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The water we eat: challenges for ACP countries in times of scarcity

Resources on Water Scarcity in ACP Countries[1]

Compiled by Isolina Boto (Head of CTA Brussels Office)
Isaura Lopes and Marie-Pierre Godeau (Young researchers at the CTA Brussels Office)

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Resources on Water Scarcity in ACP Countries[1]

Brussels, 13th April 20112

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Revised version September 2012

The information in this document was compiled as background reading material for the 26th Brussels Development Briefing on new challenges and opportunities for pastoralism in the context of African countries[1]. The Reader and most of the resources are available at http://brusselsbriefings.net

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Context

Water is integral to all aspects of human welfare, including security, energy, food, and health. It affects the economy of countries as a whole and transcends a number of crucial productive sectors, including water and sanitation supply, irrigation, drainage and food production, renewable energy generation and the environment and in the last years it has been recognized as one of the key resources for development, growth and poverty reduction[2]. With international consensus around the importance of water, it is clear that in the development arena water has ceased to be an issue for only water specialists. Indeed, achievement of all eight Millennium Development Goals hinges on access to and availability of essential water resources. Yet, with the number of people without access to safe water expected to rise from just over 1 billion to 2 billion by 2025[3] water scarcity represents a major political, economic, and human right issue. Today the competition for scarce water resources in many places is intense. Many river basins do not have enough water to meet all the demands—or even enough for their rivers to reach the sea. Further appropriation of water for human use is not possible because limits have been reached and in many cases breached. Basins are effectively closed, with no possibility of using more water. The lack of water is thus a constraint to producing food for hundreds of millions of people. Agriculture is central in meeting this challenge because the production of food and other agricultural products takes 70% of the freshwater withdrawals from rivers and groundwater[4].

Food and feed crop demand will nearly double in the coming 50 years. The two main factors driving how much more food we will need are population growth and dietary change.

With rising incomes and continuing urbanization, food habits change toward more nutritious and more varied diets—not only toward increasing consumption of staple cereals but also to a shift in consumption patterns among cereal crops and away from cereals toward livestock and fish products and high-value crops. Producing meat, milk, sugar, oils, and vegetables typically requires more water than producing cereals—and a different style of water management. Increasing livestock production requires even more grain for feed, leading to a 25% increase in grains. Thus, diets are a significant factor in determining water demands. While feed-based meat production may be water costly, grazing systems behave quite differently. From a water perspective grazing is probably the best option for large land areas, but better grazing and watering practices are needed.

To keep pace with the growing demand for food, it is estimated that 14 percent more freshwater will need to be withdrawn for agricultural purposes in the next 30 years[5].
To harness the potential of water to function as a driver of growth, the indispensable ingredients are increased investments in the water- related sectors—water resources management, water supply and sanitation, irrigation and drainage, hydropower, and water/ environment—accompanied by urgently needed reforms..

1. Overview of the global water scarcity

What is water scarcity? There are several ways of defining water scarcity. The definition used by the United Nations in 2006 refers to water scarcity as: the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully[6]. Water scarcity is a relative concept and can occur at any level of supply or demand. Scarcity may be a social construct (a product of affluence, expectations and customary behaviour) or the consequence of altered supply patterns stemming from climate change, wide climate variability, combined with population growth and economic development. But the main reasons for water problems lie elsewhere—lack of commitment to water and poverty, inadequate and inadequately targeted investment, insufficient human capacity, ineffective institutions, and poor governance[7].

Water scarcity is distinct from water security, in that the latter is defined by the predictability of water supply and often the presence of contingency measures to compensate in times of water scarcity. Two distinct forms of water scarcity include physical and economic scarcity.

1.1 Physical and economic water scarcity

Physical water scarcity occurs when available water resources are insufficient to meet all demands, including minimum environmental flow requirements[8]. Arid regions are most often associated with physical water scarcity, but an alarming new trend is an artificially created physical water scarcity, even where water is apparently abundant. This is due to the overallocation and overdevelopment of water resources, leaving no scope for making water available to meet new demands except through interbasin transfers[9]. Symptoms of physical water scarcity include severe environmental degradation, such as river desiccation and pollution; declining groundwater tables; water allocation disputes; and failure to meet the needs of some groups. Some 1.2 billion people live in river basins where the physical scarcity of water is absolute (human water use has surpassed sustainable limits). And another 500 million people live in river basins that are fast approaching this situation. While physical scarcity introduces complex problems, investments in good management can mitigate many of them[10].

Economic water scarcity can occur in regions with adequate water reserves, but where poor governance and infrastructure prevent it from being fully usable or where inefficient use and mismanagement of water resources leads to waste and contamination[11]. Much of the scarcity felt by people is due to the way institutions function—favoring one group over another, not listening to the voices of women and disadvantaged groups. Symptoms of economic water scarcity include inadequate infrastructure development, so that people have trouble getting enough water for agriculture and domestic purposes; high vulnerability to seasonal water fluctuations, including floods and long- and short-term drought; and inequitable distribution of water even though infrastructure exists. Much of Sub-Saharan Africa experiences economic water scarcity, and there are many places across the globe where water resources are inequitably distributed. Further water development could ease problems of poverty and inequality.

The global water scarcity map shows regional variations for some countries like China, India, South Africa, Mexico and the U.S. Unlike countries such as Saudi Arabia and Israel, which have experienced physical water scarcity for a long time, many countries that are experiencing water scarcity today are major agricultural producers (e.g.: China, India). Ever increasing production of thirsty crops and livestock production have brought severe strains on water resources in many other parts of the world as well, including parts of North America and the European Union[12].

There is greater scope to tackle *economic water scarcity* through better governance and investment in infrastructure, but physical water scarcity is projected to grow steadily against the compounded impacts of climate change and population growth. Currently, 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical water scarcity, while another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage. Further, projections indicate that by 2025, 800 million people will be living in countries or regions with absolute water scarcity and two-thirds of the world's population could be under severe water stress conditions[13]. For example, by 2025, the Middle East

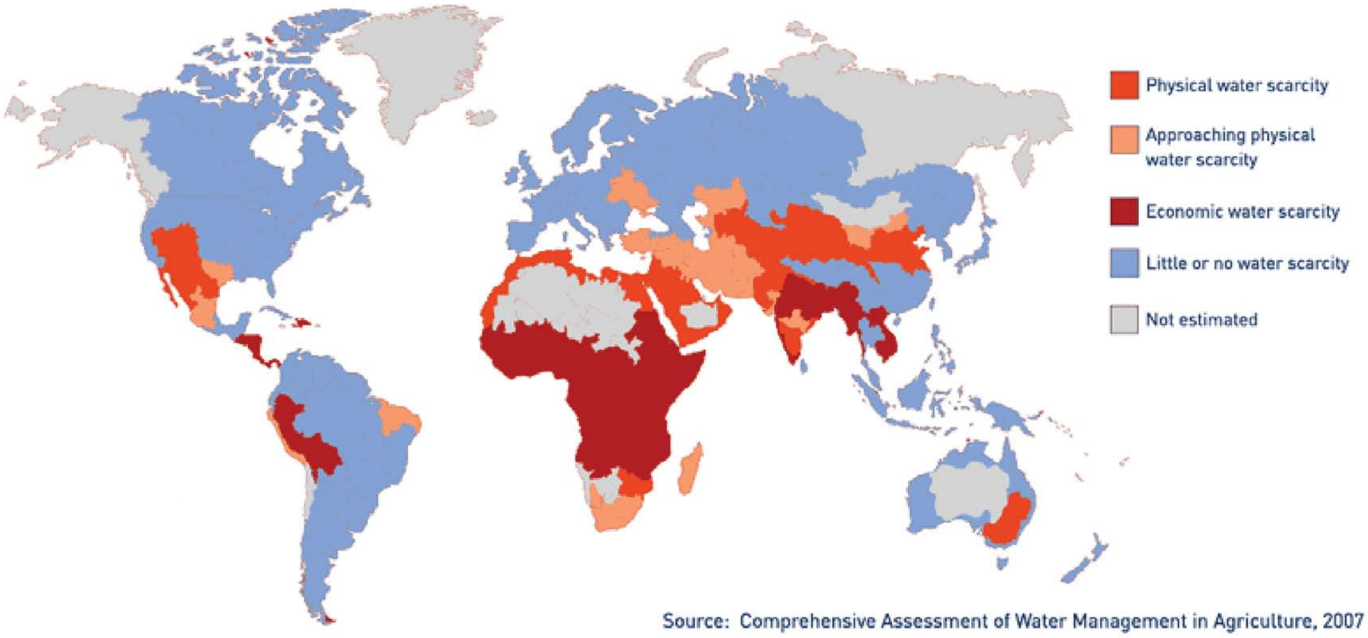
AREAS OF PHYSICAL AND ECONOMIC WATER SCARCITY

Physical water scarcity water resources development is approaching or has exceeded sustainable limits). More than 75% of the river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.

Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.

Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.

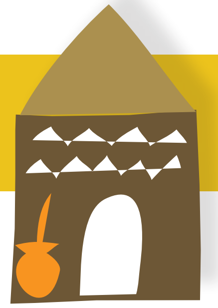


Source: Comprehensive Assessment of Water Management in Agriculture, 2007

and North Africa (MENA) region is set to experience a decline of per capita annual renewable water resources from 750 cubic meters to 500[14].

Irrigated agriculture, which represents the bulk of the demand for water in these countries, is also usually the first sector affected by water shortage and increased scarcity, resulting in a decreased capacity to maintain per capita food production while meeting water needs for domestic, industrial and environmental purposes. Historically, large-scale water development projects have played a major role in poverty alleviation by providing food security, protection from flooding and drought, and expanded opportunities for employment. In many cases, irrigated agriculture has been a major engine for economic growth and poverty reduction. However, at the same time, poor communities have tended to suffer the greatest health burden from inadequate water supplies and, as result of poor health, have been unable to escape from the cycle of poverty and disease.

Thus, growing scarcity and competition for water stand as a major threat to future advances in poverty alleviation, especially in rural areas. In semi-arid regions, increasing numbers of the rural poor are coming to see entitlement and access to water for food production, livestock and domestic purposes as more critical than access to primary health



care and education. Rainwater is the primary source of water in agriculture. It has also been used successfully to augment water for industrial and domestic purposes, while being an essential element in the functioning of natural ecosystems. However, rainwater is rarely integrated into water management strategies, which usually focus exclusively on surface water and groundwater. Countries need to integrate rainwater harvesting more fully into their Integrated Water Resources Management (IWRM) strategies and to promote its use to alleviate water scarcity[15].

1.2 Water withdrawal, demand and consumption[16]

Total global freshwater use is estimated at about 4,000 cubic kilometres (km^3) a year[17]. Another 6,400 km^3 of rainwater is also used 'directly' in agriculture. Nature is the most important user of water. An estimated 70,000 km^3 of water a year are evaporated from forest, natural (uncultivated) vegetation and wetlands[18]. Evaporation from human-made reservoirs is difficult to estimate but is considerable in arid areas and is estimated to be about 200 km^3 a year. For example, an estimated 10 km^3 – about 12% of the total storage in Lake Nasser, upstream of the High Aswan Dam at the high storage level – are lost through evaporation each year[19].

But we know only part of what humans use: only the volume of water used off-stream (withdrawn) is generally measured (or estimated), and only a part of what is withdrawn is effectively consumed. Most of the flow is returned – usually at a lower quality – to the water systems, where it can be reused. Agriculture is by far the most significant consumer of water, particularly in dry areas where irrigation has been developed. The consumptive uses of freshwater from agriculture, industry and domestic sectors place the greatest pressures on natural systems in quantity (withdrawals) and quality (returns of lower quality). Increasing in urbanized economies, industrial (including energy) use accounts for only 20% of total water use and domestic use for about 10%[20]. Water withdrawals for energy generation – hydropower and thermo-cooling – are on the rise, but energy is one of the economic sectors that consumes the least water and it returns most of the water withdrawn back to the water system (about 95%)21. This is only a partial picture of sectoral usage as there are many unaccounted-for uses. Little is known about water use in informal urban settlements or informal irrigation systems, both of which are generally unaccounted for in official statistics. Finally, there are numerous on-stream uses (such as fishing, navigation

Consumption by sector%

Users	**Consumption of water withdrawn**
Domestic (urban)	10 - 20
Industry	5 - 10
Energy (cooling)	1 - 2
Agriculture (irrigation)	
Surface irrigation	50 - 60
Localized irrigation	90

Source: http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/18_WWDR3_ch_7.pdf and ecosystems), which although generally non-consumptive, depend on a certain level of flows and water quality to function. Such uses cannot be measured in volume terms, and these uses are therefore not reflected in statistics on water use. From a water use perspective the world can be divided into two groups. In one group of countries (in Africa, most of Asia, Oceania, Latin America and the Caribbean) agriculture is by far the main water user, while in the other group (in Europe and North America) withdrawals are related mostly to industry and energy.

Water withdrawal per person

The domestic supply is essential to life (drinking, hygiene and bathing) but remains the smallest water user for both groups. Currently around 3 830 km3 of freshwater is withdrawn annually for human use, which is equivalent to about 600 m3 per person per year. To produce enough food to satisfy a person's daily dietary needs takes about 3,000 liters of water converted from liquid to vapor—about 1 liter per calorie. Only about 2–5 liters of water are required for drinking[22]. Globally this represents about 9 percent of the renewable freshwater resources. However, large differences exist between continents and regions, ranging from less than 2 percent in Oceania to more than 20 percent in Asia, 52 percent in South Asia and up to 63 percent in the Near East and North Africa region[23].

Around 20% of total water used globally is from groundwater sources (renewable or not), and this share is rising rapidly, particularly in dry areas[24]. This rise has been stimulated by the development of low-cost pumps and by individual investment for irrigation and urban uses. Private investment in self-supply of groundwater – essentially uncontrolled and unmonitored – has mushroomed in response to

(Cubic kilometres per year unless otherwise indicated)

Region	Renewable water resources	Total water withdrawals	Agriculture amount	Agriculture percent	Industry amount	Industry percent	Domestic (urban) amount	Domestic (urban) percent	Withdrawals as percent of renewable resources
Africa	3, 936	217	186	86	9	4	22	10	5.5
Asia	11 94	2 378	1 936	81	270	11	173	7	20.5
Latin America	13 477	252	178	71	26	10	47	19	1.9
Caribbean	93	13	9	69	1	8	3	23	14.0
North America	6253	525	293	39	232	48	70	13	5.4
Oceania	1703	26	118	71	1	12	5	19	1.5
Europe	6 601	418	132	32	223	53	63	15	6.3
World	43 659	3 829	2 663	70	784	20	382	19	8.8

Source: Based on Comprehensive Assessment of Water Management in Agriculture 2007.

inadequate public services. As a result, groundwater withdrawals rose fivefold during the 20th century, leading to a rapid drawdown of aquifers in some areas, putting at risk the sustainability of the uses that rely on it. In areas of scarce freshwater resources, brackish water and wastewater are often used to meet water demand. While accounting for less than 5% of global water use, the potential is substantially greater

1.3. Trade as a variable in agriculture water management

Many countries confront the prospect of emerging water scarcity in the long term. Countries in the Middle East and North Africa have already passed the point at which no more water can be applied to land and hence have resorted to commercial food imports. A water-scarce country pursuing food security may be forced to import water at some point. If water becomes the scarce factor, it may be more sensible to 'import' it embodied in products in general and food in particular, especially if food is available on favourable trade terms. Egypt, a water-scarce country, regularly imports food. California obtains 73 percent of its daily water input by importing food, though it also 'exports' water by selling cotton, fruit and vegetables[25]. It should be remembered that macro-economic policies and sectoral policies that are not aimed specifically at the water sector can have a strategic impact on resource allocation and aggregate demand in the economy.

A country's overall development strategy and use of macro-economic policies - including fiscal, monetary and trade policies - directly and indirectly affect demand and investment in waterrelated activities. The most obvious example is government expenditure (fiscal policy) on irrigation, flood control or dams. But a less apparent example is trade and exchange rate policies aimed at promoting exports and earning more foreign exchange.

Therefore, efficiency gains in the global food trade in terms of water resource utilization are possible and the consequence of increasing reliance on irrigation for food production in many countries, including food exporting countries, need to be well understood before such policy commitments are made.

1.3.1. The Concept of Virtual Water

The concept of Virtual water has been introduced by Professor John Anthony Allan from King's College of London and the School of Oriental and African Studies in about late 1994 some years after finding that the term embedded water did not have much impact. The idea is derived from Israeli analysis by Gideon Fishelson that in the late 1980s pointed out that exporting Israeli water in water intensive crops did not make much sense[26].

The water used in the production process of an agricultural or industrial product is called the 'virtual water' contained in the product.[27] For example for producing 1 kg of grain we need for instance 1000-2000 kg of water, equivalent to 1-2 m^3. Producing livestock products generally requires even more water per kilogram of product. For producing 1 kg of cheese we need for instance 5000- 5500 kg of water and for 1 kg of beef we need in average 16000 kg of water[28] . This explains why food production use about 70% of the fresh water withdrawals and that diets and their evolution do have a great impact on water resources. But virtual water is a term that links water, food, and trade. If it comes to a more precise quantitative definition, principally two different approaches have been proposed and applied so far. In one approach, the virtual water content is defined as the volume of water that was in reality used to produce the product. This will depend on the production conditions, including place and time of production and water use efficiency. Producing one kilogram of grain in an arid country for instance can require two or three times more water than producing the same amount in a humid country. In the second approach, one takes a user rather than a producer perspective, and defines the virtual water content of a product as the amount of water that would have been required to produce the product at the place where the product is needed[29]. This definition is particularly relevant if one poses the question: how much water do we save if we import a product instead of producing it ourselves? In the second approach to the definition of virtual water' a difficulty arises if a product is imported to a place where the product cannot be produced, for instance due to the climate conditions.

What for instance is the virtual water content of rice in the Netherlands, where rice is not being produced but imported only? In this case we have to look at the virtual water content of a proper substitute of the product considered[30]. The importance of virtual water lies with its potential to balance water rich and water-poor areas in the world through the international trade in agricultural products. If a country exports a water-intensive product to another country, it exports water in virtual form. For the water scarce countries it is attractive to achieve water security by importing water-intensive products. And also water rich countries can profit from their abundance of water resources by producing water-intensive products for export. The national economy can balance its water needs by accessing invisible water outside its national boundaries. In the global scale that the food trades is thus an indirect trade in water.

The term of virtual water has been presented as an instrument to improve global water use efficiency, to achieve water security in water –poor regions of the world and to alleviate the constraints or environment by using best-suited production sites[31].

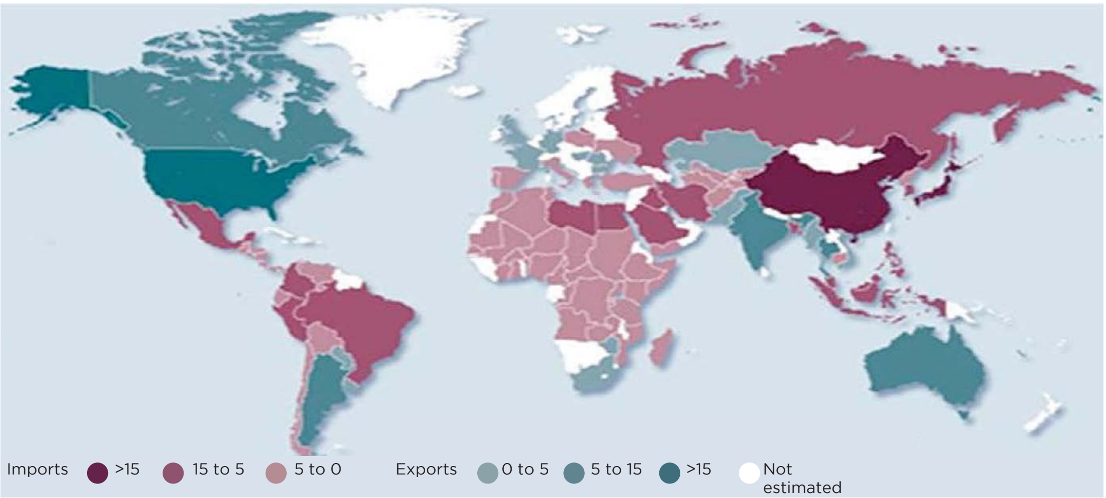
More firmly stated, and this is the political argument that has been put forward by Tony Allan from the beginning of the virtual water debate, virtual water trade can be an instrument in solving geopolitical problems and even prevent wars over water[32]. Next to the political dimension, there is the economic dimension, equally stressed by Professor Allan[33].

1.3.2. The Virtual Water Trade

The water that is used in the production process of a commodity is called the 'virtual water' contained in the commodity. International trade of commodities brings along trade of virtual water. The growing global interest and attention to the virtual water issue is at least partly because of its increasing importance for food security in many countries where water is becoming scarcer with the continuous expansion of population. Virtual water trade can improve the water availability and can also be used to building a regional economical solidarity, and fuel the agricultural sector. Inclusion of the possibility of virtual water trade, especially food imports, allows a wider spectrum of alternatives in water and environmental management policies[34]. The strength of the virtual water concept is that it embraces the whole water management in a country or basin and allows for a deeper understanding of water use through for example diet description or broader optimization of water allocation between different ester uses by incorporating access to external water resources through virtual water trade. This makes the concept a practical policy tool that can be extended to detailed analysis of water resources[35].

Professor Allan states that virtual water trade is so successfully

Virtual Water flow in cubic kilometres

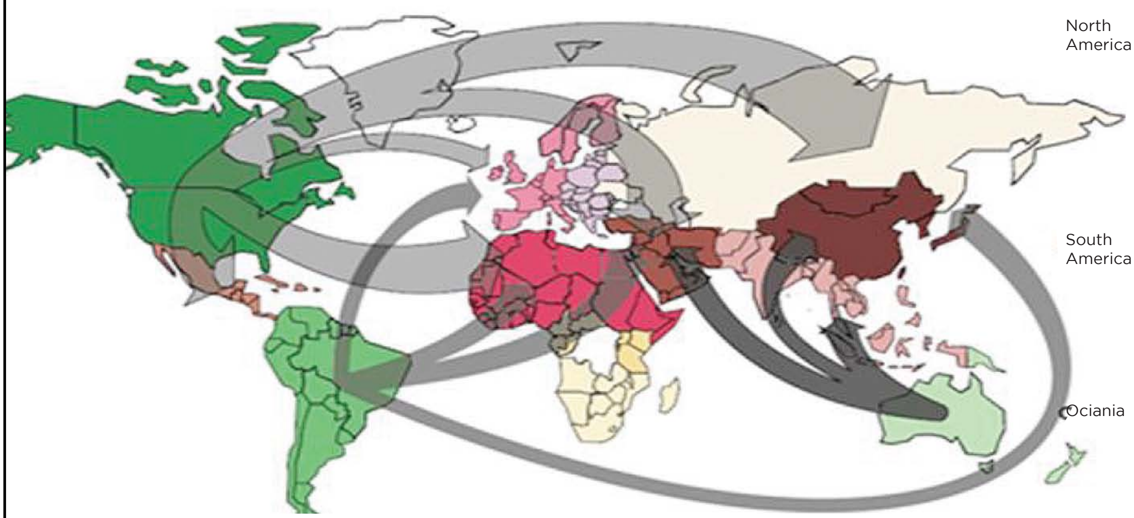


Sources: Water Resources Atlas, 2000

because it is invisible and is applied beyond the general political debate[36]. In addressing the policy relevance of virtual water trade water scarcity –induced imperative of food imports must be give appropriate attention. Virtual water trade can also be implemented beside the world market on local or river basin level.

Poor water-scarce countries rely very much on the subsistence farming systems. In case of any drought or flood, food shortages occur which are replenished by imports (or food-aid), otherwise famines occur[37]. For such countries the challenge is to stimulate and direct the investments in the agricultural sector to enable activities beyond subsistence farming. This requires managements of water resources where optimum economic returns can be pursued and markets can be physically acceded to generate the financial means for financing the purchase of food. The concept of virtual water is relevant to most of the developed, developing and LDC's countries because local planning and regional collaboration that incorporate the notion of virtual water trade could result in exchange of goods, diversification of crops, diet awareness, creation or crop replacement actions for any country. Beside the direct financial cost, other costs to be considered related to imports by water deficit countries to solve food security deficiency are: 1) Increased dependency on main exporting countries: 2) if not able to adapt or compete, local agriculture may be damaged, because of the importing food; 3) the exporting country may start interfering in internal affairs of importing country: and 4) imports may result in foreign reserve depletion if there is no expert compensation of less water intensive or higher value commodities[38].

Virtual water flows from export and import perspectives



Exporter VW (km3)		Importer VW (km3)	
North America	73	E- Asia	149
	30	C-Am	64
	22	N-W-Afr	58
	17	M-East	55
	12	W-Eur	17
	27	Others	71
South America	30	W-Eur	26
	21	E-Asia	25
	18	M-East	35
	12	N-W-Afr	21
	15	Others	38
Ociania	15	E-Asia	20
	11	S-E Asia	24
	10	M-East	14
	13	Others	24

Yangh. & Zehnder.A, 2006.

The estimates on present Virtual Water trade range from 1040, 1340 km^3 depending on the perspective taken as water saver/importer or producer/exporter[39]. In perspective, the total annual freshwater withdrawals (blue water) amount some 3,800 km3 of which 2000 km3 are consumed for agriculture; these values are respectively 2.500 km3 for withdrawals and 1,750 km3 for consumption[40]. This means that an amount of 50-70% of the total consumed blue water is traded.

However a great amount of virtual water is green water. So if we include the soil water (green water), then the virtual water trade amounts some of the 15% use on earth, including rain-fed agriculture.

Some researchers suggest that international food trade can be used as an active policy instrument to mitigate local and regional shortages.

But there are several factors that need to be considered, including international trade agreements, the cost of engaging in trade and the nature of domestic economic objectives and political consideration. Moreover, as we have seen before, the relation between saving water, positive impact on water scarcity and virtual water trade are not clear and direct.

Is it realistic to assume that countries will change trade policies because emerging global water scarcity issues? Will possible adverse affect of import on national rural economies and food security, especially in poor countries vulnerable to fluctuations in world market prices, be outweighed by benefit on reduces pressure on water resources? Moreover, the question remains whether the countries that will be hit by water scarcity will be able to afford to import virtual water. These questions are still open.

1.4. Measuring water use: the water footprint

In 2002, the water footprint concept was introduced in order to have a consumption based indicator of water use that could provide useful information in addition to the traditional production-sector-based indicators of water use[41]. The water footprint of a nation is defined as the total volume of freshwater that is used to produce the goods and services consumed by the people of the nation.

Since not all goods consumed in one particular country are produced in that country, the water footprint consists of two parts: use of domestic water resources and use of water outside the borders of the country. The water footprint has been developed in analogy to the ecological footprint concept as was introduced in the 1990s[42].

The ecological footprint‘ of a population represents the area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a certain population at a specified material standard of living, wherever on earth that land may be located. Whereas the ecological footprint‘ thus quantifies the area needed to sustain people‘s living, the water footprint‘ indicates the water required to sustain a population. The US appears to have an average water footprint of 2,480 cubic metres per capita per year (m^3 /cap/yr), while China has an average footprint of 700 m^3 /cap/yr. The global average water footprint is 1,240 m3 /cap/yr[43]. The four major factors that determine the water footprint of a country are volume of consumption (related to the gross national income); consumption patterns (e.g. high versus low meat consumption); climate (growth conditions); and agricultural practice (water use efficiency). The water footprint concept is closely linked to the virtual water concept.

A multisectoral approach to water scarcity

Addressing water scarcity calls for an intersectoral and multidisciplinary approach to water resources management, one that ensures the coordinated development and management of water and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Integration across sectors is needed. This integration needs to take into account development, supply, use and demand, and to place the emphasis on people and the ecosystems that sustain them. On the demand side, enhancing the productivity of water use in all sectors is paramount to successful programmes of water scarcity alleviation. Furthermore, protecting and restoring the ecosystems that naturally capture, filter, store and release water, such as rivers, wetlands, forests and soils,

is crucial to increasing the availability of water of good quality.
Addressing water scarcity requires actions at local, national and river basin levels. It also calls for actions at global and international levels, leading to increased collaboration between nations on shared management of water resources (rivers, lakes and aquifers) and of the benefits thereof.

2. Current and future trends exacerbating water availability

2.1. Impact of climate change on water resources and management

The relationship between climate change and agriculture is complex. Agriculture contributes to, but is also a victim of, climate change. It contributes to global warming through the emission of methane and nitrous dioxide, which increase, for instance, the degradation of land resources through soil erosion, over-extraction of groundwater and associated salinisation and over-grazing of dryland. But agriculture is also extremely sensitive to climate change.

The average temperature of the earth's surface has risen by 0.6 iC since the late 1800s. It is expected to increase by another 1.4 to 5.8 iC by the year 2100, and the sea level may rise from 9 to 88 cm during the same period[44]. Climate change is expected to have significant impact on agriculture and food production patterns through three major factors: global warming, change in rainfall patterns and the increase in carbon dioxide (CO^2) concentration in the atmosphere. A temperature increase of more than 2.5 iC could affect global food supply and contribute to higher food prices[45].

Climate change affects the hydrological cycle and thus water availability, water quality and water services. It therefore has both a direct and indirect impact on agriculture and rural development.

The principal climate changes are the distribution of precipitation in time (seasonal distribution), in space and strength, variation on the rate of evaporation, rising temperatures and an increasing frequency of extreme events such as flood, drought, etc. All of these have a direct and indirect impact on rural development. They will increase a region's susceptibility to a variety of factors, including: flooding, soil erosion, groundwater supplies or soil moisture availability, etc. These factors are likely to affect key economic components of the GDP such as agricultural productivity or land values.

The productivity of agricultural, forestry and fishery systems depends critically on temporal and spatial distribution of precipitation and evaporation—and especially for crops, on the availability of freshwater resources. Smallholder agriculture in such marginal areas is especially vulnerable to climate change and variability, and socio-economic stressors often compound already difficult environmental conditions.

The recent IPCC Fourth Assessment Report indicates that climate change will have a significant impact on crop production and water management systems in the coming decades. In addition, there is the potential for earlier negative surprises linked to the increased frequency of extreme events.

Climate change is expected to alter the hydrologic regimes and patterns of freshwater availability with an impact both on rain-fed and irrigated agriculture. For example, severe reductions in river runoff and aquifer recharge are expected in the semi-arid areas of southern Africa, Australia and the Americas.

The projected increase of floods and droughts will hurt crop yields and livestock, with a greater impact coming earlier than previously predicted. This will alter the distribution of agricultural potential and therefore local production. A combination of reduced river base flows, increased flooding and rising sea levels are expected to impact highly productive irrigated systems that help maintain the stability of food production.

Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation. This is expected to lead to decreased food security and increased vulnerability of poor rural farmers, especially in the arid and semi-arid tropics and Asian and African megadeltas46. The impact on crop yields would vary considerably from one region to another. Heat stress, shifting monsoons and drier conditions can reduce yields by as much as one-third in the tropics and subtropics. Dry continental areas, such as central Asia and the African Sahel, would be expected to experience drier and hotter climates, whereas longer growing seasons and increased In a scenario of moderate climate change (a temperature increase of less than 2 iC), gradual adaptation of cultivars and

agricultural practices could occur with no expected major impact on food production in tropical areas[47]. However, regional impact would vary widely, affecting the production capacity of some countries.

Those most vulnerable to these changes are the poor and landless in rural areas dependent on isolated rainfed agricultural systems in semi-arid and arid regions. The changes in the hydrological cycle and rainfall patterns – more precipitation, more frequent intense rainfall events and more evaporation – would affect soil moisture and increase erosion. In drought prone areas, the number and duration of dry spells would be expected to increase, affecting crop production. It is generally admitted that higher levels of CO^2 in the atmosphere could stimulate photosynthesis and contribute to an increase in crop productivity. This is particularly true for C^3 crops that include wheat, rice, soybeans, barley, cassava and potato, for which a CO^2 concentration increase of 50 percent leads to a 15 percent increase in potential production. At the same time, as most weeds are also C^3 plants, they will also become more aggressive. C^4 crops, which include several tropical crops like maize, sugar cane, sorghum and millet, as well as many pasture and forage grasses, are less responsive to higher levels of CO^2.

One of the most pressing challenges of climate change is addressing the vulnerability of human populations to the impacts of extreme hydrologic events, such as floods, storm surges and droughts. Over the longer term the effects of incremental climate change are likely to influence decisions about food security, energy security and land use, all with vital implications for water resources and management and environmental sustainability. In this context climate change can intensify existing pressures, thereby increasing risk, vulnerability and uncertainty. For water managers anthropogenic climate change poses a new set of challenges – because they can no longer plan, design and operate hydrologic systems based on historical statistics.

For water adaptation measures to be effective, however, there must be complementary climate change mitigation measures outside the water sector. Because climate variability and change affect all the major water drivers, adaptation measures are needed in all sectors. Over the long term adaptation means applying a long-term, climate-focused approach to existing policies and programmes. But because the poor are the most vulnerable and the least able to cope with change, it is particularly important to strengthen the link between adaptation to climate change and economic development – a difficult challenge. Over the shorter term the best approach might be to manage climate variability by prioritizing risk-reduction strategies and reinforcing the capacity of hydro meteorological services to provide information for development needs. Each country will face its own challenges and must determine how to respond in the short, medium and long run. With multiple challenges but limited financial and natural resources and capacities, countries will need to make hard choices about water use and allocation. There tends to be a push and pull effect between identifying adaptation needs based on a climate change rationale and anchoring response options in baseline development activities[48].

Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies. The former improve water-use efficiency, e.g., by recycling water. An expanded use of economic incentives, including metering and pricing, to encourage water conservation and development of water markets and implementation of virtual water trade, holds considerable promise for water savings and the reallocation of water to highly valued uses. Supply-side strategies generally involve increases in storage capacity, abstraction from water courses, and water transfers.

Integrated water resources management provides an important framework to achieve adaptation measures across socio-economic, environmental and administrative systems. To be effective, integrated approaches must occur at the appropriate scales[49].

2.2. Increasing water and energy demand

Energy and water are inextricably linked. Water is an integral part of energy resource development and use; it is needed for cooling and energy production but is also consumed passively as reservoirs built for energy production and other purposes evaporate substantial amounts of water.

For hydroelectric, wave or tidal energy production water offers an active' medium for transferring kinetic energy into electricity. For cooling thermal and nuclear plants or producing bioenergy, water plays a more passive, though equally important, role.

The demand for energy is therefore a major driver of water and agriculture development, creating pressures that strongly affect the quantity and quality of freshwater resources. Energy is important for pumping water, transporting it, processing it and using it. Desalination is also an energy-intensive process. Energy demand is affected by many of the same drivers that are putting direct pressure on water resources: demographic, economic, social and technological processes, including changes in consumption patterns. Energy consumption is also the main driver behind climate change which threatens the sustainability of water resources. Growing pressure and efforts to curb greenhouse gas emissions are leading to increasing demand for cleaner' sources of renewable energy. Hydropower has been earmarked as one of the most important of these sources[50].

The International Energy Agency (IEA)[51] forecasts that energy demand, driven primarily by population and GDP growth, will rise by over 50 percent between now and the year 2030. Over 70 percent of this increase in energy demand will stem from population growth in the developing world, and dwindling fossil fuel reserves will continue to account for 83 percent of this demand. As witnessed by the different oil price shocks generated unprecedented interest in the cultivation of ethanol biofuel crops. However, bio-fuel production is the most significant consumer of water in the alternative energy sector. Yet, global biofuel demand, and with it agricultural demand for water, is projected to continue to increase as fossil fuels become scarcer and hence more prohibitive in cost. While energy production may divert water from household or personal consumption, these energy production processes also risk contamination of underground and surface water supplies.

2.3. Water, population growth and food security

Today, the global population is 6.8 billion, and by 2025, it will approximate 8 billion[52]. Of this increase, the net population of developing countries is expected to rise from 5.6 billion in 2009 to 7.9 billion in 2050[53]. Water use has been growing at more than twice the rate of population increase in the last century. While this rapid increase in global population and acceleration of global economic activity clearly translates to increased demand for both renewable and finite natural resources, including water, the mere ability to feed everyone in 2050 requires 50 percent more water than is needed now[54]. Moreover, the most rapid population growth is occurring in regions where water is already scarce and where current populations do not have reliable access to potable water and adequate sanitation. For example, sub-Saharan Africa and Northern Africa are the two regions in the world facing both the most rapid population growth and the greatest water stress. Thus, given the difficulty and expense of transporting water, proximity of water supply is a crucial factor in the water scarcity challenge. The increasing strain on water and sanitation infrastructure in urban settlements will decrease water quality, making water resources less potable. About 40 percent of slum populations migrated from rural areas due to climatic concerns. At present, 92 percent of urban areas have access to water, but only 72 percent of rural areas.

By 2025, it is expected that the global population will shift from current figures of 55 percent rural and 45 percent urban to 41 percent rural and 59 percent urban[55]. Environmentally-induced migration, especially in agricultural economies where climate change contributes to or aggravates drought, is predicted to account for much of this shift. In addition to the required quantity, many factors in changing food demand and production patterns, sometimes cancelling out one another, influence agricultural production and the way inputs are managed. The distribution of bulk grain has become more reliable and just-in-time', allowing world reserves to be progressively reduced over the past decades from about four months to less than three months of global demand[56].

Food commodities are produced, conditioned, refrigerated and transported over increasing distances at the cost of energy and environmental degradation.

Meat demand has been shifting towards poultry, and the world is now consuming more poultry meat than bovine meat. Given that poultry has a much better conversion rate of cereals into meat (two to one) than cattle (between five and seven to one), this shift releases some of the pressure projected on the cereal sector and water demand for the irrigated cereal production.

Cereals therefore continue to be the most important source of total food consumption in the world, but there are large regional differences in the commodity composition of the diet. In Sub-Saharan Africa roots and tubers are by far the most important component and are expected to remain so for some time. In all regions except Sub-Saharan Africa there has been a significant increase in the consumption of vegetable oils over the last three decades. As diets diversify and become healthier and better balanced, the demand for fresh vegetables and fruits increases.

These goods are produced under intensive farming methods, including the use of greenhouses and irrigation for timely year-round production following exacting specifications. The controlled agro-ecological environment under which vegetables and fruits are produced also allows for accurate water control with minimum wastage. However, this form of agriculture is only possible under full control of water, which should be available on demand and in good quality. Many irrigation systems are not equipped with the necessary storage, conveyance and control systems and do not have the capacity to deliver water under these stringent conditions. The amount of water needed to produce food depends on diets and how the food is produced. It is estimated that in 2000 crop production to feed 6.1 billion people used about 7,130 cubic kilometers of water through evapotranspiration.

2.4. Urbanization and migration

In the 1960s two-thirds of the world's population lived in rural areas and 60% of the economically active population worked in agriculture. Today, half of the people live in rural areas, and just a little more than 40% of the economically active population depend directly on agriculture. In absolute terms the rural population will start to decline in the next few years[57]. But, again, global averages mask considerable regional variation. In many poor countries in South Asia and Sub-Saharan Africa the rural population will continue to grow until about 2030, and the number of people depending on agriculture will continue to rise. Rapid rural to urban migration in developing countries influences farming practices and water demand. Also, it is often the men who migrate to cities, leaving women, older people, and children behind in rural areas. As a consequence, in developing countries women's share in the economically active population in agriculture is growing, rising from 39% in 1961 to 44% in 2004, while in developed countries it is falling, dropping from 44% to 35%[58]. Cities are rapidly increasing their claim on water at the expense of rural uses such as farming. Furthermore, urban centers represent a source of pollution that has impacts on downstream irrigation and aquatic ecosystems. City wastewater, often untreated, is an increasing source of irrigation water, especially in non-coastal cities. Wastewater use has its own unique set of health and environment considerations.

2.5. Drivers of biodiversity loss and ecosystem change

Biological diversity is in rapid decline in all the world's major biomes. While rates of loss differ between regions and biomes, loss of biodiversity is greatest among freshwater-dependent species—almost twice as fast as for marine and terrestrial species. This has happened because biodiversity associated with inland waters is concentrated within limited areas, because many inland water-dependent species are especially vulnerable to changes in environmental conditions, and because freshwater is subject to rapidly escalating threats from land-based impacts as demands placed on water to meet growing populations and development pressures rises59. Many factors contribute to biodiversity change. The most important direct drivers of biodiversity loss are habitat change (land use change, physical modification of rivers, water withdrawal from rivers, damage to sea floors from trawling), climate change, invasive alien species,

species overexploitation, and pollution. For most ecosystems the impacts are constant or growing.

- Habitat transformation and fragmentation. This includes the impact of land cover change, such as the conversion to agriculture and the release of nutrients into rivers, and of water withdrawals for irrigation

- Modifications to water regimes. Many rivers have been fragmented through the construction. of dams and barrages. River-regulating structures have changed flow regimes (the quantity and timing of flow in rivers)

- Spread of invasive alien species. Increased trade and travel have contributed to the spread of invasive alien species (and disease organisms). The introduction of non-native invasive species is now a major cause of species decline in freshwater systems. While measures are increasingly being taken to control some of the pathways through which invasive species make inroads, many pathways remain inadequately regulated

- Nutrient loading. Since 1950 anthropogenic increases in nitrogen, phosphorus, sulfur, and other nutrient-associated pollutants have emerged as one of the most important drivers of change in terrestrial, freshwater, and coastal ecosystems. Humans now produce more reactive (biologically available) nitrogen than all natural pathways combined.

The majority of biomes have been greatly modified, with 20%–50% of 14 global biomes transformed to croplands. For terrestrial ecosystems the most important direct driver of change in the past 50 years has been changes in land cover[60]. Further land use changes causing habitat loss are associated primarily with the additional expansion of agriculture and secondarily with the expansion of cities and infrastructure.

For freshwater ecosystems the most important direct drivers of change in the past 50 years include direct physical changes to freshwater habitat, such as draining wetlands and building dams, and deliberate modification of water regimes through, for example, water extraction and pollution. All these factors are also influenced indirectly through the impacts of land use; for example, excessive erosion leads to sedimentation in rivers, estuaries, and lakes. Invasive species are also an important driver. Many of these drivers arise due to agriculture-related activities (including livestock, fisheries, and aquaculture).

3. The Role of Water in Agriculture: Key Trends and Future Projections

During the second half of the twentieth century, the global food system responded to the doubling of the world's population by more than doubling food production, and this in an environment of decreasing prices for agricultural products. From 1963 to 2000 food production grew more rapidly in developing countries than in developed countries, with food production growth exceeding population growth, except in Africa[61]. During the same period, the group of developing countries increased per capita food consumption by 30 percent and nutritional situations improved accordingly. In addition, agriculture continued producing non-food crops, including cotton, rubber, beverage crops and industrial oils. However, there was wide variability in food production within and across regions. And kilocalories per 17 person per day, which in 2000 averaged 2,800 globally, ranged from 2,200 in Sub-Saharan Africa and 2,400 in South Asia to 2,850 in Latin America and 2,875 in East Asia, to a high of 3,450 in industrial countries[62]. The growth in crop production was achieved through a combination of expansion in arable land, increase in cropping intensities (multiple cropping or shorter fallow periods), and increases in yield. The increases in arable land were small, with much of the expansion onto marginal lands as urbanization spread onto good quality agricultural lands[63] .

The amount of cropland per person is currently about 0.25 ha, compared with 0.45 ha in 1961. Intensification and yield growth have been the dominant factors in production growth, and irrigated agriculture has played a major role.

Nearly all the growth in cereal grain production since 1970 has been from higher yields. In developing countries growth accelerated in the 1970s with the introduction and spread of the high-yielding varieties of rice and wheat under irrigation— the green revolution. Yield increases have come at different times in different regions of the world. For example, maize yields maize yields started rising before the 1940s in the United States, in the 1960s in China, in the 1970s and again in the 1990s in Latin America, but have not yet taken off in Africa64. In some areas yields have reached their upper limits and are showing signs of leveling off.

To produce enough food to satisfy a person's daily dietary needs takes about 3,000 liters of water converted from liquid to vapor—about 1 liter per calorie. Only about 2–5 liters of water are required for drinking. In the future more people will require more water for food, fiber, industrial crops, livestock, and fish. But the amount of water per person can be reduced by changing what people consume and how they use water to produce food.

Today's agriculture uses 70 percent of all fresh water withdrawals globally, and up to 95 percent in several developing countries, to meet the present food demand. To keep up with growing food demand and shifting diets over the next 30 years, FAO estimates that the effective irrigated area will need to increase by 34 percent in developing countries, and 14 percent extra water needs to be withdrawn for agricultural purposes. It should also be remembered that irrigated agriculture provides some 40 percent of the global food supply on 20 percent of cultivated land. Historically, large-scale irrigation projects have played a major role in ensuring food supply for a rapidly growing population, and in contributing to poverty alleviation by providing food security, protection from flood and drought, and expanded opportunities for employment. In many cases, irrigated agriculture has been a major engine for economic growth and poverty reduction.

In arid and semi-arid regions, where water scarcity is almost endemic, groundwater has played a major role in meeting domestic and irrigation demands. In many regions, massive use of groundwater has been made for some time for irrigation. However, groundwater mining and the lack of adequate planning, legal frameworks and governance have opened a new debate on the sustainability of the intensive use of groundwater resources.

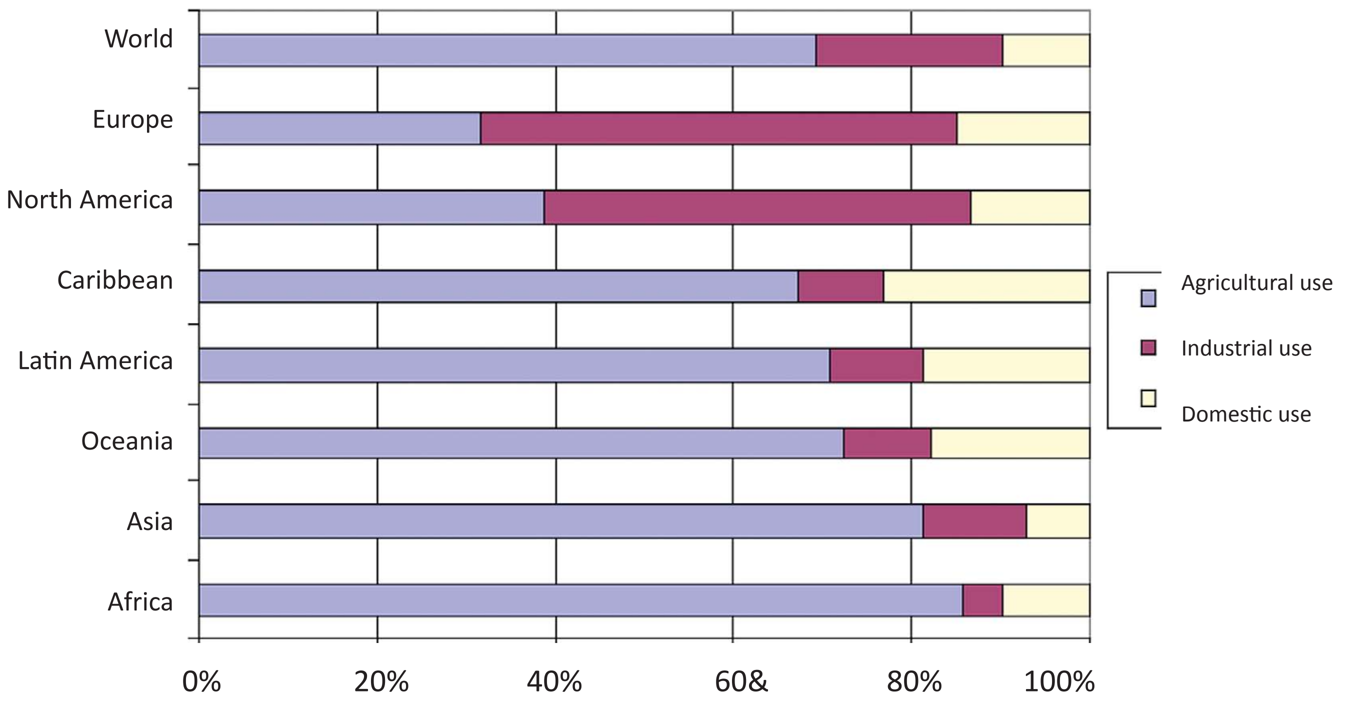
In semi-arid regions, increasing numbers of the rural poor are coming to see entitlement and access to water for food production, livestock and domestic purposes as critical as access to primary health care and education. There is thus need to also focus on issues relating to equity and rights in access to water.

Typically only 30 to 50 percent of the water diverted for irrigation is actually used by crops. Best management practices and technology for irrigated and rainfed farming systems (not only limited to water-related practices) have still to play a significant impact on the productivity of water. Trade has not been fully explored in the optimization of water use. Therefore, within this sector, the wider range of options to cope with water scarcity exists[65]. World agriculture faces an enormous challenge over the next 40 years: to produce almost 50% more food up to 2030 and double production by 2050. This will probably have to be achieved with less water, mainly because of pressure from growing urbanisation, industrialisation and climate change. Today the competition for scarce water resources in many places is intense. Many river basins do not have enough water to meet all the demands—or even enough for their rivers to reach the sea. Further appropriation of water for human use is not possible because limits have been reached and in many cases breached. Basins are effectively closed, with no possibility of using more water. The lack of water is thus a constraint to producing food for hundreds of millions of people. Agriculture is central in meeting this challenge because the production of food and other agricultural products takes 70% of the freshwater withdrawals from rivers and groundwater[66].

Agriculture's use and impact on water resources are complex and dynamic, especially in the context of the impacts of climate change and variability on agricultural systems, and involve trade-offs between economic, social and environmental demands. While agriculture is one among many different demands for water (i.e.urban, industrial, recreational uses, and for maintaining aquatic ecosystems), for most countries it is the major user of water resources (for irrigated farming and the livestock sector), while its impact on water quality is also significant in many cases. On the other hand, improvements in water productivity by agriculture over the past 40 years have played an important role in helping to expand food production and provide employment in rural areas.

It is possible to produce the food—but it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world. Only if we act to improve water use in agriculture will we meet the acute freshwater challenges facing humankind over the coming 50 years[67]. New investments in irrigation and agricultural water management have the potential to spur economic growth within agriculture and other sectors. An increase in global trade in food products and in consequent flows of virtual water offers prospects for better national food security and the possibility of relieving water stress.

Figure 1 - Distribution of water withdrawal between sectors (year 2000)



ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

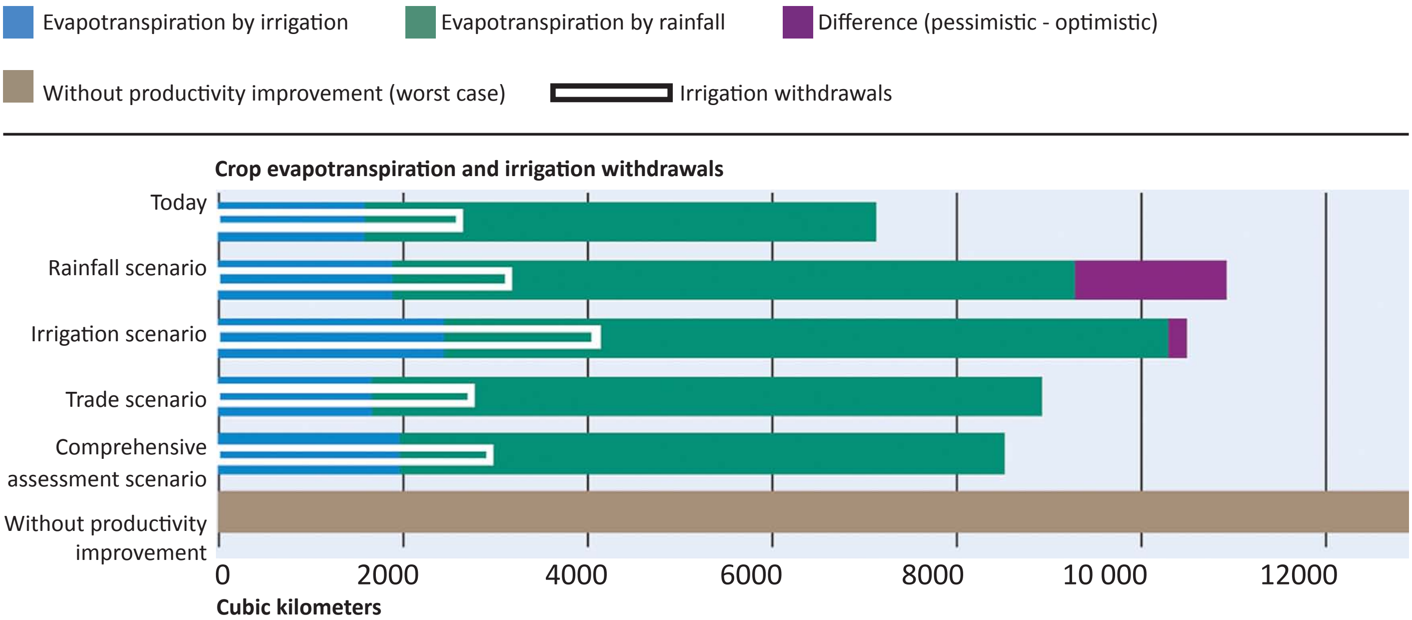
3.1. Increasing water and land productivity[68]

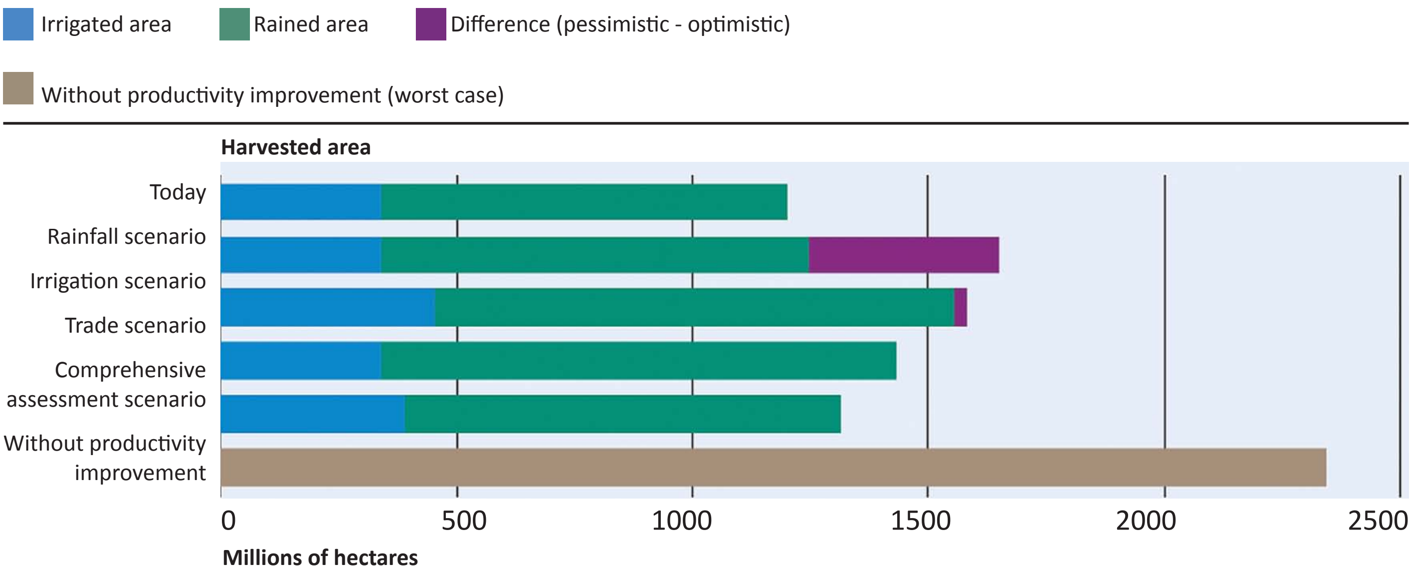
Without further improvements in water productivity or major shifts in production patterns, the amount of water consumed by evapotranspiration in agriculture will increase by 70%– 90% by 2050. The total amount of water evaporated in crop production would amount to 12,000–13,500 cubic kilometers, almost doubling the 7,130 cubic kilometers of today[69]. This corresponds to an average annual increase of 100–130 cubic kilometers, almost three times the volume of water supplied to Egypt through the High Aswan Dam every year. On top of this is the amount of water needed to produce fiber and biomass for energy. Cotton demand is projected to grow by 1.5% annually, and demand for energy seems insatiable. By 2030 world energy demand will rise by 60%, two-thirds of the increase from developing countries, some from bioenergy.

Fortunately, water productivity in agriculture has steadily increased in the past decades, in large part due to increases in crop yields, and will continue to do so.

The pace of this increase can vary substantially according to the type of policies and investments put in place, with substantial variation in impacts on the environment and the livelihoods of agricultural populations. Key options are explored below, using a set of scenarios (See figure below)

Land and water use today and in the future under different scenarios[70]





Note: The figure shows projected amounts of water and land requirements under different scenarios. The Comprehensive Assessment scenario combines elements of the other approaches (see chapter 3 for details). The purple segments of the bars shown above show the differences between optimistic and pessimistic assumptions for the five rainfed and two irrigated scenarios. The brown bar shows the worst cases scenario of no improvement in productivity.

Source: International Water Management Institute analysis done for the Comprehensive Assessment for Water Management in Agriculture using the Watersim model, chapter 3.

Managing the application of water to the root zone and obtaining higher overall productivity is contingent upon soil fertility, cultivar selection, cropping density, pest and disease management and then post-harvest controls up to the farm gate. This sets the systemic value added chain in which water use efficiency can be evaluated and the scope for on farm systemic improvement analysed. Under conditions of limited water availability at the farm gate, the improvement of on-farm water management becomes an imperative. Sprinkler and trickle irrigation methods, deficit irrigation and other water saving irrigation technologies have demonstrated viable financial and health safety returns. Biotechnology can provide further advantages as well. The benefits of these technologies are increased further when combined with accurate determination of crop water and irrigation system requirements, with well established irrigation scheduling, and with the above-mentioned agricultural practices[71].

Increasing the productivity of land and water

75% of the additional food we need over the next decades could be met by bringing the production levels of the world's low-yield farmers up to 80% of what high-yield farmers get from comparable land. Better water management plays a key role in bridging that gap. The greatest potential increases in yields are in rainfed areas, where many of the world's poorest rural people live and where managing water is the key to such increases[72]. While there will probably be some need to expand the amount of land we irrigate to feed 8–9 billion people, and while we will have to deal with the associated adverse environmental consequences, with determined and focused change there is real scope to improve production on many existing irrigated lands. Doing so would lessen the need for more water in these areas and for even greater expansion of irrigated land.

In rural Sub-Saharan Africa comprehensive water management policies and sound institutions would spur economic growth for the benefit of all. And despite the bad news about groundwater depletion, there is still potential in many areas for highly productive pro-poor groundwater use, for example, the lower Gangetic plains and parts of Sub-Saharan Africa. Sub-Saharan Africa requires investments in infrastructure, supporting institutions, low-cost technologies, favorable institutional and market conditions.

3.1.1 Sources of water in agriculture: rainfed and irrigated agriculture

Rainfed agriculture

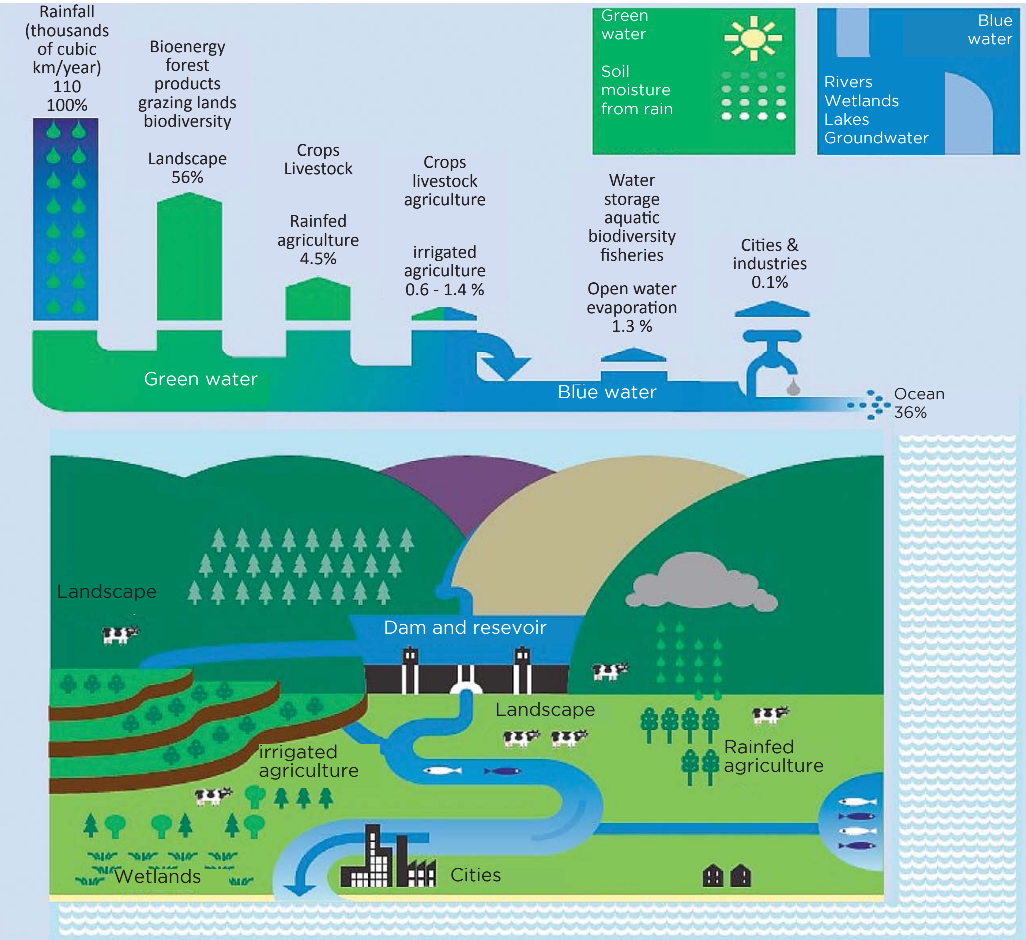
Despite dramatic increases in large-scale irrigation infrastructure over the past half century, the bulk of the world's agricultural production is rainfed, not irrigated73. Rainfed agriculture covers 80% of the world's cultivated land, and is responsible for about 60% of crop production[74].

Rainfed areas support both permanent crops such as rubber, tea, and coffee and annual crops such as wheat, maize, and rice. Many people dependent on rainfed agriculture are highly vulnerable to both short-term (two to three weeks) dry spells and long-term (seasonal) droughtand thus are reluctant to invest in agricultural inputs that could increase yields. This situation will become worse for many small farmers with climate change.

Water use in rainfed and irrigated agriculture

The illustration below shows how water is used globally and the services each use provides. The main source of water is rain falling on the earth's land surfaces (110,000 cubic kilometers). The arrows express the magnitude of water use, as a percentage of total rainfall, and the services provided. So, for example, 56% of green water is evapotranspired by various landscape uses that support bioenergy, forest products, livestock grazing lands, and biodiversity, and 4.5% is evapotranspired by rainfed agriculture supporting crops and livestock. Globally, about 39% of rain (43,500 cubic kilometers) contributes to blue water sources, important for supporting biodiversity, fisheries, and aquatic ecosystems. Blue water withdrawals are about 9% of total blue water sources (3,800 cubic kilometers), with 70% of withdrawals going to irrigation (2,700 cubic kilometers). Total evapotranspiration by irrigated agriculture is about 2,200 cubic kilometers (2% of rain), of which 650 cubic kilometers are directly from rain (green water) and the remainder from irrigations water (blue water). Cities and industries withdraw 1,200 cubic kilometers but return more than 90% to blue water, often with degraded quality. The remainder flows to the sea, where it supports coastal ecosystems. The variation across basins is huge. In some cases people withdraw and deplete so much water that little remains to flow to the sea.

Global water use



Source: Calculations for the Comprehensive Assessment of Water Management in Agriculture based on data from T. Oki and S. Kanae, 2006, Global Hydrological Cycles and World Water Resources, Science 313 (5790): 1068–72

Improving on-farm water management

An important option is to upgrade rainfed agriculture through better water management practices. Better soil and land management practices can increase water productivity, adding a component of irrigation water through smaller scale interventions such as rainwater harvesting. Integrating livestock in a balanced way to increase the productivity of livestock water is important in rainfed areas. At the global level the potential of rainfed agriculture is large enough to meet present and future food demand through increased productivity (see figure above on rainfed scenario). An optimistic rainfed scenario assumes significant progress in upgrading rainfed systems while relying on minimal increases in irrigated production, by reaching 80% of the maximum obtainable yield. This leads to an average increase of yields from 2.7 metric tons per hectare in 2000 to 4.5 in 2050 (1% annual growth). With no expansion of irrigated area, the total cropped area would have to increase by only 7%, compared with 24% from 1961 to 2000, to keep pace with rising demand for agricultural commodities. Improvement of on-farm water management calls for an integrated use of water conservation practices, and economic incentives to influence water use – both the total level of water use and the pattern of use. Under the circumstances of limited water supply, maximizing the crop yield per unit of land should give ways to achieve the maximum yield per unit of water use. The latter is achieved at a water supply at least 20-30 percent less than the amount needed for maximum yield. Another important factor affecting on-farm water management is related to the skills of human resources that also deserve due consideration in the future.[75]

Irrigated Agriculture

In the past half century there have been massive investments in large-scale public surface irrigation infrastructure as part of efforts to increase world staple food production and ensure food self-sufficiency. Irrigation water was essential to achieve the gains from high yielding fertilizer-responsive crop varieties. These investments by international development banks, donor agencies, and national governments to develop and expand irrigation systems established the foundation of food security in much of the developing world. During this period more than half the agricultural budget in many countries, particularly in Asia, and more than half of World Bank agricultural lending was devoted to irrigation[76].

At the same time irrigation demand dominated steadily increasing water withdrawals. While the world's cultivated land increased by about 13% from 1961 to 2003 (from 1,368 million ha to 1,541 million ha), equipped irrigated area (photo 2.3) almost doubled, from 139 million ha to 277 million ha, an increase from 10% to 18% of cultivated area[77].

Harvested irrigated area, which includes double cropping, is estimated at 340 million ha. New incomplete evidence suggests that the harvested irrigated area might actually be higher because of a higher cropping intensity and unreported, often informal, groundwater or private irrigation[78]. Approximately 70% of the world's irrigated land is in Asia, where it accounts for 34% of cultivated land. China and India alone account for more than half of irrigated land in Asia. Over time Asia, with its high population densities, has come to rely increasingly on irrigated agriculture to boost agricultural productivity and thus to ensure domestic food security. More than two-thirds of the increase in cereal grain has come from irrigated land. By contrast, there is very little irrigation in Sub-Saharan Africa. Several large publicly funded irrigation schemes were commissioned in the 1960s and 1970s, mostly as settlement schemes funded through bilateral loans. Water application methods were largely surface irrigation, and little was done to improve water productivity. Decision making was centralized, and profitability was low. Many of the schemes became unsustainable, and some closed. World Bank lending for irrigation and drainage fell sharply after 1985[79].

During the 1990s most countries in East and Southern Africa emphasized implementation of poverty reduction strategies, which allocated inadequate budgets for agriculture, particularly water management. Meanwhile, as the costs of inputs escalated and inflation grew, the prices of farm produce plummeted. Even though lending for irrigation and drainage partially recovered in the late 1990s, lending for 2002–05 was still less than half the level for 1978–81, very low compared with lending in other regions. Also, investment in agricultural water in Sub-Saharan Africa has been only a small proportion of the total for the water sector—just 14% of African Development Bank lending to the water sector as a whole during 1968–2001, for example[80].

Globally, donor spending on irrigation reached a peak of more than $1 billion a year (in 1980 US dollars) in the late 1970s and early 1980s and then fell to less than half that level by the late 1980s[81] .Four factors contributed to the decline in public investments in irrigation in the 1980s. First, there was a sharp drop in cereal prices in the 1980s.

Second, there was growing recognition of the poor performance of irrigation systems[82]. Third, there was a rise in construction costs of irrigation infrastructure, although it is now decreasing83.Falling grain prices and rising construction costs reduced benefit-cost ratios, discouraging further investments. Fourth, there was growing opposition to large dams and to the environmental degradation and social dislocation they sometimes caused. Reflecting these environmental concerns, the World Commission on Dams, created in 1997, reviewed the experience with large dams and established a framework for decision-making regarding new large-scale dam projects[84].

Recently, there has been renewed interest in investment in agricultural water management. The World Bank's new Water Resources Sector Strategy[85], for example, calls for a principled but pragmatic approach to balanced investment in both infrastructure and institutions and spells out a strategy for reengaging in agricultural water management[86]. Two major investment trends exist today. One is the emergence of mega-projects such as the south-north diversion project in China and the interlinking rivers project in India, which intend to transfer water from water-abundant to water-scarce areas. The other is extensive individual and small-scale investments in irrigation and groundwater.

Private and community-based irrigation systems in developing countries, particularly groundwater pumping, have grown rapidly since the 1980s, propelled by the availability of cheap drilling technology, rural electrification, subsidized energy, and inexpensive small pumps that farmers can afford to purchase themselves. Pumping enabled small-scale irrigation to develop within rainfed systems and to supplement other sources of irrigation water. In India, with 26 million pump owners, irrigation from groundwater now exceeds irrigation from surface water systems. One consequence has been accelerating rates of groundwater decline. A fairly polarized debate has arisen in some circles over the relative benefits of large and small-scale infrastructure. In reality, the appropriate scale of infrastructure should be determined in the context of the specific environmental, social, and economic conditions and goals, with the participation of relevant stakeholders.

Pressures to modernize irrigation system

Pressures to modernize irrigation systemtechnology and related institutions have built up in response to increasing competition among water users, better articulation of farmer needs, and more generally due to political reforms and policy shifts with respect to responsibility and cost sharing in management of natural resources. Consequently, the evaluation of the performance of large irrigation systems is no longer limited to crop related indicators.
It is now recognized that water management in irrigation is multi-objective, providing a wide range of benefits to both farmers and local communities, from recharge of local aquifers for potable supplies to the maintenance of shelter belts and orchards. Therefore increasing the performance of irrigation systems implies the genuine recognition that irrigation systems can complement the natural systems over the annual water cycle. Improving performance implies that irrigation management needs to refocus on water delivery to farmers.

3.1.2 Green and blue water use in agriculture

The concept of 'blue' and 'green' water has been used for quite some time to distinguish between two fundamentally different elements of the water cycle. When atmospheric precipitation reaches the ground, it divides into several sections, which pursue the terrestrial part of the hydrological cycle along different paths. Out of a total annual amount of 110,000 cubic kilometres (km^3) of precipitation on the land surface, about 40,000 km^3 is converted into surface runoff and aquifer recharge (blue water) and an estimated 70,000 km^3 is stored in the soil and later returns to the atmosphere through evaporation and plant transpiration (green water)[87].

Blue water is the freshwater that sustains aquatic ecosystems in rivers and lakes; it can also be applied to drinking or domestic purposes, to industry or hydropower or to irrigated agriculture. Rainfed agriculture uses only green water. Irrigation uses blue water in addition to green water to maintain adequate soil moisture levels, allowing the crop plants to absorb the water and fulfil their crop yield potential. The green water/blue water concept has proven to be useful in supporting a more comprehensive vision of the issues related to water management, particularly in reference to agriculture. It is estimated that crop production takes up 13 percent (9,000 km^3 per year) of the green water delivered to the soil by precipitation, the remaining 87 percent being used by the non-domesticated vegetal world, including forests and rangeland.

While irrigation currently withdraws about 2,300 km^3 of freshwater per year from rivers and aquifers, only about 900 km^3 is effectively consumed by crops (this issue is addressed in more detail later in the section on water use efficiency). Out of the world's total land area of 13 billion hectares (ha), 12 percent is cultivated, and an estimated 27 percent is used for pasture. The 1.5 billion ha of cropland include 277 million ha of irrigated land, representing 18 percent of cropland. In population terms, cropland amounts to a global average of 0.25 ha per person[88].

"New water" for agricultural production

Since significant volumes of drainage water are produced in many irrigation schemes, reuse of drainage water is becoming more apparent in water scarce countries. Agriculture's use of water resources of marginal quality, such as treated wastewater and saline water (mainly groundwater and drainage water) has also become an important issue. This is especially the case for irrigated agriculture in the arid and semi-arid zones of water scarce countries and in rapidly growing peri-urban settings in both humid and arid climates. In reducing the gap between supply and demand, water scarce countries have been compelled to develop nonconventional water resources as measures to improve efficiency of water use, reduce losses and increase recycling. The selection and subsequent investment in suitable technology for water treatment should result from an evaluation process that takes into account health protection, minimizing pollution, costs, the scale of operation (rural/household vs. urban), as well as the quality of water needed for specific purposes[89].

Water harvesting, which can be defined as a process of collecting and concentrating runoff from a runoff-area into a runon-area, also has the potential to contribute substantially to increased food production, both in rainfed and irrigated agriculture, by making best use of available rainfall while securing the natural resource base and easing pressure on available resources.

4. How will bioenergy affect agricultural water use?

Bioenergy is energy derived from biological origins, such as grains, sugar crops, oil crops, starch, cellulose (grasses and trees) and organic waste. Liquid biofuel (bioethanol and biodiesel), while representing only a small percentage of all bioenergy products, currently dominates the debate because of its capacity to substitute for fossil fuel and because most of its source feedstock can also be used to produce food[90].

4.1. Biofuels and Water

The last decade has witnessed a rapid and accelerating expansion of bioethanol and biodiesel[91] production. Projections suggest that biofuel production is likely to continue expanding in the coming years. The major factors that account for the explosive growth of the biofuel sector and the widespread enthusiasm for the technology are: 1) energy security: biofuels are seen as part of a strategy to lower dependence on fossil fuels and diversify energy sources to reduce supply risk. 2) Trade balance: a reduction of oil imports by substituting biofuels helps reduce the oil bill. 3) GHG emission: reducing the net emissions of carbon dioxide in the atmosphere (although some studies indicate that biofuel production generates more GHG than it saves in burning). 4) Rural development: It has the potential to raise commodity prices, improve farmer income and create jobs[92].

At the same time, the world is on the brink of an unprecedented water crisis. Water is likely to be the most important strategic resource by the end of the next decade and the key to achieving economic development globally.

Food and feedstock			
Crop	**Global production for food and feed 2030 (million tonnes)**	**Need to meet biofules demand (Million tonnes)**	**% increase to meet biofuel demand**
Maize	890	177	20
Sugarcane	2 136	525	25
Rapeseed	64	51	80
CA secenario using WATERSIM model (see Fraiture, 2007 and Fraiture et al., 2007)			

Biodiesel and bioethanol derived from conventional food crops typically require more water than biofuels based on lignocellulosic crop. In fact, sugarcane, corn (bioethanol) and soya (biodiesel) are the three most developed energy crops. The current biofuel development strategy focuses on intensive cultivation of monoculture cash crops such as sugarcane, etc. In this context of biofuel development, there has been very limited awareness and discussion of the water crisis. In regions already under water stress, the production of biofuels may further decrease the freshwater availability for other development options and may limit water both for sustaining the ecosystem and for meeting peoples' basic needs.

There has been an explosion of biofuel production since 2000. Between 2004 and 2006 alone the global ethanol production increased nearly 30% (from 10.77 billion gallons to 13.49)[93]. These biofuels are not strictly renewable in the same way solar, wind or tidal energy sources are, since their production depends on finite resources such as land and water. Biofuels and agricultural water use are linked in synergic and conflicting ways. Higher demand for energy derived from biomass increase water demand and changes in water uses[94].

The increase in biofuel production may potentially lead to more intense competition between food and biofuel for land and water resources, particularly in water scarce areas. Different studies clearly demonstrate that the water demand of bio-energy production will become large if biomass becomes one of the major primary energy sources. Public policies that support the development of biofuels should consider the effect of the production of biofuels on water availability necessary to meet local, basic needs for water and food and limit the implications on economic, environmental and human rights perspectives.

4.1.1 Current and projected trends in bioenergy

Around 10% of the total energy supply comes from biomass, and most of that (80%) comes from the traditional‘ biomass sources of wood, dung and crop residues. These represent a significant part of the energy used in many developing countries. Of commercial or ‘modern’ bioenergy, two-thirds is produced from fresh vegetable material and organic residue used to produce electricity and heat. About 5% of biomass is used to produce liquid biofuel for transport, which currently accounts for less than 2% of transport energy worldwide. The quest for greater energy autonomy, the rise in oil prices until the second half of 2008 and concerns about the impacts of greenhouse gas emissions in OECD countries are behind a recent surge in transport bioenergy[95].

The production of bioethanol, from sugarcane, corn, sugar beet, wheat and sorghum, tripled between 2000 and 2007 to an estimated 77 billion litres in 2008[96].Brazil (using sugarcane) and the United States (using mostly maize) are the main producers, accounting for 77% of global supply.

Biodiesel production, derived from oil- or tree-seeds such as rapeseed, sunflower, soybean, palm oil, coconut or jatropha, increased 11-fold between 2000 and 2007, with 67% produced in the European Union. In 2007 approximately 23% of maize production in the United States was used to produce ethanol, as was about 54% of Brazil‘s sugarcane crop. In the European Union about 47% of vegetable oil produced was used in the production of biodiesel, necessitating higher imports of vegetable oil to meet domestic consumption needs. In energy equivalence the 2008 ethanol share of the gasoline transport fuel market in these economies was estimated at 4.5% for the United States, 40.0% for Brazil and 2.2% for the European Union. The biodiesel share of the diesel transport fuel market was estimated at 0.5% for the United States, 1.1% for Brazil and 3.0% for the European Union[97]. The international policy environment, national policy support and oil prices will strongly influence future demand for biofuel. Global ethanol production is projected to increase rapidly to 127 billion litres in 2017, with production concentrated in the United States, Brazil and, to a lesser extent, the European Union and China. Global biodiesel production is expected to reach 24 billion litres in 2017[98].

4.1.2 Implication of increased crop demands for land, water and the environment

The potential impact of biofuel production on land and water resources varies with local agroclimatic conditions and policies. The potential impact on freshwater resources is greatest where agricultural production depends on irrigation and is practically negligible where rainfed production is practiced. Where agriculture requires irrigation, increased production of biofuel could result in reduced water allocation to other crop commodities. Globally, irrigation water allocated to biofuel production is estimated at 44 km3, or 2% of all irrigation water[99]. Under current production conditions it takes an average of roughly 2,500 litres of water (about 820 litres of it irrigation water) to produce 1 litre of liquid biofuel (the same amount needed on average to produce food for one person for one day). But regional variations can be substantial, depending primarily on the relative percentage of irrigation in biofuel crop production. The share of irrigation water used for biofuel production is negligible in Brazil and the European Union and is estimated to be 2% in China and 3% in the United States[100]. In India, where sugarcane is fully irrigated, nearly 3,500 litres of water are withdrawn for each litre of ethanol produced. The markets for biofuel

and agricultural products are strongly meshed. Because of crop substitutability, all crops tend to compete for the same inputs, land, fertilizers and irrigation water, and farmers select crops that offer the best return on their investment[101].

Implementing all current national biofuel policies and plans would take 30 million hectares of cropland and 180 km^3 of additional irrigation water. Although globally less than a few percentage points of total area and water use, the impacts could be large for some countries, including China and India, and for some regions of large countries, such as the United States. There could also be significant implications for water resources, with possible feedback into global grain markets. The volume of water and area of land used for biofuel production depend on the crop and the agricultural system. Private investors are showing increasing interest in land and irrigated schemes in Africa for agricultural products for biofuel production. According to the OECD, growth of the bioenergy industry is likely to place additional pressure on the environment and biodiversity[102]. The potential of bioenergy to mitigate climate change is complex and varies by type of crop and farming system. Among current technologies only ethanol produced from sugarcane in Brazil, ethanol produced as a by-product of cellulose production (as in Sweden and Switzerland) and biodiesel produced from animal fats and used cooking oil can substantially reduce greenhouse gas emissions compared with gasoline and mineral diesel. The study concludes that all other conventional bioenergy technologies typically deliver greenhouse gas emissions reductions of less than 40% compared with their fossil fuel alternatives. When impacts such as soil acidification, fertilizer use, biodiversity loss and the toxicity of agricultural pesticides are taken into account, the adverse environmental impacts of ethanol and biodiesel can exceed those of petrol and mineral diesel. An exception was biofuel produced from woody biomass, which rated better than gasoline. A key question is how to ensure that production will be sustainable. One answer being explored is certification of conformity to a set of environmental and social standards on a life-cycle basis[103]. Benefits or losses may take the form of reduced vulnerability to shocks, increased productive capacity, increased social benefits and increased capacity to maintain service levels.

5. Focus on the ACP countries

5.1 Africa

At the continental level, Africa's 3 931 km^3 of renewable water resources represent around 9 per cent of the world's total freshwater resources; by comparison, South America and Asia have the highest proportion each with 28.3 per cent, followed by North America with 15.7 per cent, and Europe with 15 per cent[104]. Africa is the world's second-driest continent, after Australia, but also the world's most populous continent after Asia. For the year 2008, the continental annual average water availability per person was 4 008 m3, well below the global average of 6 498 m^3/capita/yr[105].

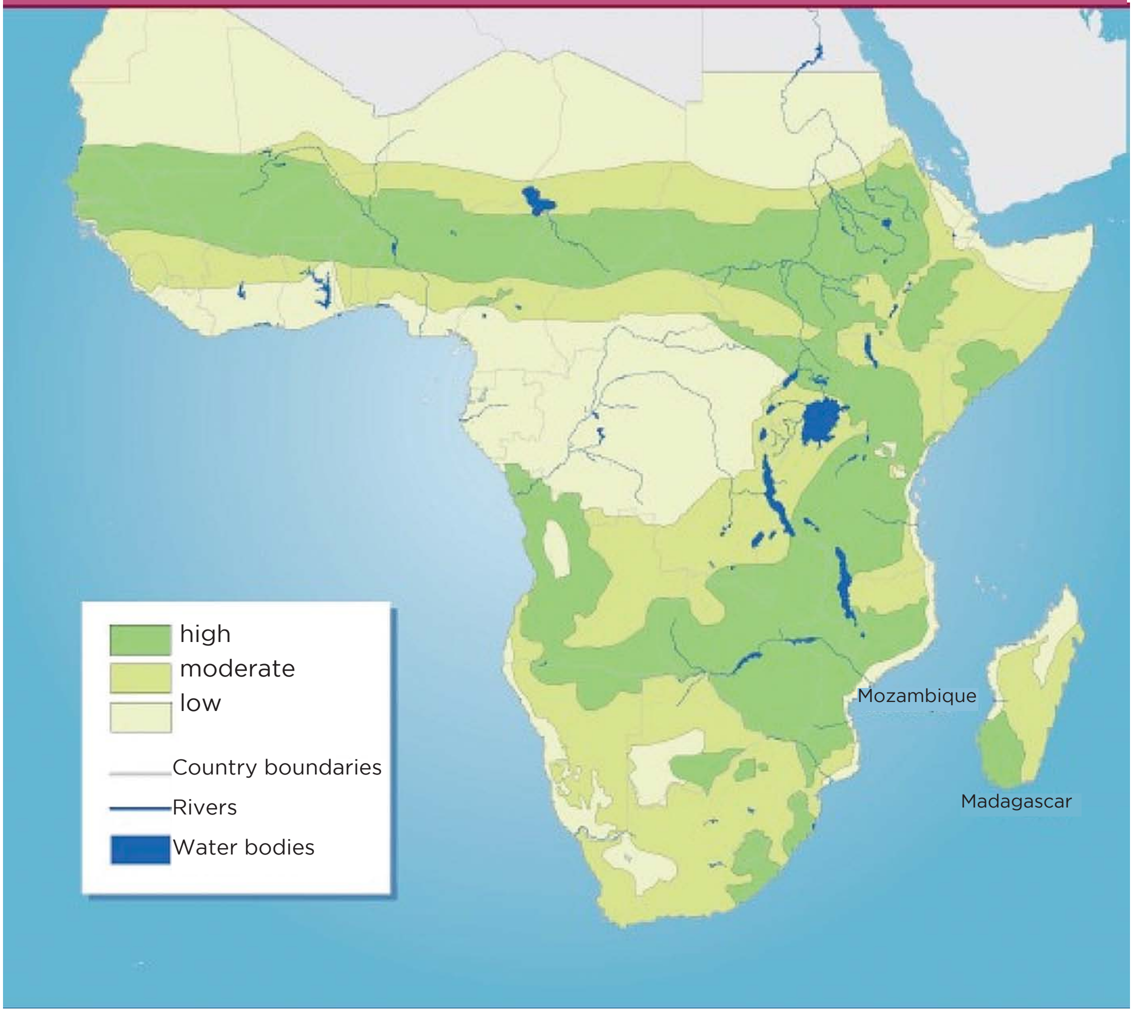
There are wide differences in natural water distribution within Africa's sub-regions. Central and Western Africa are endowed with the highest proportions at 51 and 23 per cent respectively, while the share is as low as 3 per cent for Northern Africa. A combination of human and natural factors is responsible for differences in water abundance within African countries. When actual total renewable water resources are considered, Nigeria appears to have an abundance of water resources, along with the Democratic Republic of Congo and Madagascar. However, average water availability depends not only on internal renewable water resources, but also on the number of people using that water. There are wide variations in average water availability per person among countries in the continent For example, the annual per capita water availability for Nigeria, Africa's most populous nation, is lower than that of relatively dry states such as Botswana and Namibia in Southern Africa. Annual per capita water availability is high for countries such as Guinea, Sierra Leone and Liberia in West Africa; the Democratic Republic of Congo, Central African Republic and Gabon in Central Africa; and in the Indian Ocean island of Madagascar. In the southern part of the continent, water availability per capita is relatively low for South Africa, as it is in North African states such as Algeria and Libya, as well as Kenya in East Africa. Africa's geography and climate, including periodic drought and highly variable rainfall, are not the only—or necessarily the most significant—reasons for the situations of water scarcity that exist on the continent.

Growing populations and the associated increased water demand, the costs of providing water and dwindling water supplies compound the problem. Water availability is also restricted by a trend towards urbanization and higher standards of living, poor or no city planning, a lack of resources and competition for available freshwater between sectors such as industry, municipal water and agriculture and even between nations that share watercourses. These have resulted in water stress or water scarcity conditions in the region where the quantity and quality of water may not be enough to adequately provide safe drinking water, food and hygiene, may limit economic development, and can severely constrain environmental resource.

Current water stress in Africa is likely to be increased by climate change, but water governance and water-basin management must also be considered in future assessments of water stress in Africa. Increases in runoff in East Africa (and increased risk of flood events) and decreases in runoff (and increased risk of drought) in other areas (e.g., southern Africa) are projected by the 2050s. Any changes in the primary production of large lakes will have important impacts on local food supplies. Lake Tanganyika currently provides 25–40% of animal protein intake for the surrounding populations, and climate change is likely to reduce primary production and possible fish yields by roughly 30%. The interaction of poor human management decisions, including over-fishing, is likely to further reduce fish yields from lakes.

Potential for poverty reduction in SSA through water interventions

low, moderate and high impact areas



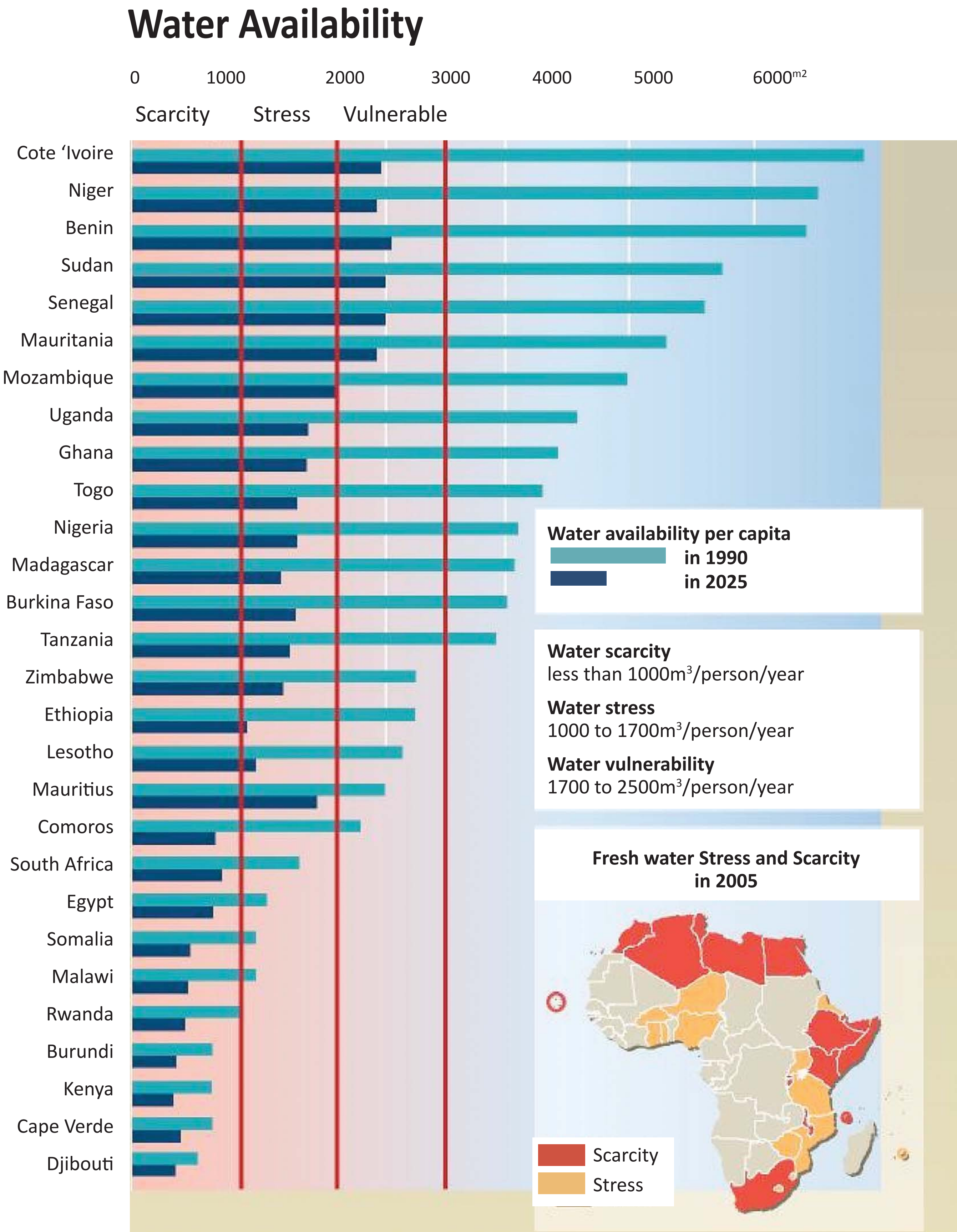
Source: FAO Water http://www.fao.org/nr/water/art/2008/ssabig.gif

African Water resources

The Nile River is the world's longest and the Congo and Niger are within the top 25. Africa is also home to some of the world's largest natural lakes (Table 1.6) and human-constructed lakes, or dams. In terms of volume, Africa's natural lakes and dams have a combined capacity that is twenty times that of Latin America's[106].The Lake Victoria is the second-largest freshwater lake in the world, with an area of approximately 68 600 km2[107]. Widespread but limited groundwaters represent only 15 per cent of the continent's renewable water resources, but the source of drinking water for three quarters of the continent's population[108]. Groundwater plays an important role in providing water for people and animals in rural areas of Africa and may be the only practical means of meeting rural community needs in its arid and semiarid regions[109].

Africa's rising population is one of the main drivers behind the slow progress in water and sanitation provision and in the increasing demand for, and degradation of water resources.

Among the world's regions, the continent's average population growth rate of 2.3 per cent for the period 2005 to 2010 was the highest110. Africa is the second-most populous continent after Asia (Figure 1.9). Africa also had the highest urban growth rate for the period 2005-2010, although on average it also had the largest proportion of rural population in 2009[111]. About 40 per cent of Africa's population now lives in cities. Between 2005 and 2010, Africa's urban population grew at a rate of 3.4 per cent, or 1.1 per cent more than the rural population. The urban growth rate over that time was highest in Central, Eastern and Western Africa, although at 58 per cent in 2009, Southern Africa had the highest proportion of urban population. Agriculture—largely rain-fed—is the single most important driver of economic growth for most African countries[112].The agricultural sector accounts for about 20 per cent of Africa's GDP, 60 per cent of its labour force and 20 per cent of the total merchandise exports, and is the main source of income for 90 per cent of the rural population [113].



Water Availability
0
1000
2000
3000
4000
5000
6000m2
Scarcity
Stress
Vulnerable
Cote 'Ivoire
Niger
Benin
Sudan
Senegal
Mauritania
Mozambique
Uganda
Ghana
Togo
Nigeria
Madagascar
Burkina Faso
Tanzania
Zimbabwe
Ethiopia
Lesotho
Mauritius
Comoros
South Africa
Egypt
Somalia
Malawi
Rwanda
Burundi
Kenya
Cape Verde
Djibouti
Water availability per capita
in 1990
in 2025
Water scarcity
less than 1000m3/person/year
Water stress
1000 to 1700m3/person/year
Water vulnerability
1700 to 2500m3/person/year
Fresh water Stress and Scarcity in 2005
Scarcity
Stress

Comparative table of internal renewable freshwater resources by world region

Continent/ Region	Volume per year (km² or 10⁹ m³	Percentage of World Freshwater Resources	Per capita (m³/year) (2008)
WORLD	43 802	100.0	6498
Africa	3 931	9.0	4008
Asia	12 393	28.3	3 037
South America	12 380	28.3	32 165
Central America & Caribbean	6 877	15.7	15 166
Oceania	892	2.0	32 366
Europe	6 548	14.9	8 942

Source: FAO. (2009).AQUASTAT database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/aquastat

5.2. The small islands context

There is strong evidence that, under most climate change scenarios, water resources in small islands are likely to be seriously compromised. Most small islands have a limited water supply, and water resources in these islands are especially vulnerable to future changes and distribution of rainfall. Many islands in the Caribbean are likely to experience increased water stress as a result of climate change.

5.2.1. The Caribbean region

The Caribbean is made up of mostly Small Island Developing States (SIDS) – apart from Guyana and Suriname on the South American mainland – and is characterized by limited resources, fragile environments and susceptibility to natural hazards. In recent decades the region has experienced a shift from agrarian to industrial economies resulting in new and competing demands for water for agricultural, industrial, tourism and domestic uses. Many countries face challenges in water resources management including financing, governance, environmental impacts and decreasing fresh water resources. The impact of climate change is expected to significantly raise the sea level, increase salt-water intrusion, flooding and hurricanes, and decrease rainfall. Recognition of the need for an integrated approach to the management of water resources has gained greater prominence, especially in the context of the Mauritius Strategy and the Barbados Plan of Action. However, many countries have not taken steps to develop or implement IWRM policies and plans[114].

Several small-island countries (e.g., Barbados, Maldives, Seychelles and Tuvalu) have begun to invest in the implementation of adaptation strategies, including desalination, to offset current and projected water shortages.

Water Resources Management Challenges in the Caribbean

Viewed on a global scale[115], the Caribbean region is well endowed with water resources. However, current predictions indicate that per capita water availability will shrink by 50% by the year 2025[116]. This is due to rapid population growth and trends in urbanization, tourism, rural development, and agricultural and industrial development. Concerns about the status of water resources management in the Caribbean have abounded for at least three decades. However, within the last six to ten years the issues relating to water resources management have gained prominence in the region. While commendable strides to establish policy and institutional frameworks to manage water resources have been made by countries such as Barbados, Jamaica, Antigua and Barbuda and Trinidad and Tobago; as a region, there is still a lot to be done. For the SIDS, water resources management takes on added importance as a result of their small size, fragile environment and limited natural, human and financial resources.

Water resources in Caribbean SIDS are also extremely vulnerable to the impacts of climate variability and change as a result of sea level rise and associated saltwater intrusion into coastal aquifers. Other issues that are relevant to the water sector in the Caribbean Region include high water demand, inappropriate land use and watershed degradation, pollution, fragmented approaches to water resources management and a lack of technical expertise. There is also limited stakeholder participation/public awareness and education as well as inadequate data and information management structures. In addition, water is also not perceived as an economic good. While as a region, there is ample supply to meet demand for the next fifteen to twenty years, the picture changes drastically at the country level. Some countries such as Dominica and Guyana have more than adequate water resources, but the infrastructure is inadequate to provide the necessary services. Overall, demand for water resources is increasing rapidly. The tourism sector also generates higher wastewater discharges that pollute surface and groundwater resources as well as the near shore coastal zone. The region is heavily dependent on rainfall to feed surface water intakes and replenish groundwater reserves. The major causes of pollution include the discharge of untreated or inadequately treated domestic and industrial waste and wastewater as a result of badly maintained and supervised package treatment plants serving hotels, as well as insufficient solid waste collection systems and wastewater treatment systems. There is also rapid population growth and high population densities, especially in urban areas, allowing for concentration of direct pollution sources to surface and groundwater.

The fragmented approach to water resources management in the region is another critical factor. In all of the countries there are multiple institutions and agencies involved in water resources management, resulting in poor coordination. The assessment of the Caribbean island states'[117] water resources management issues would seem to suggest that the region must adopt fundamentally new approaches to water resources management, including resource assessment, development and management within a framework of partnership. Without fundamentally new approaches to both environment and development, the present widespread degradation of the water resources that the region faces could become an unmanageable crisis. These changes can only be brought about through political commitment and involvement from the highest levels of Government to the smallest communities and backed by substantial and immediate investments, public education and awareness campaigns, legislative and institutional changes, technology development and capacity building programmes.

The problem with water resources data and information seems to be caused by the disparate agencies responsible for data collection and the fragmented approach to the management of the sector, inadequate human and institutional capacity, inadequate training, poor organization and inadequate financial resources. The weaknesses of the data gathering and information generation processes, also manifest themselves in the countries' poor inventory of water resources. Adequate assessment of the nature and distribution of water resources, including present and future demands, is key to good water resources management. To address these concerns regarding water resources information and knowledge, a number of initiatives are presently underway at partnership building.

These include partnership arrangements among sectors, between the public and private sectors, and at the regional, national and international levels. Some of these initiatives include the Sustainable Development Network in Jamaica and Guyana, Integrating Watershed and Coastal Areas Management in the Caribbean SIDS, Caribbean Dialogue on Water and Climate and Inter-American Water Resources Network[118].

5.2.2. The Pacific Region

Pacific Island Developing Countries (PIDCs). Countries within the Pacific subregion exhibit significant differences in their territorial and physical characteristics, which are reflected in the characteristics of their water resources. For the purposes of water resources management, they can be grouped into at least two subgroups: (a) small island countries, comprising low-lying and limited areas, where groundwater is the primary water resource; and (b) countries that have elevated land and larger territories, and consequently possess significant surface water resources. In contrast to the low-lying atoll-based territories, other islands are of volcanic origin and may possess mountainous areas with steep slopes and short, fast-flowing streams[119].

In the Pacific, a 10% reduction in average rainfall (by 2050) would lead to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. Reduced rainfall, coupled with increased withdrawals, sea-level rise and attendant salt-water intrusion, would compound this threat

Surface water and groundwater resources

The relative importance of surface water and groundwater in the countries of the Pacific subregion differs significantly, depending on the territorial nature of the country. Those States possessing elevated and mountainous terrain as well as significant surface water resources include Papua New Guinea, New Caledonia, Fiji and Samoa. Other States, in contrast, have no significant surface water resources; those countries comprise small low-lying islands where groundwater is the only usable resource, occurring in the form of freshwater lenses no more than several metres deep, frequently lying above seawater.

This resource is highly vulnerable to damage through overuse, inappropriate use or pollution and degradation. Examples of such countries are Nauru, Tuvalu and Kiribati. The two types of territory at these extremes clearly have very different water management characteristics and requirements. The expertise needed for the assessment and management of surface water and groundwater is found in different technical fields, and the expertise required for resource protection tends to have more commonality regardless of the nature of the resource. The management issues are also different, although related. Some land in Pacific island countries is not suitable for habitation, being either too rugged or in the form of small islands without adequate water resources for any purpose, or are low-lying and subject to frequent flooding[120] .Groundwater is the critical water resource for small, low-lying islands. Some countries in the subregion are composed entirely of such islands. Freshwater lenses are very shallow on coral atolls and bore drilling is normally kept within 20 metres. Rapid urbanisation is claimed to be a significant factor in the Pacific subregion. Population growth in the subregion is forcing migration from rural areas, where land is limited, towards urban areas. Therefore, the region is experiencing a relatively high rate of urban growth, with the associated issues for water resources including: (i) The need for augmented urban water supply schemes; (ii) The need for increased sanitation; and (iii) Urban-sourced pollution of surface waters and groundwater.

However, in some cases, (for example, in Polynesia and Micronesia) population growth is almost completely offset by emigration. Agriculture in the subregion is characterized by a combination of large-scale commercial production of cash crops and a smaller sector providing food crops for local consumption

This structure is in transition, driven by changing world markets, trade imbalances, the quest for food security and growing human populations[121]. Large-scale agricultural schemes have frequently failed. Large rice farms, developed in the 1970s are now abandoned and almost all rice is imported. Cattle herds have declined steadily over the past decade. Land disputes were often at the heart of the inability to develop economic agriculture, but many other factors have contributed to the failures including the unsuitability of western farming techniques, storms and pests. The subregion is characterized by the relative absence of traditional or modern irrigation schemes when compared to Asia or Australia and New Zealand. Thus, the irrigation departments found in the neighbouring Asian region are not a feature of the water sector in the Pacific subregion, Agriculture relies to a larger degree on rainfed cropping and is thus more exposed to climatic fluctuations without the buffering facility of large water storage dams.

6. Changing responses

It is possible to produce enough food and other agricultural products at a global level to meet demand while reducing the negative impacts of water use in agriculture. But doing so will require a change from today's food production and environmental trends, which, if continued, will lead to crises in many parts of the world[122]. A combination of supply- and demand-side measures is needed to address the acute water challenges in the coming 50 years. The difficult task at hand is to manage the additional water supply in a way that minimizes the adverse impacts and – where possible – enhances ecosystem services and aquatic food production, while achieving the necessary gains in food production and poverty alleviation. The Comprehensive Assessment of Water Management in Agriculture[123] scenario analysis shows opportunities and options – in rainfed, irrigated, livestock and fisheries systems – for preserving, and even restoring, healthy ecosystems. But gains require major changes in the way water is managed, especially by farmers. The behavior of different categories of farmers is shaped not only by agricultural policies but also by the capacity to allocate water according to wider financial restrictions and by local capacity to overcome pollution and environmental damage in emerging market economies[124]. China has succeeded over the last 10 years in improving its water use efficiency by around 10% without increasing its water allocation to agriculture .Improved water management in agriculture includes reduced water wastage in irrigation. Irrigated agriculture is often seen as inefficient, in both water use and added value. While on average only an estimated 37% of the water withdrawn for agriculture is effectively consumed by plants, a substantial share of the unused water returns to rivers and aquifers and is available for downstream uses[125]. The net loss of water due to irrigation is therefore substantially less than may be apparent, and the potential gains from programmes aimed at increasing water use efficiency are often overestimated. Programmes aimed only at reducing losses in irrigation are unlikely to have a substantial impact on water use. Most large irrigation schemes also serve other functions, such as providing water for drinking, bathing, swimming, fishing and livestock, and water savings may take water away from these uses. Management thus needs to focus instead on multiple use strategies. Technological improvements can occur at all levels and affect all types of irrigation systems .Better technologies are not necessarily new, expensive or sophisticated options, but rather ones that are appropriate to agricultural needs and demands, the managerial capacity of system managers and farmers, and the financial and economic capacity needed to ensure proper operation and maintenance. Better design and better matching of technologies, management and institutional arrangements are needed. Technological innovation will occur in broadly three categories: At the irrigation system level: water level, flow control and storage management within surface irrigation systems at all scales[36]

6.1. Options for water management in agriculture

6.1.1 Improving on-farm water management

In practice, agricultural water services are just one of many crop production inputs, but they are a critical lead input without which intensification and diversification of agricultural production would be impossible. Managing the application of water to the root zone and obtaining higher overall productivity is contingent upon soil fertility, cultivar selection, cropping density, pest and disease management and then post-harvest controls up to the farm gate[126]. This sets the systemic value added chain in which water use efficiency can be evaluated and the scope for on farm systemic improvement analysed. Under conditions of limited water availability at the farm gate, the improvement of on-farm water management becomes an imperative. Sprinkler and trickle irrigation methods, deficit irrigation and other water saving irrigation technologies have demonstrated viable financial and health safety returns. Biotechnology can provide further advantages as well.

The benefits of these technologies are increased further when combined with accurate determination of crop water and irrigation system requirements, with well established irrigation scheduling, and with the above-mentioned agricultural practices.

Improvement of on-farm water management calls for an integrated use of water conservation practices, and economic incentives to influence water use – both the total level of water use and the pattern of use. Under the circumstances of limited water supply, maximizing the crop yield per unit of land should give ways to achieve the maximum yield per unit of water use. The latter is achieved at a water supply at least 20-30 percent less than the amount needed for maximum yield[127]. Another important factor affecting on-farm water management is related to the skills of human resources that also deserve due consideration in the future.

6.1.2. Improving the performance of irrigation system services

At the very minimum, the supply of water within large irrigated systems has to be reliable. The farmer has to be able to predict the timing and volume of supply. At best, supply has to be available on-demand and just-in-time to give the farmer maximum flexibility in crop choice and growing season. This explains the farmer preference for groundwater supplied irrigation in the face of unreliable water service. However, the irrigated sub-sector is characterized by large scale irrigation systems that are publicly financed and operated. These are generally systems that were designed to offer employment and alleviate poverty when water supply was not considered to be a constraint or the necessity of long-term commercial viability was not considered to be a primary objective. Circumstances have changed.

Pressures to modernize irrigation system technology and related institutions have built up in response to increasing competition among water users, better articulation of farmer needs, and more generally due to political reforms and policy shifts with respect to responsibility and cost sharing in management of natural resources[128].

Consequently, the evaluation of the performance of large irrigation systems is no longer limited to crop related indicators. It is now recognized that water management in irrigation is multi-objective, providing a wide range of benefits to both farmers and local communities, from recharge of local aquifers for potable supplies to the maintenance of shelter belts and orchards. Therefore increasing the performance of irrigation systems implies the genuine recognition that irrigation systems can complement the natural systems over the annual water cycle.

Improving performance implies that irrigation management needs to refocus on water delivery to farmers while looking for paradigm shifts such as enlarging the concept of performance to multiple uses (positive and negative externalities); encompassing the conjunctive use of water; extending the participative management to various local actors; developing cost-effective management of water; mitigating environmental externalities associated with water logging and salinity, and the disposal of drainage water.

6.1.3 National policies and water allocation to agriculture

Agriculture has been highly successful in capturing the bulk of the world's freshwater resources, but with little accountability. Since agriculture will continue to be the main water user, improved agricultural water use in irrigated and rainfed agriculture will have a direct impact on local and regional water availability[129]. Allocation of raw water out of agriculture to other higher utility uses – municipal supplies, environmental reserves, hydropower generation, etc. is already taking place, but there is still scope for these allocations to be optimized in economic and environmental terms and this challenge has to be taken up by progressive agriculture policy as much as water policy.

To this extent, agricultural agencies need to be in a much better position to negotiate reallocation of bulk water resources before access and control is simply withdrawn through compulsory reallocation. This position can only be established through the following avenues: the provision of clear information on agricultural water use; a commitment to engage with key water sector players, including environmental agencies; establishing robust and transparent methods to negotiate allocation amongst competing uses.

Current obstacles to making progress on optimal intra and inter-sectoral water allocations are institutional, technological and economical. Institutional rigidity continues to impair the performance of irrigated agriculture and the improvement of rain-fed systems. The uptake of improved systems is also inhibited by inconsistent macro-policies that fail to provide sufficient incentives for increased production efficiency. There is continued reliance on supply-side solutions and limited analysis of the changing factors of demand. Many existing systems of irrigated agriculture and, to a lesser extent, rainfed agriculture, are predicated on technologies designed to maximise supply inputs, and are simply not flexible enough to respond efficiently to individual farmer demands[130].

At a technical level, irrigated production will need to be re-thought in order to raise water use efficiency and close crop yield gaps. But institutional shifts will also be required to enhance the economic mobility of water both within agriculture and across competing economic sectors. Irrigation is under pressure to perform as a service to agriculture, not as an end in itself. This will involve a shift in approach from a supply or input-driven, activity to a much more demand responsive activity[131].

6.1.4. Improving access to agricultural water and strengthening governance

Insecure access to reliable, safe, and affordable water keeps hundreds of millions of people from escaping poverty. Most of them rely directly on agriculture for their food and income. Unless bold action is taken, many more smallholder farmers, fishers, herders, and people dependent on wetlands will fall into poverty as rivers dry up, groundwater declines, and water rights are lost. Broadly conceived, poverty reduction strategies will entail four elements:

- Empowering people to use water better, and targeting the right groups.
- Ensuring the right to secure access.
- Improving governance of water resources.
- Supporting the diversification of livelihoods[132].

Recognizing that the root cause of many water problems related to poverty is poor water governance, there has been a wide call for reform. Common elements in such reform initiatives are decentralized decisionmaking, often involving institutionalization of user participation, assignment of private property or extensive use rights to water, and greater reliance on market mechanisms to ensure the most cost-effective allocation and management of scarce water resources.

Ensuring rural poor people's right to secure access to water represents a key challenge to water governance reform. Currently, access to water, particularly for agriculture, tends to be based on informal or customary rights associated with ownership of land containing water springs or flows or based on social norms or relations with owners of land or local water committee members. If such forms of access are not recognized and accommodated in reforms of water governance, the rural poor stand to lose their access to water for agriculture. Women in particular confront severe problems in accessing water. Because access often depends on land ownership, gender inequalities and discrimination in access to land and in livelihood opportunities in general often reproduce gender inequalities in water[133].

Clarifying water rights can ensure secure access to water for agriculture for poor women and men when carefully implemented. In certain circumstances collective water rights might be preferable to individual water rights. Redistributive policies can give the rural poor access to assets, markets, and services. Acknowledging customary laws and informal institutions can facilitate and encourage local management of water and other natural resources. The capacity of people to manage their water resources can be enhanced through specific training. Local management should be integrated with basin, regional, and national institutions—and based within the broader context of rural development. One of the main obstacles to improving the livelihoods of poor rural people is the lack of attention given to gender issues and women's access to natural resources, in particular land and water.

Where there is equity in resource distribution, the poverty reducing impact of improved water management on agricultural productivity growth has been greater.

Transboundary water co-operation is recognised as an effective policy and management tool to improve water management across large regions sharing common resources. Climate change and increased water demand in future decades will represent an added challenge to such framework agreements, increasing the potential for conflict at the local level. For instance, unilateral measures for adapting to climate-change-related water shortages can lead to increased competition for water resources. Furthermore, shifts in land productivity may lead to a range of new or modified agricultural systems, necessary to maintain production, including intensification practices. The latter, in turn, can lead to additional environmental pressures, resulting in loss of habitat and reduced biodiversity, siltation, soil erosion and soil degradation.

Water resources are a key vulnerability in Africa for household, agricultural and industrial uses. In shared river basins, regional co-operation protocols are needed to minimise both adverse impacts and the potential for conflicts. For instance, the surface area of Lake Chad varies from 20,000 km^2 during the dry season to 50,000 km^2 during the wet season. While precise boundaries have been established between Chad, Nigeria, Cameroon and Niger, sectors of these boundaries that are located in the rivers that drain into Lake Chad have never been determined, and additional complications arise as a result of both flooding and water recession. Similar problems on the Kovango River between Botswana and Namibia led to military confrontation. Growing water scarcity, increasing population, degradation of shared freshwater ecosystems and competing demands for shrinking natural resources distributed over such a huge area involving so many countries have the potential for creating bilateral and multilateral conflicts. In semi-arid Africa, pastoralism is the main economic activity, with pastoral communities including transnational migrants in search of new seasonal grazing. In drought situations, such pastoralists may come into conflict with settled agrarian systems[134]. Governance at various levels (from communities to regions) will be key for an effective management of water resources.

Selected resources available online (English and French)

En italique les documents disponibles en français

African Development Bank

AfDB, African Regional Document – Water Resources Development in Africa. 2006
http://www.reliefweb.int/rw/lib.nsf/db900sid/RURI-6N4NFJ/$file/afdb-gen-mar06.pdf?openelement

AfDB, FAO, IFAD, IWMI and World Bank, Investment in Agricultural Water for Poverty Reduction and Economic Growth in Sub Saharan Africa, 2007
http://siteresources.worldbank.org/RPDLPROGRAM/Resources/459596-1170984095733/synthesisreport.pdf.

European Commission

Biofuels in the European Union, An agricultural perspective, 2006
http://ec.europa.eu/agriculture/publi/fact/biofuel/2007_en.pdf

Les biocarburants dans l''Union EuropŽenne : une perspective agricole, 2006
http://ec.europa.eu/agriculture/publi/fact/biofuel/2007_fr.pdf

Report from the Commission in accordance with Article 3.7 of the Groundwater Directive 2006/118/EC on the establishment of groundwater threshold values
http://ec.europa.eu/environment/water/water-framework/groundwater/pdf/EN.pdf

Rapport de la Commission relatif ˆ la fixation de valeurs seuils pour les eaux souterraines, publiŽ conformŽment ˆ l'article 3, paragraphe 7, de la directive 2006/118/CE
http://ec.europa.eu/environment/water/water-framework/groundwater/pdf/FR.pdf

European Parliament

Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:HTML

Directive 2000/60/CE du Parlement europŽen et du Conseil du 23 octobre 2000 Žtablissant un cadre pour une politique communautaire dans le domaine de l'eau
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:FR:HTML

FAO

FAO, Agricultural drainage water management in arid and semi-arid areas, 2002
ftp://ftp.fao.org/agl/aglw/docs/idp61e.pdf

FAO, Agriculture and Water Scarcity: a Programmatic Approach to Water, Use Efficiency and Agricultural Productivity, 2007
ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

FAO Agriculture et raretŽ de l'eau: une approche programmatique pour l'efficacitŽ de l'utilisation de l'eau et la productivitŽ agricole
ftp://ftp.fao.org/docrep/fao/meeting/011/j9206f.pdf

FAO, Climate change, water and food security. Technical background paper. Conference on food security, 2008
http://www.fao.org/nr/water/docs/HLC08-FAOWater-E.pdf

FAO, Crops and Drops: Making the Best Use of Water for Agriculture, 2002
ftp://ftp.fao.org/agl/aglw/docs/cropsdrops_e.pdf

FAO, Eau et agriculture, produire plus avec moins d'eau. Organisation, 2002
ftp://ftp.fao.org/agl/aglw/docs/cropsdrops_f.pdf

FAO, Integrated irrigation and aquaculture in West Africa: concepts, practices, and potential, by M. Halwart & A.A. van Dam, A.A., 2006
http://www.fao.org/docrep/009/a0444e/a0444e00.htm

FAO, Crop prospects and food situation. Global Information and Warning System on Food and Agriculture. No. 4. Rome, 2007
http://www.fao.org/giews/english/cpfs/index.htm

FAO, Urbanization and food security in Sub-Saharan Africa. Twenty-fifth regional conference for Africa, Nairobi-Kenya, 2008
ftp://ftp.fao.org/docrep/fao/meeting/013/k1588e.pdf

FAO, Vingt-cinqui me Conference RŽgionale de la FAOpour l'Afrique
ftp://ftp.fao.org/docrep/fao/meeting/013/k1588f.pdf

FAO AQUASTAT Information System on Water and Agriculture: Online Database. Land and Water Development Division, 2010
http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en

FAO AQUASTAT Syst me d'Information sur l'Eau et l'Agriculture : base de donnŽes en ligne. DŽpartement de l'Eau et l'Agriculture, 2010
http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=fr

IPTRID-FAO,The irrigation challenge. Issue paper 4, 26p, 2003
ftp://ftp.fao.org/agl/iptrid/is_pa_04.pdf

Global Water Partnership

Global Water Partnership, Better water resources management – Greater resilience today, more effective adaptation tomorrow. Water and Climate Change Adaptation. World Water Council, IUCN, IWA & CPWC, 2009
http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/Climate_Change/PersPap_04._Planning_Better_WRM.pdf

IAATSD-International Assessment of Agricultural Knowledge, Science and Technology for Development

IAATSD, Agriculture at a crossroads. Synthesis Report, 2009
http://www.agassessment.org/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Synthesis%20Report%20(English).pdf

Full report

http://www.agassessment.org/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Global%20Report%20(English).pdf

IAATSD, Summary for Decision Makers of the Sub-Saharan Africa (SSA) Report. International Assessment of Agricultural Knowledge, Science and Technology for Development, 2009, Island Press.
http://www.agassessment.org/docs/IAASTD_GLOBAL_SDM_JAN_2008.pdf

International Water Management Institute

IWMI, Improving water productivity: How do we get more crop per drop? IWMI Water Policy Briefing – 8, 2003
http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/wpb08.pdf

De Fraiture, C., X. Cai, U. Amarasinghe, M. Rosegrant, and D. Molden, Does International Cereal Trade Save Water? The Impact of Virtual Water Trade on Global Water Use, Comprehensive Assessment of Water Management in Agriculture, Colombo, 2004
http://www.iwmi.cgiar.org/Assessment/files/pdf/publications/ResearchReports/CARR4.pdf

Drechsel, P., S. Graefe, M. Sonou, and O.O. Cofie Informal, Irrigation in Urban West Africa: An Overview. IWMI Research Report 102. Colombo: International Water Management Institute, 2006
http://www.iwmi.cgiar.org/publications/IWMI_Research_Reports/PDF/pub102/RR102.pdf

Galbraith, H., P. Amerasinghe, and A. Huber-Lee, The Effects of Agricultural Irrigation on Wetland Ecosystems in Developing Countries: A Literature Review. Discussion Paper 1. Comprehensive Assessment Secretariat, Colombo, 2005
http://www.iwmi.cgiar.org/assessment/files_new/publications/Discussion%20Paper/CADiscussionPaper1.pdf

Inocencio, A., D. Merrey, M. Tonosaki, A. Maruyama, I. de Jong, and M. Kikuchi. Forthcoming. Costs and Performance of Irrigation Projects: A Comparison of sub-Saharan Africa and Other Developing Regions. IWMI Research Report. International Water Management Institute, Colombo.
http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB109/RR109-final.pdf

Molden, D., Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007
http://www.iwmi.cgiar.org/assessment/

Molden, D. L'Eau pour l'Alimentation, l'Eau pour la Vie: Une Evaluation Globale de la Gestion de l'Eau en Agriculture. London Earthscan, and Colombo, International Water Management Institute, 2007.
http://www.iwmi.cgiar.org/assessment/files_new/synthesis/Summary_French.pdf

Molden D., Amarasinghe U. & Hussain I., Water for Rural Development. Prepared for the World Bank – IWMI, 96 p, 2001
http://www.iwmi.cgiar.org/

Publications/Working_Papers/working/WOR32.pdf

Peacock, T.,C. Ward, and G. Gambarelli, Forthcoming. Investment in Agricultural Water for Poverty Reduction and Economic Growth in Sub-Saharan Africa. Synthesis Report. Collaborative Programme of African Development Bank, Food and Agriculture Organization, International Fund for Agricultural Development, International Water Management Institute, and World Bank. Columbo,2007
http://siteresources.worldbank.org/RPDLPROGRAM/Resources/459596-1170984095733/synthesisreport.pdf

Penning de Vries, F.W.T., H. Acquay, D. Molden, S.J. Scherr, C. Valentin, and O. Cofie, Integrated Land and Water Management for Food and Environmental Security. Research Report 1. International Water Management Institute, Colombo, 2002
http://www.iwmi.cgiar.org/Assessment/files/pdf/publications/ResearchReports/CARR1.pdf

Rockstršm, J., Hatibu, N., Oweis, T. & Wani, S., Managing water in rainfed agriculture. In D. Molden, D.,Water for food, water for life. A comprehensive assessment of water management in agriculture. Chapter 8, London, Earthscan, and Colombo, IWMI, 2007
http://www.fao.org/nr/water/docs/Summary_SynthesisBook.pdf

Rockstrom, J. Barron J.and Fox. P., Water Productivity in Rain-fed Agriculture: Challenges and Opportunities for Smallholder Farmers in Drought-prone Tropical Agro ecosystems. Water Productivity in Rain-fed Agriculture, UNESCO-IHE, 2000
http://www.iwmi.cgiar.org/publications/CABI_Publications/CA_CABI_Series/Water_Productivity/Unprotected/0851996698ch9.pdf

IFAD

IFAD, Wahaj R.& Hartl M., 2007. Gender and water Securing water for improved rural livelihoods: The multiple-uses system approach. 2007
http://www.ifad.org/gender/thematic/water/gender_water.pdf

IFPRI

IFPRI, Global Water outlook to 2025 – Averting an impending Crisis. Food Policy Report IWMI, 2002
http://www.ifpri.org/sites/default/files/publications/fprwater2025.pdf

IFPRI, Climate Change - Impact on Agriculture and Costs of Adaptation. International Food Policy Research Institute, 2009
http://www.ifpri.org/sites/default/files/publications/pr21.pdf

IPCC

Bates, B.C., Z.W. Kundzewicz., S. WU & J.P. Palutiko F., Climate change and water, 2008
http://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers.shtml

IPCC, Climate Change 2007, Fourth Assessment Report (AR4), 2007
http://www.ipcc.ch/

OECD

OECD Food sovereignty in West Africa: From Principles to Reality, 2007
http://www.oecd.org/dataoecd/55/5/38525866.pdf

OECD-FAO Agricultural Outlook 2008-2017, Organisation for Economic Co-operation and Development/Food and Agriculture Organisation of the United Nations, 2008
http://www.fao.org/es/esc/common/ecg/550/en/AgOut2017E.pdf

SIWI

SIWI, The Impact of the Global Financial Crisis on Financial Flows to the Water Sector in Sub-Saharan Africa ,2010
http://www.siwi.org/documents/Resources/Reports/Report28_Global_Financial_Crisis_WEB.pdf

SIWI-IWMI, Water—More Nutrition Per Drop: Towards Sustainable Food Production and Consumption Patterns in a Rapidly Changing World, Stockholm: Stockholm International Water Institute, 2004
http://www.siwi.org/documents/Resources/Policy_Briefs/CSD_More_nutrition_per_drop_2004.pdf

Gunilla B.,Water Management in Developing Countries-Policy and Priorities for EU Development Cooperation. A Background Document for an EC Communication.-SIWI, 2001
http://www.siwi.org/documents/Resources/Reports/Report12_Water_Management_in_Developing_Countries_Recommendations_2001.pdf

United Nations

UN, Water for Food, Water for Life: The United Nations World Water Development Report 1. Paris and New York: United Nations Educational, Scientific and Cultural Organization and Berghahn Books, 2003
http://www.un.org/waterforlifedecade/pdf/waterforlifebklt-e.pdf

ONU, L'eau, source de vie, Nations Unies, 2005
http://www.un.org/waterforlifedecade/pdf/waterforlifebklt-f.pdf

UNCCD, Water scarcity and desertification, Thematic fact sheet series ni 2, 2p
http://www.unccd.int/documents/Desertificationandwater.pdf

UN-DESA. Population Division, Population Estimates and Projections Section. World Population Prospect, The 2008 Revision.
http://esa.un.org/unpd/wpp2008/index.htm

UNECA Economic Report on Africa 2007
http://www.uneca.org/era2007/

CEA Rapport Economique sur l'Afrique, 2007
http://www.uneca.org/fr/era2007/

UNEP, Africa: Atlas of our changing environment. United Nations Environment Programme. Division of Early Warning, Nairobi, 2008

UNEP, Afrique -Atlas de l'eau, RŽsumŽ pour les dŽcideurs,2010
http://na.unep.net/atlas/africaWater/downloads/Africa_Water_Atlas_Executive_Summary_French.pdf

UNEP, Vital Climate Change Graphics for Latin America and the Caribbean, 2010
http://www.grida.no/_res/site/file/publications/LAC_Web_eng_2011-01-03.pdf

UNEP/GRID, Arendal (Areas of physical and economic water scarcity, UNEP/ GRID-Arendal Maps and Graphics Library,2008
http://maps.grida.no/go/graphic/areas-of-physical-and-economic-water-scarcity

UNFPA, State of world population ,Facing a changing world: women, population and climate. United Nations Population Fund. New York, 2009
http://www.unfpa.org/swp/2009/en/pdf/EN_SOWP09.pdf

UNFPA, L'Žtat de la population mondiale 2009.
http://www.unfpa.org/swp/2009/fr/index.shtml

UN-Habitat, State of the World's Cities 2006/7: The Millennium Development Goals and Urban Sustainability,London: Earthscan, 2006

UNESCAP, Climate Change and the Pacific Islands. Ministerial Conference on Environment and Development in Asia and the Pacific ,2000
http://www.caribsave.org/assets/files/UNDP%20Final%20Report.pdf

UNESCO–UN World Water Assessment Programme, Water—A Shared Responsibility:The United Nations World Water Development Report 2. Paris and New York: UNESCO and Berghahn Books, 2006
http://unesdoc.unesco.org/images/0014/001444/144409E.pdf

UNESCO, 2 me Rapport mondial des Nations Unies sur la mise en valeur des ressources en eau : l'eau, une responsabilitŽ partagŽe, Paris and New York: UNESCO and Berghahn Books, 2006
http://unesdoc.unesco.org/images/0014/001444/144409F.pdf

UNESCO, World Water Assessment Programme, The United Nations World Water Development Report 3, Case Study Volume: Facing The Challenges. United Nations Educational, Scientific and Cultural Organization, 2009
http://webworld.unesco.org/water/wwap/wwdr/wwdr3/case_studies/pdf/WWDR3_Case_Study_Volume.pdf

UN, Water in changing World. Chapter 5,Climate change and possible futures. World Water Development Report 3, World Water Assessment Programme. UNESCO publishing, 2009
http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/15_WWDR3_ch_5.pdf

Dourojeanni A.,The Status of Integrated Water: Management in Latin America and the Caribbean. UNESCO, 2005
http://www.unesco.org.uy/phi/biblioteca/bitstream/123456789/438/1/0528.pdf

UN Water, Transboundary Waters: Sharing Benefits, Sharing Responsibilities. UN-Water Thematic Paper, 2008
http://www.unwater.org/downloads/UNW_TRANSBOUNDARY.pdf

UN Water, Climate change and Water. An overview from the World Water Development Report 3: Water in a Changing World. World Water Assessment Programme, 2009
http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/13_WWDR3_ch_3.pdf

UN Water Thematic Initiatives, Coping with Water Scarcity, A strategic issue and priority for system wide action, 2006
http://www.unwater.org/downloads/waterscarcity.pdf

OCHA, Water Scarcity and Humanitarian Action : Key Emerging Trends and Challenges, OCHA Occasional Policy Briefings No.4, 2010
http://ochanet.unocha.org/p/Documents/OCHA%20OPB%20Water%20%2011Nov10%20fnl.pdf

World Bank

World Bank, World Development Indicators. Online database. 2009
http://databank.worldbank.org/ddp/home.do?Step=12&id=4&CNO=1147

World Bank. Water Resources Sector Strategy: Strategic Directions for World Bank Engagement. Washington, D.C., World Bank, Investment in agricultural water for poverty reduction and economic growth in sub-Saharan Africa. Synthesis Report. A collaborative programme of AfDB, FAO, IFAD, IWMI and the World Bank, 2007
http://www.fanrpan.org/documents/d00508/1-Agric_water_investments_World_Bank.pdf

World Bank. World development report 2008. Agriculture for development. Washington, DC, World Bank,2007
http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192111580172/WDROver2008-ENG.pdf

World Water Council

Timmerman Jos G., Bernardini F., Adapting to climate change in transboundary water management. Water and Climate Change Adaptation. World Water Council, IUCN, IWA & CPWC, 2009
http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/Climate_Change/PersPap_06._Transboundary_Water_Management.pdf

World Water Council, IUCN, IWA & CPWC, Perspectives on water and climate change adaptation, Introduction and summarize, 2009
http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/0._Introduction__Summaries_and_Key_Messages.pdf

World Water Council, World Water Action,? Eau et Agriculture – Chapitre 10,
http://www.worldwatercouncil.org/fileadmin/wwc/Library/WWActions/WWA_CHAP-10.pdf

World Water Council, L'eau l'affaire de tout le monde. World Water Vision, 2010
http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/Visions/FrenchExSum.pdf

Other Sources

Allan, J. A., Virtual water – the water, food and trade nexus: useful concept or misleading metaphor? Water International, Vol. 28, 2003

Berndes G., Bioenergy and water—the implications of large-scale bioenergy production for water use and supply. Elsevier Science Ltd, Global Environmental Change, 2002

Biggs, T., Thenkabail, P.S., Krishna, M., GangadharaRao, P., and Turral, H.,Vegetation phenology and irrigated area mapping using combined MODIS time-series, ground surveys, and agricultural census data in Krishna River Basin, India. International Journal of Remote Sensing, 2006

Boelee, E., Laamrani, H. & van der Hoek, W., Multiple use of irrigation water for improved health in dry regions of Africa and South Asia. Irri. Drain, 2007

Bruinsma, Jere., World Agriculture: Towards 2015/2030. An FAO Perspective. London: Earthscan, 2003

Burke J. & Kuylenstierna J., The Water Variable – Producing enough food in a climate insecure world, Water and Climate Change Adaptation, World Water Council, IUCN, IWA & CPWC, 22p, 2009

De Fraiture, C., M. Giodano, and Yongsong L. 2007. Biofuels: Implications for Agricultural Water

Use: Blue Impact of Green Energy, January 2007, Hyderabad, India

De Fraiture C. & Berndes G., Chapter 8: Biofuels and Water, in Biofuels: Environmental Consequences and Interactions with Changing Land Use. Scientific Committee on Problems of the Environment (SCOPE), 2009 http://www.uneptie.org/energy/activities/water/pdf/Reading%20list%20materials_15April2010/Reading%20list%20materials_15April2010/Berndes%20Fraiture%20-%20Biofuels%20and%20Water.pdf

Department for International Development-DFID, Agricultural Sustainability, 2004 http://dfid-agriculture-consultation.nri.org/summaries/wp12.pdf

Dixon, J., Gulliver, A. and Gibbon, D, Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. Rome/Washington DC, FAO/World Bank, 2001

Donkor, S., Development Challenges of Water Resource Management in Africa. African Water Journal 1: 1, 2003

Dornbosch, Richard, and Ronald Steenblik, Biofuels: Is the Cure Worse than the Disease? Round Table on Sustainable Development, 11-12 September 2007, Paris, Organisation for Economic Co-operation and Development, 2007 http://www.foeeurope.org/publications/2007/OECD_Biofuels_Cure_Worse_Than_Disease_Sept07.pdf

Faur s J-M. & Santini G.,Water and the Rural Poor Interventions for improving livelihoods in sub-Saharan Africa. IPAD-FAO Land and Water Division, 2008

Hasnip, N., S. Mandal, J. Morrison, P. Pradhan, and L. Smith L., Contribution of Irrigation to Sustaining Rural Livelihoods. KAR Project R 7879, Literature Review. Report OD/TN 109. HR Wallingford and UK Department for International Development, Wallingford, UK, 2001

Hoekstra A., Chapagain A. K., Water footprints of nations: Water use by people as a function of their consumption pattern http://www.waterfootprint.org/Reports/Hoekstra_and_Chapagain_2006.pdf

Hoekstra A. and Hung P., Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade, Value of Water Research Series No. 11, UNESCO-IHE, 2002

HolmŽn, H.,The state and agricultural intensification in sub-Saharan Africa. In G. Djurfeldt, H. HolmŽn, M. Jirstršm & R. Larsson, eds. The African food crisis: lessons from the Asian green revolution. Wallingford, UK, CABI Publishing, 2005

Hope, R.A.,Water, Workfare, and Poverty: The Impact of the Working for Water Programme on Rural Poverty Reduction. Environment, Development, and Sustainability, 2006

Hussain, I., Poverty-reducing impacts of irrigation: evidence and lessons. Irri. Drain., 2007

Kemper, K. & Sadoff, C. The global water challenge. World Bank Global Issues Seminar, 2003 http://siteresources.worldbank.org/EXTABOUTUS/Resources/WaterPaper.pdf

Lewis L., Rural and Urban Water Issues in Africa. The water project, 2010

Millennium Ecosystem Assessment, Ecosystem Services and Human Well-being: Wetlands and Water Synthesis, Washington, D.C.: World Resources Institute, 2005

Molle F. & Berkoff J., Cities versus Agriculture: Revisiting Intersectoral Water Transfers, Potential. Gains and Conflicts. IWMI, Comprehensive Assessment Research Report 10, 2006

Overmars M., Adapting to climate change in water resources and water services in Caribbean and Pacific small island countries. Water and Climate Change Adaptation. SOPAC -World Water Council, IUCN, IWA & CPWC, 2009 http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/Climate_Change/PersPap_03._Small_Island_Countries.pdf

Peden D., Freeman A., Astatke A., Notenbeart A., Investment options for integrated water-livestock-crop production in sub-Saharan Africa. International Water Management Institute, 2005

Rees WE (1992) Ecological footprints and appropriated carrying capacity: what urban economics leaves out. Environ Urban 4(2):121–130

Renault, D., Value of virtual water in food: principles and virtues. A.Y. Hoekstra (ed.), Virtual Water Trade, Proceedings of the International Expert Meeting on Virtual Water Trade, Delft, the Netherlands, UNESCOIHE,2003

Ringersma, J., Batjes, N. and Dent, D, Green Water: Definitions and Data for Assessment. Wageningen, the Netherlands, ISRIC, 2003

Rijsberman, F.R., Water Scarcity: Fact or Fiction?, Agricultural Water Management, 2006

WRI Agricultural Inputs: Fertilizer consumption. World Resources Institute, 2007 http://earthtrends.wri.org/searchable_db/index.php?step=countries&cID[]=183&theme=8&variable_ID=196&action=select_years

Roche P.-A., L'eau, enjeu vital pour l'Afrique. Afrique contemporaine, Dossier, 2003 *http://www.pseau.org/outils/biblio/resume.php?docu_document_id=1258*

Saleth, R. M., Understanding Water Institutions: Structure, Environment and Change Process' in Perret, S., Farolfi, S. & Hassan, R. (eds) Water Governance for Sustainable Development: Approaches and Lessons from Developing and Transitional Countries, Earthscan, London, UK, 2006

Tacoli, C. Links between Rural and Urban Development in Africa and Asia. Paper presented at United Nations Expert Group Meeting on Population Distribution, Urbanization, Internal Migration and Development, United Nations Secretariat, New York, 2007 http://www.un.org/esa/population/meetings/EGM_PopDist/P09_Tacoli.pdf

The resources outlook to 2050. By how much do land, water and crop yields need to increase by 2050?, Paper presented at the FAO Expert Meeting, 24-26 June 2009, Rome on 'How to Feed the World in 2050'. http://www.inta.gov.ar/ies/foro2050/DocumentosdeExpertos/05-Bruinsma_ResourceOutlookto2050.pdf

Third Africa Water Week, Financing Investments in Water for Growth and development, 4p. 2010 http://www.afdb.org/fileadmin/uploads/afdb/Documents/GenericDocuments/24%20Nov%20sub%20theme%201%20programme%20%20Final%20-%2010%20Nov%202010_CORRECTED.pdf

Webersik C., and Wilson C., Achieving Environmental Sustainability and Growth in Africa: The Role of Science, Technology and Innovation, Sustainable Development, vol. 17, no. 4, Wiley, 2009

World Commission on Dams, Dams and Development: A New Framework for Decision-Making. London: Earthscan, 2006

World Economic Forum, Managing our Future Water Needs for Agriculture, Industry, Human Health and the Environment. Discussion Document for the World Economic Forum Annual Meeting 2008, 11p. http://www3.weforum.org/docs/WEF_ManagingFutureWater%20Needs_DiscussionDocument_2008.pdf

Van Hofwegen P. & Svendsen M., A vision of water for food and rural development, Executive summary, prepared for the Second World Water Forum. UNESCO-IHE –BSCW, 7p, 2000 http://bscw.ihe.nl/pub/bscw.cgi/d2840597/water%20for%20food(by-Hofwegen).pdf

Varghese S., Biofuels and Global Water Challenges. Institute for agriculture and trade policy. 7p.2007 http://www.tradeobservatory.org/library.cfm?refid=100547

Websites (English and French)

European Commission

European Commission-Directorate General Agriculture
http://ec.europa.eu/agriculture/index_en.htm

Commission EuropŽenne -Direction GŽnŽrale Agriculture et DŽveloppement Rural
http://ec.europa.eu/agriculture/index_fr.htm

European Commission-EuropeAid Development and Cooperation
http://ec.europa.eu/europeaid/index_en.htm

Commission EuropŽenne-DŽveloppement et CoopŽration EuropeAid
http://ec.europa.eu/europeaid/index_fr.htm

European Commission-Directorate General External Relations
http://ec.europa.eu/external_relations/index.htm

Commission EuropŽenne-Direction GŽnŽral Relations ExtŽrieures
http://ec.europa.eu/external_relations/index_fr.htm

ECHO - European Commission-Humanitarian Aid and Civil Protection
http://ec.europa.eu/echo/index_en.htm

Commission EuropŽenne-Direction GŽnŽral Aide Humanitaire et Protection Civile
http://ec.europa.eu/echo/index_fr.htm

European Commission-Directorate General Environment
http://ec.europa.eu/dgs/environment/index_en.htm

Water Scarcity & Droughts in the European Union
http://ec.europa.eu/environment/water/quantity/scarcity_en.htm

European Commission-Directorate General Climate Change
http://ec.europa.eu/dgs/clima/mission/index_en.htm

International, ACP and Bilateral Organizations

AGRA-Alliance for a Green Revolution in Africa
http://www.agra-alliance.org/

AGRA-Alliance pour une rŽvolution verte en Afrique
http://www.agra-alliance.org/section/fr

Africa development Bank
http://www.afdb.org/en/

Banque Africaine de DŽveloppement
http://www.afdb.org/fr/

CEHI-Caribbean Environmental Health Institute
http://www.cehi.org.lc/

CGIAR-The Consultative Group on International Agricultural Reserach
http://www.cgiar.org/index.html

CGIAR-Groupe Consultatif pour la Recherche Agricole Internationale
http://www.cgiar.org/languages/lang-french.html

CTA
http://www.cta.intCTA seminar on Water - 2010 http://annualseminar2010.cta.int/ Brussels Development Briefing Bloghttp://brusselsbriefings.net/ Knowledge for Development http://knowledge.cta.int/en

EIONET -European Environment Information and Observation Network
http://www.eionet.europa.eu/

GDPRD -Global Donor Platform for Rural Development
http://www.donorplatform.org

GWP-Global Water Partnership
http://www.gwp.org/

IAEA -International Atomic Energy Agency
http://www.iaea.org/

ICID -International Commission on Irrigation and Drainage
www.icid.org/

IFAD- International Fund for Agricultural Development
http://www.ifad.org/

IMF-International Monetary Fund
http://www.imf.org/external/index.htm

FMI-Fonds MonŽtaire International
http://www.imf.org/external/french/index.htm

IUCN-International Union for Conservation of Nature

http://www.iucn.org/

UICN-Union Internationale pour la Conservation de la Nature.
http://www.iucn.org/fr/

MEA-Millennium Ecosystem Assessment
http://www.maweb.org/en/Index.aspx

EM -ƒvaluation des Žcosyst mes pour le millŽnaire
http://www.maweb.org/fr/index.aspx

OECD-Organisation for Economic Co-operation and Development
http://www.oecd.org/home/0,2987,en_2649_201185_1_1_1_1_1,00.html

Organisation de coopŽration et de dŽveloppement Žconomiques
http://www.oecd.org/home/0,3305,fr_2649_201185_1_1_1_1_1,00.html

DCD-DAC- Development Co-operation Directorate
http://www.oecd.org/department/0,2688,en_2649_33721_1_1_1_1_1,00.html

DCD-CA- Direction de la coopŽration pour le dŽveloppement
http://www.oecd.org/department/0,3355,fr_2649_33721_1_1_1_1_1,00.html

NEPAD-New Partnership for Africa's Development
http://www.nepad.org/

NEPAD Nouveau Partenariat pour le Développement de l'Afrique
http://www.nepad.org/home/lang/fr

WHO -World Health Organization
http://www.who.int/en/

OMS-Organisation Mondiale de la SantŽ
http://www.who.int/fr/index.html

Rural Poverty Portal

http://www.ruralpovertyportal.org/web/guest/home

Portail de la Pauvreté Rurale
http://www.ruralpovertyportal.org/web/guest/home

World Water Forum
http://www.worldwaterforum5.org/

Le Forum mondial de l'eau
http://www.worldwaterforum5.org/index.php?id=1870&L=1

The World Bank
http://www.worldbank.org/

La Banque Mondiale
http://www.banquemondiale.org/

World Bank /Agriculture and rural development
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/0,,menuPK:336688~pagePK:149018~piPK:149093~theSitePK:336682,00.html

WPF-World Food Programme
http://www.wfp.org/

PAM-Programme Alimentaire Mondiale
http://fr.wfp.org/

WTO-World Trade Organization
http://www.wto.org/index.htm

OMC-Organisation Mondiale de Commerce
http://www.wto.org/indexfr.htm

WRI-World Resources Institute
http://www.wri.org/

United Nations Organizations

United Nations

http://www.un.org/en

Nations Unies
http://www.un.org/fr/

UNECA- The United Nations Economic Commission for Africa
http://www.uneca.org/

CEA-Commision Economique pour l'Afrique
http://www.uneca.org/fr/fr_main.htm

UNDP-United Nations Development Programme
http://www.undp.org/

PNUD-Programme des Nations Unies pour le dŽveloppement
http://www.undp.org/french/

UNEP-United Nations Environment Programme
http://www.unep.org/

PNUE-Programme des Nations Unies pour le DŽveloppement
http://www.unep.org/french/

UNESCAP-United Nations Economic and Social Commissions for Asia & the Pacific
http://www.unescap.org/

UNESCO -United Nations Educational, Scientific and Cultural Organization
http://www.unesco.org/new/en/unesco/

UNESCO-Organisation des Nations Unies pour l'Žducation la science et la culture.
http://www.unesco.org/new/fr/unesco/

UNESCO-IHE-Institute for Water Education
http://www.unesco-ihe.org/

UNESCO Water
http://www.unesco.org/new/en/natural-sciences/environment/water/

UNESCO-Eau
http://www.unesco.org/new/fr/natural-sciences/environment/water/

UNFCCC
http://unfccc.int/2860.php

CCNUCC
http://unfccc.int/portal_francophone/items/3072.php

UNFPA
http://www.unfpa.org/public/

UNFPA
http://www.unfpa.org/public/home/sitemap_fr

UNW-DPC -UN-Water Decade Programme on Capacity Development
http://www.unwater.unu.edu/article/read/water-for-food

MDG-Millennium Development Goals
http://www.un.org/millenniumgoals/

OMD-Objectifs du MillŽnaire pour le DŽveloppement
http://www.un.org/fr/millenniumgoals/

FAO-The Food and Agriculture Organization of the United Nations
http://www.fao.org/

FAO-Organisation des Nations Unies pour l'Alimentation et l'Agriculture
http://www.fao.org/index_fr.htm

FAO-AQUASTAT
http://www.fao.org/nr/water/aquastat/dbases/index.stm

http://www.fao.org/nr/water/aquastat/main/indexfra.stm

FAO-IPTRIP-International Programme for Technology and Research in Irrigation and Drainage
http://www.fao.org/landandwater/iptrid/index.html

FAO-IPTRIP- Division de la mise en valeur des terres et des eaux.
http://www.fao.org/landandwater/iptrid/index_fr.html

FAO-LAND AND WATER
http://www.fao.org/ag/agl/default.html

FAOSTAT
http://faostat.fao.org/default.aspx

http://faostat.fao.org/default.aspx?lang=fr

FAO-WATER

http://www.fao.org/nr/water/index.html
http://www.fao.org/nr/water/index_fr.html

IPCC -Intergovernmental Panel on Climate Change
http://www.ipcc.ch/index.htm

GIEC-Groupe d'experts intergouvernemental sur l'Žvolution du climat
http://www.ipcc.ch/home_languages_main_french.shtml

WWAP-World Water Assessment Programme

http://www.unesco.org/water/wwap/

WWAP-Programme mondial pour l'Žvaluation des ressources en eau.
http://www.unesco.org/water/wwap/index_fr.shtml

NGOs, Think Tank and Networks

ACTION CONTRE LA FAIM
http://www.actioncontrelafaim.org/

http://www.actioncontrelafaim.org/english/

ACTION AID
http://www.actionaid.org/

CONCORD
http://www.concordeurope.org/Page.php?ID=4&language=eng

http://www.concordeurope.org/Page.php?ID=4&language=fre

EURODAD

http://www.eurodad.org

http://www.eurodad.org/index.aspx?&LangType=103635

European Water Association
http://www.ewaonline.de/portale/ewa/ewa.nsf/home?readform

FIAN-Food first Information and Action Network
http://www.fian.org/?set_language=en

OXFAM
http://www.oxfam.org

http://www.oxfamsol.be/fr

SOS Faim-Belgique

http://www.sosfaim.be

http://www.sosfaim.be/ong-developpement-EN-sosfaim_en-about_us.htm

UK Food Group
http://www.ukfg.org.uk

Water Aid
http://www.wateraid.org/uk/

Research Organisations

Africa and Europe : Partnerships in Food and Farming
http://www3.imperial.ac.uk/africanagriculturaldevelopment

CGIAR-Consultative Group on International Agriculture Reserach
http://www.cgiar.org

CGIAR-Groupe Consultatif pour la Recherche Agricole Internationale
http://www.cgiar.org/languages/lang-french.htm

FARA-Forum for agriculture research in Africa
http://www.fara-africa.org/

FARA-Forum pour la recherche agricole en Afrique
http://fr.fara-africa.org

Global Water Partnership
http://www.gwp.org/en/

GWA-Gender and water alliance
http://www.genderandwater.org/

GWA-Alliance Genre et Eau.
http://www.fr.genderandwater.org/page/670

GWP-Global Water Partnership

http://www.gwp.org/

IATP -Institute for Agriculture and Trade policy
http://www.iatp.org/

IEA -International Energy Agency
http://www.iea.org/

ICID-International Commission on Irrigation and Drainage
http://www.icid.org/

IIAASTD-International Assessment of Agricultural Knowledge, Science and Technology for Development
http://www.agassessment.org

IIED -International Institute for Environment and Development
http://www.iied.org/

IFAD - International Fund for Agricultural Development
http://www.ifad.org/

IFPRI–International Food Policy Research Institute
http://www.ifpri.org/34

IFPRI-Institut International de Recherche sur les Politiques Alimentaires
http://www.ifpri.org/french

IWA-International Water Association
http://www.iwahq.org/Home/

IWMI -International Water Management Institute
http://www.iwmi.cgiar.org/

IWMI Global Irrigated Area Mapping -GIAM: http://www.iwmigiam.org

MOMAGRI-Mouvement pour une Organisation Mondiale de l'Agriculture.
http://www.momagri.org/UK/momagri-home.html

http://www.momagri.org/FR/accueil-momagri.html

ODI-Overseas Development Institute
http://www.odi.org.uk

SIWI -Stockholm International Water Institute
http://www.siwi.org/

http://www.siwi.org/fr

The Stockholm Water Prize
http://www.siwi.org/stockholmwaterprize

The Sphere Project
http://www.sphereproject.org/index.php?lang=english

Le Projet Sph re
http://www.sphereproject.org/

Water Foot Print
http://www.waterfootprint.org/?page=files/home

Empreinte sur l'eau
http://www.empreinte-de-l-eau.org/index.php?page=files/home

WWC-World Water Council
http://www.worldwatercouncil.org/

http://www.worldwatercouncil.org/index.php?id=1&L=1

Glossary[135]

Agricultural water management

Planned development, distribution and use of water resources in accordance with predetermine agriculture-related objectives

Blue water

Fresh surface and groundwater, i.e. the water in freshwater lakes, rivers and aquifers.

Blue water footprint

Volume of surface and groundwater consumed as a result of the production of a good or service. Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product. It also includes water abstracted from surface or groundwater in a catchment and returned to another catchment or the sea. It is the amount of water abstracted from ground- or surface water that does not return to the catchment from which it was withdrawn.

Blue water scarcity

The ratio of blue water footprint to blue water availability. Blue water scarcity varies within the year and from year to year.

Critical load

The load of pollutants that will fully consume the assimilation capacity of the receiving water body.

Crop water requirement

The total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield.

Direct water footprint

The direct water footprint of a consumer or producer (or a group of consumers or producers) refers to the freshwater consumption and pollution that is associated to the water use by the consumer or producer. It is distinct from the indirect water footprint, which refers to the water consumption and pollution that can be associated with the production of the goods and services consumed by the consumer or the inputs used by the producer.

Dry spell

Short period of water stress during critical crop growth stages and which can occur with high frequency but with minor impacts compared with droughts

Economic water productivity

Economic value of the products produced per unit of water consumption or pollution. See also water productivity‘.

Effective precipitation

The portion of the total precipitation that is retained by the soil so that it is available for crop production.

Environmental flow requirements

The quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

Evapotranspiration

Evaporation from the soil and soil surface where crops are grown, including the transpiration of water that actually passes crops.

External water footprint of national consumption

The part of the water footprint of national consumption that falls outside the nation considered. It refers to the appropriation of water resources in other nations for the production of goods and services that are imported into and consumed within the nation considered.

Global water saving through trade

International trade can save freshwater globally if a water-intensive commodity is traded from an area where it is produced with high water productivity (small water footprint) to an area with lower water productivity (large water footprint).

Green water

The precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (but not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth).

Green water availability

The evapotranspiration of rainwater from land minus evapotranspiration from land reserved for natural vegetation and minus evapotranspiration from land that cannot be made productive.

Green water footprint

Volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood.

Green water scarcity

The ratio of green water footprint to green water availability. Green water scarcity varies within the year and from year to year.

Grey water footprint

The grey water footprint of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards.

Indirect water footprint

The indirect water footprint of a consumer or producer refers to the freshwater consumption and pollution behind' products being consumed or produced. It is equal to the sum of the water footprints of all products consumed by the consumer or of all (non-water) inputs used by the producer.

Internal water footprint of national consumption

The part of the water footprint of national consumption that falls inside the nation, i.e. the appropriation of domestic water resources for producing goods and services that are consumed domestically.

Irrigation

Irrigation refers to water artificially applied to soil, and confined in time and space for the purpose of crop production. They are different type of irrigation systems depending of the level of control, institutional setting, farm size, etc. The equipment may be for permanent or supplementary irrigation.

Irrigation potential

Total possible area to be brought under irrigation in a given river basin, region or country, based on available water and land resources.

Irrigation requirement

The quantity of water exclusive of precipitation, i.e. quantity of irrigation water, required for normal crop production. It includes soil evaporation and some unavoidable losses under the given conditions. It is usually expressed in water-depth units (millimetres) and may be stated in monthly, seasonal or annual terms, or for a crop period.

National water footprint

Is the same as what is more accurately called the water footprint of national consumption', which is defined as the total amount of fresh water that is used to produce the goods and services consumed by the inhabitants of the nation. Part of this water footprint lies outside the territory of the nation. The term should not be confused with the water footprint within a nation', which refers to the total freshwater volume consumed or polluted within the territory of the nation.

Operational water footprint of a business

The operational (or direct) water footprint of a business is the volume of freshwater consumed or polluted due to its own operations.

Overhead water footprint

The water footprint of a product consists of two elements: the use of freshwater that can immediately be related to the product and the use of freshwater in overhead activities. The latter element is called the overhead water footprint'. The overhead water footprint refers to freshwater use that in first instance cannot be fully associated with the production of the specific product considered, but refers to freshwater use that associates with supporting activities and materials used in the business, which produces not just this specific product but other products as well. The overhead water footprint of a business has to be distributed over the various business products, which is done based on the relative value per product.

Production system

A production system of a product consists of all the sequential process steps applied to produce the product. A production system can be a linear chain of processes, it can take the shape of a product tree (many inputs ultimately resulting in one output product) or it may rather look like a complex network of interlinked processes that eventually lead one or more products.

Rainfed agriculture

Agricultural practice relying exclusively on rainfall as its source of water

Return flow

The part of the water withdrawn for an agricultural, industrial or domestic purpose that returns to the ground- or surface water in the same catchment as where it was abstracted. This water can potentially be withdrawn and used again.

Supply-chain water footprint of a business

The supply-chain (or indirect) water footprint of a business is the volume of freshwater consumed or polluted to produce all the goods and services that form the input of production of a business.

Virtual-water balance

The virtual-water balance of a geographically delineated area (e.g. a nation or catchment area) over a certain time period is defined as the net import of virtual water over this period, which is equal to the gross import of virtual water minus the gross export. A positive virtual-water balance implies net inflow of virtual water to the nation from other nations. A negative balance means net outflow of virtual water.

Virtual-water content

The virtual-water content of a product is the freshwater embodied in the product, not in real sense, but in virtual sense. It refers to the volume of water consumed or polluted for producing the product, measured over its full production chain. If a nation exports/imports such a product, it exports/imports water in virtual form. The virtual-water content of a product' is the same as the water footprint of a product', but the former refers to the water volume embodied in the product alone, while the latter term refers to that volume, but also to which sort of water is being used and to when and where that water is being used. The water footprint of a product is thus a multi-dimensional indicator, whereas virtual-water content refers to a volume alone.

Virtual-water export

The virtual-water export from a geographically delineated area (e.g. a nation or catchment area) is the volume of virtual water associated with the export of goods or services from the area. It is the total volume of freshwater consumed or polluted to produce the products for export.

Virtual-water flow

The virtual-water flow between two geographically delineated areas (e.g. two nations) is the volume of virtual water that is being transferred from the one to the another area as a result of product trade.

Virtual-water import

The virtual-water import into a geographically delineated area (e.g. a nation or catchment area) is the volume of virtual water associated with the import of goods or services into the area. It is the total volume of freshwater used (in the export areas) to produce the products.

Water access

The degree to which a household can obtain the water it needs from any source in a reliable way for agriculture or other purposes

Water control

The physical control of water from a source to the location at which the water is applied.

Water harvesting

The process of collecting and concentrating rainfall as runoff from a catchment area to be used in a smaller area, either for agriculture or other purposes.

Water productivity

An efficiency term quantified as a ratio of product output (goods and services) to water input.

Water withdrawal

The gross volume of water extracted from any source, either permanently or temporarily, for a given use. Agricultural water withdrawal refers to the annual volume of freshwater withdrawn for agricultural purposes

Acronyms

afDB	African Development Bank
AWDR	African Water Development Report
CWP	Country Water Partnership
DDP	Dams and Development Project
DFID	Department for International Development
ECA	Economic Commission of Africa
GWP	Global Water Partnership
IMF	International Monetary Fund
ISD	Indicator of Sustainable Development
IWRM	Integrated Water Resource Management
JPOI	Johannesburg Plan of Implementation
LUFC	Land Use Change and Forestry
MDGs	Millennium Development Goals
OECD	Organisation for Economic Co-operation and Development
UNCED	United Nations Conference on Environment and Development
WFD	Water Framework Directive (EU)
WMA	Water Monitoring Alliance
WWAP	World Water Assessment Programme
WWDR	World Water Development Report
FAO	Food and Agriculture Organization of the United Nations
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IAEA	International Atomic Energy Agency
IFAD	International Fund of Agricultural Development
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNECLAC	United Nations Economic Comm. for Latin America and the Caribbean
UNEP	United Nations Environment Programme
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCWA	United Nations Economic and Social Commission for Western Asia
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UN	Habitat United Nations Human Settlements Programme
UNHCR	United Nations High Commission for Refugees
UNICEF	United Nations Children's Fund
WB	World Bank
WHO	World Health Organization
WMO	World Metrological Organization
WWAP	World Water Assessment Programme
WWC	World Water Council
WTO	World Trade Organisation

Footnotes

1 The information in this document was compiled as background reading material for the 26th Brussels Development Briefing on new challenges and opportunities for pastoralism in the context of African countries[1]. The Reader and most of the resources are available at http://brusselsbriefings.net

2 Kemper, K. & Sadoff, C. The global water challenge. World Bank Global Issues Seminar,2003 http://siteresources.worldbank.org/EXTABOUTUS/Resources/WaterPaper.pdf

3 OCHA Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges, Occasional Policy Briefing Series No.4, 2010

4 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

5 UN-Water Thematic Initiatives, Coping with Water Scarcity, A strategic issue and priority for system wide action, 2006

6 UN-Water Thematic Initiatives, Coping with Water Scarcity, A strategic issue and priority for system wide action, 2006

7 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

8 IWMI Improving water productivity: How do we get more crop from every drop? IWMI Water Policy Briefing – 8, 2003

9 IWMI Improving water productivity: How do we get more crop from every drop? IWMI Water Policy Briefing – 8, 2003

10 IWMI Improving water productivity: How do we get more crop from every drop? IWMI Water Policy Briefing – 8, 2003

11 OCHA Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges, Occasional Policy Briefing Series No.4, 2010

12Varghese S., Biofuels and Global Water Challenges, Institute for Agricultural and Trade Policy, 2007 http://www.tradeobservatory.org/library.cfm?refid=100547

13 OCHA Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges, Occasional Policy Briefing Series No.4, 2010

14 OCHA Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges, Occasional Policy Briefing Series No.4, 2010

15 FAO , Agriculture and Water Scarcity: a Programmatic Approach to Water, Use Efficiency and Agricultural Productivity, 2007 ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

16 Margat and AndrŽassian 2008 http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/18_WWDR3_ch_7.pdf

17 Margat and AndrŽassian 2008 http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/18_WWDR3_ch_7.pdf

18 IWMI- Comprehensive Assessment of Water Management in Agriculture , 2007

19 FAO-AQUASTAT database , www. fao. org/nr/water/aquastat/main/index. Stm

20 FAO-AQUASTAT database (www. fao. org/nr/water/aquastat/main/index. stm).

21The OECD-FAO Agricultural Outlook 2008-2017 http://www.agrioutlook.org/pages/0,2987,en_36774715_36775671_1_1_1_1_1,00.html

22 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI,2007

23 FAO , Agriculture and Water Scarcity: a Programmatic Approach to Water, Use Efficiency and Agricultural Productivity, 2007 ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

24 IWMI- Comprehensive Assessment of Water Management in Agriculture , 2007

25 http://www.fao.org/nr/water/docs/wateratfao.pdf

26 Allan, J.A. (1998) Ç Virtual water : strategic resource. Global solutions to regional deficits. Groundwater,

27 Allan, J.A. (1998) Ç Virtual water : strategic resource. Global solutions to regional deficits. Groundwater,

28 Chapagain, A.K. ,Hoekstra, A.Y. (2003). 'Virtual water flows between nations in relation to trade in livestock and livestock products', Value of Water Research Report Series No.13, UNESCO-IHE

29 Hoekstra A.Y. et P.Q. HUNG, 2005, Globalisation of water resources : international virtual water flows in relation to crop trade. Global environmental change, Vol. 15, ni 1, p. 45-56.

30 Zimmer D. et D. Renault, 2003, Virtual water in food production and global trade: review of methodological issues and preliminary results, In Virtual water trade: proceedings of the international expert meeting on virtual water trade, sous la dir. de A.Y. Hoekstra, Value of water research report series No.12, Delft (the Netherlands), UNESCO-IHE, p. 93-107

31 Turton, A.R. 2000. Precipitation, People, Pipelines and Power: Towards a Political. Ecology Discourse. Water issue Study Group, SOAS, University of London.

32 Allan J.A., 2003, Virtual water – the water, food, trade nexus: useful concept or misleading metaphor ? Water international, Vol. 28, ni 1, p.-106-113.

33 Allan J.A.,2000, Contending environmental knowledge on water in the Middle East: global, regional and national contexte. In Political ecology : Sience, myth and power, sous la dir. de Philip Stott et Sian Sullivan (Ed.), New York, Oxford University Press,

34 Renault D., 2003, Value of virtual water in food: principles and virtues, In Virtual water trade : proceedings of the international expert meeting on virtual water trade, Delft (the Netherlands), UNESCO-IHE

35 Allan J.A., 1997, 'Virtual water' : a long term solution for the water short Middle Eastern economies ? Occasional paper 3, School of oriental and African studies (SOAS), University of London

36 Allan J.A., 2001, The Middle East water question : hydropolitics and the global economy, Londres, I.B. Tauris,

37 Hoekstra A.Y. et P.Q. Hung, 2002, Virtual water trade : A quantification of virtual water flows between nations in relation to international crop trade, Value of water research report series No.11, Delf (the Netherlands), UNESCO-IHE Institute for water education.

38 Hoekstra A.Y. et P.Q. Hung, 2005, Globalisation of water resources : international virtual water flows in relation to crop trade. Global environmental change, Vol. 15

39 Hoekstra A.Y., 2003, Virtual water: An introduction, In Virtual water trade : proceedings of the international expert meeting on virtual water trade, Value of water research report series No.12, Delft (the Netherlands), UNESCO-IHE,

40 Cosgrove, W.J. and F.R. Rijsberman (2000) World Water Vision: Making. Water Everybody's Business. London: Earthscan Publications

41 Hoekstra AY, Hung PQ (2002) Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. Value ofWater Research Report Series No. 11, UNESCO-IHE Institute for Water Education, Delft, The Netherlands, http://www.waterfootprint.org/Reports/Report11.pdf

42 Rees WE (1992) Ecological footprints and appropriated carrying capacity: what urban economics leaves out. Environ Urban 4(2):121–130

43 Hoekstra AY, Hung PQ (2002) Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. Value ofWater Research Report Series No. 11, UNESCO-IHE Institute for Water Education, Delft, The Netherlands, http://www.waterfootprint.org/Reports/Report11.pdf

44 http://www.unep.org/resourceefficiency/News/PressRelease/tabid/428/language/fr-FR/Default.aspx?DocumentID=573&ArticleID=6101&Lang=en

45 IPCC, Climate Change 2007, Fourth Assessment Report (AR4),2007

46 Climate change and Water, IPCC, June 2008

47 ECOWAS-SWAC/OECD The Atlas on Regional Integration in West Africa, 2008 http://www.fao.org/nr/clim/docs/clim_080502_en.pdf

48 The United Nations, 2009, Water in changing World. Chapter 7: Evolution of water use. WDR 3, World Water Assessment Programme. UNESCO publishing, p.96-126.

49 Climate change and Water, IPCC, June 2008

50 UN Water, Climate change and Water. An overview from the World Water Development Report 3: Water in a Changing World,2009

51 http://www.iea.org/

52 OCHA Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges, Occasional Policy Briefing Series No.4, 2010

53 OCHA Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges, Occasional Policy Briefing Series No.4, 2010

54 Gelsdorf K., Global Challenges and their Impact on International Humanitarian Action, Occasional Policy Briefing Series No.1, 2010 http://ochanet.unocha.org/p/Documents/Global_Challenges_Policy_Brief_Jan10.pdf

55 Gelsdorf K., Global Challenges and their Impact on International Humanitarian Action, Occasional Policy Briefing Series No.1, 2010 http://ochanet.unocha.org/p/Documents/Global_Challenges_Policy_Brief_Jan10.pdf

56The 2nd UN World Water Development Report: Water, a shared responsibility. World Water Assessment Programme, UN,2006

57 http://www.ruralpovertyportal.org/web/guest/home

58 FAO Stat 2006 http://faostat.fao.org/default.aspx

59 MEA, Ecosystems & Human Well-being: Synthesis, 2005 http://www.maweb.org/documents/document.356.aspx.pdf

60 MEA, Ecosystems & Human Well-being: Synthesis, 2005 http://www.maweb.org/documents/document.356.aspx.pdf

61 Department for International Development (DFID), Agricultural Sustainibility, 2004 http://dfid-agriculture-consultation.nri.org/summaries/wp12.pdf

62 FAO Stat 2006 http://faostat.fao.org/default.aspx

63 Penning de Vries, F.W.T., H. Acquay, D. Molden, S.J. Scherr, C. Valentin, and O. Cofie, Integrated Land and Water Management for Food and Environmental Security. Research Report 1. International Water Management Institute, Colombo, 2002

64 FAO Stat 2006 http://faostat.fao.org/default.aspx

65 ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

66 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management

in agriculture. London, Earthscan, and Colombo, IWMI,2007

67 The Comprehensive Assessment of Water Management in Agriculture is a critical evaluation of the benefits, costs, and impacts of the past 50 years of water development, the water management challenges communities face today, and the solutions people have developed around the world. It is a multi-institute process aimed at assessing the current state of knowledge and stimulating ideas on how to manage water resources to meet the growing needs for agricultural products, to help reduce poverty and food insecurity, and to contribute to environmental sustainability. The findings will enable better investment and management decisions in water and agriculture in the near future by considering their impact over the next 50 years.

68 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI,2007

69 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI,2007

70 Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture (Earthscan, 2007), http://www.fao.org/nr/water/docs/Summary_SynthesisBook.pdf

71 ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

72 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

73 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

74 UN, Water—A Shared Responsibility: The United Nations World Water Development Report 2. Paris and NewYork: United Nations Educational, Scientific and Cultural Organization and Berghahn Books, 2006

75 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

76 Rosegrant M.W. & Svendsen M., Asian food production in the 1990s: irrigation investment and management policy. Food Policy 18: 13–32,1993

77 The 2nd UN World Water Development Report: Water, a shared responsibility. World Water Assessment Programme, UN,2006

78 Biggs, T., Thenkabail, P.S., Krishna, M., GangadharaRao, P., and Turral, H.,Vegetation phenology and irrigated area mapping using combined MODIS time-series, ground surveys, and agricultural census data in Krishna River Basin, India. International Journal of Remote Sensing, 2006

79 Donkor, S. 2003. Development Challenges of Water Resource Management in Africa. African Water Journal 1: 1–19.

80 Peacock, T., C. Ward, and G. Gambarelli. Forthcoming. Investment in Agricultural Water for Poverty Reduction and Economic

Growth in Sub-Saharan Africa. Synthesis Report. Collaborative Programme of AFDB, FAO, IFAD, IWMI and WB. Columbo.

81 Rosegrant M.W. & Svendsen M., Asian food production in the 1990s: irrigation investment and management policy. Food Policy 18: 13–32,1993

82 United Nations, The 3rd United Nations World Water Development Report: Water in a Changing World. World Water Assessment Programme. The United Nations, March 2009

83 Inocencio, A., D. Merrey, M. Tonosaki, A. Maruyama, I. de Jong, and M. Kikuchi. Forthcoming. Costs and Performance of Irrigation Projects: A Comparison of sub-Saharan Africa and Other Developing Regions. IWMI Research Report. International Water Management Institute, Colombo, 2007

84 WCD World Commission on Dams..Dams and Development: A New Framework for Decision-Making. London: Earthscan, 2006

85 World Bank, Water Resources Sector Strategy: Strategic Directions for World Bank Engagement, 2004

86 World Bank, Water Resources Sector Strategy: Strategic Directions for World Bank Engagement, 2004

87 http://www.unesco.org/bpi/wwap/press/pdf/wwdr2_chapter_7.pdf

88 http://www.unesco.org/bpi/wwap/press/pdf/wwdr2_chapter_7.pdf

89 ftp://ftp.fao.org/docrep/fao/meeting/011/j9206e.pdf

90 Bioethanol and biodiesel are typically mixed with gasoline and diesel, respectively, as so-called flex-fuel. Blends vary between a few percent of biofuel to nearly 25% in Brazil

91 We use the term Biofuels in this document because it's the most common word in English. The correct word would be agro-fuels, facing its link with agriculture.

92 Varghese, S.,Biofuels and global water challenges. Institute for Agriculture and Trade policy. IATP, 2007

93 Varghese, S.,Biofuels and global water challenges. Institute for Agriculture and Trade policy. IATP, 2007

94 De Fraiture C., Giordano M. and Liao Y., Biofuels and implications for agricultural water use: blue impacts of green energy. IWMI, 2007

95 MŸller et al. 2008; De Fraiture, Giodano, and Yongsong 2007; OECD and FAO 2008.

96 OECD-FAO Agricultural Outlook 2008-2017, OECD/FAO,2008

97 OECD-FAO Agricultural Outlook 2008-2017, OECD/FAO,2008

98OECD-FAO Agricultural Outlook 2008-2017, OECD/FAO,2008

99 De Fraiture, C., M. Giodano, and Yongsong L. 2007. Biofuels: Implications for Agricultural Water Use: Blue Impact of Green Energy, January 2007, Hyderabad, India.

100 De Fraiture, C., M. Giodano, and Yongsong L. 2007. Biofuels: Implications for Agricultural Water Use: Blue Impact of Green Energy, January 2007, Hyderabad, India.

101 Dornbosch, Richard, and Ronald Steenblik, Biofuels: Is the Cure Worse than the Disease? Round Table on Sustainable Development, 11-12 September 2007, Paris. SG/SD/RT(2007)3, Organisation for Economic Co-operation and Development. http://www.foeeurope.org/publications/2007/OECD_Biofuels_Cure_Worse_Than_Disease_Sept07.pdf

102 Dornbosch, Richard, and Ronald Steenblik, Biofuels: Is the Cure Worse than the Disease? Round Table on Sustainable Development, 11-12 September 2007, Paris. SG/SD/RT(2007)3, Organisation for Economic Co-operation and Development. http://www.foeeurope.org/publications/2007/OECD_Biofuels_Cure_Worse_Than_Disease_Sept07.pdf

103 Zah et al. 2007; Dornbosch and Steenblik 2007.

104 FAO. (2009). AQUASTAT database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/aquastat

105 FAO. (2009). AQUASTAT database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/aquastat

106 UNEP/GRIS Africa Water Atlas, Summary for Decision Makers http://www.unep.org/pdf/Africa_Water_Atlas_Executive_Summary.pdf

107 http://www.unep.org/pdf/Africa_Water_Atlas_Executive_Summary.pdf

108 UNECA-Economic report on Africa, 2006, http://www.uneca.org/era2006/full.pdf

109 http://www.uneca.org/era2006/full.pdf

30 Among the world's regions, the continent's average population growth rate of 2.3 per cent for the period 2005 to 2010 was the highest110. Africa is the second-most populous continent after Asia (Figure 1.9). Africa also had the highest urban growth rate for the period 2005-2010, although on average it also had the largest proportion of rural population in 2009111. About 40 per cent of Africa's population now lives in cities. Between 2005 and 2010, Africa's urban population grew at a rate of 3.4 per cent, or 1.1 per cent more than the rural population. The urban growth rate over that time was highest in Central, Eastern and Western Africa, although at 58 per cent in 2009, Southern Africa had the highest proportion of urban population. Agriculture—largely rain-fed—is the single most important driver of economic growth for most African countries112.The agricultural sector accounts for about 20 per cent of Africa's GDP, 60 per cent of its labour force and 20 per cent of the total merchandise exports, and is the main source of income for 90 per cent of the rural population 113.

110UNFPA, State of world population ,Facing a changing world: women, population and climate. United Nations Population Fund. New York, 2009 http://www.unfpa.org/swp/2009/en/pdf/EN_SOWP09.pdf

111 UNFPA, State of world population ,Facing a changing world: women, population and climate. United Nations Population Fund. New York, 2009 http://www.unfpa.org/swp/2009/en/pdf/EN_SOWP09.pdf

112 Webersik C., and Wilson C., Achieving Environmental Sustainability and Growth in Africa: The Role of Science, Technology and Innovation, Sustainable Development, vol. 17, no. 4, Wiley, 2009

113 UNECA Economic Report on Africa 2007 http://www.uneca.org/era2007/

114 http://www.gwp.org/en/gwp-in-action/Caribbean/

118 http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=1441456

119 UNFPA, ICPD Goals and thresholds: how well have THE PACIFIC ISLAND COUNTRIES performed?", 2009 http://www.un.org/popin/regional/asiapac/fiji/disc/disc21.htm

120 Economic and Social Commission for Asia and the Pacific http://www.unescap.org/

121 Economic and Social Commission for Asia and the Pacific http://www.unescap.org/esid/psis/population/popseries/apss156/ref.asp

122 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

123 http://www.iwmi.cgiar.org/assessment/Publications/books.htm

124 WCD, World Commission on Dams,Dams and

Development: A New Framework for Decision-Making. London: Earthscan,2000

125 Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

126 FAO, Agriculture and Water Scarcity: a Programmatic Approach to Water, Use Efficiency and Agricultural Productivity, 2007

127 IFAD, Linking land and water governance – IFAD experience. Proceedings of workshop, Farmers' views first: Land and water governance. World Water Week, Stockholm, 2004, www.ifad.org/events/water

128 IFAD, Linking land and water governance

129Molden, D. ed. 2007. Water for food, water for life. A comprehensive assessment of water management in agriculture. London, Earthscan, and Colombo, IWMI, 2007

130 http://www.iwmi.cgiar.org/assessment/Water%20for%20Food%20Water%20for%20Life/Chapters/Chapter%204%20Poverty.pdf

131 FAO, Agriculture and Water Scarcity: a Programmatic Approach to Water, Use Efficiency and Agricultural Productivity, 2007

132 http://www.fao.org/nr/water/docs/Summary_SynthesisBook.pdf

133 http://www.iwmi.cgiar.org/assessment/Water%20for%20Food%20Water%20for%20Life/Chapters/Chapter%204%20Poverty.pdf

134 http://www.ipcc.ch/pdf/technical-papers/ccw/chapter4.pdf