshwater ecosystems

However, the fact findings show clearly, that cotton is a relevant factor for the destruction of freshwater ecosystems on a regional as well as on a global scale. We hope that the draft report forms a good starting point for the discussion on the issue of Cotton and Freshwater in the WWF network.

call for comments and additional information

Readers are invited to comment the report critically. Any inputs and additional information, especially good sources of regional cases of impacts of cotton on freshwater ecosystems and biodiversity are most welcome. They can be integrated into following publications and feed into the ongoing process for the project development for Fresh Water and Cotton.

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EXECUTIVE SUMMARY

Cotton and global freshwater resources

Only a tiny fraction of the total amount of global freshwater is available as a yearly renewable resource. Moreover this resource is very unequally distributed between different countries and different continents.

Regarding national water data it can be concluded that some cotton producing countries can provide their total freshwater withdrawal with internal, i.e. national, renewable freshwater but others, for example Egypt or Uzbekistan, depend highly on renewable freshwater from other countries. Considering that the renewable water resources differ regionally and that irrigated cotton is grown mainly in dry climates than the sufficient availability of renewable freshwater on a local or regional level must be questioned.

With 69%, the agricultural sector has by far the largest share of global freshwater withdrawal compared with industrial and municipal use. Depending on the climatic situation, this share can increase in some countries to up to 98%.

Among the major cotton producing countries[1], in Pakistan or Uzbekistan the freshwater withdrawal figures for agriculture are well above the world average and account for 84% and 98% respectively, whereas those for Turkey and the USA for example, are below. In dry climates, freshwater withdrawal can challenge annual renewable freshwater resources, which in turn can lead to a long-term depletion of freshwater resources.

The consumption of freshwater for irrigation purposes

Irrigated cotton is mainly grown in regions with Mediterranean , desert or near-desert climates where freshwater is in short supply (e.g. Pakistan, Uzbekistan or Australia). The extensive irrigation of cotton has therefore a severe impact on the regional freshwater resources. This leads to a depletion of surface or ground water which can affect the river catchments and the wetlands laying downstream.

Considering that agriculture takes up about 69% of global freshwater withdrawal and that rice, wheat and cotton hold together 58% of the world-wide irrigated area, it is obvious that these three crops are the major consumers of freshwater. Of these three crops, rice is the most important, on a global scale, followed by wheat and cotton.

About 53% of the global cotton area is irrigated and mainly located in dry regions: Egypt, Uzbekistan and the province Xinjiang of China are entirely irrigated whereas in Pakistan and the North of India irrigation supplies most of crop water. As a result, in Pakistan already 31% of all irrigation water is drawn from ground water and in China the extensive freshwater use has caused falling water tables.

1 *The six major cotton producing countries are China, the USA, India, Pakistan, Uzbekistan and Turkey. Throughout the text these six countries will be referred to as "the top six".*

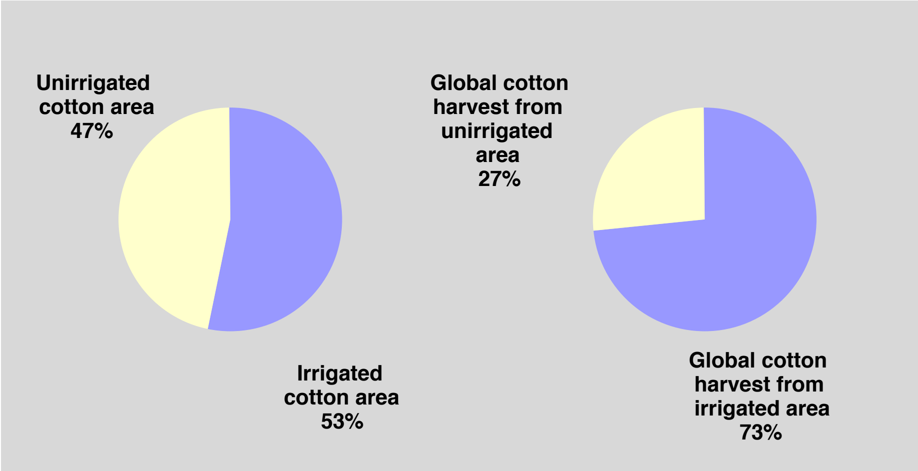

Figure I
World-wide irrigated cotton area and its harvest.

Most irrigation systems in cotton production rely on the traditional technique of flood irrigation – freshwater is taken out of a river, lake or reservoir and transported through an open canal system to the place of its consumption. Losses of freshwater occur through evaporation, seepage and inefficient water management. World-wide, irrigation efficiency is lower than 40%.

In some developing cotton producing countries, a shift in national agricultural policies towards local food production in support of food security (mostly determined by global and regional politics) may constrain cotton production. In others, new water management's policies (reduced water allocation to agriculture for economic and environmental conservation reasons) may reduce irrigated cotton production. Therefore, there might be a high interest of the cotton sector to promote improved water management for cotton (improved irrigation practices resp. improved soil moisture conservation in rain-fed cotton).

Technical innovations like drip irrigation or an improved water management (demand driven water supply) can reduce the extensive water demand for cotton production. Until today however, only 0.7% of the world-wide irrigated area (all crops) are supplied with drip irrigation.

Cotton and freshwater ecosystems

Cotton production uses agricultural chemicals heavily and therefore offers a significant risk of pollution of freshwater ecosystems with nutrients, salts and pesticides.

The share of cotton on global pesticide sales has averaged 11% and on the global insecticides market even 24%. At the same time, cotton acreage amounts to only 2.4% of the world's arable land. Therefore it is obvious that the pesticide use for cotton in relation to the area is disproportional.

Most pesticides used in cotton production are hazardous. From 46 insecticides and acaricides (90% of market share in cotton) five are extremely hazardous, eight are highly hazardous and twenty are moderately hazardous.

Figure II
The share of cotton on the global pesticide and insecticide market and on the world's arable land. It is obvious that the pesticide use for cotton in relation to the area of arable land that cotton takes up is disproportional.

The impact of cotton production on freshwater ecosystems and wetland follows different ways and mechanism. A view of the main mechanism is given in table I.
Run-off from fields and drainage water contaminates rivers, lakes and wetlands with pesticides and fertilisers and salts respectively. This pollutants can directly affect the biodiversity of freshwater ecosystems due to its toxicity or indirectly by accumulating.
The improper handling of pesticides (e.g. washing of equipment in rivers or leakage) has the same impact on surface waters and leads to a direct contamination of ground water systems.
The water withdrawal for an extensive irrigation can lead to falling water tables and to a depletion of freshwater resources in the end. On the other hand, extensive irrigation in dry climates results in a direct salinisation of soil. At the same time the water tables along the irrigation canals can increase leading to water-logging of soils and destruction of ecosystems.
Water logging and raising water tables occur as damaging side effects of badly managed irrigation schedule and due to missing drainage systems. Both can result in a secondary salinisation of soils.
The dam construction for irrigation and the land reclamation for cotton fields destroy

the original vegetation and the freshwater habitats. Besides, damming up rivers and streams does affect the flow regime of surface waters and can destroy freshwater ecosystems laying downstream.

Table I
Major impacts of cotton on freshwater ecosystems and freshwater biodiversity.

Mechanism	Pollutant/Change	Impact	Cases
Run off from fields	Fertiliser	Eutrophication and pollution	
	Pesticides	Wildlife contamination	
	Sediments		
Drainage	Saline drainage water	Salinisation of freshwater	China, Egypt, Uzbekistan
	Pesticide or fertiliser contaminated drainage water	Pollution of freshwater	
Application of pesticides	Insecticides, fungicides, herbicides and defoliants	Wildlife contamination	
	Spray drift (e.g. aerial application)	Contamination of adjacent wetlands, surface and ground water	
	Leakage of equipment	Contamination of surface and ground water	
Water withdrawal for irrigation	Use of ground water	Change of water table or depletion of ground water	New South Wales, Australia
	Use of surface water	Degradation of wetlands and lakes	Aral Sea, Yellow River Valley
Extensive irrigation	Water logging	Raising water tables and salinisation of soil surface	Australia, Indus River Valley, Uzbekistan, Pakistan
Dam construction for irrigation	Regulated water flow	Habitat destruction, change of water table and change of water flow	
Land reclamation	Change of vegetation	Habitat destruction	

BASIC INFORMATION ON COTTON

role as textile fibre

Together with flax and wool, cotton is one of the three natural fibres that have been in use by humankind for 5,000 years. Up until the 18th century, the share of these fibres used in textiles was 78% wool, 18% flax and only 4% cotton. Due to technical innovations however this has now changed and today cotton takes up 48% of textile production, while 45% is taken up by synthetics and the rest accounted for by other fibres.

cotton growing area

Cotton production occurs between 36° South latitude and 46° North latitude and is located in tropical and subtropical regions (Reller, 1997). The broad belt of irrigated cotton lays in Mediterranean and desert climate. It stretches from Spain to central Asia and contains those regions with similar climates in the west of North and South America and Australia (Gillham, 1995).

river catchment

Many cotton regions are located in important river catchments. The Indus River valley in Pakistan for example incorporates one of the greatest irrigation systems in the world. In table I the major river catchments are listed which can be affected by cotton production.

Table 1

River catchments in cotton producing areas

Country	River catchment
Brazil	e.g. Parana
China	Yellow River Valley (30.6%) Yangtse River (61.3%)
Egypt	Nile Valley
India	e.g. Narmada
Mali	Niger
Pakistan	Indus Valley (largest irrigation system world-wide; continues to India)
Turkey	Menderez, Gediz GAP Scheme A (Euphrat and Tigris)
Uzbekistan	Amu-Dar, Syr-Dar

irrigated cotton and rain-fed cotton

About 73% of cotton is produced in irrigated fields and only 27% under rain-fed conditions (freshwater is provided mainly by rain). The average yield of cotton is 854 kg per hectare for irrigated cotton and 391 kg per hectare for rain-fed cotton.

world production of cotton

In 1998 the world production of cotton amounted to 18.3 Mio tonnes of cotton lint and today, 33 Mio hectares of land are given over to cotton plantations. Whereas the area of cotton plantation's have remained more or less constant since 1930, cotton production has tripled in the last 70 years.

major cotton producing countries

The cotton production is unequally distributed over the world. Over 71% of the total cotton harvest occurs north of latitude 30° N where the major cotton producing countries are located (Gillham, 1995). Over 70 countries are involved in cotton production but the six major ones (China, USA, India, Pakistan, Uzbekistan and Turkey) account for over 75% of total world production (ICAC, 1995, Figures on cotton production by country are listed in appendix A3)

economy

Cotton plays a major role in the economy of many cotton producing countries. Cotton production however, is only one element in the multisectoral processing of cotton which has a high economical relevance. The cotton sub-sector in Mali for example represents 50% of the exports. In Pakistan over two thirds of the export earnings are derived by cotton and textiles and in Uzbekistan the sale of cotton lint accounts for even 75% of the export earnings. Besides, in many developing countries in Asia, Africa and Latin America cotton is the cash crop of smallholders.

1 COTTON AND GLOBAL FRESHWATER RESOURCES

Summary

Only a tiny fraction of the total amount of global freshwater is available as a yearly renewable resource. Moreover this resource is very unequally distributed between different countries and different continents.

Regarding national water data it can be concluded that some cotton producing countries can provide their total freshwater withdrawal with internal, i.e. national, renewable freshwater but others, for example Egypt or Uzbekistan, depend highly on renewable freshwater from other countries. Considering that the renewable water resources differ regionally and that irrigated cotton is grown mainly in dry climates than the sufficient availability of renewable freshwater on a local or regional level must be questioned.

With 69%, the agricultural sector has by far the largest share of global freshwater withdrawal. Depending on the climatic situation, this share can increase in some countries to up to 98%.

Among the major cotton producing countries[1], in Pakistan or Uzbekistan the freshwater withdrawal figures for agriculture are well above the world average and account for 84% and 98% respectively, whereas those for Turkey and the USA for example, are below. In dry climates, freshwater withdrawal can challenge annual renewable freshwater resources, which in turn can lead to a long-term depletion of freshwater resources.

1.1 GLOBAL FRESHWATER RESOURCES

global distribution of freshwater

Global freshwater resources consisting of hydrological water bodies (e.g. atmosphere, lakes or glaciers) are unequally distributed among different freshwater systems. The most visible form of freshwater, in lakes and river systems, holds only 0.26% of global freshwater resources. Another 0.9% is stored in soil moisture, swamp water and permafrost. About 30% is held in ground water systems, while ice and permanent snow contain another 68.9% (Shiklomanov, 1998).

sustainable freshwater withdrawal

These freshwater resources are only sustainable if the withdrawal of water is locally or regionally adapted to the temporal characteristics of the respective freshwater bodies. A ground water system, for example, can take hundreds or even several thousands of years to be refilled, whereas lakes need a few decades and river systems only several weeks (Baumgartner, 1990). In order to ensure the sustainability of freshwater resources, these time scales should be born in mind when freshwater resources are used extensively for agriculture or cotton production.

renewable freshwater resources

By considering the temporal characteristics of freshwater bodies the yearly renewable freshwater amount on a national or global level can be calculated. According to

1 *The six major cotton producing countries are China, the USA, India, Pakistan, Uzbekistan and Turkey. Throughout the text these six countries will be referred to as "the top six".*

Shiklomanov (1998), the mean value for the total amount of global renewable freshwater is 40,673 km^3 per year or 7,420 m^3 per capita and year (data for 1992). Compared to the annual withdrawal of freshwater of 644 m^3 per capita the renewable freshwater amount seems to be sufficient. This data, however, does not illustrate the distribution of renewable freshwater on a local or regional level where freshwater is scarce in some places.

renewable freshwater in cotton producing countries

Of the top six[1] cotton countries, China, USA, India Turkey, and Pakistan could provide their annual freshwater withdrawal with their internal renewable freshwater resources (see table 1.1), only Uzbekistan depends highly on an annual freshwater flow from other countries to meet its demands. This fact, along with that of the high freshwater flow from Pakistan to India and the freshwater flow from Turkey to its neighbours, are indicators of possible future water crises or conflicts if the "exporting" countries start using their renewable freshwater for themselves.

Table 1.1

Key data on freshwater resources for the top six cotton producing countries. Annual renewable freshwater according to internal sources of country and river flows to and from other countries for 1992 (WRI, 1994, n.a.: not available).

	Annual internal renewable freshwater		**Annual freshwater withdrawal**		**Annual river flows**	
	Total (km^3/yr)	Per capita (m^3/person/yr)	Per capita (m^3/person/yr)	Year of data	From other countries (km^3/yr)	To other countries (km^3/yr)
China	2800	2360	462	1980	0	n.a.
USA	2478	9710	1868	1990	n.a.	n.a.
India	1850	2100	612	1975	235	n.a.
Pakistan	298	2390	2053	1975	170	n.a.
Uzbekistan	9.5	440	4007	1989	98.1	n.a.
Turkey	186.1	3190	433	1989	7	69
World	40'673	7420	644	1987		

Critical remarks

hydrological data and freshwater ecosystems

Hydrological data on a global or national scale is only appropriate for discussion and estimation of the problem of water crises and freshwater availability on a national level. This data is not sufficient to estimate the availability of freshwater on a local or regional level or the impact of freshwater consumption on freshwater ecosystems. Furthermore, the amount of freshwater is only one quantitative aspect. For freshwater ecosystems, the temporal distribution of the available amount of freshwater during the year, or the quality

1 *top six refers to the six major cotton producing countries.*

of freshwater, are also extremely important.

data

The detailed data per country should be viewed with a healthy scepticism because many countries do not measure or report detailed freshwater resource data. Even though there is a global network to measure hydrological data, there still exist a lot of blind spots for which data is indirectly estimated.

1.2 GLOBAL FRESHWATER WITHDRAWAL

freshwater withdrawal in different sectors

An analysis of the freshwater withdrawal by sector shows that agriculture has the greatest freshwater withdrawal both world-wide and in most individual countries (see figure 1.1 and table 1.2). Globally, agriculture has a share of 69% on total freshwater withdrawal, followed by industry and municipal with 23% and 8% respectively (see figure 1.1). In some countries or continents the impact of agriculture is even higher. In Asia the mean share of agriculture is 86% and in Africa 88%. In some cotton growing countries like India, Pakistan or Egypt it amounts to over 90% (see table 1.2).

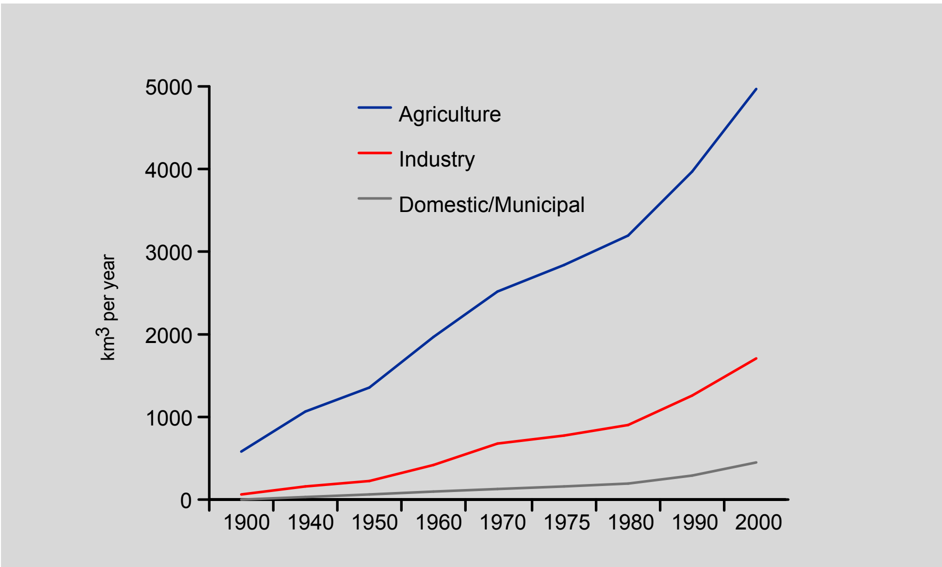

Figure 1.1
Global freshwater withdrawal by sector, 1900 – 2000 (in the three sectors agriculture, industry and municipal, data from Shiklomanov, 1993).

global freshwater withdrawal

Due to the growing world population, the increase in irrigation and socio-economic changes, global freshwater withdrawal has increased more than six times in this century (from 579 km^3 per year to 3,750 km^3 per year) and will further increase to 5,100 km^3 per year for 2025 (Shiklomanov, 1993; Shiklomanov, 1998).

freshwater withdrawal in the major cotton producing countries

The annual freshwater withdrawal per capita and the impact of agriculture on this withdrawal vary among the top six cotton producing countries. The freshwater withdrawal of these countries amounts to between 433 m^3 per person and year (Turkey) and over 4,000 m^3 per person and year (Uzbekistan). This amounts to between 8% (Turkey) and

76% (Uzbekistan) of total annual renewable freshwater. In very dry countries like Egypt or Mali the percentage can be as high as 97% (WRI, 1994). In the top six cotton producing countries Except for the USA and in Turkey, the significance of the agricultural sector on freshwater withdrawal is higher than the global average. Between 84% (Uzbekistan) and 93% (India) is used for agriculture, compared to the global average of 69%.

Table 1.2

Freshwater withdrawal in the top six cotton producing countries (data from Gleick, 1993)

Country (year of data)	Freshwater withdrawal		Per capita	Domestic	Industrial	Agricultural
	km^3/yr	% of renewable freshwater	m^3/person/yr	%	%	%
China (1980)	460	16	462	6	7	87
USA (1990)	467	19	1868	13	45	42
India (1975)	380	18	612	3	4	93
Pakistan (1975)	153.4	33	2053	1	1	98
Uzbekistan (1989)	82.2	76	4007	4	12	84
Turkey (1985)	15.6	8	433	24	19	57
World (1987)	3240	8	644	8	23	69

Critical remarks

accepted data base

Even though different definitions of freshwater 'withdrawal' or 'consumption' exist, the data cited above seems to be widely accepted and is used in publications of FAO, OECD or World Bank. Nevertheless it should still be used with care.

validity of data

The survey of consumption data does not cover all countries. Therefore freshwater withdrawal must be estimated and calculated indirectly by using other regional, national or continental data (e.g. hydrological data).

definition of withdrawal and consumption

There exist different ways of defining freshwater use by human activities. Freshwater *withdrawal* refers to all freshwater transferred from its source to its place of use, but does not mean that it is necessarily used for an activity (e.g. losses are included). On the other hand, the term *consumption* often indicates the direct consumption of freshwater by an activity (i.e. without losses). In some studies, however, the term 'consumption' is also used to refer to the total freshwater needed to provide a product or a service, including all losses and indirect freshwater uses. Furthermore, in many cases the system boundaries of the investigation are not properly defined. For the estimation of the amount of freshwater used by agriculture and other sectors, statistical data on freshwater withdrawal is used because the database for withdrawal seems to be the most comprehensive.

2 THE CONSUMPTION OF FRESHWATER FOR IRRIGATION PURPOSES

Summary

Irrigated cotton is mainly grown in regions with Mediterranean or desert or near-desert climates where freshwater is in short supply (e.g. Pakistan, Uzbekistan, Australia or the South of the USA). The extensive irrigation of cotton has therefore a severe impact on the regional freshwater resources. This leads to a depletion of surface or ground water which can affect the river catchments and the wetlands laying downstream.

Considering that agriculture takes up about 69% of global freshwater withdrawal and that rice, wheat and cotton hold together 58% of the world-wide irrigated area, it is obvious that these three crops are the major consumers of freshwater. Of these three crops, rice is the most important, on a global scale, followed by wheat and cotton.

About 53% of the global cotton area is irrigated and mainly located in dry regions: Egypt, Uzbekistan and the province Xinjiang of China are entirely irrigated whereas in Pakistan and the North of India irrigation supplies most of crop water. As a result, in Pakistan already 31% of all irrigation water is drawn from ground water and in China the extensive freshwater use has caused falling water tables.

Most irrigation systems in cotton production rely on the traditional technique of flood irrigation – freshwater is taken out of a river, lake or reservoir and transported through an open canal system to the place of its consumption. Losses of freshwater occur through evaporation, seepage and inefficient water management. World-wide, irrigation efficiency is lower than 40% (Gleick, 1993).

Technical innovations like drip irrigation or an improved water management (demand driven water supply) can reduce the extensive water demand for cotton production. Until today however, only 0.7% of the world-wide irrigated area (all crops) are supplied with drip irrigation.

2.1 IRRIGATED AGRICULTURE

higher yield in irrigated cotton

Irrigation together with the use of high-yielding cotton crops, pesticides and fertilisers leads to an increased cotton yield. For irrigated fields the average yield is 854 kg per ha in contrast to 391 kg per ha for rain-fed cotton. Therefore, irrigated fields (53% of the global cotton area) provide 73% of the global cotton harvest (see figure 2.1, Hearn, 1995).

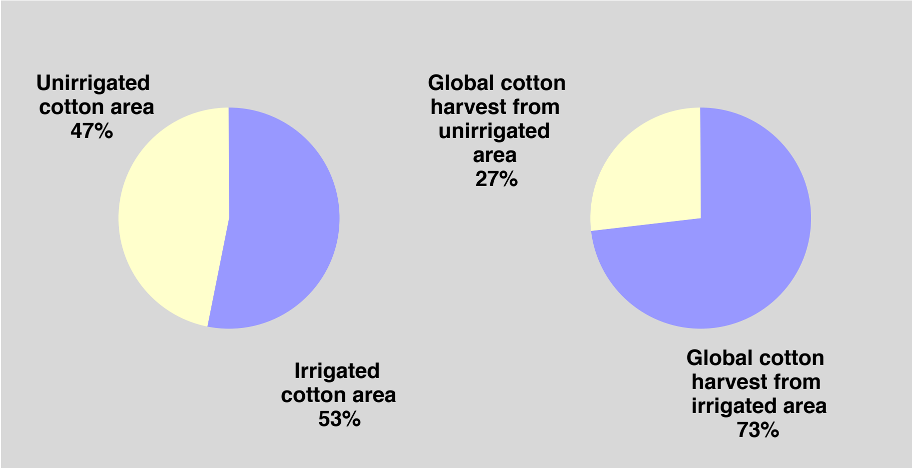

Figure 2.1
World-wide irrigated cotton area and its harvest (Hearn, 1995, cited in Gillham, 1995).

Critical remarks

freshwater withdrawal for irrigation

Although detailed data on other uses is unavailable, not all freshwater withdrawn for agricultural purposes is used for irrigation. Data on livestock farming, for example, suggests that it is something that should also be taken into account (WRI, 1994; Klohn, 1998).

national data for irrigated cotton

For a discussion of the significance of irrigation in cotton producing countries, national data on irrigated cotton area and its harvest would be needed. Unfortunately, the available data is not crop-specific.

2.2 COMPARISON BETWEEN DIFFERENT IRRIGATED CROPS

irrigated crops

Rice holds the biggest share on the world-wide irrigation acreage with 34%, followed by wheat with 17% and cotton with 7%. Irrigation is also used to produce other types of crop, vegetables, sugar cane and fruits (see figure 2.2; Wolff, 1995).

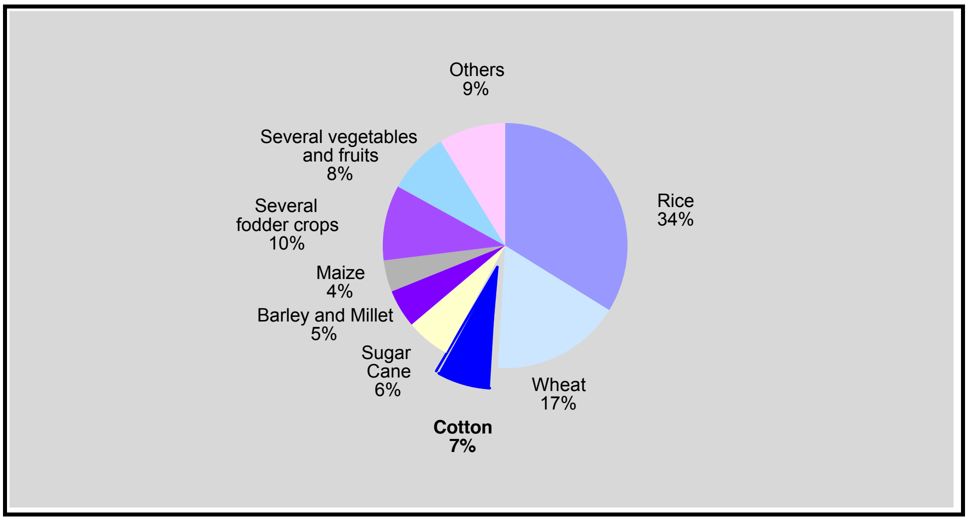

Figure 2.2
Share of different crops and plants on the global irrigated acreage (Data from Wolff,

1995).

irrigated agriculture in cotton producing countries

Among the top six cotton countries, the percentage of irrigated acreage for cotton in relation to the total irrigated acreage is higher than the global average. In Egypt, for example, the cotton acreage takes up 15% of the national irrigation area and in Pakistan about 16% (calculated from Postel, 1992 and ICAC, 1993, see also table 2.1 and 2.3). The projected share of cotton on the total irrigated area in the new South-east Anatolia program in Turkey is between 14% and 43% (Mart, 1997).

Table 2.1
Cropland, irrigated land, cotton acreage and cotton yield in the top 6 cotton producing countries ([1]: WRI, 1994; [2]: ICAC May 1995).

	Total cropland 1991[1] Mio ha	Irrigated land 1989-1991[1] Mio ha	Cotton acreage 1993/94[2] Mio ha	Cotton yield 1993/94[2] t per yr
China	96554	34081	4985	3738750
USA	187776	18777	5173	3512467
India	169700	45819	7315	2092090
Pakistan	21140	16912	2804	1312272
Uzbekistan	26100	10701	1676	1300576
Turkey	27689	17998	559	580801
World	1441573	245067	30527	16667742

2.3 THE IMPACT OF COTTON IRRIGATION ON FRESHWATER WITHDRAWAL

freshwater consumption for irrigation

The amount of freshwater used to irrigate a field depends on the crops or vegetables planted, on climatic factors and on soil characteristics, but also on the irrigation systems used and on water management. According to estimated water requirements based on evapotranspiration figures (see table 2.2), the water intensity of cotton per area is similar to rice. Wheat, as well as beans and different vegetables, needs less freshwater per area. Sugar cane however has a higher water requirement per area.

freshwater withdrawal for irrigated crops

By considering the global irrigated acreage and water requirements per area of the different crops, it can be estimated that rice is the crop with the greatest impact on global freshwater withdrawal, followed by wheat an then by cotton and sugar cane.

qualitative aspects of cotton irrigation

Irrigated cotton is not uniformly distributed around the globe but is located in a belt containing among others the top six cotton producing countries. Furthermore, the irrigated cotton belt lays in Mediterranean or desert or near-desert climates where cotton must be fully irrigated without significant rainfall during the growing season (see table 2.3). To meet the water demand for cotton production, surface and ground water must be extensively used. In Pakistan for example already 31% of all irrigation water is drawn from ground water resources. In China's Yellow River Valley the extensive water withdrawal has caused falling ground water tables and therefore there is a shortage of water for irrigation (Gillham, 1995).

Table 2.2
Freshwater requirements for different agricultural products. "Water requirement per area" is based on evapotranspiration figures (FAO, 1977 and Kammerer, 1982) and "Water requirement per kilogram product" is based on selected data from Klohn (1998), Vaidya (1993) and Rehm (1996).

Crop	Water requirement per area (litres per m^2)	Water requirement per kg product (litres per kg)
Potatoes	350-625	500
Wheat	450-650	900
Rice	500-950	1'900
Soya	450-825	2'000
Sugar	1,000-1,500	1,500-3,000
Cotton lint	550-950	7,000-29,000

Table 2.3
Extent of irrigation for cotton in selected countries (Gillham, 1995).

Extent of irrigation	Country (Region)
Entirely irrigated	e.g. China (Xinjiang), Egypt, India (North), Pakistan, Uzbekistan
Partially irrigated	e.g. China, India
Entirely rain-fed:	e.g. Brasil, Mali, Tanzania

freshwater withdrawal for cotton irrigation

Calculated per kilogram of product (e.g. grain or cotton lint), cotton is the most freshwater-intensive crop. It uses between 7,000 and 29',000 litres of freshwater per kilogram of cotton lint, the lower value standing for highly efficient drip irrigation in Israel. When calculating the global freshwater consumption of cotton irrigation, two assumptions must be taken into consideration: Firstly, it is assumed that the freshwater use stated above comprises the total freshwater demand for cotton production. Secondly, according to Klohn (1998) generally only 40% of the freshwater demand in irrigated arises actually provided by irrigation, the remaining 60% by rain. Taking these two assumptions into consideration, the global freshwater withdrawal for cotton production would equal between 50 km^3 and 210 km^3 per year. This is between 1% and 6% of total global freshwater withdrawal.

Critical remarks

global data

The figures concerning the freshwater demand of different crops and plants are only mean values and the variation is very high depending on climate, soil characteristics and irrigation systems. For this reason, the data cited above can give an indication of the global share of cotton on freshwater consumption but can not be applied on a local or regional level.

comparison is difficult

When comparing the freshwater demand of different crops or products, it should be taken into account that different products serve different needs. A kilogram of wheat, for example, can not be directly compared to a kilogram of cotton because the former can not shelter you from the elements while the latter can not fill your stomach.

economical perspective

A similar consideration also applies to the question, of whether a high freshwater demand is better or worse than a low freshwater demand. When considering scarce resources, economists tend to stress the allocation efficiency – freshwater should be used for those crops where it produces the most value. For this reason, the allocation of freshwater to different uses (e.g. wheat, maize or cotton) should rely on the analysis of marginal cost and benefits rather than on mean freshwater consumption data (Kirda, 1999).

2.4 THE INFLUENCE OF IRRIGATION METHODS ON FRESHWATER CONSUMPTION

flow irrigation with high losses

Agriculture is not only the world largest water user in terms of volume, it is also a relatively low-value, low-efficiency and highly subsidised water user (Kandiah, 1998). Most irrigation systems in cotton production rely on the traditional technique of flood irrigation – freshwater is taken out of a river, lake or reservoir and transported through an open canal system to the place of its consumption. Losses of freshwater occur through evaporation, seepage and inefficient water management. World-wide, irrigation efficiency is lower than 40% (Gleick, 1993).

cotton yield

An example in Pakistan shows that the yield of farmers with inefficient water management was between 60% and 70% below the upper range of yields that some other farmers in the same region achieved (Postel, 1992). With better practice of conveyance and application, water losses should be not higher than 15% of the freshwater diverted by the reservoir (Ait Kadi, 1993, cited from Kirda 1999).

supply driven irrigation

There are several reasons for low water efficiency. The water schedule often does not match the actual freshwater demand of plants but relies on the characteristics of the water supply system. This supply-driven water distribution exists, for example, in Pakistan, India, Uzbekistan and Egypt (Gleick, 1993), and results in a loss of between 50% and 80% of the freshwater used (Shiklomanov, 1996). Furthermore, large cotton production areas rely on canals developed 50 or sometimes 100 years ago, which are in disrepair and cause major freshwater losses (Gillham, 1995; Reller, 1997). Other reasons are run off, tail waters, deep percolation and lack of training and experience (Kirda, 1999).

improved irrigation techniques

The impact of water management and irrigation techniques can be illustrated through the example of Israel. With sophisticated drip irrigation the freshwater demand of cotton could be cut down to 7,000 litres per kilogram of lint cotton (Reller, 1997). At the same time, the yield of cotton in Israel is the highest in the world with 1,833 kg per hectare of cotton fibres (ICAC, 1998, cited from Meyers, 1999). However, the world-wide share of drip irrigation or sprinkler irrigation is still very low. It is used on only 0.7% of world-wide irrigated area (Postel, 1992). Furthermore, according to recent scientific studies, cotton can also be grown under a controlled water stress (deficit irrigation) without severe negative impact on its yield and sometimes with an improvement of quality (Kirda, 1999b).

Critical remarks

obstacles for new irrigation techniques

From a technical perspective, new irrigation methods like drip irrigation or deficit irrigation promise a simple solution to increase water efficiency. However, the implementation of such technology runs into several obstacles. Firstly, drip or sprinkler irrigation systems need investment, energy and technical know-how in order to maintain and run, whereas flood irrigation needs only manual labour. Secondly, in countries with a long history of irrigation, traditional flood or furrow irrigation systems are an integral part of their cultural system of values, habits and traditions.

irrigation in general

Inefficient freshwater use in irrigation is a problem concerning not only cotton, but all crops and plants cultivated under irrigation.

2.5 TRENDS IN IRRIGATION

historical development

Along with a growing world population, the global irrigated area has steadily increased during the last 60 years. Between 1930 and 1995 agricultural area under irrigation increased from 47.3 Mio hectares to 254 Mio hectares (Kirda, 1999; Shiklomanov, 1998).

decreasing growing rate

Although, on a world-wide scale, area under irrigation is still increasing, its growth, decreasing from 2.3% to 1% at the end of the 1970's, does not match the rate of world population growth any more. Between 1978 and 1989 area under irrigation decreased from 48 to 45 hectares per capita.

restrictions for cotton production

In some developing cotton producing countries, a shift in national agricultural policies towards local food production in support of food security (mostly determined by global and regional politics) may constrain cotton production. In others, new water management's policies (reduced water allocation to agriculture for economic and environmental conservation reasons) may reduce irrigated cotton production (Kandiah, 1998). Therefore, there might be a high interest of the cotton sector to promote improved water management for cotton.

rising costs for new irrigation systems

Low commodity prices, high energy costs and economic conditions that discourage investments in agriculture are the reasons for the decreased rate of growth. If these conditions change, then the rate of growth will increase again (Gleick, 1993). Another reason is the increasing demand to build new irrigation systems. In India and Indonesia, for example, the real costs of new irrigation projects have doubled in the last 25 years. On a global average the real costs have risen by between 70% and 116% during the 1980s (Serageldin, 1996, cited from Dinar, 1998).

economical efficiency

The world as a whole, and countries with limited water supplies in particular, will be obliged to give up water for higher value uses in the near future. It is predicted, that agriculture's share will drop (Kandiah, 1998). This will put an enormous pressure on agricultural development in general and might specifically affect irrigated cotton production, where water use efficiency should be improved.

technical view

Further considerations, such as a critical perspective of the actual freshwater demand of cotton, or measures for soil moisture conservation should also be taken into account.

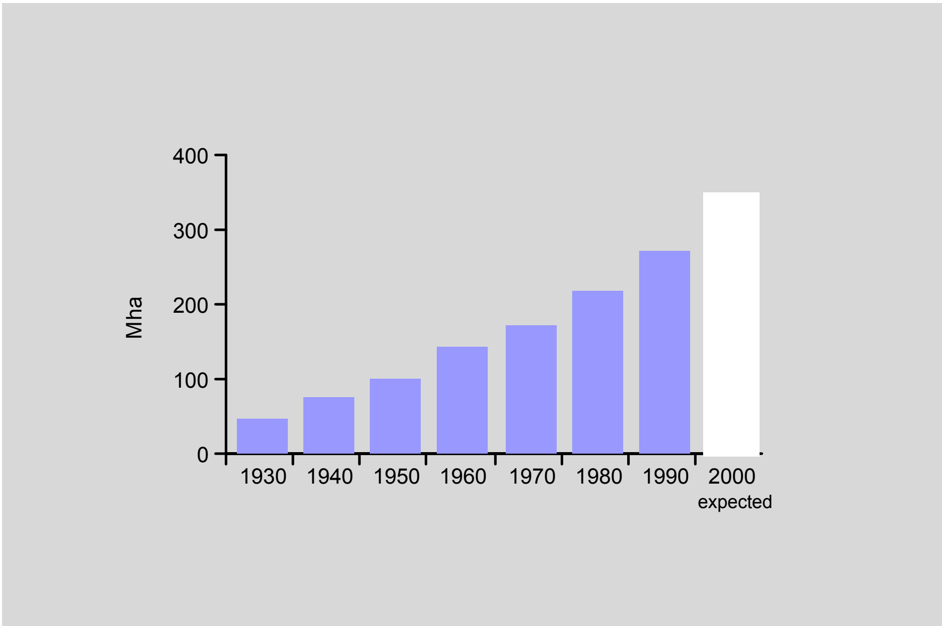

Figure 2.3

The growth in world-wide irrigated area (Data from Shiklomanov, 1991, cited from Kirda, 1999).

3 COTTON AND FRESHWATER ECOSYSTEMS

Summary

Cotton production uses agricultural chemicals heavily and therefore offers a significant risk of pollution of freshwater ecosystems with nutrients, salts and pesticides.

The application of pesticides in cotton production is disproportional compared to the area under cotton cultivation. Besides, most insecticides used for cotton production are hazardous.

The cotton production impacts rivers, lakes and wetlands by different mechanism. Run-off from fields and drainage water contaminate rivers, lakes and wetlands with pesticides and fertilisers and salts respectively. This pollutants can directly affect the biodiversity of freshwater ecosystems due to its toxicity or indirectly by accumulating. The improper handling of pesticides (e.g. washing of equipment in rivers or leakage) has the same impact on surface waters and leads also to a direct contamination of ground water systems.

The water withdrawal for an extensive irrigation can lead to falling water tables and to a depletion of freshwater resources in the end. On the other hand, extensive irrigation in dry climates results in a direct salinisation of soil. At the same time the water tables along the irrigation channels can increase leading to water-logging of soils and destruction of ecosystems.

The dam construction for irrigation and the land reclamation for cotton fields destroy the original vegetation and the freshwater habitats. Besides, damming up rivers and streams does affect the flow regime of surface waters and can destroy freshwater ecosystems laying downstream.

3.1 RELEVANCE OF COTTON FOR FRESHWATER POLLUTION

major impacts on lakes, rivers and ground water

Agriculture, industry and municipal are all sources of impact on rivers, lakes or wetlands. The major impacts, especially for irrigated agriculture, are salinity, raising water tables, contamination of ground waters and degradation of wetlands and lakes (Gillham, 1995).

agriculture as the main source

Studies of freshwater ecosystems support the claim that, today, agriculture is the main source of impact. A study for the USA shows that about 72% of assessed rivers and 56% of assessed lakes are impacted mainly by agriculture. Furthermore, agriculture is also cited as a primary cause of ground water pollution with nitrate as the principal contaminant, followed by pesticides (US-EPA, 1994). A recent study in Europe compares industrial, agricultural and domestic sources of pollution from the coastal zone of Mediterranean countries and concludes that agriculture is the major source of phosphorus compounds (Ongley, 1996).

significance of non-point sources

In contrast with the improved environmental policy regulating the emissions of industrial and urban waste water little has been done to prevent water pollution from agriculture. Emissions from agriculture are defined as 'non-point' sources – a lot of small sources with small emissions contribute to a large impact. In contrast with well identifiable 'point' sources like factories or sewage systems, agricultural impact on freshwater ecosystems can not be solved by 'end-of-pipe' technologies such as sewage treatment plants.

Extensive use of pesticides

high pesticide use

Cotton production uses agricultural chemicals heavily and therefore offers a significant risk of pollution of freshwater ecosystems with nutrients, salts and pesticides. One reason for the extensive use of pesticides is that the species of cotton planted today are not well adapted to appropriate site-conditions where they are used (Meyers, 1999). The one-sided selection in breeding for high fibre quality and high yield led to less pest resistant cotton plants.

over proportional use

The use of pesticide on cotton plantations in relation to the amount of arable land taken up by cotton plantations is disproportional. Between 1984 and 1994, the share of cotton on global pesticide sales has averaged 11% and on the global insecticides market even 24% (Meyers, 1999). At the same time, cotton acreage amounts to only 2.4% of the world's arable land (see figure 3.1).

Figure 3.1
The share of cotton on the global pesticide and insecticide market and on the world's arable land. It is obvious that the pesticide use for cotton in relation to the area of arable land that cotton takes up is disproportional.

relevance of insecticides

The relevance of pesticide use in cotton production for Wildlife is governed from insecticides which are the predominant class of pesticides used, as shown in table 3.1 (see also appendix A4 for more information on pesticides). The reason is not only that they are the major class involved. It is also due the acute toxicological properties of major subclasses of insecticides (Organophosphate and Carbamates).

highly dangerous pesticides

The high share of pesticide use is only a quantitative aspect. According to the recommendation of WHO, most pesticides used for cotton are hazardous. From the 46 insecticides and acaricides, which together account for over 90% of the market share in the cotton sector, five are extremely hazardous, eight are highly hazardous and twenty are moderately hazardous. The use of these pesticides is not only a risk for workers but for all animals and ecosystems that are linked to the cotton fields either directly, (e.g. birds or beneficial insects), or indirectly (e.g. freshwater ecosystems). A severe problem in many cotton growing regions is the resistance of pests, which severely threatens production.

Table 3.1
Percentage of different pesticide groups in all the pesticides used in cotton cultivation in 1994 (data Woodburn, 1995).

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

3.2 MAJOR IMPACTS OF COTTON PRODUCTION ON FRESHWATER ECOSYSTEMS AND BIODIVERSITY

The major impacts of cotton production on freshwater ecosystems and wetlands are listed in table 3.2.

Run off from fields

wildlife contamination

Due to inappropriate water management and irrigation technology, water run-off from fields to adjacent rivers, wetlands and lakes is common. This run-off, however, does not only contain soil sediments but also pesticide residues, salts and fertilisers. The pesticides have a direct toxic effect upon wildlife and, by accumulating in the biosphere, also an indirect effect. Evidence shows that this indirect effect, leading to a decrease in animal fertility, affects long-term freshwater biodiversity (Woodward, 1993).

fish kill due to run-off in the USA

Investigations into a case of fish-death in the USA showed that, even when pesticides are properly applied according to the technical instructions, impacts on freshwater ecosystems are still possible. In this case Endosulfan was sprayed on cotton fields. In August 1995 contaminated run-off from these fields resulted in the death of more than 240,000 fish along a 25 km stretch of a river in the State of Alabama (PANUPS 1996).

eutrophication

So, run-off can also lead to contamination by fertiliser of rivers, lakes and wetlands. In contrast with pesticides, fertilisers are not directly toxic but instead alter the nutrient system and in consequence the species composition of a specific freshwater ecosystem.

Their most dramatic effect is eutrophication of a freshwater body – an explosive growth of algae which causes disruption to the biological equilibrium, including killing fish.

Table 3.2
Major impacts of cotton on freshwater ecosystems and freshwater biodiversity.

Mechanism	Pollutant/Change	Impact	Cases
Run off from fields	Fertiliser	Eutrophication and pollution	
	Pesticides	Wildlife contamination	
	Sediments		
Drainage	Saline drainage water	Salinisation of freshwater	China, Egypt, Uzbekistan
	Pesticide or fertiliser contaminated drainage water	Pollution of freshwater	
Application of pesticides	Insecticides, fungicides, herbicides and defoliants	Wildlife contamination	
	Spray drift (e.g. aerial application)	Contamination of adjacent wetlands, surface and ground water	
	Leakage of equipment	Contamination of surface and ground water	
Water withdrawal for irrigation	Use of ground water	Change of water table or depletion of ground water	New South Wales, Australia
	Use of surface water	Degradation of wetlands and lakes	Aral Sea, Yellow River Valley
Extensive irrigation	Water logging	Raising water tables and salinisation of soil surface	Australia, Indus River Valley, Uzbekistan, Pakistan
Dam construction for irrigation	Regulated water flow	Habitat destruction, change of water table and change of water flow	
Land reclamation	Change of vegetation	Habitat destruction	

Drainage and leaching

salt contamination

To avoid water logging and salinity of soils (see below), drainage systems are used. In some countries, in addition to the water used in irrigation for cotton production, the fields are irrigated with extra freshwater to establish a downward water flow, which removes the salt from the soil. China, Egypt and Uzbekistan specifically mention extra water requirements for leaching, the last two quantitatively (Gillham, 1995). However, by returning to the rivers, the salt-contaminated drainage water has a severe impact on rivers and wetlands (Gillham, 1995). It can be assumed that drainage water contains not only salt but also pesticide residues and fertiliser, which enter rivers and lakes directly.

Application of pesticides

non-target organism

Even when pesticides are applied properly, affecting non-target organism can not be prevented. Beneficial insects in and around the cotton fields can be killed and other animals eating these insects can be injured or even poisoned.

case laughing gulls

In one case, although 20 years ago, a breeding colony of laughing gulls near Corpus Christi, Texas, was poisoned by a parathion application designed to kill bollworms on a cotton field about three miles away. The gulls were killed by ingesting poisoned insects from the cotton field (White, 1979; White, 1983).

contamination of surface and ground water

In addition to run-off contaminated with pesticide, by certain application methods, surface water and even ground water can be directly polluted with pesticides and fertilisers. Pesticide application by aeroplane, for example, can lead to spray drift, i.e. pesticides do not hit the targeted field but adjacent fields, rivers or wetlands instead, this leads to direct poisoning of freshwater species. Ground water, on the other hand, is impacted by deep percolation, which can also be contaminated by pesticides and fertilisers, by faulty equipment (e.g. leakage) or improper handling of equipment (e.g. cleaning of equipment in surface water).

Freshwater withdrawal

Aral Sea

The depletion of the Aral Sea is the most drastic consequence of extensive freshwater withdrawal for irrigation purposes (Gillham, 1995). The two rivers Amu-Darja and Syr-Darja were over-used for producing cotton and other corps and vegetables. The surface level of the Aral Sea decreased, leading to the extinction of a range of fish species, i.e. 20 of 24 native fish species disappeared (Krever et al., 1998 (?)). Furthermore, wide areas of acreage and former lake area suffer from surface salination.

falling water tables

In China's Yellow River Valley, where cotton is grown under irrigated and rain-fed conditions, a shortage of irrigation water due to falling water tables was also reported (Gillham, 1995).

Extensive irrigation

water logging

Investigations conducted in Australia concluded that irrigated cotton cropping can lead to increased run-off into ground water (deep percolation). The consequence of this are rising ground water tables and eventually the establishment of shallow water tables (Willis, 1996). This does not only decrease agricultural productivity but also leads, in dry climates, to the salination of soils (Zilberman, 1998).

Salinisation

In regions where evapotranspiration exceeds, both rain-fall and the amount of freshwater used for irrigation, a salinisation of soil is inevitable. This is especially true of all countries in the broad belt of irrigated cotton, which have desert and Mediterranean climates. In Uzbekistan, for example, 50% of the irrigated area is affected by salinity and in Pakistan 15% is affected. Brazil, with its small area of irrigated crop, also reports problems with salinity (Gillham, 1995).

Dam construction for irrigation

impacts of dams

In addition to habitats and ecosystems which are directly destroyed by dammed water, the reduced and regulated water flow also affects freshwater ecosystems which lay downstream of the dam. Freshwater ecosystems are adapted to a certain water flow and any alteration in water amount or its temporal distribution can affect either single species or whole freshwater ecosystems.

increasing number of dams

In only 30 years, from the 1950s to the late 1980s more than 35,000 large dams were built world-wide (WWF, 1999). Whereas the bigger dams are used mainly for hydropower, the smaller dams were primarily built for irrigation purposes. Most dams however can be used for irrigation, hydropower, flood control and other purposes (ICOLD, 1998). Because of the lack of appropriate data, the significance of cotton production on dam building can not be estimated at this point of the study.

Land reclamation

The increase in arable land leads directly to a change from natural landscape to agricultural area. In particular, flood plains and wetlands with their flat shape and usually fertile soil are preferable areas for agriculture and irrigation schemes. However, due to drainage of the soil and to the monocultural cultivation of cotton, the farmland no longer provides a habitat for its original plants and animals. Besides, the remaining natural habitats are fragmented into isolated pieces which are too small to secure the continued existence of the natural ecosystem. Even though this initially concerns terrestrial ecosystems and wetlands, freshwater ecosystems in rivers or lakes are affected by the interrupted links between ecosystems.

amount of affected area

Even though the area of cotton cultivation has remained constant since 1930, there has been a need for land reclamation due to a gradual change from over-used farmland to newly cultivated areas. One reason for this change is the salinisation of soil taking place through inappropriate irrigation and water logging. Because of this change, the area affected by cotton planting over the last 50 years is much larger than the recently cultivated area. In the top 6 cotton producing countries, between 12% and 36% of the irrigated area is damaged through salinisation (Dinar, 1998).

Critical remarks

rain-fed cotton

Consequences of the use of pesticides and fertilisers can affect irrigated cotton as well as rain-fed cotton. There are indications however, that less pesticides and fertilisers are used on rain-fed cotton. On the other hand, irrigated cotton has a higher yield than rain-fed cotton. A concluding comparison between irrigated and rain-fed cotton is not yet possible because more data is necessary.

sources of pollution

In areas like river deltas where agricultural, industrial and urban areas are often mixed, the impact on freshwater ecosystems can not be allocated to any one of the three sectors in particular.

indirect impact on freshwater ecosystems

Impacts on freshwater ecosystems can also be caused indirectly by human use of other resources than freshwater, such as land, vegetation and air. For example, reduction of vegetation cover, increased soil compaction and surface sealing reduce infiltration and increase run-off and soil erosion, thus altering the water balance of a catchment.

links between land and freshwater ecosystems

Freshwater ecosystems are linked to land ecosystems. Therefore, a severe impact on one can influence the other. The poisoning of birds and insects in a land ecosystem through pesticides for example can alter the food chain and thus impact the neighbouring freshwater system.

indirect effects

Loss and fragmentation of habitats is caused not only by the agricultural area itself but also the surrounding infrastructures. This also applies to roads, buildings and a population migration into newly developed areas as well as dams and their effects. Besides the resultant direct loss of land, further impacts like nutrient turn-over and siltation will be accentuated.

APPENDICES

A1 GLOSSARY

Acaricide
Synthetic chemical which kill spiders and mites.

Biodiversity
Refers to species diversity, genetic diversity and ecological diversity, i.e. the diversity of functional groups and the linkages within and between biological communities.

Boll
The seed-vessel of the cotton plant.

Bollworm
Several species of Lepidoptera that feed on cotton bolls.

Cash crop
Production of income-earning crops for export or local consumption.

Catchment
Land from which a river or reservoir draws its rainfall.

Cotton bale
A package of compressed cotton lint after ginning, tied with wire or metal bands and wrapped in cotton, jute or polypropylene.

Cotton fibre / Cotton lint
Fibre that develops as an extension of cells in the walls of developing cotton seed; product that results from the separation of cotton fibre from the cotton seed in the ginning process.

Cotton seed
The seed of the cotton plant.

Deep percolation
Increased run-off into ground water.

Degradation
Degradation of ecosystems involves changes that lead to the loss or impairment of ecosystem functions.

Ecosystem
System of interactions between plants, animals, etc. and their inanimate surroundings, e.g. a river or a lake.

Endosulfan
Insecticide which is applicated on cotton cultivation.

Eutrophication
Eutrophication is the process of nutrient enrichment leading to enhanced primary production, resulting in modification to natural processes and colonisation structures and to increased biological decomposition.

Evaporation
Evaporation is the release of water vapour from waterbody surfaces and soils.

Evapotranspiration
Refers to the sum total of evaporation resulting from the release of vapour from surface waterbodies and soils (evaporation) and from plants (transpiration).

Extensive agriculture
Forms of agriculture characterised by larger land surfaces per farmer who are then not pressed to intensify production, e.g. through the use of external inputs, to make a living.

Fertilisers
Synthetic or organic nutrient for plants, e.g. nitrates and phosphates.

Freshwater ecosystem
According to the WWF Freshwater Advisory Group Freshwater ecosystems are considered to be those in which the "fundamental physical, chemical and biological processes are driven by presence of freshwater, and in which the dominant life forms are adapted to at least periodic saturation or inundation by freshwater, beyond the tolerance levels of terrestrial animals. This includes wetlands, lakes, freshwater lagoon and river systems including their flood plains and estuaries, where natural, permanent or temporary, with water that is surface or underground, static or flowing".

Fungicide
Pesticide which kills fungi.

Ground water
Water beneath the ground that fills interconnected pores in the upper part of the Earth's crust. The ground water's movement is determined by gravitational and frictional forces.

Ground water table
Level below which the ground is saturated with water.

Habitat
Usual natural place and conditions of growth for animals and plants, e.g. aquatic habitat.

Herbicide
Synthetic chemical which kills plants.

Hydrological water body
The Earth's reservoirs of water resources, e.g. atmosphere, lakes, glaciers, etc.

Insecticide
Synthetic chemical which kills insects.

Irrigation efficiency
The amount of water which is used by the plant versus the irrigated water.

Monoculture
Growing one crop continuously without using rotation.

Non-point and point source pollution
Non-point source pollution arises from human activities for which the pollutants have no obvious point of entry into receiving watercourses. On point-source pollution the pollutants, e.g. waste water, is routed directly into receiving water bodies.

Pesticides
Synthetic chemical which kills pests.

Pesticide resistance
Resistance developed by some pests and diseases species to specific pesticides, rendering them worthless or less effective.

Rain-fed irrigation
Refers to irrigation on which freshwater is provided mainly by rain.

Run-off
Water flow on the surface to rivers, lakes, the sea or into the ground water.

Salinisation
Refers to the accumulation of soluble salts in or on soils or waters.

Siltation

Transport of sand, mud, etc. by moving water, left e.g. at the mouth of a river.

Waterbody pollution

Refers to pollutant, pathogen and thermal loads, causing impairment of ecosystems and of the potential utilisation of freshwater resources.

Water logging

Soil is saturated or nearly saturated with water, a state in which water and dissolved substances move freely but gases move so slowly that oxygen normally becomes deficient. Impermeable horizons, or bedrock near the soil surface, are often responsible for saturated soils.

Water supply

The net total of water resulting from precipitation, water inflows from upstream and water losses in a given area.

Water withdrawal and consumption

Freshwater *withdrawal* refers to all freshwater transferred from its source to its place of use, but does not mean that it is necessarily used for an activity (e.g. losses are included). On the other hand, the term *consumption* often indicates the direct consumption of freshwater by an activity (i.e. without losses).

Wetland

Shallow water bodies (such as lakes, ponds, rivers and coastal zones) and land that is inundated or saturated with water at least periodically, such as marshes, moor land, swamps and flood plains.

A2 FURTHER READING

Organic cotton: From filed to final product.

Meyers, D.; Stolton, S. (Eds.), 1999: Organic cotton: From field to final product. London, (Intermediate Technology Publications).

An excellent compilation of the current discussion on organic cotton. This book gives a broad view on different topics concerning organic cotton.

Cotton Production Prospects for the next decade

Gillham, F. et al., 1995: Cotton Production Prospects for the next decade, World Bank Technical Paper Number 287, the World Bank, Washington DC.

Extensive information about cotton production in Brazil, China, Egypt, India, Mali, Mexico, Pakistan, Tanzania and Uzbekistan. Covers technical, economical and environmental data on cotton production.

A3 COTTON PRODUCING COUNTRIES

Table A3.1 (to be continued on next page)
Cotton producing countries. Data on cotton production and cotton acreage.

Country	Cotton production	Share on world-wide cotton production	Total acreage	Cotton acreage	Share of cotton on national acreage
	ICAC, 1998		Gleick, 1993	FAOSTAT, 1998	
	thousand tons	%	thousand ha	thousand ha	%
China	4'000	20.41%	96'115	4'750	5%
United States	3'970	20.26%	189'915	4'199	2%
India	2'711	13.83%	168'990	9'070	5%
Pakistan	1'859	9.49%	20'730	2'930	14%
Uzbekistan	1'200	6.12%		1'530	
Turkey	799	4.08%	27'885	700	3%
Australia	577	2.94%	48'934	440	1%
Brazil	425	2.17%	78'650	847	1%
Argentina	419	2.14%	35'750	764	2%
Greece	415	2.12%	3'924	412	10%
Egypt	338	1.72%	2'585	300	12%
Turkmenistan	237	1.21%		580	
Mali	229	1.17%	2'093	464	22%
Syria	227	1.16%	5'503	251	5%
Mexico	179	0.91%	24'710	200	1%
Benin	171	0.87%	1'860	375	20%
Iran	151	0.77%	14'830	265	2%
Tajikistan	118	0.60%		245	
Sudan	111	0.57%	12'510	260	2%
Paraguay	110	0.56%	2'216	210	9%
Zimbabwe	108	0.55%	2'810	270	10%

Table A3.1 (to be continued on next page)

Cotton producing countries. Data on cotton production and cotton acreage.

Country	Cotton production	Share on world-wide cotton production	Total acreage	Cotton acreage	Share of cotton on national acreage
	ICAC, 1998		Gleick, 1993	FAOSTAT, 1998	
	thousand tons	%	thousand ha	thousand ha	%
Cameroon	96	0.49%	7'008	172	2%
Azerbaijan	93	0.47%		217	
Spain	89	0.45%	20'345	95	0%
Nigeria	81	0.41%	31'335	240	1%
Burkina Faso	78	0.40%	3'564	277	8%
Chad	73	0.37%	3'205	336	10%
Tanzania	67	0.34%	5'250	350	7%
Sou.th Africa	63	0.32%	13'174	90	1%
Togo	62	0.32%	1'444	145	10%
Kazakhstan	61	0.31%		114	
Columbia	51	0.26%	5'380	85	2%
Peru	51	0.26%	3'730	74	2%
Uganda	48	0.24%	6'705	130	2%
Israel	48	0.24%	433	28	6%
Bolivia	41	0.21%	3'460	50	1%
Senegal	24	0.12%	5'226	54	1%
Zambia	24	0.12%	5'268	64	1%
Afghanistan	22	0.11%	8'054	60	1%
Bangladesh	22	0.11%	9'292	37	0%
Venezuela	20	0.10%	3'895	30	1%
Kyrghyzstan	19	0.10%		32	
Myanmar	18	0.09%	10'034	298	3%
C.A.R.	17	0.09%	2'006	70	3%

Table A3.1 (end)
Cotton producing countries. Data on cotton production and cotton acreage.

Country	Cotton production	Share on world-wide cotton production	Total acreage	Cotton acreage	Share of cotton on national acreage
	ICAC, 1998		Gleick, 1993	FAOSTAT, 1998	
	thousand tons	%	thousand ha	thousand ha	%
Ethiopia	15	0.08%	13'930	43	0%
Ghana	13	0.07%	2'720	49	2%
Mozambique	13	0.07%	3'100	198	6%
Madagascar	12	0.06%	3'092	21	1%
Thailand	10	0.05%	22'126	56	0%
Kenya	6	0.03%	2'428	30	1%
Nicaragua	4	0.02%	1'273	2	0%
Ecuador	2	0.01%	2'653	15	1%
Phillipines	2	0.01%	7'970	7	0%
Guatemala		0.00%	1'875	2	0%

A4 PESTICIDES USED IN COTTON

Figure A4.1

Insecticide impact on wildlife population.

How insecticides currently used in cotton cultivation disturb wildlife population

- Direct mortality due to:
  - High acute toxicity of organophosphates and carbamates
  - Unspecific mode of action: Target AchE is commom in nervours system of all animals
- Indirect effects
  - Mortality via secundary poisoning of predatory animals
  - Starvation via depression of food
  - Starvation via anorexia
  - Predation
  - Sublethal effects
- Hazards due to application form of insecticides
- A case example of combined effects: Laughing gulls killed by Parathion application in cotton production in Texas 1993

Figure A4.2

Insecticide impact on freshwater ecosystems.

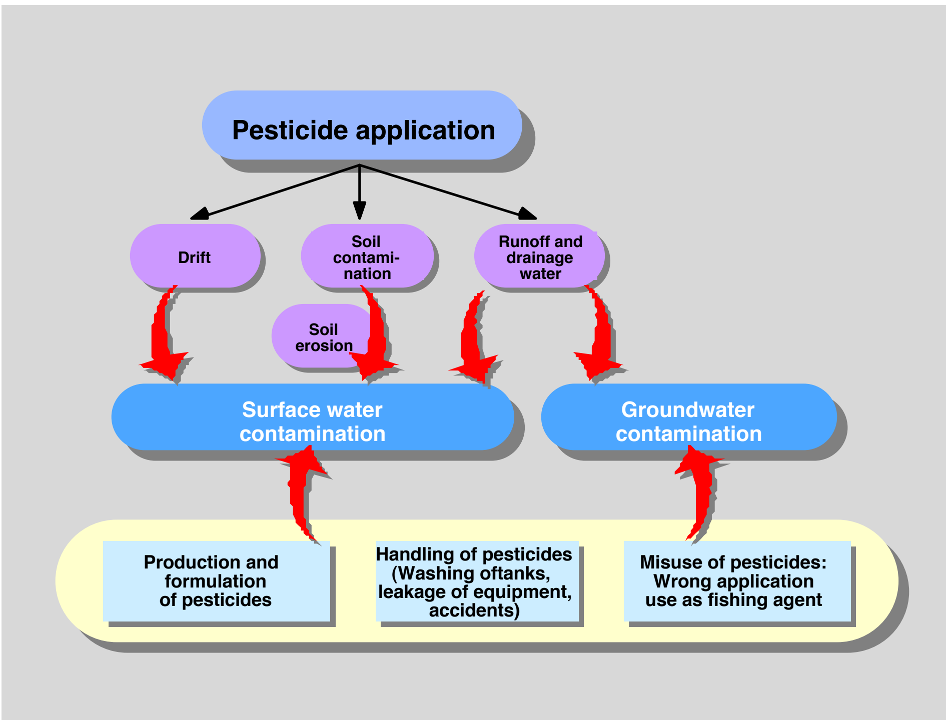

Table A4.1

The most important insecticides used in cotton cultivation in 1994. These 8 insecticides made up to 63% of the global cotton insecticide market, 1994 (data Allan Woodburn Associates Ltd., 1995)

Designation of the substance (trade name)	Chemical group of the substance	Toxicity Class (WHO)	Share (%) in the global cotton insecticide market
Deltamethrine (Decis)	Pyrethroid	II	12 %
Lamda-Cyalothrine (Karate)	Pyrethroid	III	9%
Monoctrotophos (Azodrin)	Organophosphorus	Ib	9%
Alpha-Cypermethrine (Fastac)	Pyrethroid	II	8%
Chlorpyriphos (Dursban,Lorsban)	Organophosphorus	II	7%
Esfenvalerate (Sumi-alpha)	Pyrethroid	II	7%
Methamidophos (Tamaronb)	Organophosphorus	Ib	6%
Dimethoate (Rogor,Perfekthion)	Organophosphorus	II	5%

Pesticides

Insecticides	CASRN[1]	Brand name (Example)	Chemical group of pesticide	Water solubility at 20-25°C	Breakdown in soil	Acute hazard rating for				Chronic effects	Comments
				[ppm or mg/l]	[days]	Birds a)	Mammals a)	Fish b)	Bee c)		
DELTAMETHRIN	52918-63-5	Decis®, Butoflin®	Synthetic pyrethroid	< 0.1	7 to 14 days	Low	Moderately	Moderately	Highly	no evidence so far	very toxic to predatory mites
CYHALOTHRIN	91465-08-6	Karate®	Synthetic pyrethroid	0.005	30 to 100 days	Low	Low	Extremely toxic	Highly	no evidence so far	-
MONOCROTOPHOS	2157-98-4	Azodrin®	Organophosphate	1000000	1 to 7 days	Highly	Highly	Moderately	Highly	possible mutagenic	causes reproductive damage in crustaceans
CYPERMETHRIN	52315-07-8	Ammo®	Synthetic pyrethroid	0.009	6 to 63 days	Low	Moderately	Extremely toxic	Highly	possible carcinogenic, suspected endocrine disruptor	-
CHLORPYRIFOS	2921-88-2	Lorsban®	Organophosphate	1.18	12 to 102 days	Highly	Low to Moderately	Extremely toxic	Highly	accumulates in the tissues of aquatic organisms, suspected endocrine disruptor	-
ESFENVALERATE	66230-04-4	Asana XL®	Synthetic pyrethroid	< 0.02	15 to 90 days	Low	Low	Extremely toxic	Highly	suspected endocrine disruptor	-
METHAMIDOPHOS	10265-92-6	Tamaromb®, Monitor®	Organophosphate	90	1 to 12 days	no data	no data	no data	Highly	no evidence so far	-
DIMETHOATE	60-51-5	Cygon®, Dimate®	Organophosphate	25	2 to 122 days	Highly	Highly	Extremely	Highly	possible teratogenic, mutagenic, carcinogenic	-
Herbicides											
TRIFLURALIN	1582-09-8	Treflan®	Dinitroanilin	0.7	116 to 189 days	Low	Low	Moderately	Low	possible carcinogenic, suspected endocrine disruptor	toxic to Daphnia, toxic to earthworm at high application rates
PENDIMETHALIN	40487-42-1	Prowl®	Dinitroanilin	0.3	40 to 90 days	Low	Low	Highly	Low	possible carcinogenic	-
DIURON	330-54-1	Di-on®, Diater®	Substituted urea	42	30 days to 365 days	Low	Low	Moderately	Low	no evidence so far	moderately toxic to fish but highly toxic to aquatic invertebrates
FLUOMETURON	2164-17-2	Cotoran®	Substituted urea	90	11 to 365 days	Low	Low	Moderately	Low	no evidence so far	-
FLUAZIFOP-P-BUTYL	69806-50-4	Fusilade 2000®	Phenoxy, pyridine	1	1 to 21 days	Low	Low	Highly	Low	no evidence so far	-
MSMA	2163-80-6	Arsonate®, Bueno®	Organoarsenic	1400000	100 days	no data	no data	Low	no data	no evidence so far	-
PROMETRYN	7287-19-6	Caparol®	Substituted triazine	30	30 to 365 days	Low	Low	Moderately	Low	no evidence so far	-
CYANAZINE	21725-46-2	Bladex®	Substituted triazine	171	2 to 63 days	Low	Low	Low	Low	possible teratogenic	-

1 *CAS (Chemical Abstract Service) Numbers serve to identify chemicals properly.*

GLYPHOSATE	1071-83-6	Roundup®	Phospanoglycine	900000	1 to 174 days	Low	Low	Low	Low	no evidence so far	Glyphosate is highly adsorbed on most soils
BROMOXYNIL	1689-84-5	Brominal®, Buctril®	Nitrile	130	10 to 14 days	Moderately	Low	Highly	Low	inhibits nitrification processes in soil by microorganisms, possible teratogenic	-

a) Wildlife hazard rating based on the following toxicities

	LD_{50} [mg/kg]	LC_{50} [ppm]
Highly toxic	less than 30	less than 500
Moderately toxic	30-100	500-1000
Low toxicity	greater than 100	greater than 1000

b) Fish hazard based on the following 96-hour LC_{50} toxicities

	LC_{50} [ppm]
Extremely toxic	
Highly toxic	less than 500
Moderately toxic	500-1000
Low toxicity	greater than 10

c) Bee hazard based on LD_{50}. Ratings rely on EXTOXNET Database

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Table A4.2

The most important herbicides in cotton cultivation in 1994. In 1994, these 8 herbicides made up to 70% of the global cotton herbicide market (data Allan Woodburn Associates Ltd., 1995* MSMA: Mononatriummethylarsonate)

Designation of the substance (trade name)	Chemical group of the substance	Toxicity Class (WHO)	Share (%) in the lobal cotton herbicide market
Trifluraline (Treflan)	Dinittroaniline herbicide	III+	19 %
Pendimethaline (Prowl)	Aniline herbicide	III	12%
Diuron (Karmex)	Urea herbicide	III+	9%
Fluometuron (Cotoran)	Urea herbicide	III+	7%
Fluazifob-P-butyl (Fusilade)	Alcanoic acid herbicide	III+	6%
MSMA* (Ansar,Bueno)	Organoarsenic herbicide	III	6%
Prometryne (Gesagard)	Triazine herbicide	III+	5%
Cyanazine (Bladex)	Triazine herbicide	II	5%

Table A4.3

Percentage of different pesticide groups in all the pesticides used in cotton cultivation in 1994 Among the cotton pesticides, insecticides range highest with a share of 67% (Allan Woodburn Associates Ltd., 1995)

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

Table A4.4

Recommended restrictions on availability of insecticides (Plestina, 1984).

WHO Class		Available to:
Ia	Extremely hazardous	• Only individually licensed operators
Ib	Highly hazardous	• Well trained, educated, strictly supervised operators
II	Moderately hazardous	• Trained and supervised operators who are known to observe strict precautionary measures
III	Slightly hazardous	• Trained operators who observe routine precautionary measures
III+	Unlikely to present hazard in normal use	• No restrictions

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