AGRICULTURAL WATER USE AND RIVER BASIN CONSERVATION

A summary report compiled and edited by
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Adapted from *Water Use for Agriculture in Priority River Basins*, a study prepared for WWF by Rob de Nooy, available from www.panda.org/livingwaters/publications.

Designed by Tim Davis

Cover photo: Wild rice, Tanzania.
WWF-Canon / Sandra Mbanefo

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Foreword

We are all used to United Nations agencies and environmental groups pointing to the looming food crisis as a result of unsustainable management of freshwater resources and ecosystems. But it is a sign of the seriousness of the situation when commercial banks also start advising their clients of the risks to investment posed by scarcity of water, and to start treating water as a strategic asset for agriculture, as the largest domestic bank in the Netherlands did recently.

Conserving freshwater resources and ecosystems is a global priority for WWF. That agriculture is responsible for 70 per cent of water withdrawal worldwide makes it a necessity for WWF to work with farmers to identify and implement more sustainable practices. On a daily basis, farmers make rational decisions about what to farm and how to do it. The problem is that, often, through no fault of their own, farmers make decisions that are unsustainable economically, environmentally and socially.

In rich countries farmers are encouraged to farm unsustainably by subsidies and market barriers that virtually force them to produce ever more intensively, and cause environmental degradation in other countries as farmers strive to compete, or simply survive. In developing countries farmers often lack rights to the land they farm, reliable water supplies and other inputs, and access to knowledge about better farming technologies and practices. In all too many cases it is the poorest people and nature that pay the difference.

The present study, Agricultural Water Use and River Basin Conservation , is an important contribution to our policy and field actions. It provides an assessment of the crops that use most water in nine large river basins that are globally important for biodiversity conservation. The study also recommends a series of measures for the four thirstiest crops — cotton, sugar, rice, and wheat — that could be adopted by farmers and irrigation system managers to increase water efficiency while maintaining agricultural output. Widespread adoption of such measures, and a watershed perspective in resource management decisions, would enable more water to be left in ecosystems to maintain other critical functions and resources, such as fisheries.

WWF aims to join forces with new partners so that we can successfully balance the water and food needs of people with the environment. It is my hope that by valuing the ecosystems and water on which we all depend, we will guide decisions for immediate and long-term benefit.

Dr Claude Martin
Director General, WWF International

Introduction

Water is indispensable for farming. Farming in turn uses the vast majority of all water withdrawn for human use, and food production needs to increase in the coming decades to support a growing world population. The potential for political conflicts within and between countries over water are intensified by the increasing scarcity of freshwater resources. It seems clear that if human needs are to be met, while at the same time conserving biodiversity and maintaining vital ecosystem services, a new approach is required that makes the best use of the limited water that is available.

With this in mind, WWF s Living Waters Programme has selected about 40 river basins in different parts of the world in which to concentrate its efforts to conserve and restore healthy freshwater ecosystems for people and nature. This report summarizes a study carried out by WWF on the major irrigated crops and their respective water consumption in nine of these river basins (Table 1).

The main aim of the study was to support WWF s Living Waters Programme by identifying a limited number of global agricultural commodities that have probable impacts on priority freshwater ecosystems through their overall use of fresh water.

Approach

This report provides an overview of the findings on water use by agriculture in priority river basins. Further information on each river basin can be downloaded from www.panda.org/livingwaters/publications. To evaluate the probable future water situation in the countries covered by the nine river basins, results from the International Water Management Institute s (IWMI) Working Paper No.32 *Water for Rural Development* were used as a basis (see panel on next page). The IWMI data are based on each country s potential utilizable water resources and expected population growth. Calculations were made to quantify future water needs and the outcome was set against current water use and available water supplies. The IWMI working paper then made forecasts of the required level of cereal production to feed the expected populations in each country in 2025, as well as the corresponding increases in irrigated and rain-fed cropland.

Against this background, the WWF study looked first at the countries sharing each of the nine basins and assessed the impact of each country on the river s flow. Countries covering a large portion of the river basin (generally over 25%) were then selected for further study. In each case, data on water resources, irrigation and agriculture were collected, in large part from the Food and Agriculture Organisation (FAO) website. Calculations were then made to establish the total water requirement per crop in each river basin. This enabled the most thirsty crops to be identified and ranked, on the basis of their total water consumption in each river basin, as well as across the nine basins studied.

The study also describes various options for increasing the efficiency of irrigation water used in growing the highest-ranked crops, bearing in mind the constraints on future availability of water for agriculture in each of these river basins in the coming decades.

Table 1. River basins included in the WWF study

Continent*	River basin
Africa	Niger, Lake Chad, Zambezi
Europe and West Asia	Great Konya Basin (Turkey)
East Asia and the Pacific	Mekong, Yangtze
South Asia	Indus
Australia	Murray-Darling
North and Central America	Rio Grande

* A river basin in South America was not included as insufficient data could be collected in the time available.

IWMI's base scenario for future water supply

The International Water Management Institute's 'base scenario'[1] for the future water supply and demand of countries with a substantial rural population sets the following four major objectives:

1. Provide an adequate level of per capita food consumption to reduce extreme forms of nutritional poverty
2. Provide the basic human needs from domestic and industrial use of water
3. Increase food security and rural income through agricultural development, with a focus on reducing food imports
4. Improve water quality and support environmental uses of water.

One of the challenges of the last objective is to maintain river ecosystem integrity and variability whilst meeting water requirements for agriculture. It is a weakness of the IWMI analysis that it does not consider explicitly the water regime required to maintain environmental integrity. The analysis does however make allowances in its assumptions intended to ensure that part of the developed water resources is available directly or as return flows for environmental uses such as supplies to estuaries and coastal areas. Finding ways to maintain ecological integrity could be key to sustaining the natural goods and services that river systems provide, and on which many poor people depend for food and other resources.

[1]Source: International Water Management Institute (IWMI), Working Paper No.32, *Water for Rural Development* (2001).

Key terms

A country s internally renewable freshwater resource is the volume of water that is available each year in the form of river flow. About one-third of this resource, termed **potentially utilizable water resource (PUWR)**, can be captured for use, usually via various forms of water infrastructure, such as reservoirs, dams, or underground storage. The share of this volume that is actually developed and diverted is called the **primary water supply (PWS)**. According to the IWMI paper, almost all countries will have to increase their PWS as a result of the growing demand for cereals to feed their populations.

Economic water scarcity is defined as a situation where the increase in PWS is more than 25 per cent of its current level, but where, after this increase, it will be lower than 60 per cent of PUWR. Countries suffering such water scarcity are expected to face financial and institutional constraints in developing their water resources. All of the countries included in this study will experience economic water scarcity by 2025.

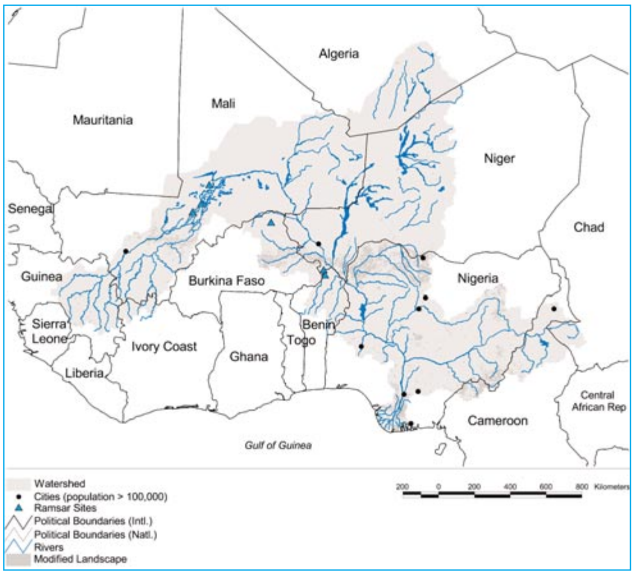
Some, like Pakistan, will also face **physical water scarcity**, a situation where PWS exceeds 60 per cent of PUWR. This means that a country will experience absolute scarcity of internal water resources irrespective of the financial or management means available.

Many of the countries included in this study are predicted by IWMI to fall short of the required cereal production to feed their populations and will thus become increasingly dependent on imported cereals.

Niger River Basin and Lake Chad Basin

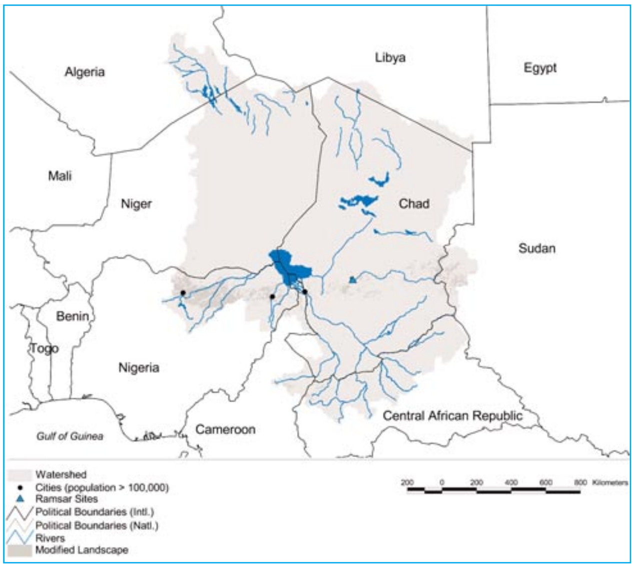
The Niger River, some 4,100km long, is the third-longest river in Africa, after the Nile and the Congo/Zaire Rivers, and the longest and largest river in West Africa. The Niger Basin covers more than 2.2 million km^2 (7.5%) of the African continent. Nine of the ten basin countries are members of the Niger Basin Authority which was set up to address regional cooperation on development of natural resources. The source of the Niger is located in Guinea but this country only covers 4 per cent of the basin. Algeria and Chad together cover about 9 per cent but contain almost no renewable water resources. Mali, Niger and Nigeria contain the largest surface areas of the Niger Basin (25% each), and Mali and Niger are almost entirely dependent on the Niger River for their water resources. Mean annual rainfall in the basin is 690mm, with a maximum of 2,845mm.

The Lake Chad Basin, located in northern Central Africa, covers over 2.3 million km^2 (almost 8%) of the continent, incorporating all or part of seven countries. About 20 per cent of the total area of the Lake Chad Basin (427,000km^2) is called the Conventional Basin (42% in Chad, 28% in Niger, 21% in Nigeria and 9% in Cameroon) and falls under the mandate of the Lake Chad Basin Commission. The Commission was created in 1964 by the four member states with the objective of ensuring the most rational use of water, land and other natural resources, and to coordinate regional development. Mean rainfall in the basin is 415mm, with a maximum of 1,590mm.



Above: Niger River Basin.

Below: Lake Chad Basin.



Biodiversity

The Niger River can be regarded as the lifeline of West Africa and supports a rich and varied biodiversity. The basin s freshwater wetlands are highly productive and support millions of resident and migratory birds, including the threatened black-crowned crane. Of the river s 164 fish species, 13 are found nowhere else. Vast floodplains and the river itself are home to mammals including hippopotamus and threatened species such as the West African manatee. The river basin links together three of WWF s priority ecoregions (see panel opposite): the Guinean Moist Forests; Sudd-Sahelian Flooded Grassland and Savannas; and the Niger River Delta.

Lake Chad was once Africa s largest freshwater lake but it has shrunk by 80 per cent in 40 years. Despite these changes, wrought in part by climate change and desertification, the river and its floodplains support a rich mosaic of wildlife.

An important part of Lake Chad, and the Chari River that feeds into it, is to be designated a wetland of international importance under the (Ramsar) Convention on Wetlands. Hundreds of species of terrestrial and water birds migrate to, or live in, the Lake Chad region, along with over 40 species of fish in the lake itself. The Chad portion of the lake is the only place that supports the endemic Kouri ox, which is threatened with

Table 2. Irrigated crop areas in West Africa (thousand hectares)

		Wheat	Rice	Sugarcane	Vegetables	Fruits	Millet	Sorghum	Groundnut	Cotton	Maize
Benin			10	1							
Burkina Faso			21	4	6	2					
Cameroon			12		15	5					
Chad		2	10	3	3						
Côte d'Ivoire			14	20	4	6					
Gambia			2								
Ghana			12								
Guinea			65		20						
Liberia					2						
Mali		4	213	4	3		12	12	2		
Niger		2	30	6	12				32	3	
Nigeria		50	10	26	152						19
Senegal			34	8	9	8					5
Sierra Leone			19	2	9						
Togo			2	1	3	1					
Total	**ha**	**58**	**454**	**75**	**238**	**22**	**12**	**12**	**34**	**3**	**24**
	%	**6.2**	**48.7**	**8.0**	**25.5**	**2.4**	**1.3**	**1.3**	**3.6**	**0.3**	**2.6**

extinction through interbreeding. The region around Lake Chad is a priority Sudd-Sahelian Flooded Grasslands and Savannahs ecoregion, while the southern regions of Chad and the northern part of the Central African Republic form part of the Sudanese Savannas ecoregion.

Main findings

On the basis of crop area in West Africa (Table 2), rice is the main irrigated crop, in both the wet and dry seasons (48.7%). Vegetables, cultivated mainly in the dry season, come next (25.5%), with sugarcane third (8%) followed by wheat, also a dry-

Saving special places – the Global 200 Ecoregions

Recognizing that local conservation problems often have their roots in wider social and economic issues, which influence how people use and consume resources and affect the environment, WWF increasingly focuses on areas whose boundaries are defined by nature – what WWF terms 'ecoregions'. WWF has identified some 200 such places – the 'Global 200 Ecoregions' – which contain the best part of the world's remaining biological diversity, and which must be protected if we are to leave a living planet for future generations. WWF alone cannot save all of them, so the organization has chosen a representative selection of 40 for which to develop action plans. Ambitious, broad-scale, and involving partners from all sectors, these plans combine environmental, economic, and social actions to conserve or restore the biodiversity of an entire ecoregion.

Table 3. Water consumption by the 'thirstiest' crops in the Niger River Basin

	Rice		Vegetables		Sugarcane		Wheat	
	ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
Mali	2,800	631	3,000	59	4,000	200	4,000	112
Niger	30,000	1,050	12,000	278	6,000	493	3,000	72
Nigeria	374,000	10,800	100,000	1,777	26,000	1,296	50,000	1,000
Total	**406,800**	**12,481**	**115,000**	**2,114**	**36,000**	**1,989**	**57,000**	**1,184**

season crop (6.2%).

Water use by all of the crops grown in the Niger River and Lake Chad Basins was calculated and the top four selected on the basis of their total water use. The results for these two basins revealed a pattern similar to the overall picture for West Africa (Tables 3 and 4).

When considering water consumption by the major crops in the two basins, it should be kept in mind that agriculture south of the Sahara is still mainly rain-fed (80%) and that the water use presented in Tables 3 and 4 only represents part of the food production in the region.

Future water demand

IWMI s general conclusion for the West Africa region is that, by 2025, the region will face economic water scarcity — that is, primary water supply less than 60 per cent of potential utilizable water resources, with an increase in primary water supply of more than 25 per cent over current levels.

Twareg farmer with ripening crop of irrigated wheat, Tadek Aïr mountains, Niger.
WWF-Canon / John E Newby

Table 4. Water consumption by the 'thirstiest' crops in the Lake Chad Basin

	Rice		Vegetables		Sugarcane		Wheat	
	ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
Chad	10,000	243	3,000	39	3,000	96	2,000	31

This means that West African countries are expected to face primarily financial and institutional constraints in developing their water resources (Table 5).

It should be recognized that the predicted increases in irrigated area to meet future food needs, although substantial in terms of the percentage of the currently irrigated surface area, are in fact relatively small when compared to the total of rain-fed cultivated area.

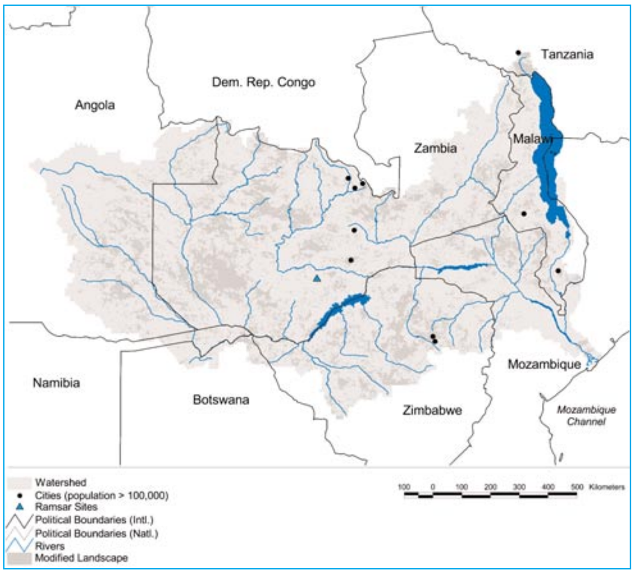
A challenge for the future in the Niger and Lake Chad Basins will be to devise means of increasing the area of cropland under irrigation without undermining the sustainability of freshwater ecosystems. This means improving the productivity of rain-fed agriculture, increasing the efficiency of existing irrigated areas, and expanding the use of irrigation practices appropriate to the region. Another option would be to encourage farmers to change from growing rice to wheat in the dry season, resulting in water savings of around 25—40 per cent. Reducing water demand in this way could be significant for ecosystem health during periods of low river flows

Table 5. Water demand forecasts for four West African countries

	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
Mali				
1995	0.12	1.18	2.75	76.5
2025	0.16	1.56	4.32	
Increase (%)	33	35	57	
Niger				
1995	0.03	0.7	6.49	28.2
2025	0.05	1.3	10.83	
Increase (%)	66	90	67	
Nigeria				
1995	1.06	5.0	16.75	158.3
2025	1.43	7.6	26.41	
Increase (%)	35	53	58	
Chad				
1995	0.00	0.17	1.51	25
2025	0.00	0.32	2.37	
Increase (%)	0	54	36	

Zambezi River Basin

The Zambezi Basin is Africa s fourth-largest river basin after the Congo/Zaire, Nile, and Niger Basins. Its total area represents about 4.5 per cent of the entire continent and embraces eight countries (Angola, Namibia, Botswana, Zimbabwe, Zambia, Tanzania, Malawi, and Mozambique). The Zambezi River rises in the Kalene hills in north-western Zambia and flows eastwards for about 3,000km to the Indian Ocean. There are two major man-made lakes on the Zambezi River: Lake Kariba on the border between Zambia and Zimbabwe, and Lake Cahora Bassa in Mozambique. At its mouth, the Zambezi River splits into a wide, flat, marshy delta. The annual discharge flowing to the sea is estimated at 106km^3. Annual rainfall in the basin decreases from almost 1,800mm in the north to less than 550mm in the south.



Biodiversity

The Zambezi River, its tributaries and associated wetlands support some of the largest intact blocks of wildlife habitat in Africa. Major floodplain areas, such as the Kafue Flats and the Zambezi Delta, are wetlands of international importance supporting major bird faunas, including the wattled crane, as well as rare and threatened mammals such as Kafue lechwe and sitatunga, together with kudu, duiker, oribi and warthog, and vast numbers of hippos and crocodiles.

Five distinct priority ecoregions defined by WWF occur in the region: Central and Eastern Miombo Woodlands, Zambezian Flooded Savannahs, Southern Rift Montane Woodlands, East African Mangroves, and Rift Valley Lakes.

Main findings

In the eight countries of the Zambezi Basin, sugarcane covers the largest area (95,000ha — 24.9%), followed by rice (73,000ha), wheat (68,000ha) and vegetables (66,000ha) (Table 6). The

Table 6. Irrigated crop areas in Southern Africa (hectares)

	Rice	Wheat	Sugarcane	Vegetables	Cotton	Maize	Fruits	Barley	Soybean
Angola	16,000		9,000	15,000					
Botswana					1,000	1,000			
Malawi	13,000					2,000			
Mozambique			18,000	3,000					
Namibia		1,000			1,000	2,000	1,000		
Tanzania	34,000		13,000	38,000		16,000	7,000		
Zambia	10,000	11,000	15,000	9,000	4,000		5,000		
Zimbabwe		56,000	40,000	1,000		9,000	5,000	5,000	20,000
Total ha	**73,000**	**68,000**	**95,000**	**66,000**	**6,000**	**30,000**	**18,000**	**5,000**	**20,000**
%	**19.1**	**17.8**	**24.9**	**17.3**	**1.6**	**7.9**	**4.7**	**1.3**	**5.2**

Table 7. Water consumption by the 'thirstiest' crops in the Zambezi River Basin

	Sugarcane		Rice		Wheat		Vegetables	
	ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
Zambia	15,000	682	10,000	92	11,000	165	9,000	115
Zimbabwe	40,000	1,480			56,000	769		
Mozambique	20,000	389	22,000	327	1,200	12	7,000	36
Malawi	18,000	1,105	13,000	415			3,000	39
Total	**93,000**	**3,656**	**45,000**	**834**	**68,200**	**946**	**19,000**	**190**

main irrigated crops in terms of area are thus similar to those in West Africa, although their sequence differs.

The results for total water use by the thirstiest crops in the four main countries of the Zambezi Basin (Table 7) are representative of overall water consumption by crops in the whole Southern Africa region.

The prominence of sugarcane probably results from its importance as a foreign currency earner, while the staple food crop is maize, which is generally grown under rain-fed conditions.

Future water demand

IWMI s general conclusion for the Southern Africa region is that, by 2025, it will face economic water

Preparing a rice paddy for sowing.
WWF-Canon / John E Newby

scarcity — that is, the primary water supply will be less than 60 per cent of the potential utilizable water resource, with an increase in primary water supply of more than 25 per cent over current levels. This means that Zambezi Basin countries are expected to face primarily financial and institutional constraints in developing their water resources (Table 8).

It should be recognized that the predicted increases in irrigated area to meet future food needs, although substantial in terms of the percentage of the currently irrigated surface area, are in fact relatively small when compared to the total rain-fed cultivated area.

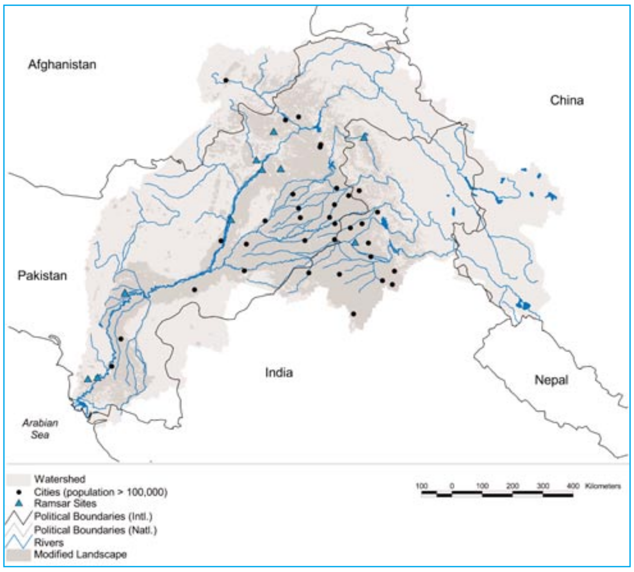
A future challenge for Zambezi Basin countries will be to devise means of increasing irrigated areas of cropland without undermining the sustainability of freshwater ecosystems. This means improving the productivity of rain-fed agriculture, increasing the efficiency of existing irrigated areas, and expanding the use of irrigation practices appropriate to the region.

Table 8. Water demand forecasts for three Southern African countries*

	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
Zambia				
1995	0.02	0.80	0.75	53
2025	0.04	1.56	1.37	
Increase (%)	100	73	83	
Zimbabwe				
1995	0.06	1.42	1.88	60
2025	0.09	2.24	2.16	
Increase (%)	50	52	15	
Mozambique				
1995	0.10	0.66	1.54	160
2025	0.14	1.03	2.07	
Increase (%)	40	51	34	

*Malawi was not included in the IWMI analysis

The Indus River is Pakistan s lifeline, providing water for towns and cities as well as for agriculture and energy generation. The Indus Basin covers an area in excess of 1 million km^2 and drains four Asian countries, with Pakistan and India controlling more than 80 per cent of the basin area, and China and Afghanistan the remainder. The 3,180km long river originates in Lake Ngangla Ringco, 6,714m above sea level on the Tibetan plateau, and traverses Jammu, Kashmir and Pakistan before emptying into the Arabian Sea. The drainage area contributes to an average annual inflow of $226km^3$. The flow of the Indus fluctuates seasonally, with melting Himalayan glaciers accounting for almost 90 per cent of the water in the upper Indus Basin. Although most of the basin lies in a zone of low rainfall (<250mm annually), abundant flows occur during the monsoon season (July–September), which accounts for 80 per cent of the annual flow. The Indus Basin Irrigation Scheme is one of the largest in the world, covering some 14 million hectares, an area roughly three times the size of Switzerland.



Biodiversity

The headwaters, tributaries, floodplains, delta, and marine coastal zone of the Indus River Basin represent a complete range of ecosystems and exhibit unique geographical and geological features. The delta and near-shore waters, in particular,


Irrigated farmland in Pakistan.
WWF-Canon / Mauri Rautkari

Table 9. Irrigated crop areas in Afghanistan, north and west India, and Pakistan (thousand hectares)

	Wheat	Rice	Maize	Barley	Potatoes	Pulses	Vegetables	Fruit	Oil crops	Cotton	Fodder	Millet	Sorghum	Soybean	Sugarcane
Afghanistan	1,426	167	179	93	14	25	55	87	34	60	115				
Pakistan	7,554	2,419	720	100	90	893	273	571	262	2,955	916	105	240		1,059
India West	9,994	1,970	523	158	138	1,839	369	417	302	1,671	459	387	268	777	
India North	6,526	6,786	413	125	147	1,309	394	444	154	1,749		363	305	286	1,650
Total	**25,500**	**11,342**	**1,835**	**476**	**389**	**4,066**	**1,091**	**1,519**	**752**	**6,435**	**1,031**	**927**	**932**	**554**	**3,486**
%	**42.1**	**18.7**	**3.0**	**0.8**	**0.6**	**6.7**	**1.8**	**2.5**	**1.2**	**10.6**	**1.7**	**1.5**	**1.5**	**0.9**	**5.8**

provide habitat for important freshwater and marine fisheries. The waters of the Indus are home to one of the few species of freshwater dolphin, the Indus River dolphin. Important food species, like large freshwater shrimps, are part of the delta s abundant aquatic life. The river basin is also home to endangered vertebrate species such as snow leopard and markhor.

Two important freshwater lakes, Haleji and Kinjhar (Kalri), lie within the basin and are listed as Ramsar wetlands of international importance. Haleji supports a variety of flora and fauna and up to 103,000 waterfowl have been counted during the winter. Kinjhar, one of the largest freshwater lakes in Pakistan with a surface area of 13,468ha, supports about 150,000 waterfowl. These lakes are the source of drinking water for the city of Karachi. They also mitigate flooding in the region and support major fisheries.

Four WWF priority ecoregions lie in the Indus Basin: Western Himalayan Temperate Forests, Rann of Kutch Flooded Grasslands, Tibetan Plateau Steppe, and the Indus River Delta.

Main findings

In the South Asia region, the total area of irrigated cropland was estimated for Afghanistan, Pakistan, and northern and western India (Table 9). This was done to determine whether the cropping pattern found in Pakistan is typical of neighbouring countries with similar climatic conditions.

Wheat was shown to occupy the largest area (42.1%) overall, followed by rice (18.7%), cotton (10.6%) and sugarcane (5.8%). For Pakistan the sequence of crops by area was: wheat (41.6%), cotton (16.3%), rice (13.3%), sugarcane (5.8%), and fodder (5%). The cropping pattern for Pakistan can thus be

Table 10. Water consumption by the 'thirstiest' crops in the Indus River Basin in Pakistan

Wheat		Cotton		Rice		Sugarcane	
ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
7,554,000	51,418	2,955,000	51,427	2,419,000	70,508	1,059,000	48,882

Terraced fields in the Indus Valley, Pakistan.
WWF-Canon / Hartmut Jungius

said to follow the pattern typical for the wider region.

For the Indus Basin, data were then collected on the irrigated crops, their water requirements in the wet and dry seasons, and the area under cultivation in each of these seasons. As there is a wide difference in climatic conditions between the north and south of Pakistan, calculations of crop water requirements were carried out for both regions. This resulted in a total water use by each irrigated crop for the whole country. The four crops that were the most important by area are also the largest water users (Table 10). However, rice is the largest water user by a considerable margin, while sugarcane uses nearly as much water as cotton or wheat despite being grown on a much smaller area.

Future water demand

IWMI s general conclusion for Pakistan is that the country will face physical water scarcity by 2025 — that is, primary water supply more than 60 per cent of the potential utilizable water resource. Consequently, Pakistan will require 102 per cent of its potential utilizable water resource to feed its population. This means it will experience absolute scarcity of internal water resources irrespective of the financial or management means available (Table 11).

Given this forecast and the fact that opportunities to increase total water supply are severely limited, it is clear that, to meet future demands for food production, Pakistan will have to invest significantly in increasing water efficiency in existing irrigated areas. Water allocations in the Indus Basin will also need to take account of the fact that people in the lower part of the basin rely on sufficient water being left in the river for their food security (e.g. maintenance of fisheries).

Food requirements not met through improvements to Pakistan s agriculture will have to be provided through imports of grain, with consequent socio-economic implications, particularly for poorer sections of the populace.

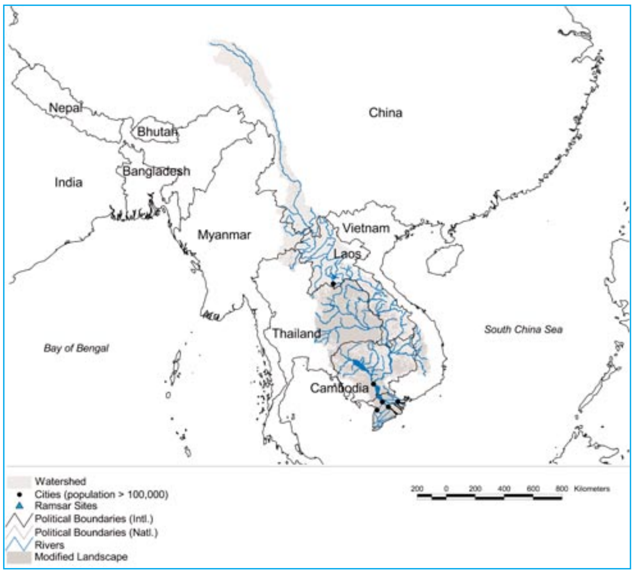
Table 11. Water demand forecast for Pakistan

	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
1995	10.30	177.67	0.00	199
2025	12.17	203.35	0.00	
Increase (%)	18	14	0	

Mekong River Basin

The Mekong River is the longest river in South-East Asia. From its source in China s Qinghai Province near the border with Tibet, the Mekong flows generally south-east to the South China Sea, a distance of more than 4,000km. It crosses Yunnan Province in China, and forms the border between Myanmar (Burma) and Lao People s Democratic Republic (Lao PDR), and most of the border between Lao PDR and Thailand. It then flows across Cambodia and southern Vietnam into a rich delta before emptying into the South China Sea. The four downstream countries are members of the Mekong River Commission for Sustainable Development to build regional cooperation on water resources management.

Water resource management issues and priorities differ in each of these countries, as do the level of economic development and size of population. In brief, Thailand wants more water; Lao PDR wants capital and expertise to develop energy supplies for probable export to Thailand and Vietnam; Cambodia wants capital and infrastructure and to secure sustainable fishery resources in the Tonle Sap (Great Lake); and



Vietnam, while in need of capital for resource management, does not want any upstream development to exacerbate salt-water intrusion into the Mekong delta during the dry season.

Although dams currently regulate less than 5 per cent of the Mekong basin, more than 100 large dams have been proposed for the region over the

The Mekong River in north-east Thailand.
WWF-Canon / Gerald S Cubitt

Table 12. Irrigated crop areas in South-East Asia (thousand hectares)

	Rice	Sugarcane	Vegetables	Cotton	Citrus	Bananas	Sweet potatoes	Fruit	Maize	Soybean	Wheat	Pulses	Tobacco
Thailand	4,531	605	154		230	170		520					
Vietnam	4,500	168	276		35	23	16		110				
Lao PDR	150	3	18	6	9								
Cambodia	313	6											
Java	3,578	181	98						171	37		13	
Indonesia	1,927	181	147						171	56		20	
Myanmar	1,600	57	46	100				25	20		71	204	
Malaysia	434	24	32										11
Total	**17,033**	**1,225**	**771**	**106**	**274**	**193**	**16**	**545**	**472**	**93**	**71**	**237**	**11**
%	**80.9**	**5.8**	**3.7**	**0.5**	**1.3**	**0.9**	**0.1**	**2.6**	**2.2**	**0.4**	**0.3**	**1.1**	**0.1**

past ten years by the governments concerned and by institutions such as the Asian Development Bank. Some of these dams are already under construction and others are at advanced stages of planning. One of the more controversial issues is China s plan to construct eight dams on the Upper Mekong. Two have already been completed and construction of a third, Xiaowan, began in January 2002. These dams will inevitably have widespread impacts on the livelihoods of downstream Mekong communities and on the natural ecology of the river system.

Biodiversity

The Mekong is enormously rich in biodiversity: its fish fauna alone has been estimated to total 1,300 species, some of which migrate hundreds of kilometres between the sea and upstream river reaches. Among the numerous remarkable and charismatic fish in the Mekong River Basin, one of the most endangered and extraordinary is the endemic giant Mekong catfish, the largest scale-less freshwater fish in the world, which can grow to over 300kg. Other endemic fish that are under threat include the Laotian shad, Mekong stingray, and seven-striped barb, as well as numerous unusual endemic species in smaller tributaries, such as the cave fish *Barbus speleops*. Due to our limited knowledge, particularly of these remote tributaries, many more of such species are likely to still be awaiting scientific discovery. The Mekong River also provides habitat for one of only three riverine populations of the endangered Irrawaddy dolphin. This ecoregion is also a vitally important feeding and breeding ground for numerous waterbirds, including the endangered giant ibis and the endemic Mekong wagtail.

WWF has identified seven ecoregions in the Mekong Basin: Annamite Range Moist Forests, Cardamom Mountains Moist Forests, Hengduan Shan Coniferous Forests, Indochina Dry Forests, Mekong River, Northern Indochina Subtropical Moist Forests, and Tibetan Plateau Steppe.

Main findings

Rice is the main irrigated crop by area in South-East Asia in both the wet and dry seasons (80.9%), followed by sugarcane (5.8%) and vegetables (3.7%). The development of irrigation in Lao PDR

Table 13. Water consumption by the 'thirstiest' crops in the Mekong River Basin

	Rice		Sugarcane		Vegetables	
	ha	million m^3	ha	million m^3	ha	million m^3
Lao PDR	150,000	2,566	3,000	69	18,000	179
Cambodia	313,000	5,347	6,000	138	-	-
Vietnam	2,250,000	33,750	84,000	1,680	146,000	1,587
Thailand	788,130	11,634	300,000	9,490	77,000	1,099
Total	**3,501,130**	**53,297**	**293,000**	**13,377**	**218,000**	**2,865**

and Cambodia, for which there remains significant potential, is lagging behind the other countries. However, the irrigated crops in these two countries follow the same general pattern, by area, as in the much larger countries of Vietnam and Thailand (Table 12).

A calculation was then made of the total volume of water withdrawn for agricultural purposes in the Mekong Basin, making the following assumptions:

- Vietnam: 50 per cent of the rice, sugarcane, and vegetable areas are assumed to be located in the north of the country and thus lie outside the Mekong River Basin;
- Thailand: 25 per cent of the wet season rice area and 10 per cent of the dry season area are assumed to be located in the north-east region, which roughly coincides with Thailand s share of the Mekong Basin. Sugarcane is estimated at 50 per cent of its

Vietnamese rice varieties are scored for damage by bacterial leaf blight at the International Rice Research Institute in Manila, Philippines.
WWF-Canon / Vin J Toledo

total irrigated area;

- Irrigated agriculture in Cambodia and Lao PDR is assumed to be located entirely in the Mekong River Basin.

The general pattern of importance of the main crops by area is repeated in terms of total water use. Rice is by far the most important water user, with sugarcane using a considerable volume of water despite its relatively small area overall.

Future water demand

IWMI s general conclusion is that the South-East Asia region will face economic water scarcity by 2025 — that is, primary water supply less than 60 per cent of the potential utilizable water resource. There will be a need to increase primary water supply by more than 25 per cent over current levels. This means that the Mekong Basin countries are expected to face primarily financial and institutional constraints in developing their water resources.

The large percentage increases that will be required in Cambodia (Table 14) need to be seen in relation to the current low level of irrigation development. The increases forecast for Thailand and Vietnam are more questionable given the large areas already in use. In Thailand, it is projected that the rain-fed cereal area will fall by 43 per cent from 1995 levels, while the irrigated cereal area will increase by approximately the same figure. Whether this development will happen is currently unclear, as water demand from industrial and urban sectors is increasing rapidly and new water storage options are limited, or located in areas that are densely populated or designated as protected areas. In Thailand and Vietnam, increasing the efficiency of existing irrigated areas would appear the most viable option for increasing food production sustainably.

Table 14. Water demand forecasts for three South-East Asian countries*

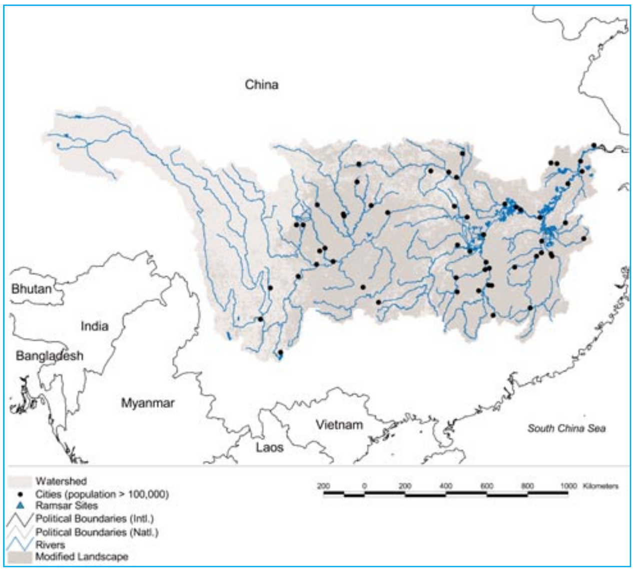
	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
Cambodia				
1995	0.22	0.6	1.59	200.0
2025	0.38	1.1	2.05	
Increase (%)	73	83	29	
Vietnam				
1995	2.66	22.1	4.64	387.7
2025	3.21	30.1	6.62	
Increase (%)	21	36	43	
Thailand				
1995	3.44	16.0	7.44	95.2
2025	5.12	30.0	4.25	
Increase (%)	49	87.5	-43	

*Lao PDR was not included in the IWMI analysis

Yangtze River Basin

Flowing 6,300km from western China s Qinghai-Tibet Plateau to the East China Sea, the Yangtze River stretches across nine provinces and drains 1.1 million km^2. It is shorter only than the Amazon and Nile. For over two centuries the Yangtze has served as a transportation highway and commercial thoroughfare. Ocean-going vessels can navigate upriver for 1,000km and steamers can travel as far as Yichang, 1,600km from the sea. Every year, the Yangtze deposits more than 170 million cubic metres of silt. It also provides crucial irrigation waters for the fertile plains of Jiangsu Province, one of the most productive areas of agriculture in China.

Today, China accounts for 35 per cent of the world s rice production, globally the single most important food crop and a primary food for more than a third of the world s population. China is endeavouring to provide for its growing population using improved agricultural technology and production methods.



Biodiversity

Little in the way of unspoiled nature still exists along the Yangtze, yet its still rich flora and fauna are adapted to the river s extreme changes in size and depth with the seasons. The river and its wetlands support dwindling populations of rare species like the Chinese river dolphin, Chinese sturgeon, Chinese water deer, otter and Yangtze alligator, and provide wintering sites for more than 150 migratory bird species. These include 95 per

Rice being harvested in Yunnan Province, China.
WWF-Canon / Chris Elliott

Table 15. Irrigated crop areas in China (thousand hectares)

	North-east China	South-east China	West China	Total area	%
Rice	6,317	29,612	3,553	39,482	46.6
Wheat	14,412	4,118	2,059	20,589	24.3
Maize	9,712	1,439	839	11,990	14.2
Soybean	1,284	1,314	388	2,986	3.5
Cotton	1,236	588	203	2,027	2.4
Groundnut	831	851	251	1,933	2.3
Fruits	612	626	185	1,423	1.7
Vegetables	430	440	130	1,000	1.2
Cereals	221	227	67	515	0.6
Potatoes	215	220	65	500	0.6
Sugarcane	200	204	60	464	0.5
Citrus	183	187	55	425	0.5
Sorghum	160	164	48	372	0.4
Millet	157	161	47	365	0.4
Oilseed crops	126	129	38	293	0.3
Sunflower	125	128	38	291	0.3
Total	**36,221**	**40,408**	**8,026**	**84,655**	**100**

cent of the world population of Siberian cranes, and 85 per cent of the world population of lesser white-fronted geese.

There are five ecoregions identified by WWF in the basin: the Yangtze River and Lakes, South-west China Temperate Forests, Hengduan Shan Coniferous Forests, Tibetan Plateau Steppe, and Yunnan Lakes and Streams.

Main findings

For China as a whole, the pattern of cropping reflects the country s varying climatic conditions. In terms of cultivated area, rice is by far the largest, with wheat, maize, soybean and cotton the next in order. In the temperate areas of China wheat and maize are the dominant crops, whereas rice is the dominant crop in subtropical areas (Table 15). Much of the agriculture in the Yangtze Basin corresponds to the south-east region of China.

For the major crops grown in the Yangtze Basin, water requirements were then calculated (Table 16). In terms of their water requirement, rice, wheat, maize and cotton are the four most important irrigated crops in south-east China. Rice accounts for more than 90 per cent of water use despite occupying only 70 per cent of land area. Similarly, because of its high water requirement, cotton uses more water in total than soybean despite the fact that the area under soybean is considerably larger.

Future water demand

IWMI s general conclusion for the East Asia region is that, by 2025, there will be economic water scarcity — that is, primary water supply less than 60 per cent of the potential utilizable water resources but an increase of more than 25 per cent over the current levels (Table 17). A more detailed regional assessment of future water demands suggests that the north-eastern regions of China will suffer physical water scarcity.

A reduction in rain-fed cereal area forecast by IWMI is not compensated for by a similar increase in irrigated cereal area. China aims to maintain self-sufficiency in cereal production through an increase in irrigated area and improved agricultural production methods. Since yields from irrigated agriculture are on average twice that of rain-fed crops, the further increase in cereal production should be achieved primarily through more efficient irrigation and improved agricultural production methods.

Farmers in rice fields at Dongting Hu Lake, Hunan Province, China.
WWF-Canon / Michel Gunther

Table 16. Water requirements for the ‘thirstiest’ crops in the Yangtze Basin

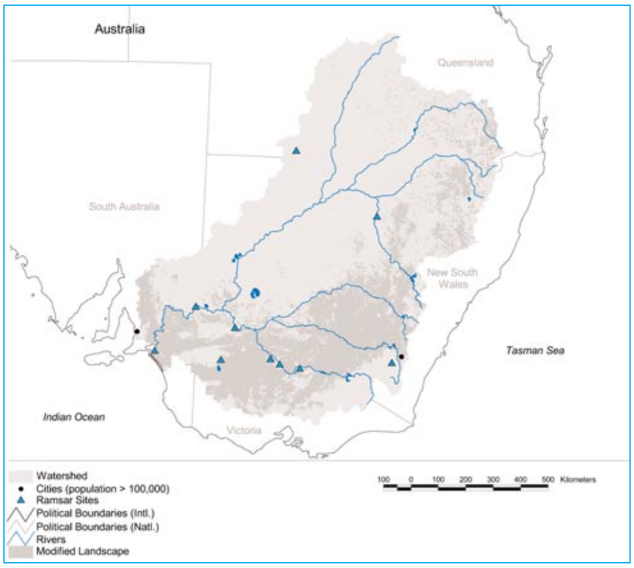
		Area (ha)	Irrigation requirements (mm/ha)	Total water requirement (million m^3)
Rice	– single-crop	1,945,000	150	8,104
	– early double-crop	3,891,000	250	27,020
	– late double-crop	3,892,000	375	40,541
Wheat		1,352,000	75	2,816
Maize		472,000	150	1,966
Cotton		193,000	150	804
			Total	**81,254**

Table 17. Water demand forecast for China

	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
1995	73.93	359.0	39.36	810
2025	102.50	504.2	10.80	
Increase (%)	1.1	40	-4.2	

Located in the south-east of Australia, the Murray-Darling Basin covers over 1 million km^2, equivalent to 14 per cent of the country s total area. East-west, the basin extends for 1,250km, while from the source of the Warrego River in the north to the headwaters of the Goulburn River in the south, the distance is some 1,365km. The basin covers four states and the entire Australian Capital Territory, and contains about half the irrigated agriculture in Australia.

Past management practices, which have led to unsustainable land and water use, and current practices, which focus on achieving sustainability, provide an essential context for determining priority crops. The biophysical characteristics of the basin reveal the inherent difficulty of applying European-style water use practices in a very different geological and hydrological setting. The attempt to harness water resources in Australia has led to a particular type of agricultural use and this in turn has led to a wide range of environmental problems.



Biodiversity

The natural diversity of the Murray-Darling Basin ranges from temperate and semi-arid grasslands through open acacia and eucalyptus woodlands to dense eucalyptus forests and alpine regions. It supports a large number of plants and animals, many of which are unique to Australia and of national or international significance. Originally, 20 fish species, 24 frogs, 151 reptiles, 367 birds and 85 mammals were found within the basin. Many species are now either extinct or seriously threatened, and the survival of the remainder is dependent upon the health of the river system and adjoining habitats.

There are three distinct ecoregions situated in the Murray-Darling Basin: Eastern Australia Temperate Forests, Southern Australian Mallee and Woodlands, and Eastern Australia Small Rivers and Streams.

Table 18. Areas of irrigated agriculture in Australia, 1996/1997

	Ha
Livestock, pasture, grains and other agriculture	1,174,687
Vegetables	88,782
Sugar	173,224
Fruit	82,316
Grapes	70,248
Cotton	314,957
Rice	152,367
Total	**2,056,581**

Fields along the Murray River on the New South Wales-Victoria border, Australia.
WWF / Frédy Mercay

Table 19. Water consumption by the 'thirstiest' crops in Australia

	State / river basin	Area (ha)	Water use (million m^3)
Pasture	Murray-Darling	862,155	5,300
Cotton	Murray-Darling	231,684	1,300
Rice	Murray-Darling	109,186	1,200
Sugarcane	Queensland	172,267	1,200

Main findings

Irrigated agriculture in Australia is dominated by livestock, pasture and grains, the latter presumably for livestock feed. Cotton, sugar and rice are important, but are nearly an order of magnitude smaller in terms of area (Table 18).

About half of Australia s irrigated agriculture is located in the Murray-Darling Basin. By area and by water use a similar pattern occurs across the rest of the country, with the exception of sugarcane. Sugarcane is grown mainly in Queensland and covers an area of 172,267ha. Total water consumption for this area is estimated at 1.2km^3, which places sugarcane among the top four water-consuming crops in Australia (Table 19).

Future water demand

IWMI s general conclusion is that Australia will face economic water scarcity by 2025 — that is, primary water supply less than 60 per cent of the potential utilizable water resource, with an increase in primary water supply of more than 25 per cent over current levels (Table 20). This means that the Australian states concerned are expected to face primarily financial and institutional constraints in developing their water resources.

Given that the total cereal area in Australia is not expected to change, the projected decrease in rain-fed cereal area is expected to be compensated by an increase in irrigated land of 490,000ha, according to IWMI. However, since the vast majority of Australia s agricultural commodities are exported, sizeable fluctuations occur in annual production due to seasonal conditions and commodity prices. This is considered more significant than the assumption that an increase in irrigated farming will compensate for any reduction in dryland production.

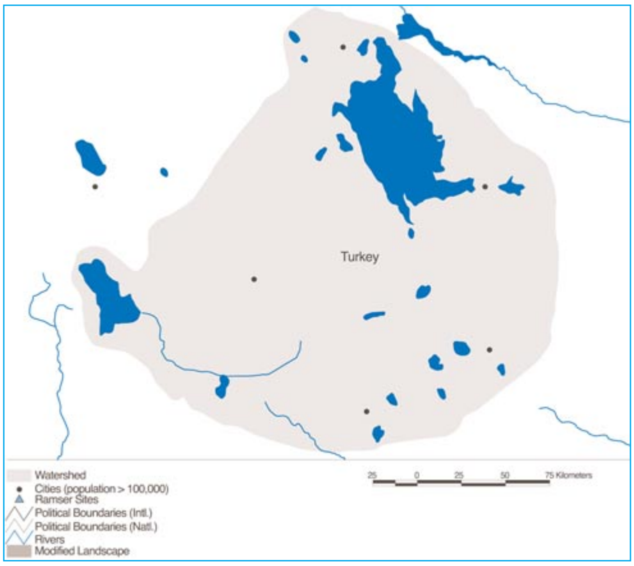
Although progress has been made, there is still substantial scope for improving the efficiency of water used in irrigation, especially for water-intensive crops such as cotton and rice. There are also some benefits to be gained from crop switching. This is because the crops that use more water — pasture and rice — also have the lowest value per unit of water. Where land is suitable for this, switching to fruit and vegetable cultivation could be considered as this ought to reduce total water use and provide higher income per unit of available water.

Table 20. Water demand forecast for Australia

	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
1995	0.62	24.4	13.43	211
2025	1.11	36.3	12.94	
Increase (%)	79	49	-3.6	

Great Konya Basin

The Great Konya Basin in Turkey is one of several closed basins within the Central Anatolian Plateau. Several rivers flow into the Great Konya Basin, feeding lakes and marshes in the lower central parts of the basin, which consists of several plains separated by plateaus. The most important areas for agriculture are the Konya, Hotamıs, Karapınar, Eregli and Karaman plains. To the south the basin is bordered by the Toros mountains and to the north by the Pontic range. The basin is filled with sediments from different geological periods. Most have come from the surrounding mountains, but there are also some volcanic deposits. In some places these sediments reach depths of 400m.



Biodiversity

The Great Konya Basin contains diverse running water and lake environments. Due to the basin s isolated position between two bio-geographic regions, the flora and fauna are exceptionally rich in rare and endemic species. The richest and largest stands of rangeland surviving in Turkey lie within the basin. Historically it has supported about 20 species and ten subspecies of endemic fish, many with very local distributions. Lakes are abundant and provide important habitat for migratory waterbirds. The extensive areas of remaining salt

Rice fields in the Göksu Delta, Turkey.
WWF-Canon / Magnus Sylven

Table 21. Irrigated crop areas in Turkey

	Ha
Wheat	1,004,000
Cotton	728,000
Sugarbeet	334,000
Vegetables	327,000
Fruits	189,000
Barley	122,000
Maize	122,000
Pulses	121,000
Potatoes	104,000
Oil crops	100,000
Citrus	84,000
Sunflowers	67,000
Tobacco	60,000
Rice	58,000
Fodder	35,000
Groundnut	21,000
Total	**3,476,000**

steppe are the largest and most pristine in Turkey.

The Great Konya Basin forms part of the Anatolian Freshwater ecoregion, which falls across parts of both Turkey and Syria.

Main findings

In Turkey wheat is the dominant irrigated crop by area, with cotton, sugarbeet and vegetables as the next highest ranked (Table 21). A considerable proportion of Turkey s irrigated crops (about 10%) are grown in the Great Konya Basin, with wheat, sugarbeet, fruit, vegetables and lucerne being the main crops. Cotton is not grown in the basin as the climate is too cold. The water needed to grow the main crops in the Konya Basin (Table 22) was calculated using the FAO s CROPWAT program for the range of irrigated area figures obtained.

Given that naturally occurring water in the Great Konya Basin amounts to around 4,200 million m^3, it can be seen that irrigated crops demand between 50 and 88 per cent of this. This means that the balance has to be imported from outside the basin in a series of water transfer schemes.

Future water demand

IWMI s general conclusion is that Turkey will face economic water scarcity by 2025 — that is, primary water supply less than 60 per cent of the potential utilizable water resource, with an increase in

Table 22. Water consumption by the 'thirstiest' crops in the Great Konya Basin

	Area (ha)	Irrigation requirements (mm/ha)	Crop water withdrawal (million m^3)
Wheat (cereals)	164,199 – 298,507	195	800 – 1,455
Sugarbeet	23,457 – 42,643	719	421 – 766
Fruit trees (grapes)	23,457 – 42,643	645	378 – 687
Vegetables (tomatoes)	11,728 – 21,322	668	195 – 356
Lucerne (alfalfa)	11,728 – 21,322	795	233 – 423
Total	**234,571 – 426,439**		**2,029 – 3,689**

primary water supply of more than 25 per cent over current levels (Table 23). Owing to lack of data, it was not possible to make a specific water demand forecast for the Great Konya Basin, but the situation in the basin is likely to be considerably worse than the average for Turkey since water is already being imported from other areas to meet demands.

The current irrigation practices in the Konya Basin appear to be unsustainable without significant inter-basin water transfers. Increased efficiency in irrigation and water conservation methods — such as drip irrigation for grapes and vegetables, or broad-bed irrigation for wheat (see page 35) — will help, but are unlikely to be enough to solve the problems. More fundamental agricultural reforms may be needed in order to move towards sustainability in the long term.

Table 23. Water demand forecast for Turkey

	Irrigated cereal area (million ha)	Primary water supply (km^3)	Rain-fed cereal area (million ha)	Potential utilizable water resource (km^3)
1995	0.69	51.42	14.04	128.57
2025	1.18	92.85	14.10	
Increase (%)	1.8	80.5	0	

Rio Grande Basin

The Rio Grande Basin is one of the largest in North America and home to over 9 million people. It covers about 466,000 km^2, including portions of three US and five Mexican states. A large segment of the river (2,000km) forms the border between Mexico and the United States. The limited water resources of this arid basin have been developed and, in many instances, over-exploited to provide a year-round supply of water for irrigated agriculture, industry, and growing municipalities. During the last century, a number of large reservoirs were built on the Rio Grande and its major tributaries, and extensive well fields were drilled in the basin s aquifers. The dams, while providing storage, have greatly reduced the downstream flow of the main stream and its tributaries. In some areas, groundwater pumping has reduced or even eliminated spring flow or allowed the infiltration of saline water into freshwater zones.

Biodiversity

The waters of the Rio Grande descend from snow-capped mountains in Colorado and New Mexico, draining 415,000km^2 as they make their way to the Gulf of Mexico. The basin is home to many endangered and threatened plants, animals and habitat types. Forests in the upper basin areas support an impressive avifauna, including Mexican jay, zone-tailed hawk, maroon-fronted parrot, and northern goshawk. Predators with large ranges, such as the endangered Mexican grey wolf and the mountain lion, manage to persist. The lower Rio Grande basin contains 84 fish species, of which 16 are endemic. This high level of endemism is considered continentally outstanding in the freshwater ecoregions of North America. The upper Rio Grande transitions from a cold-water fishery characterized by trout species, to a broad, shallow warm-water fishery where minnows and catfish are abundant.

Water from underground aquifers used to irrigate wheat and other crops in the Gulf of California, Mexico.
WWF-Canon / Edward Parker

Table 24. Major irrigated crop areas in US states in the Rio Grande Basin

Crop	Colorado (ha)	New Mexico (ha)	Texas (ha)	Total (ha)
Alfalfa	39,200	50,870	20,517	110,587
Barley	23,600			34,717
Cotton		11,117	83,674	107,064
Maize		13,510	13,477	26,987
Pasture		23,390	16,964	26,141
Pecan		9,117	7,131	27,427
Sorghum			23,363	23,363
Sugarcane			11,916	11,916
Vegetables		20,296	66,955	66,955
Wheat	12,000	3,513	12,948	28,461

Two WWF priority ecoregions are situated in the Rio Grande Basin: Sierra Madre Oriental and Occidental Pine-Oak Forests, and the Chihuahuan-Tehu can Deserts.

Main findings

Due to time constraints, only the US side of the Rio Grande Basin was studied in any detail. It is possible that some of the general patterns and conclusions might change if data from the Mexican portion of the basin were to be incorporated.

In the US part of the basin the top five irrigated crops in terms of area are: alfalfa, cotton, vegetables, barley, and wheat, followed by pecan (a valuable nut tree) (Table 24).

The top three crops (alfalfa, cotton and vegetables) generally rank among the highest water consumers. However, a recalculation of the ranking is required because alfalfa, maize, and wheat are commonly used for animal feed in livestock rearing, which is an important agricultural activity in the states of Colorado, New Mexico and Texas. The use of these crops for animal feed makes livestock rearing the highest water consuming commodity, followed by cotton, vegetables, pecan, and sugarcane.

This shows that the individual crop approach has to be considered with caution in all basins since the data available do not indicate whether the crop is intended for human or animal consumption. In some cases, therefore, the figures need to be combined in order to assess the total impact of an agricultural commodity on water withdrawals.

Future water demand

IWMI s general conclusion is that overall water scarcity levels for Mexico are defined as economic , while the USA is considered as being free from water scarcity. However, all Mexican states bordering the Rio Grande are forecast to face physical water scarcity by 2025, a situation that will inevitably impact upon the US side of the border as well.

Among the options available to reduce the demands on water made by agriculture are metering of use and improvements in irrigation technology. This includes use of ultra-narrow row density for cotton, and drip irrigation systems. It may also be necessary to consider importing livestock feed instead of growing it locally, and to use the water saved for irrigating high-value, less thirsty crops such as citrus fruits. A more drastic solution would be to relocate intensive livestock production away from this region.

Harvested cotton from the irrgated lands of the Chihuahua Desert, Mexico.
WWF-Canon / Edward Parker

Future water scarcity

All of the countries covered by the present study are forecast by IWMI to experience at least economic water scarcity by 2025. In technical terms, their primary water supply will increase by more than 25 per cent, but exploitation of their potential utilizable water resources will remain below 60 per cent. This means that these countries are expected to face primarily financial and institutional constraints in developing their water resources. As a result, most will probably fall short of the cereal production that will be required to feed their populations, and they will thus become dependent on imported cereals.

Of the countries studied, Pakistan is the only one in its entirety expected to face physical water scarcity, as it is projected to need to use 102 per cent of its potential utilizable water resources by 2025. However, parts of China and Turkey may also face such situations. From a river basin perspective, the Rio Grande Basin is also expected to experience physical water scarcity, although the two countries that share this basin — Mexico and the US — are predicted overall to experience little or no water scarcity.

At face value, these situations would suggest the need for storing more water through dam and reservoir construction which would be costly from financial and environmental perspectives. However, by making significant improvements in the efficiency of agricultural irrigation, this could largely be avoided — a scenario that applies to all countries that are presently experiencing, or are predicted to experience, economic water shortages.

The thirstiest crops

Although, in Table 26, the same crops appear repeatedly as the largest water consumers in the river basins studied, there is a significant difference between the agricultural systems in developing countries and those in the industrialized world. Since combining results from river basins in Australia and the United States with those from developing countries could therefore cloud the results of this study, a differentiation has been made in Table 27.

In the two river basins studied in industrialized countries (the Rio Grande and the Murray-Darling) where irrigation is practised extensively, livestock rearing is the major agricultural activity. In both cases pasture ranks among the highest consumers of water, along with the irrigated cereal crops (wheat, barley and maize) that are used for livestock feed. These same irrigated cereals in basins in developing countries are primarily used for human consumption.

Table 25. Summary of projected levels of water scarcity

Level	Increase in primary water supply	Use of potential utilizable water resource	Global regions
Little or no water scarcity	<25%	n/a	North America Europe Central Asia
Economic water scarcity	>25%	<60%	Africa Australia South-East Asia South and Central America
Physical water scarcity	>25%	>60%	Middle East North African countries South Africa Pakistan North-west India West and north-east China

Table 26. Area and water use for major irrigated crops per river basin in developing and developed countries

Crop	Rice		Wheat		Sugarcane		Cotton		Vegetables		Pasture		Cereals (maize, barley)	
River basin	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Niger	0.42	12.7	0.06	1.22	0.04	2.01			0.12	2.1				
Zambezi	0.45	0.8	0.07	0.9	0.93	3.6			0.19	0.2				
Indus	2.42	70.5	7.54	51.4	1.06	0.5	2.96	51.4						
Mekong	3.36	51.0			0.29	0.2			0.22	0.3				
Yangtze	9.73	75.7	2.82	1.4			0.80	0.19					1.96	0.5
Konya			1.49	7.2	0.21[c]	3.4			0.11	1.7	0.11	2.1		
Points[e]	**17**		**13**		**13**		**4**		**9**		**2**		**2**	
Crop ranking	**1**		**2**		**2**		**4**		**3**					
Murray-Darling[d]	0.11	1.2			0.17	1.2	0.23	1.3			0.86	5.3	0.14	0.9
Rio Grande							0.10	?	0.07	?	0.11	?	0.03	
Points[e]	**1**						**5**		**3**		**8**		**3**	
Crop ranking	**4**						**2**		**3**		**1**		**3**	

a Irrigated area under cultivation in millions of hectares.
b Water consumption per crop in billions of cubic metres.
c In the Konya basin, sugar is produced from sugarbeets.
d Sugarcane is not grown in the Murray-Darling Basin, but is one of the major water-consuming crops in Australia, for which reason it has been included in this table. However, it was not taken into account for the crop ranking.
e Points were attributed as follows: The top four water-consuming crops for each basin were identified. Number 1 was given four points, number 2 three points, etc. The total number of points accumulated by each crop was then calculated and serves as an indicator of the worldwide ranking of the crop. In this way, differences of scale in area under cultivation were avoided. If area or water consumption had served as the basis for the evaluation, the cropping pattern of China would have been the standard irrigated cropping pattern for the world.

Table 27. Crop ranking by water consumption

Crop	Developing countries	Industrialized countries
Rice	1	4
Wheat	2	
Sugarcane/Sugarbeet	2	
Cotton	4	2
Vegetables	3	3
Pasture		1
Cereals (maize/barley)		3

The crop ranking for the basins studied in developing countries presents no major surprises. Food cereals, namely rice and wheat, are the thirstiest crops. These are followed by sugarcane/sugarbeet, vegetables and cotton. This same grouping of crops also has high water use in industrialized countries, however the sequence is different; overall, pasture makes the highest demand on water, reflecting the dietary preferences for meat and dairy products in these countries.

Options for water conservation

The International Water Management Institute has


Examples of broad bed cultivation, a useful method for saving water, particularly in irrigated wheat.
Bottom right: alternate furrow cultivation of beans and maize at WWF's Lake Nakuru project, Kenya. WWF-Canon / Donald Miller


Table 28. Water-saving practices for thirsty crops

Crop	Selected water-saving practices
Rice	■ Shorter land preparation period ■ Direct or dry seeding ■ Laser levelling ■ Aerobic rice varieties.
Sugarcane	■ Drip, sprinkler and alternate furrow irrigation ■ Water deficit during crop elongation ■ Replanting crop die-off each year.
Cotton	■ Knowledge about cotton growth models ■ Water deficit in non-critical growth periods ■ Shallow soil cultivation ■ Drip, sprinkler and alternate furrow irrigation.
Wheat	■ Broad-bed cultivation ■ Drip, sprinkler and alternate furrow methods ■ Zero tillage and laser levelling ■ Water deficit in non-critical growth periods ■ Crop varieties that grow under sub-optimal water availability.

estimated that the world s irrigated area would need to increase by 29 per cent from 1995 onwards to meet food and other nutritional requirements by 2025. Such an increase would need to be supported by a number of measures. These include the construction of additional storage and diversion facilities to develop an additional 17 per cent of the world s primary water supplies, while yields from irrigated crops would have to increase from 3.3 to 4.7 tonnes per hectare. A more appealing first option, however, must be to implement measures for conserving and making more efficient use of the water already allocated to agriculture. This is especially so given that current overall water-use efficiency is low: only some 20—50 per cent of diverted waters actually reach the crops for which they are intended.

The many opportunities that exist for improving water efficiency, in both irrigated and rain-fed agriculture, mean that more food could be grown without increasing existing levels of water use. There are two basic means by which water-use efficiency can be improved: (a) increasing the share of transpiration (i.e. the water actually taken up by plants) in the water used for irrigation, and (b) producing more crop per unit of water.

The cultivation practices used may also be important. Farmers in Israel have observed that cotton grown under organic conditions requires around 30 per cent less water than cotton grown under conventional practices. An explanation for this could be that organic practices lead to a better soil structure, build-up of biomass, and thus a higher water retention capacity. Losses as a result of deep percolation would thus be reduced. Similar results have been found elsewhere with other crops where mulching practices, or no-till approaches, are used.

Main Conclusions

Although there are many local variations, some crop-specific approaches that either maintain or increase the crop produced per drop of irrigation water are given in Table 28.

Field projects carried out in the Maikaal project area in India indicate that cotton can be produced with significantly less water input. Compared to conventional flood irrigation systems, low-cost drip irrigation systems can make water savings of up to 80 per cent. Field studies in Pakistan have revealed water savings of close to 50 per cent can be made by various furrow irrigation methods compared to flood irrigation.

Irrigation systems and the watershed perspective

To prevent wider water shortages in river basins, and to conserve natural systems and their functioning, more is required than simply producing more crops with less water. In many countries individual farmers are dependent for their water supply on whoever controls large-scale irrigation systems. Much can be done to improve efficiencies through better system design, regular maintenance and effective drainage, and equitable procedures for allocating water among farmers when there are shortages.

There is also a need to consider the basin or watershed within which the cumulative impacts of water use, chemicals and land-use change are felt by people and nature. Without agreements at the watershed level on returning saved water to natural wetland systems, the upshot will be either more intensive farming, or for cultivation to spread onto untouched land areas. This would continue the downward cycle of land and water degradation and ecosystem decline, which in turn leads to agricultural decline and the need to expand into new areas. Ignoring the watershed perspective may well jeopardize the long-term goal of achieving sustainable agriculture.

In conclusion...

This study has considered the impact of water use by global agricultural commodities in nine large river basins of international importance for biodiversity. Based on the evidence collated and evaluated, a picture seems to be emerging in which four global commodities stand out for priority attention, namely rice, sugar, cotton, and wheat. Additionally, in industrialized countries, it appears that intensive livestock rearing exerts a very considerable impact on water – perhaps the largest impact of all – and one which is harder to assess quantitatively than single crops, since water is used on pastures, for feed crops, and for the daily needs of livestock.

There is a range of strategies available to farmers, planners and developers to get more out of agricultural water supplies and to ensure that freshwater resources and ecosystems are managed sustainably. At farm level, cultivation practices that maintain and build soil biomass seem to be important, as are specific irrigation technologies and practices that either reduce losses in water delivery or uptake by the crop. Efficiency of water use in irrigation systems and on farms could be increased by up to 50 per cent, and possibly more, in many cases using appropriate practices and technologies. In dry countries, farmers could also be encouraged to switch to higher value, less thirsty crops. Feed crops for livestock could be imported from more temperate areas, or intensive livestock rearing operations could be provided with incentives to move to such areas.

Finally, a river basin/watershed and/or irrigation system perspective is required in resource management decisions. This will help to avoid situations where, although individual operations on a given farm may be very efficient, the cumulative effects of many farms undermine the capacity of freshwater resources and ecosystems to provide long-term, sustainable services for people. A river basin perspective also enables ecological flow regimes to be defined that conserve biodiversity and ensure continued related goods and services for human populations.

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– promoting the reduction of pollution and wasteful consumption.

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