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Watering Scarcity

Private Investment Opportunities in Agricultural Water Use Efficiency

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Author	World Resources Institute Piet Klop Jeff Rodgers Rabobank Peter Vos Susan Hansen
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Contact address for this publication

Rabobank International
F&A Research and Advisory
E-mail: far@rabobank.com
Website: www.rabobank.com/far

Table of contents

Preface

This report is about water. Water issues, also in relation to climate change, hit newspaper headlines regularly, creating a great amount of public attention. Hurricanes like Katrina in New Orleans, the flooding in Bihar, India, and the devastating Tsunami that shocked the world and caused some 200,000 deaths in South East Asia are just some of the more recent weather-related events concerning water. At the other side of the spectrum, it is through the droughts in Africa and Australia, and the water shortages in many other parts of the world that people come to realise the consequences of scarce water supplies. Some say that it is not so much the oil supply that we have to worry about, but water. Water is scarce, it is an essential ingredient to life, and there are no alternatives to water.

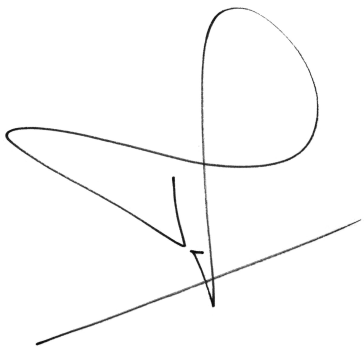
The message as such is not a happy one. Water is becoming increasingly scarce and reports from research institutes, universities and international financial institutions reveal that the world's available water resources will not be enough for the agricultural industry to keep pace with feeding the world's growing population. Massive increases in productivity are needed to meet overall demands for the agricultural industry to produce more food, feed, fuel and fibre crops. Overall agricultural production needs to increase 70% to 90% by 2050. This can only be achieved if water productivity in agriculture rises substantially.

But the message is also a promising one. Although water spillage in agricultural production is enormous - only 25% to 40% of the water withdrawn actually reaches the intended crops - there is enormous potential for increasing the efficiency of water use. Technologies and practices to improve efficiencies already exist and are ready for large-scale adoption in the agricultural industry. There are many examples of changing policies throughout the world which give the proper incentives to producers, and overcome major hurdles for private investors. There are market signals indicating that private investments are indeed taking off.

The Netherlands has a longstanding tradition in water; continuously fighting to protect the country from flooding. For Dutchmen water is in the veins and in the genes. Dutch engineers travel all over the world to share their knowledge to protect against and also to accommodate to water. Despite the fact that it seems as though there is too much instead of too little water, water-saving measures and the reuse of water are also knowledge fields that the Dutch are famous for. Drinking-water companies in the Netherlands are among the most efficiently run in the world, and the water and energy efficiency in Dutch glasshouse horticulture is exemplary.

As a co-operative bank with roots in agriculture dating back more than 100 years, Rabobank understands the importance of water and is truly attached to the issue. As one of the world's leading food and agriculture banks we have a thorough understanding of the drivers as well as risks and opportunities that the entire food supply chain is facing. Water, being an essential input in agriculture production, is one of our key concerns. Based on our long-lasting experience in food and agriculture and our excellent relationship with farmers, Rabobank is committed to sharing ideas and solutions on water issues with our clients and partners around the world. Water efficiency fits well in our ambitious agenda to remain one of the world's leading sustainable banks.

The Italian writer Guiseppe di Lampedusa stipulated that "If we want things to stay as they are, things will have to change". Rabobank is ready to take on this challenge.



Bert Heemskerk
Chairman of the Executive Board of Rabobank Nederland

Executive Summary

In many regions around the world, demand for fresh water now outstrips renewable supplies. Water scarcity is projected to worsen considerably due to a combination of factors such as population increase, higher incomes and changing lifestyles, pollution, and climate change.

Agriculture is by far the biggest water user, accounting for more than 70% of global withdrawals. With booming industrial and domestic demands for water, especially in fast-growing emerging economies, the competition for finite water resources is intensifying.

Water scarcity and increasing competition present the agricultural sector with a huge challenge. Farmers are expected to meet the rapidly increasing demand for food, feed, fuel and fibre crops even though most land and water resources have already been committed.

Consequently, crop water productivity must increase ('more crop per drop'), partly through raising irrigation water-use efficiencies, either at the system or at the farm level. This is also an investment opportunity which, we believe, will attract the necessary private capital for at least three reasons.

1. Technologies to improve water use efficiencies are mature[1] and are ready for large-scale adoption. These technologies include automated 'on-demand' irrigation, remote-sensing technology to manage soil moisture, low-pressure drip irrigation, as well as drought-resistant crop varieties.

2. Policies are starting to provide farmers and investors with the right incentives to invest in water-use efficiency. Water prices are rising to better reflect the value and delivery cost of irrigation water. Rights to water are formalised and can in some countries be traded from low to high-value uses. The private sector is engaging in providing expertise and capital as investment risks are shared. Farmers' access to product markets and financial services is expanding. Consequently, water-use efficiency in irrigated agriculture is emerging as an opportunity for private investments.

3. Market signals seem to be favourable. Food and commodity prices reversed their long decline and farmers' incomes have increased accordingly. Higher water, energy and fertiliser costs may encourage efficient irrigation technologies and practices. Some irrigation technology markets and specialised companies are reporting strong growth. Investors are increasingly aware of the opportunities in the water sector.

However, the current turbulence in the global financial markets (October 2008) may impact private investors' decision making and their investment options which we cannot oversee at the time of writing. In practise this means that some of the conclusions drawn in this report may be affected although the general picture still holds.

Rabobank is aware of its position as one of the world's leading banks in food and agribusiness. Rabobank will, through its core business of project and corporate finance as well as through its Foundation, use its expertise and network and expand its services to help to increase private-sector investments in raising irrigation efficiency and food production. It will have to be enquired whether a water lable for companies could be a useful concept to manage and diminish water use.

Introduction

The agricultural sector is confronted with the challenge to meet rising demands for food and agricultural commodities. Substantial increases in agricultural production are required to keep pace with the growing number of people that need to be fed, including the poor that still have no access to a sufficient level of food and suffer from hunger and - with the changing food patterns - of those with rising incomes. The limiting factor in this challenge might not even be land but rather the increasingly scarce water resources.

This report therefore argues that increasing water productivity is crucial and yield improvements call for higher water-use efficiencies. As government budgets are tight there has long been a need for private-sector investments. But with maturing irrigation technologies and policies that are starting to provide the right incentives, we believe that increasing the water-use efficiency in irrigated agriculture is emerging as an opportunity for private investments. Tentative market signals appear to confirm this development.

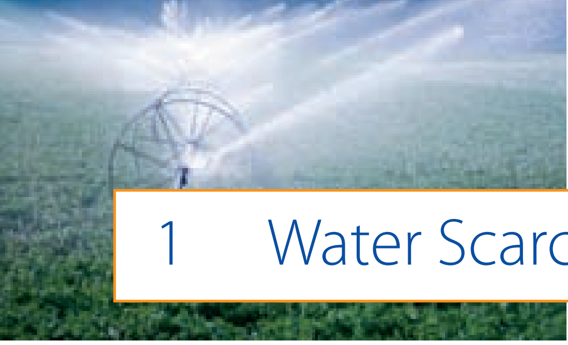
In Chapter 1 we first present the global water cycle, and describe the extent of water scarcity and its main drivers. In Chapter 2 we explore the implications for the biggest water user by far: agriculture. In Chapter 3 we discuss a number of technologies that have the potential for scaling up, either at the irrigation system level or in farmers' fields.

In Chapter 4 we explain that that potential can be realised as policies and market trends are addressing the very constraints that have historically frustrated private investments in irrigated agriculture. The possible contributions by Rabobank to further develop those private investments in 'growing efficiency' are the subject of the concluding Chapter 5.

We understand that efficient water use is a matter of where we grow crops, which crops we grow and which irrigation techniques we use. Our report mainly focuses on the irrigation techniques and how private investments could be enhanced. Other factors such as global trade issues, food security, rural development, as important as they may be, will only be addressed indirectly, or not at all.

We recognise that crop-water productivity is not going increase by technologies alone and will indeed require various long-term policy and institutional reforms, as the World Bank among other agencies has pointed out in many excellent publications. The focus - and we hope the value - of this paper, however, is to highlight the potential for private investments in water technologies from the perspective of Rabobank and its agribusiness clients.

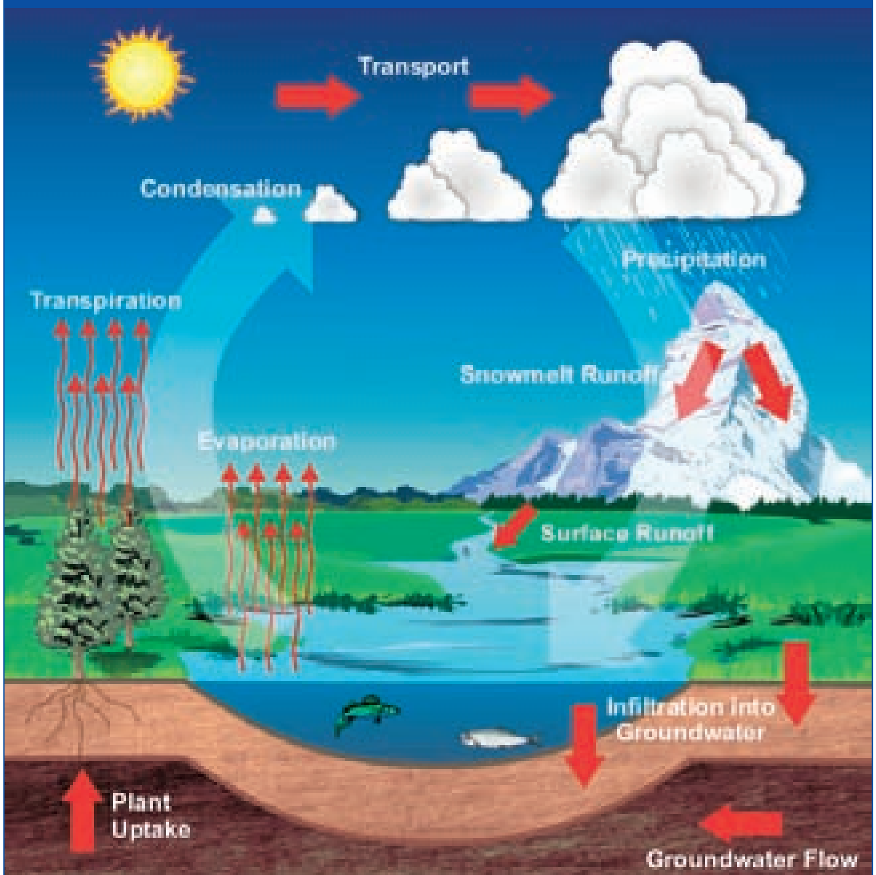
The present report 'Watering Scarcity - Private Investment Opportunities in Agricultural Water Use Efficiency' was prepared by Rabobank in collaboration with the World Resources Institute in Washington DC.



1 Water Scarcity and Its Drivers

The earth's water is in a state of constant movement known as the hydrologic cycle and consisting of evaporation (from sea and land surfaces), transpiration (by plants), condensation, and precipitation (Figure 1.1). Precipitation is partly stored as snow and ice, partly percolating into the soil and replenishing aquifers, and partly running off to rivers and seas. The global water cycle is thus a closed system with a fixed amount of water. The water cycle is clearly closely interlinked with the system of biodiversity; changes in one will have consequences for the other.

Figure 1.1 Hydrologic Cycle



Source: University of Illinois at Urbana-Champaign, 2008 [2]

The world has plenty of water but 97.5% of it is salt water. Mankind essentially depends on the remaining 2.5%. Of that share only a fraction is accessible as surface or groundwater to serve a variety of functions: sustaining life, growing food, supporting various industrial processes, and transporting and assimilating waste.

Thanks to the hydrological cycle, the world as a whole is not going to run out of water. Yet locally, water resources can be over-exploited and degraded if more ground or surface water is withdrawn than can be recharged, or if more waste ends up in rivers or lakes than can be assimilated.

Water scarcity occurs as demand for water outstrips renewable supplies, which is already happening in more and more regions in the world, and the gap is set to widen. Where water pollution is worsening, the challenge of delivering sufficient water of the required quality to households, industries and farms is further exacerbated.

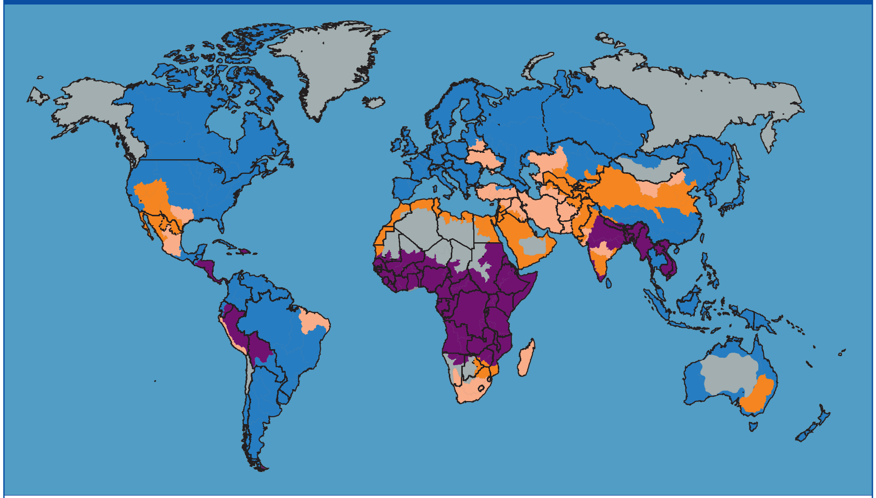
It is important to realise that water scarcity is a *local* issue. The problem is not that there is too little water overall, the problem is that water supplies are not evenly distributed in terms of time and geography. For example, the Amazon basin provides 15% of the earth's freshwater, but is home to only 1% of the world's population. On the other hand, China has 20% of the world's population but only 7% of the world's water resources. Also, throughout the year, areas may experience both flooding and water shortages. In fact, the two tend to reinforce one another through erosion, the loss of water-holding capacity and the decrease in storage capacity due to the accumulation of silt in reservoirs.

Local water scarcity can still have global ramifications through extensive supply chains and the trade in goods and services, and the water that is embedded in their production. This is the so-called virtual water trade that effectively connects local water availability with global flows of trade and investment.

Figure 1.2 shows where water is physically scarce, i.e., more than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes - the remaining 25% or less is insufficient to maintain delicate ecosystem functions. Relating water availability to demand also means that dry areas are not necessarily water scarce.

Other areas 'merely' suffer from economic water scarcity, where water resources are abundant relative to water use, but access is constrained by a lack of human or institutional capacity and/or financial capital. This tends to be the case in Sub-Saharan Africa and in other developing regions where, for example, storage capacity is insufficient to spread water availability over the year.

Figure 1.2 Physical and Economic Water Scarcity



Little or no water scarcity
Approaching physical water scarcity
Not estimated
Physical water scarcity
Economic water scarcity

Source: International Water Management Institute, 2007 [3]

While 700 million people are currently dealing with water stress or shortages, defined as less than 1,700m^3 of water per person per year, by 2035 that number is estimated to rise to three billion - i.e., one in three. Already today there are 20 countries, many in the Middle East, where water availability is down to 500m^3 per person per year. More dramatically, there are still 1.1 billion people, or 18% of the world's population, who lack access to safe drinking water.[4]

Increasing water scarcity does not necessarily mean that people will be running out of water, but it does mean that the competition amongst its agricultural, industrial, municipal, recreational and the environmental uses will be intensifying. Consequently, production and growth prospects may be constrained.

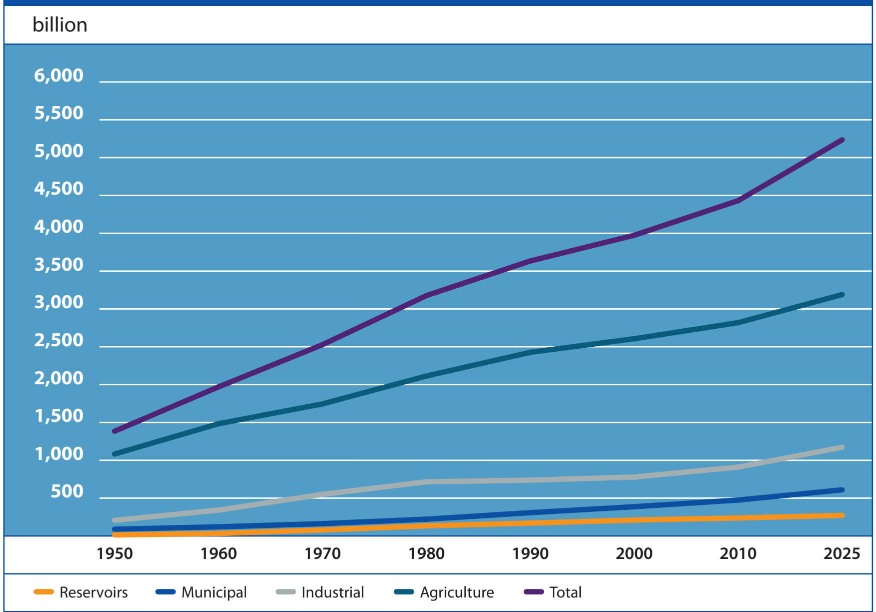
Current examples of increasing water scarcity include:

- Decreasing river flows. In 2007, the Yangtze river in China fell to its lowest level since records began in 1877.[5] The Yellow River, also in China, the Murray-Darling in Australia and the Colorado in the US fail to make it to the sea, at least for part of the year.
- Depleted aquifers. Groundwater levels under the plains of northern China, northern India and the mid-southern US are falling fast. Groundwater in the Hai basin in northern China is actually mined: annual abstractions total 26 billion m^3 while recharge is only 7 billion m^3.[6] Beijing's water table is dropping by 3 metres a year[7] and is now more than 1,000 metres below the surface. The Ogallala aquifer in the US may dry up in 25 years at current consumption rates.[8]
- Cities running dry. Atlanta very nearly ran out of water in 2007, reducing the Governor and state officials to a prayer service for rain.[9] Barcelona this summer (2008) was forced to ship in drinking water from France.[10] Lake Mead on the Colorado river, a key water source for Las Vegas, has a 50% probability of running dry by 2017.[11]

1.1 Population Growth

Global water consumption increased sevenfold over the past century. By 2025 it will be 30% higher (Figure 1.3). Much of that increase will be in fast-growing economies such as China, India and Mexico that already experience water stress or shortages. Within these countries as elsewhere, water problems tend to be concentrated in urban areas where 61% of the world's population is projected to live by 2030.[12] Mega-cities like Beijing, Mexico City and Jakarta already depend on unsustainable water withdrawals from rivers and aquifers. Lower groundwater tables, land subsidence and salt-water intrusion are just three of the consequences.

Figure 1.3 World Population



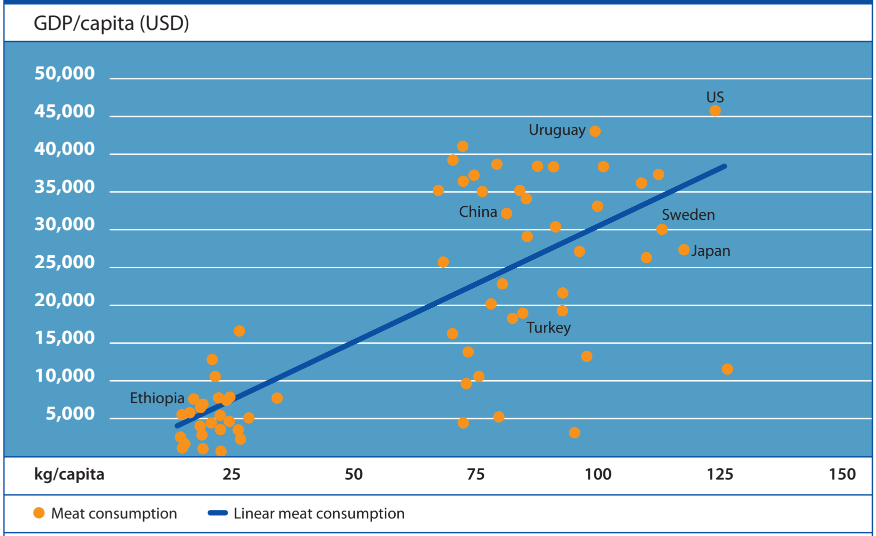
Source: FAO [13], 2008; United Nations Secretariat [14], 2006

1.2 Higher Incomes and Changing Lifestyles

With economic growth people acquire higher incomes and change their lifestyles, their consumption patterns and their diets. They will buy goods and services that require more water such as toilets, washing machines, and golf courses. The global average water withdrawal per person in 1900 was 350m^3 per year, today it is 642m^3, with the US leading the way with more than 1,600m^3 per person per year.

A big part of the income-induced increase in water consumption is due to the fact that richer people tend to adopt more meat-intensive diets (Figure 1.4)[15]. That by itself may explain a doubling of per capita water demand.

Figure 1.4 Meat Consumption



Source: Adapted from Shove, Comfort, Cleanliness and Convenience[16], 2003

As a global average, it takes about 3,000 litres of water to satisfy a person's daily dietary needs, i.e., about 1 litre per calorie.[17] The actual demand for embedded water varies with meat consumption. An American-style, red-meat intensive diet for example requires approximately 5,300 litres per person per day. A vegetarian diet requires less than half that amount, while in Africa people survive on just 1,000 litres of embedded water per day.[18]

Demand for animal products in developing countries is increasing by 2.5% to 4% a year.[19] This translates into a proportionally growing demand for feed grains and the water required for their production. In fact, if the current global population were to adopt western-style, meat-intensive diets, world agriculture would require 75% more water with current practices.[20]

1.3 Pollution

Water-quality issues interact with water availability concerns. Excessive pumping of groundwater for example can lead to saltwater intruding into aquifers, permanently reducing freshwater availability. Toxic spills or routine discharges of effluent can reduce the availability of clean surface water downstream. Where wastewater treatment is not economically feasible, water pollution can aggravate water shortages.[21]

Conversely, declining water flows mean increased concentration of pollutants, which diminishes the water's value for downstream domestic, productive and environmental uses.

Water pollution is a growing problem for densely populated, fast-industrialising countries such as China and India where wastewater treatment capacity fails to keep up with economic and population growth. Only 52% of Chinese cities' wastewater is treated. Five of the seven big river systems in China are severely polluted; the Yangtze, Yellow and Huai rivers alone carry 38 billion tonnes of untreated wastewater.[22]

Agriculture is indirectly responsible for more than 40% of surface water pollution in the form of fertiliser and crop protection chemicals. Nitrogen specifically leads to algae blooms and fish kills (eutrophication), a problem prevalent in many coastal waters around the world. The expansion of corn production for example for ethanol may make matters worse: the crop is heavily fertilised and produces high levels of runoff, which carries excess nutrients into water courses.

Too little water can concentrate pollutants, but too much water can increase the total pollution load: increased runoff because of the 2008 floods in Iowa, for example, raised nitrate and phosphorus levels at the mouth of the Mississippi in the Gulf of Mexico, further expanding the existing dead (hypoxic) zone.[23]

1.4 Climate Change

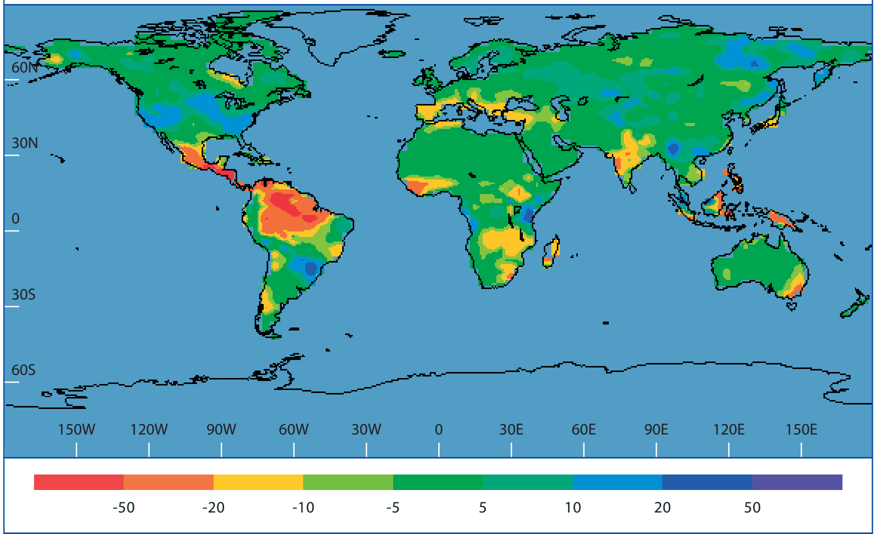
Climate change is altering the hydrological cycle, affecting the temporal and spatial distribution of rainfall. It is leading to more prolonged droughts in some parts while increasing flooding in others. For example, in 2008 the normally humid southeast region of the US is in 'exceptional drought', according to the US Department of Agriculture, while the state of Iowa experiences record floods. The International Panel on Climate Change projects increased droughts for southern Europe and much of Africa and declines in agricultural yields of up to 50% by 2020.

The resolution of current climate models is not yet sufficient to predict local meteorological and hydrological changes, but regional consequences can be predicted with some accuracy. Figure 1.5 shows which regions are projected to experience deeper and longer droughts - compared to the 1960-1990 reference period - as measured by the reduction in soil moisture content. Regions with lower rainfall and/or higher evaporation include the Amazon basin, Central America and Mexico, southern Europe, western and southern Africa, India and southeast Australia.

Australia in fact is already in the midst of a prolonged drought that knocked one percentage point off the country's growth rate in 2006.[24] It may just be the world's first advanced economy that is, again, at the mercy of the weather.[25]

Figure 1.5 Change in Annual Average Soil Moisture Content (1960-1990 to 2070-2100)

millimeters Mean: -2 Min: -98 Max: 39



Source: The Met Office[26], 2008

Additionally, higher temperatures are shrinking glaciers and causing mountain snow packs to melt earlier in the spring. With these water buffers diminishing, areas that are dependent upon snowmelt will see increased short-term water flows, followed by decreased regular water flows. Less water will be available during the dry summer months when it is most needed.

Key economic and agricultural regions of the world along glacier and snow-fed rivers such as the Yangtze, Indus, Ganges and Brahmaputra are becoming more dependent on variable rainfall. This is expected to seriously affect one-sixth of the world's population, their farms and businesses: river flows will be more erratic, spring floods more extreme and summer droughts more prolonged. Water availability - the right amount of the right quality in the right place at the right time - will suffer.

One example of this is the Colorado river: 85% of its flow comes from the melting snow pack in the Rocky Mountains.[27] With less snowmelt, river flows are likely to decrease, and decrease faster, in course of the summer. Thus it will affect agricultural production in a river basin that produces 15% of US crops, creates USD 1.5 billion in agriculture economic output and serves more than 30 million Americans' needs.

Climate change will increase irrigation-water requirements as higher temperatures will cause more evapotranspiration (i.e., the sum of evaporation from land and water surfaces and plant transpiration). Projections for the extra demand for irrigation water vary, but one estimate has it that global irrigation requirements will increase 20% over the next 50 years from climate change alone (i.e., all other factors such as irrigated area, crops, technologies are constant).[28]

2 Agricultural Production and Water Scarcity

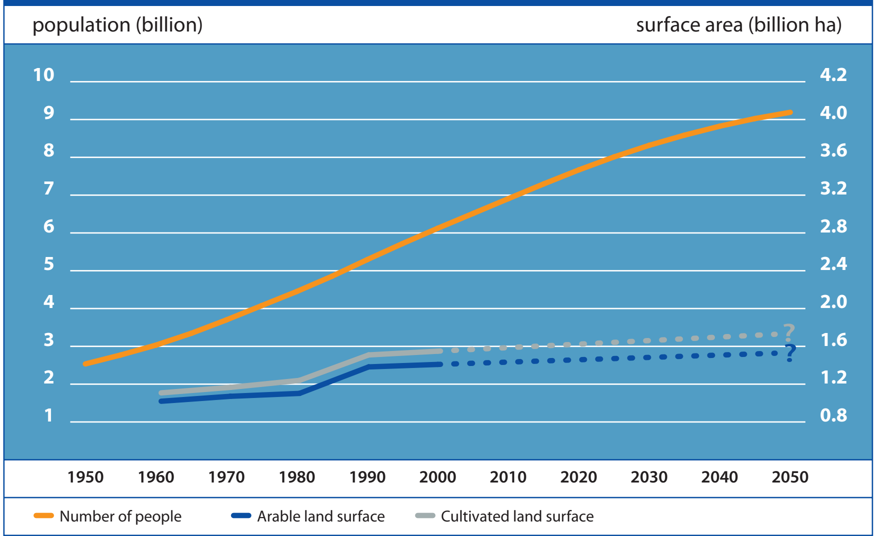
2.1 The World's Increased Demand for Food

Agriculture will need to increase production to meet the demands for food and feed due to population growth, rising incomes and changing diets. Production may have to rise with 70% to 90% by 2050.[29]

Besides food and feed, the increased demand for agricultural production is brought about by the demand for biofuels and other industrial uses of crops and biomass. Biofuel production may increase three to tenfold by 2030 in order to help meet ever-growing energy needs.[30] The demand for fibre crops such as cotton is also expected to more than double by the year 2050.[31]

The overall demand for agriculture to produce more food, feed, fuel and fibre crops will require a massive increase in productivity, since land resources are finite while the world population continues to increase (Figure 2.1).

Figure 2.1 Finite Land Resources



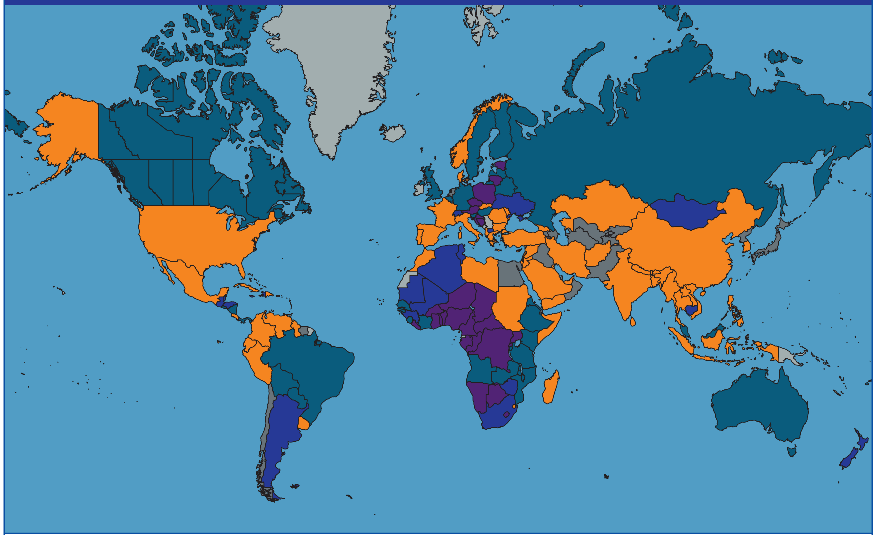
Source: FAOSTAT [32], 2002

2.2 Agriculture's Increasing Demand for Water

The world's water resources are finite and fully committed by agricultural, industrial, municipal or environmental uses.

Rainfed and irrigated agriculture both play a vital role in the global production of food, feed, fuel and fibre crops, but their relative importance differs from region to region and from crop to crop. Africa, for example, is highly dependent on rainfed agriculture, while irrigation is much more important in the Middle East and Asia (Figure 2.2). Globally, the relative importance of irrigation may actually increase as rainfall patterns become more variable due to climate change.

Figure 2.2 Irrigated Crops as Percentage of Total Cultivated Crops



< 1 | 1 - 5 | 5-10 | 10-50 | > 50% | no data

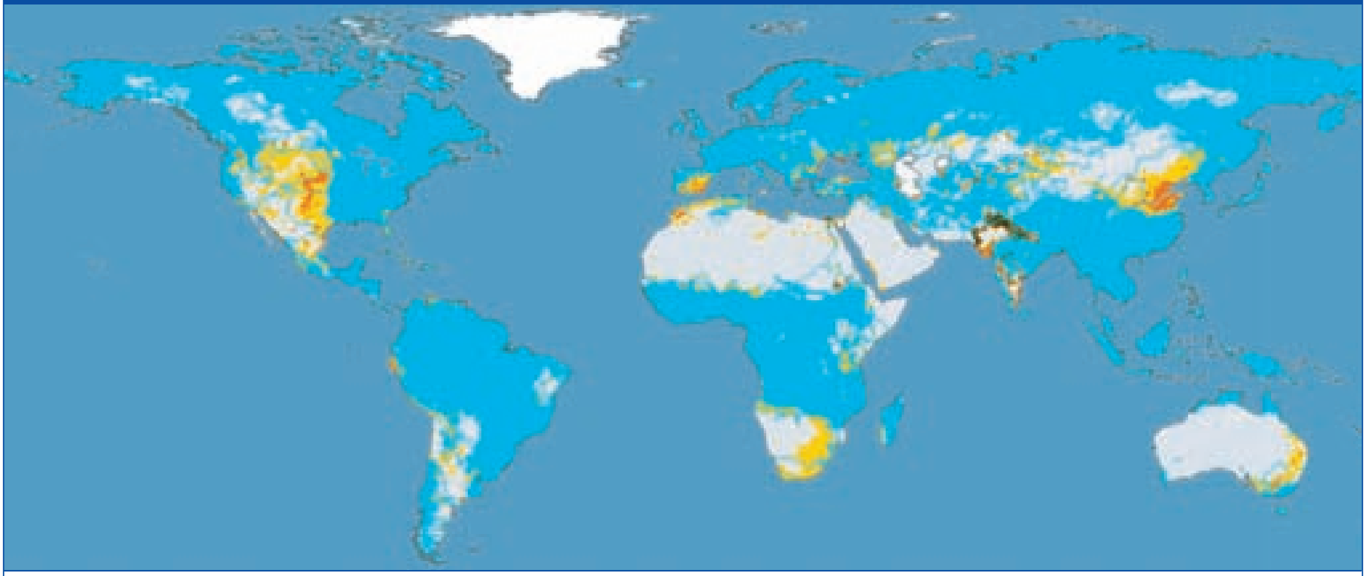
Source: UNESCO[33], 2006

Rainfed agriculture relies exclusively on rain and soil moisture to produce 62% of the world's food staples by volume.[34] Irrigated agriculture also draws from rivers or aquifers to maintain adequate soil moisture levels. It occupies only 28% of the world's cropland but as it allows for multiple cropping, it produces higher yields per hectare. As irrigated agriculture also produces higher-value crops, it accounts for 46% of the world agriculture's economic output. [35]

Current agricultural production requires an amount of water equal to a canal 10-metre deep, 100-metre wide, running nine times to the moon and back. With the projected increase in the demand for agricultural commodities this would grow to some 16 times the distance to the moon and back (at current levels of crop water productivity) by 2050. While nearly 80% of that water demand could be met by precipitation, up to 4300km^2 would be required for irrigation (at current levels of efficiency).

The problem is: that water is simply not there. Irrigation is already unsustainable in many parts of the world. According to Figure 2.3, ground water withdrawals in the US, Mexico, India, China and Spain already exceed levels that can be sustained.[36] The situation in northern India is particularly severe as 56% more ground water is being withdrawn than is replenished. In northern China that figure is 25%.[37] Other key agricultural production areas where irrigation is unsustainable as it relies on the depletion of ground water resources include Spain, South Africa, eastern Australia and the Great Plains in the US (Figure 2.3).

Figure 2.3 Unsustainable Irrigation



■ High overdraft ■ Moderate overdraft ■ Low overdraft ■ Demand = Supply ■ Supply > Demand

Source: Millennium Ecosystem Assessment[38], 2005

2.3 Water Scarcity Impacting Agriculture and Agribusiness

As much as agriculture contributes to global water scarcity (and, indeed, pollution), it also finds itself at the receiving end of the problem. Farms and agribusinesses are increasingly confronted with water shortages, regulatory constraints, and changing stakeholder values concerning the water footprint of the sector.

Occasional droughts and 'natural' water shortages have always had obvious impacts on agricultural yields at the farm level. What is new is that structural water scarcity is increasing in important agricultural production areas, and that the competition for water is intensifying. The recent declaration by governor Arnold Schwarzenegger of an official drought in the US state of California, for example, cut water supplies to Central Valley farms by 60%, resulting in hundreds of hectares of land not being planted.[39]

Water shortages also impact on agribusinesses, notably through their supply chains. In 2001, a drought in the Pacific Northwest drove up brewer Anheuser-Busch's input prices. Barley prices rose as harvests failed. The cost of beer cans also spiked with aluminium and hydro-electric power prices (due to low reservoir levels).

Reputational risks are real as Coca Cola and Perrier, for instance, experienced. In Kerala state, India, the government reacted to a sharp drop in groundwater tables by revoking the groundwater license of Coca Cola's bottling plant, despite its compliance with local laws and regulations.[40] Local opposition to a Perrier bottled water plant in Wisconsin forced Nestlé to move operations to Michigan where it agreed with community organisations to reduce its water consumption by half.[41]

Box 1 Water Scarcity-related Risks

- Financial losses in the form of reduced yields or foregone revenues due to water shortages during crop growth, or disruption of the food and beverage production process.
- Higher water prices and/or higher capital expenditures to secure, treat, save or recycle water. Regulatory compliance with water quality requirements may force up the cost of discharging wastewater. Consumer and other stakeholder values may drive up these costs beyond what is required to comply with regulations.
- Delayed or suppressed growth of a farm or food and beverage company because of the intensifying competition for water and the physical, regulatory and reputation constraints that come with it. Such conflicts can be particularly poignant in developing countries where commercial water use directly affects the livelihoods of people who may themselves not have sufficient access to clean water.

Source: Watching Water. (2008). JPMorgan with World Resources Institute [42], 2008

The overall cost of water scarcity from pollution and depleting groundwater sources in China is estimated to be USD 21 billion a year, or almost 1% of the country's annual output.[43] With increasing scarcity the competition for freshwater between agricultural, industrial, municipal and environmental uses is bound to intensify. That competition is likely to have consequences for agriculture if only because with 70% of the world's freshwater resources it is the biggest water consumer by far.

Whether it is because of increasing demands for food (section 2.1), unsustainable water use (section 2.2) or the need to manage water-related risks, agriculture is expected to produce more with less. Increasing production will depend on higher yields per hectare and per cubic metre of water. Higher irrigation water-use efficiencies are an important part of Chapter 3, in which we will discuss a number of technologies to help achieve this.

3 Technology Options to Raise Irrigation Water Use Efficiency

This chapter will focus on irrigated agriculture, which - as the biggest user of surface and ground water - is where both the necessity and opportunity for improvements in water-use efficiency are greatest.

The technical solutions presented here are broader than only technologies to increase water-use efficiency as we also deal with other technologies aimed at water conservation or techniques to increase water availability. We have collated all these techniques under the heading 'water use efficiency' in order not to dilute the main message of this report: water is becoming increasingly scarce and the efficiency of water use in irrigation has to increase drastically.

To improve irrigation efficiencies, a wide array of policy interventions and investments in irrigation equipment and practices exists. The precise nature and extent of these interventions and investments varies by type of irrigation system (Figure 3.1). Generally they are best implemented jointly to be most effective.
In this chapter we will focus on irrigation technologies, recognising that their adoption and expansion depends on the right mix with policy and institutional reforms and management expertise.

Many water technologies require a certain scale to be technically worthwhile and financially feasible. This could involve large-scale public irrigation systems and on the commercial, privately managed systems, but also small to medium-scale community-managed systems and farm-scale individually-managed systems for local markets.

Figure 3.1 Investment Options in Different Types of Irrigation Systems

System type and category	Agriculture economy, large rural population	Transition	Industrial, market-based economy
Large-scale public irrigation systems in dry and humid areas			
Policy focus	Integrated rural development	Linking water and agriculture policies	Implementing integrated water rescurces management approach
Capital investment, water	Small and large dams, gravity irrigation development, on-farm groundwater development		Upgrading irrigation and drainage infrastructure
Capital investment, other	Rural infrastructure, roads, markets, social and health infrastructure, electrification		Upgrading rural infrastructure
Regulation	Landtenure and water rights, stakeholder involvement in scheme management	Water rights, local institutions regulations, participatory irrigation management	Irrigation management transfer
Management	Increased reliability in system operation	Restructing, improved accountability an transparency, improved system control and operations, enhanced flexibility of water service, enhancingsystem multifunctionality	
Capacity building	Training irrigation staff, water user association formation and strengthening		Strengthening of professional organisations, market information systems
Finance	Term finance, rural credit and micro-credits, grants	Term finance, agricultural savings and loans	Commercial financing
Technology	Land leveling, shallow wells, small-scale pumping technology, conjunctive use of surface water and groundwater		Automation, pressurised irrigation systems, water quality monitoring
Small- to medium-scale community-managed systems			
Policy focus	Integrated rural developmant	Linking water and agriculture policies	
Capital investment, water	Runoff river, weirs, diversion, local storage and small dams	Local storage and small dams, improved water ditribution infrastructure	
Capital investment, other	Rural infrastructure,roads, market acces and information, social and health infrastructure, electrification		
Regulation	Water rights, including traditional water rights	Recognition and formalisation of water rights and bulkwater allocation	
Management	Conflict management, on-farm water management		
Capacity building	Training of extension staff, water user association formation and empowerment	Water user association monotoring and support, staff training	
Finance	Grants, targeted subsidies	Rural finance	
Technology	Small-scale microirrigation systems, tanks	Mechanised agriculture, deep tubewell drilling, pressurised irrigation system	
Commercial privately managed systems			
Policy focus	Market chain; negotiating favorable trade policies		
Capital investment, water	Diversion dams, deep tubewells	Runoff recycleing, automation of watersupply	Automation
Capital investment, other	Markets, communication and storage infrastructure, including fot export		
Regulation	Bulk water allocation, water rights, tariffs		
Management	Irrigation scheduling, soil moisture monitoring		
Capacity building	Water quality monitoring		
Finance	Commercial finance		
Technology	Overhead irrigation, sprinkler and microirrigation technologies	Precision farming, pivots, lateral moves, microirrigation, fertigation	
Farm-scale individually managed systems for local markets			
Policy focus	Food safety, food security and nutrion policies		
Capital investment, water	Shallow well drilling, canals		
Capital investment, other	Market and infrastructure development	Rural electrification, energy pricing	Market and infrastructure development, wastewater treatment
Regulation	Tenure security, water rights, food safety control		Tenure security, food safety control, environmental control
Management	Wastewater reuse		
Capacity building	Training on on-farm water management and food and water quality control		
Finance	Micro-finance		
Technology	Low cost, robust irrigation technology	Mechanised groundwater use	Water measurement and control, automation, low pressure irrigation

Note: Term finance refers to equity or medium- and long-term loan finance.

Source: International Water Management Institute [44], 2007

In this chapter we will start from 'investible' technologies that can improve water-use efficiency at the irrigation system and/or the farm level by either freeing up or saving water that would otherwise be lost.

The technical potential for water efficiency is clear: 85% of global irrigation is still done by simply flooding fields or furrows, which means that only 25% to 40% of the water withdrawn actually reaches the intended crops.[45] With sprinkler and drip irrigation, losses to evaporation from soil and water surfaces and to transpiration by non-crop plants can be reduced greatly, and irrigation efficiencies can be 70% or even 80%. Sub-surface irrigation systems may even attain 95% water-use efficiency.[46] These technologies have huge potential as their adoption starts from a very low base compared to selected OECD countries (Figure 3.2).

Figure 3.2 Irrigation Water Sources and Methods

			Source of irrigation water		Irrigation method		
Selected regions	**Total irrigated area (million hectares)**	**Farmer or privately managed (% of total)**	**Surface water (% of total)**	**Groundwater (% of total)**	**Flood (% of total)**	**Sprinkler (% of total)**	**Drip (% of total)**
East Asia & Pacific	71.8	48	46	54[47]	96	<3	<1
Eastern Europe & Central Asia	31.6	8	96	3	58	41	<1
Latin America and Caribbean	18.4	18			87	11	3
Middle East and Northern Africa	20.3	6	68	32			
South Asia	73.7	44	47	53[48]	97	<2	<1
Sub-Saharan Africa	6.2	36	78	20	78	17	5
US	52.6		54	46	44	50	6
Australia	2.4	n.a.	75	25	60	30	10
Israel	0.2				25	15	60
Spain	3.7				83	13	4
France	2.7				10	88	<2

Source: FAO, World Bank [49]

In Figure 3.2, 'farmer or privately managed' irrigation is singled out as this is the type of irrigation where individual farmers control their irrigation-water supply. This is important as many technological options at the field level require such control in order to be effective and attractive for (private) investments. For example, groundwater irrigation provides such control, as do modern, 'on-demand' open canal irrigation systems. Unreliable, supply-driven irrigation does not.

3.1 System Modernisation

As water constraints leave little room for new large-scale irrigation systems, the focus is on increasing crop-water productivity and water-use efficiency within existing irrigation systems. This requires a flexible, reliable and equitable distribution of irrigation water in systems that are less costly to operate.

Hydraulic technologies such as adjustable weirs to distribute water through a network of canals have been around for a long time. But progress in communication and electronics promises to modernise open canal irrigation systems through automated monitoring and measurement of water flows, and remote control of water-distribution devices. In the most advanced of systems these technologies allow for on-demand irrigation based on current crop water demands, instead of irrigation according to a fixed roster, as in the example from Victoria, Australia, in Box 2.

Less sophisticated technology can be employed to address the perennial problems of siltation and inadequate maintenance that affect open canal irrigation. Silt traps can be installed at the intakes, and weeds can be removed by chemical or biological methods. Water leakage and canal bank erosion can be reduced by lining canals with geosynthetics, which irrigation districts in the US claim can be installed for as little as one-third of the cost of concrete lining.[50]

Irrigation-system modernisation requires the highest standards in project planning, design and construction. It is best done gradually, from less to more sophisticated control systems (for example, local controllers before remote controls). This will allow time for system operators and users to become comfortable with the technologies.

Benefits of system modernisation include higher crop-water productivity as water losses are reduced and crop yields and values increased. Labour requirements in modernised irrigation systems are lower, even as the skills required are higher.

Box 2 Large-scale System Modernisation in Australia and Mali

In the 90s, large-scale system modernisation in Victoria, Australia, replaced the irrigation roster (requiring farmers to take water on a fixed schedule) by a new water-on-order system that allowed farmers to meet their exact crop requirements. A telemetry system provided real-time management of flows and water levels.

In the Office du Niger in Mali, also in the 1990s, a physical upgrading programme focused on improved water control in the main conveyance and distribution network, as well as land-levelling. This contributed to a fourfold increase in paddy rice yields.

Source: IPTRID [51], 2003

The average cost of 120 projects from around the world to rehabilitate and modernise open-canal irrigation was USD 630 per hectare.[52] With the large differences in the type and extent of 'modernisation' the cost varies from less than USD 100 to more than USD 9,000 per hectare.

Modernisation increasingly concerns the soft-technology side with electronics, communication systems, computers, and instrumentation. As these become cheaper, more reliable, more accessible and more available, automation for monitoring and control, and measurement (of groundwater levels, canal discharges, and even on-farm and water-course deliveries) are likely to become more widespread. Their greatest and largest potential may well be in the large open canal irrigation systems of South and East Asia. But over time these technologies could also be adopted in smaller systems and in groundwater irrigation, as well as by more commercially oriented growers at all scales.

3.2 Monitoring Crop-water Demand and Metering Deliveries

New technologies allow for the continuous monitoring of soil moisture levels and the accurate measurement of water flows. Improved information on irrigation-water requirements and actual irrigation water deliveries will be crucial in raising crop-water productivity and providing economic incentives for using water more efficiently.

New monitoring and sensor technologies allow farmers to take advantage of moisture present in the soil and optimise irrigation gifts accordingly (to the extent they can control the amount and timing of irrigation water deliveries). On-the-ground soil-level monitoring by so-called tensiometers can be supported by satellite information on precipitation, temperatures, humidity, hours of sunshine, as well as evapotranspiration rates. The spatial and temporal resolution of satellite imagery is gradually improving to the point that individual irrigation systems or farms can benefit from this information. The FORMOSAT-2 satellite offers images with a resolution of about eight metres for daily observation of irrigated areas of 500km^2. Experiments with the use of these FORMOSAT images in irrigation-water management are ongoing in the water-stressed Tensift plain in Morocco and Sonora State in Mexico.[53] Box 3 presents some of these advances in irrigated agriculture that used to driven by water-supply schedules rather than crop water demands.

Box 3 Smart Water Application in the US and Australia

California's Department of Water Resources has developed a highly integrated and automated agricultural tool known as CIMIS. CIMIS monitors key agricultural areas throughout the state, collecting data on climate, solar radiation, wind speed & direction, humidity, rainfall, and air & soil temperature. The system can determine the correct amount of irrigation water needed and when it should be used. CIMIS has been found to increase yields by more than 8% and decrease irrigation requirements by 13%. Economic benefits ranged from USD 99 per hectare for alfalfa to USD 927 per hectare of lettuce.

High-tech devices are fast becoming standard throughout Australia. In Reverina, New South Wales, farmers receive reports via cell phones from satellites that monitor evapotranspiration rates combined with in-field soil monitors that inform farmers how much water the crops may need. Farmers can then start the automated watering of their fields which will shut off when the appropriate amount of water has been sprayed. The technologies also apply the water during the best times to reduce the greatest amount of evaporation.

The adoption of water-efficient technologies was helped by the U.S. Irrigation Association which was approached by farmers to develop a standard protocol for water conservation devices. As a result, the Smart Water Applications Technologies (SWAT) protocol was developed. Standardised testing has helped users discover devices that incorporate numerous environmental factors including: soil type, slope, sun exposure, irrigation method, distribution uniformity, plant type, precipitation rate and others. SWAT devices developed according to these standards vary in their effectiveness, but having standard tests to compare has helped farmers make informed decisions.

Source: World Watch Institute [54]; Vidot, A. [55], 2008; Water Efficiency Magazine [56], 2007

Capacity building programmes can assist smaller farmers to gain access to and act upon satellite information on crop water demands. The latter does not necessarily require high-tech measures as Box 4 illustrates.

Box 4 Reducing Evapotranspiration in China

The large Hai Basin in northern China is particularly water stressed: satellite monitoring reveals that evapotranspiration exceeds precipitation rates. The Integrated Water and Environment Management Planning project now requires counties to reduce evapotranspiration rates by 15% to 20% through the reduction of waterlogged areas, weeding, covering strips of soil with plastic, night irrigation, moisture-retaining mulches, stimulating greenhouse cultivation and replacing open ditches and canals with pipes.

Source: World Bank [57], 2006

If increasing water-use efficiency is the key goal (rather than stability of irrigation service revenues or ease of administration), irrigation water should be charged for by the volume and possibly the time of irrigation water deliveries. For that, metering is the necessary first step. Water meters are more prevalent in residential and industrial settings, but there is increased emphasis on measuring the much higher agricultural water use.

The price-elasticity of water demand has to be high enough for water-metering programmes to have the desired effect on water-use efficiency. Interestingly, the mere installation of water meters may already reduce water use: studies of municipal consumers suggest that consumption drops between 10% and 20% even before the first, volume-based water bill has arrived.[58]

The value (and the price for which it may be sold or leased) of the water saved should be high enough to justify the cost of installation and maintenance of the devices as well as the administrative cost of billing and enforcing payment, as it was in the examples in Box 5. If it is not, other simpler ways to charge for irrigation water deliveries - by irrigated area, for example - can be pursued.

Box 5 Water Metering in China and Australia

In water-scarce Shandong province in China, the government introduced an automated irrigation system in which farmers use prepaid circuit cards to receive water. Irrigation prices are based on the volume of water used over which farmers have full control. The system is connected to the internet for accurate water-use recording, low administrative costs and a high collection rate: 100%. The reliability of the system has led to rapid adoption with now over 200,000 users. Automation is estimated to be saving about 5 billion m^3 annually.

The Government of Australia, through its National Water Initiative has consistently promoted market-based instruments for more efficient irrigation water use, including water metering and volume-based water pricing (as well as water trading between water users on the basis of price-value differentials). The Government attaches much value to the history of water use per water license.
In response, the Coleambaly Irrigation Co-operative Limited in Riverina adopted a water metering programme that helped it to improve water use efficiency from 73 to 90%. Through the programme, leaks were detected and farmers encouraged to use irrigation water - charged for by the volume - more efficiently.

Source: Australian Government Department of the Environment and Water Resources [59], 2007; World Bank [60], 2005; Wang, X. and Lu, J. [61], 1999

3.3 Sprinkler irrigation

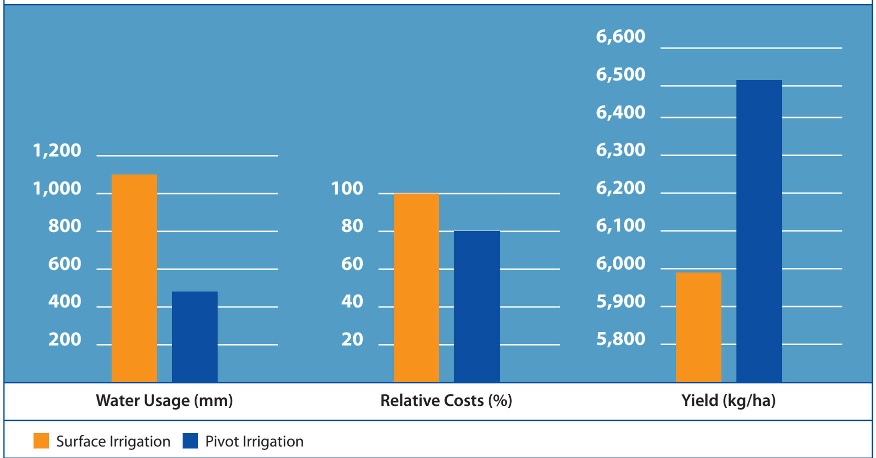
In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. Centre pivot irrigation is a form of sprinkler irrigation that moves in a circular pattern and is fed with water from the pivot point at the center of the arc. These systems require the terrain to be flat, like in Mid-West US.

Other sprinkler systems can be more flexible, with movable sprinkler lines or travelling guns. Sprinkler irrigation systems are popular because of their ease of use, and efficient operation. Sprinkler irrigation can be employed on a wide variety of crops.

Sprinkler irrigation is a mature technology that is only employed at 18% of the world's irrigated area[62] even though it promises water-use efficiency gains of 30% to 70% compared to flood irrigation. Figure 3.3 shows the water and cost savings and yield gains that sprinkler irrigation brought to a large farm in Brazil.

Figure 3.3 Sprinkler Irrigation in Brazil

Werner Arns, a farmer in Rio Grande de Sol in the southern Region of Brazil conducted rice-growing experiments utilising flood irrigation and centre pivot irrigation. Centre pivot irrigation cut water usage by half, and provided other benefits. It allowed the farmer to produce multiple crops on the same land, utilising crops that fed nutrients to the soil and improved productivity. Also, maintaining centre pivot irrigation systems turned out to be 20% less costly than surface irrigation. Not surprisingly, Werner Arns decided to phase out surface irrigation in favour of centre pivot irrigation on his 1,800ha farm.



Source: International Commission on Irrigation & Drainage [63], 2007

The economics of sprinkler (and drip irrigation, below) vary with water scarcity, water policies, topography and soil type. Capital costs for sprinkler irrigation systems can be twice those for flood irrigation, according to one detailed US analysis, which may make the option less attractive for small farmers.[64] However, relative to open canal irrigation, sprinkler economics are improving with the decreasing cost of pipes and fittings, and the increasing cost of canal maintenance.

Sprinkler irrigation requires electricity or fuel for pumping, but may save on labour, compared to flood or furrow irrigation. Besides the capital cost, the relative prices of energy and labour are the key factors in determining the viability of sprinkler irrigation in large and small systems.

3.4 Drip Irrigation

Drip irrigation, also known as trickle irrigation, delivers water at or near the root zone of plants, rather than spraying an entire field. If managed properly, drip irrigation can be the most water-efficient method of irrigation of crops grown in rows since evaporation and runoff are minimised. It can also help to reduce the amount of weed control necessary as less water is available to competing plants.

In modern agriculture, drip irrigation is also the means of delivering fertiliser. So-called 'fertigation' has numerous benefits for both the farmer and the environment. For the farmer, it reduces the application and cost of fertiliser because of its direct uptake in to the plant. As more nutrients are absorbed by the plant, less runs off to surface water courses or leaches into the ground water. The more efficient use of fertiliser and herbicides represents important reductions in farming costs.

Compared to flood irrigation, drip irrigation can save water (30% to 60%), raise crop productivity (5% to 50%), and reduce the cost of water, energy, fertiliser and herbicides. Still, it is currently only practiced at around 1% of all irrigated land.[65] China and India, countries that are highly water-stressed, have adopted sprinkler or drip irrigation in less than 5% of their irrigated area. It has been estimated that both countries could drip-irrigate twice that area, thus doubling water productivity.[66]

Highly sophisticated drip irrigation systems are expensive and can cost USD 6,000 to install. However, system costs can be reduced to as low as USD 250 per hectare with low-pressure drip irrigation techniques and inexpensive, easy-to-move plastic drip lines ('seephoses'). Such cost reductions and adequate information on methods and benefits can bring drip irrigation within reach of large and small farmers alike.

Incentives for farmers through water metering, pricing or rationing can have strong impacts, but it is also important for farmers to have profitable outlets for high-value crops. For instance in Jordan, where conditions of high prices for water and profitable outlets for high-value crops exist, nearly two-thirds of farmers have adopted drip irrigation.[67] Box 6 lists some of the reasons why farmers in different countries have taken up drip irrigation.

Box 6 Drip Irrigation in Jordan, Australia and India

Water shortage in the Jordan Valley is extreme and irrigation expensive. However, farmers have profitable market outlets for high-value fruit and vegetables. As a result, about two-thirds of the farmers have shifted from surface to drip irrigation over a 10-year period.

The Mulgowie Farm in Queensland, Australia, practices drip irrigation on its beans and corn. While it generally takes about five times as much labour as conventional irrigation, the savings in water and other resources more than recovers the cost. Elsewhere in Leeton, farmers Dean Morris and Wayne Protheroe have a drip irrigation system installed that automatically delivers nutrients to the root zone of the crop during ideal times and according to plant uptake schedules. The farm has since more than halved the amount of water use per hectare and nearly doubled the yield.

Northern India struggles with soil salinity (because of over-irrigation and inadequate drainage) and dropping groundwater levels. Farmers who adopted drip irrigation managed to reduce their water use by 40 to 70%, fertiliser costs by 30% and labour by 50% to 60%. Moreover, yields improved 20% to 100%. More farmers are now prepared to make the capital investment in order to realise similar gains.

Source: The World Bank [68], 2006; Australian Government Department of Agriculture, Fisheries and Forestry [69], 2004; Danton, E. & Marr, A.J [70]

Beyond the common drip irrigation system, innovative farmers are starting to employ sub-surface trickle irrigation. This type of irrigation places the drip irrigation system below the soil where water trickles directly to the plant's root mass. Evaporation losses are almost zero and efficiencies can be as high as 95%. Though expensive to install, subsurface irrigation may provide the best return on investment if profitable outlets for high-value crops exist, water prices are high (Israel, Jordan) and/or supplies uncertain (Australia). The latter could make subsurface irrigation worthwhile even for relatively low-value row crops as corn (Box 7).

Box 7 Subsurface Irrigation in Kansas

In Kansas, another region with dropping groundwater levels, subsurface irrigation systems have been well studied for various crop types. Research has shown that subsurface-irrigated corn, the primary crop, uses 25% less water than with boom or pivot irrigation systems. Benefits included the reduction of non-beneficial water use, avoidance of unnecessary irrigation events, improved uniformity, better soil uptake of rainfall, improved crop health, yield and quality.

Source: Lamm, F. [71], 2005

3.5 Conjunctive Use of Surface and Ground Water

Conjunctive use refers to the combined use of surface and groundwater to meet crop demands. Farmers thus manage the risks of reduced or variable surface water deliveries. Where irrigation systems are fed by snow or glacial melt, ground-water irrigation can make up for declining surface water availability in the course of the summer and protect crop yields and farmer incomes.

In many regions of the world, ground-water development has taken off in a spectacular fashion, especially in India where it has increased fivefold since 1970, driven in part by energy subsidies on groundwater pumping. As a result, groundwater is withdrawn at a much higher rate than aquifers can be recharged naturally, and water tables are dropping.

Excess surface (or storm) water can recharge overexploited aquifers through artificial infiltration in basins, canals, water traps or drainage wells. These are constructed where water easily percolates into the aquifer. By storing water underground, runoff and evaporation losses are reduced. Such 'managed aquifer recharge' can also help improve groundwater quality by decreasing the salinity level. In other locations it may be employed to treat wastewater or prevent salt water intrusion to aquifers.[72]

Box 8 Artificial aquifer recharge in South Africa and Australia

Atlantis, South Africa, only receives 450 mm of rainfall a year. However, 65% of that occurs between May and September, resulting in declining water availability during the dry season. To meet water demands, two large recharge basins were developed to collect storm runoff and wastewater. The scheme has helped to reduce water scarcity issues and delivers water to users at 20% of the cost it would take to pipe in water from a different source.

In one area of Adelaide, Australia, there was a push in the wetter years of the late 1990's to use the aquifers for larger scale storage of water to be used in dry years. Rainwater runoff is nowadays pumped into aquifers for later extraction and use.

Source: UNESCO [73], Rabobank

With more erratic river flows and floods, managed aquifer recharge is probably set to grow as an investment option. Costs and benefits vary with geohydrological conditions. In the US, so-called aquifer storage and recovery systems have multiplied tenfold over the past 10 years, thanks to some successful examples, mainly in municipal water supply.[74]

In greenhouse horticulture in the Netherlands, excess rainwater is stored in aquifers for cooling greenhouses in summer and heating in winter (through cold-heat exchange) rather than for conserving water.[75]

3.6 Wastewater Treatment and Reuse

Besides increasing the efficiency of irrigation-water use, there are ways to free up irrigation water supplies, for instance from non-traditional sources such as wastewater from polluting industrial or municipal uses.

Investments in wastewater treatment are growing fast, driven by public health and water-quality concerns. China, for example, is building numerous wastewater treatment plants towards the goal of treating 70% of its wastewater by 2010.[76] India has similar plans on the heavily polluted river Ganges. These are expensive investment programmes for the construction, operation and financing, of which governments are increasingly working with private investors.

The reuse of wastewater in irrigated agriculture - for example through ground water injection and recovery - may be more viable than municipal reuse (for potable water) as it allows a lower standard of treatment. By providing a market for the treated effluent, irrigated agriculture may further improve the investment case for private sector participation in water treatment.

For farmers, the nutrients that wastewater contains can help to reduce chemical fertiliser costs. The potential for the safe and productive reuse of wastewater is demonstrated in Israel, where 60% of the country's sewage water is being recycled, as well as in California and Australia (Box 9).

Box 9 Use of Recycled Water in California and Australia

In California, water recycling has become a viable business in the Walnut Valley Water District. The original water recycling plant developed by the district had a capacity of 11 million gallons per year to serve 21 farmers. Today the district sells more than 537 million gallons per year and is planning to expand capacity to serve increasing demand. Capacity is expected to more than double from 1,600 acre feet produced annually to more than 4,000 acre feet. The treated wastewater is discounted compared to other water sources promoting its use by irrigators whose demand continues to grow.

One of the vineyard farmers in south Australia has a contract with a municipality in the Melbourne area for the supply of so-called grey water (i.e., non-potable water). This helps him manage the risks of uncertain irrigation water supplies and saves him to costs of possible alternatives. Gray water is becoming more widely adopted with cotton farms taking the initiative.

Source: International Herald Tribune [77], Rabobank

Unfortunately, while very lucrative, wastewater irrigation may cause harm to public health if the water is untreated. It is estimated that 20 million hectares worldwide are irrigated with wastewater, much of it untreated. One million farmers rely exclusively on wastewater, and up to 200 million use it in combination with other water sources.[78] Adequate information is required on how the risks of wastewater irrigation can be mitigated, for example by irrigation methods that avoid crops - often vegetables - coming into direct contact with sewage water.

Farmers also collect agricultural waste (drainage) water in 'storage tanks' at the bottom of their fields, for reuse later in the season. Sophisticated water collection and reuse systems are employed in greenhouse horticulture and floriculture in the Netherlands, Kenya and elsewhere.

3.7 Desalination

Sea water or brackish groundwater is turned into fresh water by desalination. Large-scale desalination typically uses large amounts of energy as well as specialised, expensive facilities, making it a costly option to save or free up irrigation water. This option is a commercially viable investment when three conditions exist: energy that is inexpensive or heavily subsidised, acute water scarcity, and high-value uses for the desalinised water.

Two environmental concerns may impede desalination: its energy-intensity and associated greenhouse gas emissions, and disposal of the salty brine by-product.[79]

Meanwhile, costs are coming down with advanced desalination through reverse osmosis, now at USD 0.50 to 0.60 per m^3.[80] That means that more water uses are coming into play for desalinised irrigation water, including high-value crops such as vegetables or flowers in the Middle-East and Mediterranean countries such as Spain (Box 10).

Box 10 Desalination and Agriculture in Spain

Spain ranks number one in agricultural desalinated water use in agriculture. Despite high energy costs Spain's rising demand for different crops (as well as government subsidies) have made irrigation with desalinated water economically feasible. About a quarter of Spain's 300 desalination plants supply water for irrigation. Most are small with a capacity of less than 1,000m^3/day and treat brackish rather than sea water.

Source: FAO [81], 2006

The development of desalination worldwide varies with water scarcity. In the Middle-East desalination capacity is rapidly expanded as water demands soar. Currently, Saudi Arabia produces 3 million m^3 a day, which is expected to jump to more than 9 million in 20 years.[82] Similarly, Israel is planning to nearly double its production capabilities by 2020 from 400 million m^3 to more than 750. Water-scarce, fast-growing countries like China and India are also expanding desalination capacity, and so are Australia and California (mostly for the production of drinking water).

3.8 Supplemental and Deficit Irrigation

Supplemental irrigation in otherwise rainfed agriculture is the occasional water gift to support crops through a short drought, thus protecting yields. As such it is an irrigation strategy that may become more important with climate change.

'Regulated deficit irrigation' is a way to cope with reduced water availability in irrigated agriculture by cutting back on the frequency and/or length of irrigation. The aim is to concentrate what irrigation water is available on the critical stages of crop growth. Timeliness is key, and for deficit irrigation to succeed, a farmer must be able to control the water supply (i.e., in 'on demand' irrigation systems or in ground water irrigation).

Both irrigation strategies are meant to optimise crop-water productivity (and incomes), either by protecting yields or by saving water. According to Box 11, equipping fields for supplemental irrigation in Syria certainly proved a low-cost boon for farmers.

Box 11 Supplemental Irrigation of Rainfed Wheat in Syria

In Northern and Western Syria the area under rainfed wheat expanded from 74,000 hectares in 1980 to 418,000 in 2000 with the introduction of supplemental irrigation at a cost of approximately USD150 per hectare. The small but timely irrigation gift boosted crop water productivity as yields went up from 2 to 5 tons per hectare. Net profit of farmers increased with more than USD300 per hectare.

Source: Oweis, T. & Hachum, A. [83], 2003

Regulated deficit irrigation is often counter-intuitive to farmers and may require programmes that demonstrate that rather than maximising yields, they could pursue a strategy of optimising profits (which take the cost of irrigation into account). Profits are optimised by using less water than used for maximising yields; water is only used at critical stages in the growth cycle. This is illustrated in Figure 3.4. Profits from growing winter wheat on the north China plain improve with less irrigation, especially at higher water charges.[84]

Figure 3.4 Water Requirements and Profits in China

Source: FAO[85], 2002

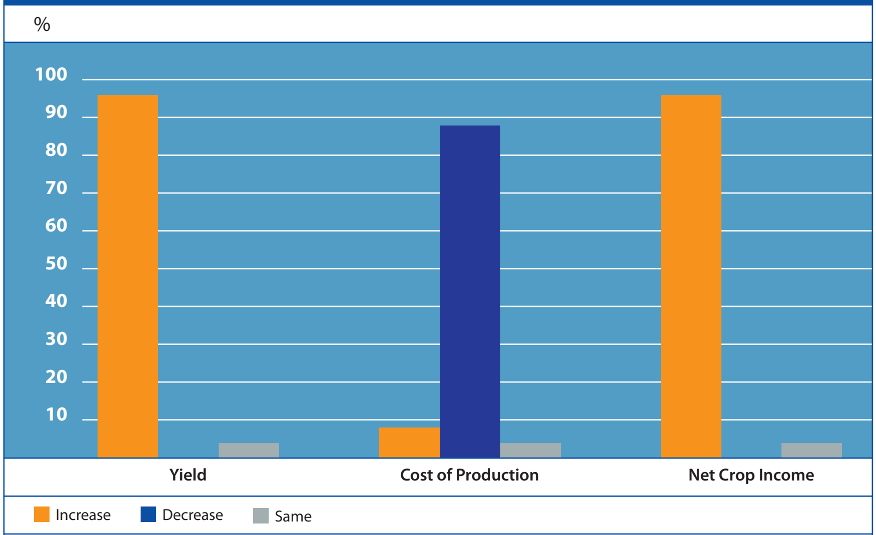
3.9 Water Conservation

Water conservation involves managing soil moisture and reducing evaporation through a variety of in-field techniques and methods. Many of these are fairly simple but still have short-term costs and long-term benefits which may be an impediment to wide-scale adoption.

Water conservation and soil fertility management are best integrated in efforts to improve crop-water productivity and include zero tillage, moisture retaining mulches, plastic sheeting, weeding and the improved timing of fertiliser and water gifts (e.g., night irrigation). Water savings from the use of soil-covering polymers, for example, can be 10% to 25%.[86] A more recent technology is the use of high-absorbent polymers in the soil, which vastly increases the water-holding capacity. Another important technique is improved levelling of fields to minimise rainwater runoff, to prevent water logging or to facilitate a more uniform application of irrigation water.

In the Indus Basin of Pakistan, researchers worked with farmers to access the impact of various water-conservation technologies and techniques. More than zero tillage, direct seeding, parachute transplanting, bed planting and crop residue management, it was the use of laser levels that had the largest impact on irrigation water use and profits. According to the vast majority of farmers' yields and profits were up as costs for water, fertiliser and other inputs were down, as shown in Figure 3.5.

Figure 3.5 Effects of Field Levelling on Yield Costs and Net Crop Income



Source: International Water management Institute[87], 2007

3.10 Drought and Salt Tolerant Crop Varieties

Besides efficiency gains in irrigated agriculture, crop water productivity can also be raised by adopting crop varieties that make optimum use of water availability, withstand droughts and higher temperatures, and tolerate saline water and soils. The latter is important as salinity, i.e., the accumulation of salts in the soil, is estimated to have affected one-third of all irrigated land worldwide.[88] When increasing the salt-tolerance of crop varieties or shifting to more salt-tolerant crops altogether (for instance, from rice to wheat or from wheat to barley), the stock of water available for agricultural production is effectively increased with inferior, saline or brackish water. Box 12 illustrates this.

Box 12 Salt-tolerant Crops in Australia

In South Austalia's Riverland area, orchardists Dave & Anita Reilly addressed increasing salinity levels on their farm by selecting date palms as a crop more suitable to water and soil conditions (as well as climate change impacts) than citrus, fruit, almonds and vine plants. They also intercropped the date palms with pomegranates and artichokes which benefited from the shade of the palms. By employing drip irrigation the Reillys have been able to reduce their water use and increase farm profits.

Source: Australian Government Department of the Environment and Water Resources [89], 2007

As above example illustrates, drought and salt tolerance is also matter of finding a suitable combination of crops, supported by appropriate farming practices. More than on financial investments, its adoption depends on targetted information and demonstration. International and commercial agricultural research has already developed millet and sorghum varieties that have improved hardiness to salt and drought conditions and now cover 34% and 23% of the total area under these crops in South Africa. A more drought-proof variety of barley, the world's fourth most important cereal crop, is widely grown in northern Africa and the Middle East.[90] Research on sugarcane, the main biofuel (ethanol) crop, has achieved an 80% increase in the level of sucrose produced per plant, as well as a crop tolerance for a drought of up to 45 days.[91]

3.11 Conclusion

In this chapter we have reviewed different technologies that exist to increase water-use efficiency. Some technologies such as system automation, wastewater reuse or desalination could be applied at the level of irrigation systems. Other technologies such as drip irrigation or water conservation are more suitable for application by individual farmers.

Beside mature technologies, innovations are continuously taking place from on-demand water distribution, to soil moisture monitoring, integrated information systems, or improved drought and salt tolerance of crop varieties.

While technologies differ in their cost and sophistication, there is at least technical scope for large and smaller farmers alike to reduce their water consumption and free up water resources. The key question thus becomes: why are these technologies not much more widely adopted?

In Chapter 4 we will confront this question and discuss how policy reforms and market developments are helping to create more favourable conditions for private investments in irrigation efficiencies and crop water productivity.

4 Scaling up Private Investments in Irrigation Water Use Efficiency

In this chapter we will first look into current public and private investment flows into the irrigation sector and discuss the reasons why these flows are declining and insufficient. After that we will highlight emerging policy examples that are lowering the risks and increasing the attractiveness for private investments in the irrigation technologies and strategies discussed in the previous chapter. Finally, we will show examples of positive market signals that might support the view that private investments in water are emerging as opportunity for private investments.

4.1 Financial Flows into Irrigation

Investments into irrigation vary by type and by country, reflecting different conditions and institutions.[92] They range from large-scale irrigation system modernisation in South Asia to on-farm investments in Chile. Irrigation systems can be built, owned and managed by public agencies (with or without development assistance), or privately financed and operated by farmers. The latter tends to be the dominant type of irrigation in most OECD countries.

There are no reliable statistics on global irrigation financing, not even for large-scale irrigation. The best estimate of annual investment and operation and maintenance costs, according to the World Bank, is in the range of USD 30 to 35 billion.[93] The Panel on Financing Water Infrastructure estimates that currently some USD 32.5 billion a year is invested in the irrigation sector whereas USD 40 billion would be required to meet Millennium Development Goal 1, i.e., halving the proportion of people who suffer from hunger. The water sector as a whole would require USD 180 billion per year to meet the Millennium Development Goals by 2015.[94]

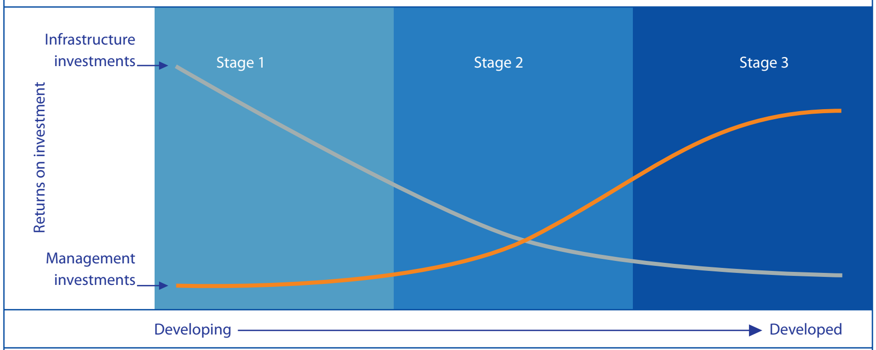
Figure 4.1 Indicative Annual Investments in the Water Sector in Developing Countries to Meet the 2015 Development Goals

	Indicative annual investments in water services in developing countries (USD billion)	
	Current	**Required from 2002 to 2025**
Drinking water	13	13
Sanitation and hygiene	1	17
Municipal wastewater treatment	14	70
Industrial effluent	7	30
Agriculture	32.5	40
Environmental protection	7.5	10
Total	75	180

Source: World Panel on Financing Water Infrastructure [95], 2003

Developing countries will need most of the investments in irrigation infrastructure whereas in most OECD countries the focus will be on management and operational improvements, as the World Bank shows in Figure 4.2.

Figure 4.2 Investment Returns by Stage of Development



Source: World Bank [96], 2006

Investments into the irrigation sector come from four sources of finance: user fees, government contributions (raised by taxes or borrowed), private investors and Official Development Assistance (ODA).

According to the World Bank, government contributions have declined, and so has lending by the World Bank itself and other donours from a peak of about USD 3 billion per year in the mid 80s to about USD 2 billion by the late 90s. This reflects fewer opportunities for the expansion of large-scale irrigation as well as an increased awareness of environmental and social impacts and related investment and reputational risks, also in the developing world. The World Bank estimates that future financing needs to increase again to USD 4 billion a year for the next 20 years.[97]

The Task Force on Financing Water for All concluded that despite all commitments for increased assistance and progress made with new financing mechanisms, it is unlikely that the total of public finance into the water sector as a whole - from government budgets or ODA - will increase substantially. The same is probably true in irrigation, even in the face of future food demands.

That moves the spotlight onto private investors. FAO estimated that private investment fully finances 20% of the world's irrigated area and provides about half of the investments for the remainder. This would imply that private investment accounts for about half of total agricultural water investment financing, which is consistent with the 50% share of the total irrigated area that is farmer or privately managed.

So far, public-private partnerships in irrigation, however, have not really taken off. As Figure 4.3 shows the World Bank has identified only 21 cases world-wide, including in France and Australia.[98] Many cases involve the public service delegation of public services (PSD) in system operation, maintenance and management (OMM), rather than investments by the private sector partner. Investment contracts without involvement in system operations are rare as repayment risks are deemed too high. Comparing irrigation to drinking-water supply and sanitation, the World Bank sees higher risks and therefore fewer public-private partnerships.

Figure 4.3 Public-Private Partnership Contracts in Irrigation

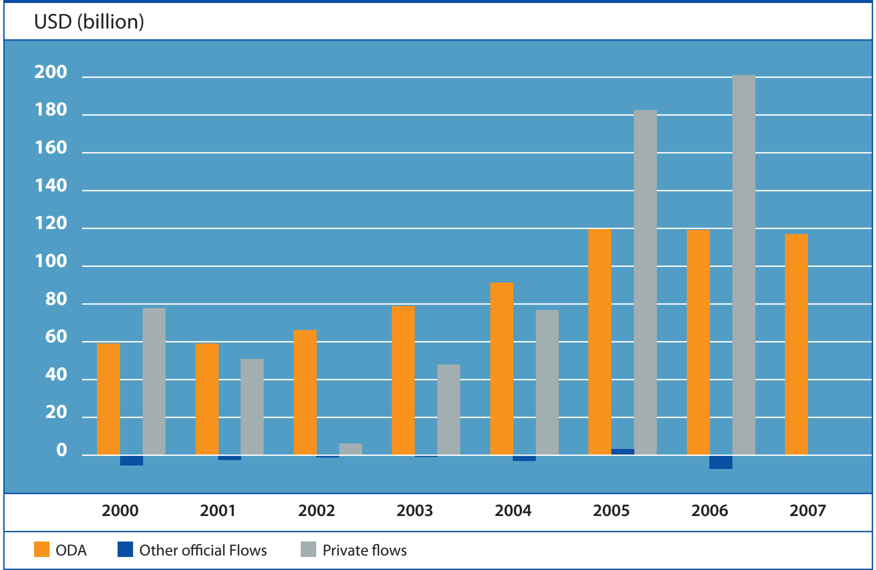
	PPP contracts in the 21 case studies			
	Number of contracts	Percentage of total	OMM	Investment
Service contracts	4	19	4	0
PSD on OMM only	7	33	7	0
PSD on investment with OMM	8	38	8	8
PSD on Investment only	2	10	0	2
Total PSD contracts	17	81	15	10
Total contracts	21	100	19 (90%)	10 (48%)

Source: World Bank [99], 2007

Private investment trends in irrigation are hard to detect as much of the investment is incremental, on-farm and indeed private. Foreign direct investments in plantation-type projects have dwindled over the years, multinational food and beverage companies have concentrated on the lower-risk, higher value-added end of the value chain such as food processing and distribution. On the other hand, ongoing efforts at private sector involvement in irrigation have attracted domestic entrepreneurs. In many countries in Latin America for example, agribusinesses are investing in irrigated agriculture on a large scale.[100]

So whereas formal public-private partnerships in large-scale irrigation are still few, it is remarkable that private investments do constitute a most important source of finance for development, in developing countries. The relative importance of the volume of private net disbursements relative to ODA is depicted in Figure 4.4. The question is now why private investments in the irrigation sector have not sparked off in the past years. We will come to that in the next paragraph.

Figure 4.4 Private Investment and ODA into Developing Countries



Source: Based on OECD

4.2 Irrigation Investment Barriers

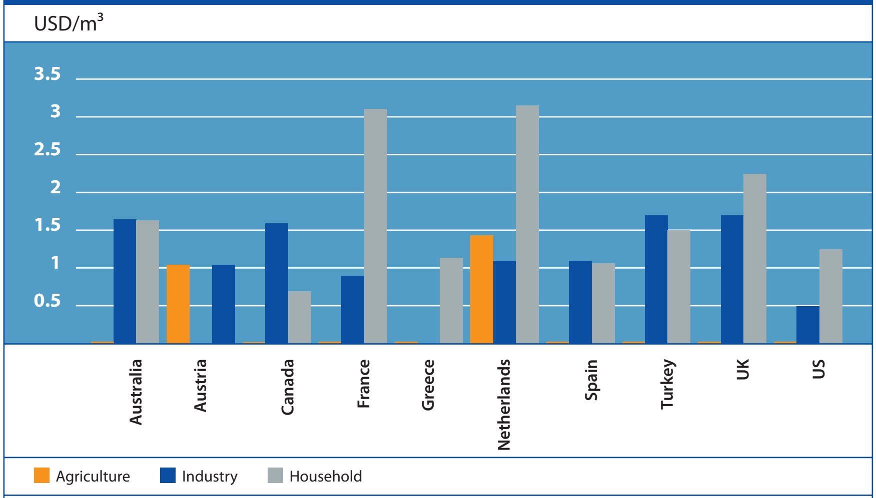
Specific characteristics of the water sector have long complicated the case for private investment. They relate to project specifics as well as to the wider institutional and political environment, and affect large-scale as well as on-farm investments in irrigation development and efficiency.

Low water prices

Irrigation water prices are invariably much lower than the economic value of the water, but in most areas they are even lower than the cost of supply. In Spain, for instance, farmers pay just 2% of the supply cost.[101] The analysis of a new project in Utah found that providing irrigation will cost 40 times more than farmers will be paying for it.[102]

Other examples are found in California's Central Valley where farmers pay only 20% of the supply cost and just 2% of what Los Angeles residents pay for their drinking water.[103] As such, average farm water prices in the US and France are about 10% of industrial water prices.[104] A similar picture emerges from the last comparative study done by the OECD: farmers pay a mere fraction of what industry and households pay for their water (some of that can be accounted for by the difference in quality of the water supplied).

Figure 4.5 Comparison of Water Prices (Late 1990s)



Source: OECD [105], 1999

Many governments subsidise water because of concerns about equitable access to drinking water and water required for food production. They also worry about the effect of (much) higher water prices on farmer incomes and may resort to irrigation quota instead to manage water scarcity, as in the Charente, France.[106]

Low water prices mean that farmers, irrigation agencies and investors lack an important incentive to use less water or to invest in water-efficient irrigation infrastructure, equipment and strategies. Physical consequences may include over-irrigation, waterlogging and salination, increased runoff and water pollution, lower groundwater tables and reduced river flows.

Financially, many irrigation systems become trapped in a low-level equilibrium of low water-fees and poor water-services. Under-priced water means underinvestment, poor maintenance and depletion of assets, low water-payment rates and increased dependency on scarce government funds.

Market distortions

Agriculture is expected to serve multiple social objectives including food security, rural development and poverty reduction. Distortions of economic efficiency proliferate as governments suppress (urban) food prices and subsidise key farm inputs such as energy (electricity or fuel for pumps). Thus farmer incomes are constrained while the use of scarce resources is being encouraged. One example is northern India where, owing to subsidised electricity, groundwater development has soared to unsustainable levels.

Tough investment profile

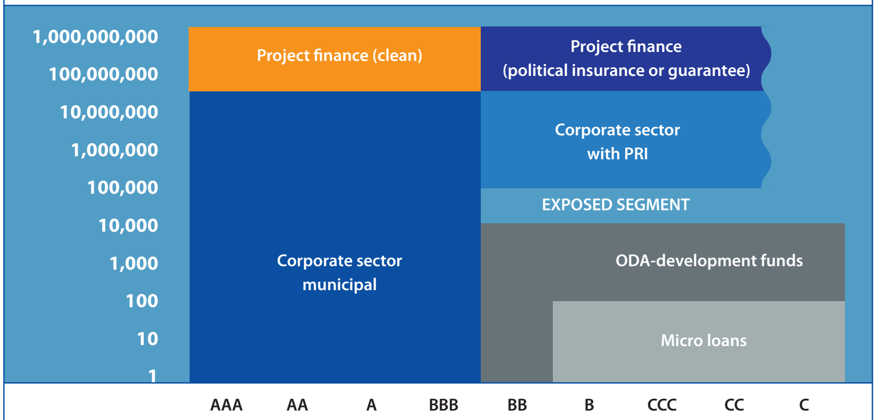
Large-scale irrigation investments typically have immediate costs, distant or uncertain real benefits and long pay-back periods, which put them in a difficult category for private investors. A number of country-, commercial- and water-related risks add to the innate unattractiveness of the investment profile. These risks include government interference in water, input and food prices, and the difficulty of liquidating fixed irrigation assets when investment projects turn sour.

High country risks

Large-scale investments in water infrastructure in developing countries are particularly hard to finance as the country risk is deemed to be too high (BB+ or lower) to be financed without some political ensurance/guarantee. The majority of the water projects tend to fall in the 'exposed segment' in Figure 4.6. where projects do not get financing as they are too big for development finance (ODA) but too small for corporate or project finance.

Figure 4.6 Water projects segmentation and financing options

Project size (USD, log scale)



Country or municipality risk rating

Source: World Water Council [107], 2003

Low water-prices, market distortions, a difficult investment profile and sector and country-specific risks seriously complicate private investments especially in large-scale irrigation infrastructure: risks are perceived as too high and incentives to invest are too low. On-farm investments on the other hand tend to be more attractive for (domestic) private finance as some of the above constraints can be mitigated.

4.3 Emerging Policies for Private Investment in Irrigation Water-use Efficiency

The World Bank, OECD and many other international organisations have produced excellent publications on irrigation policies. Here we will merely highlight key policies and examples that may favour private investors' willingness to consider investing in water infrastructure and the water technologies of Chapter 3.

Raising water prices

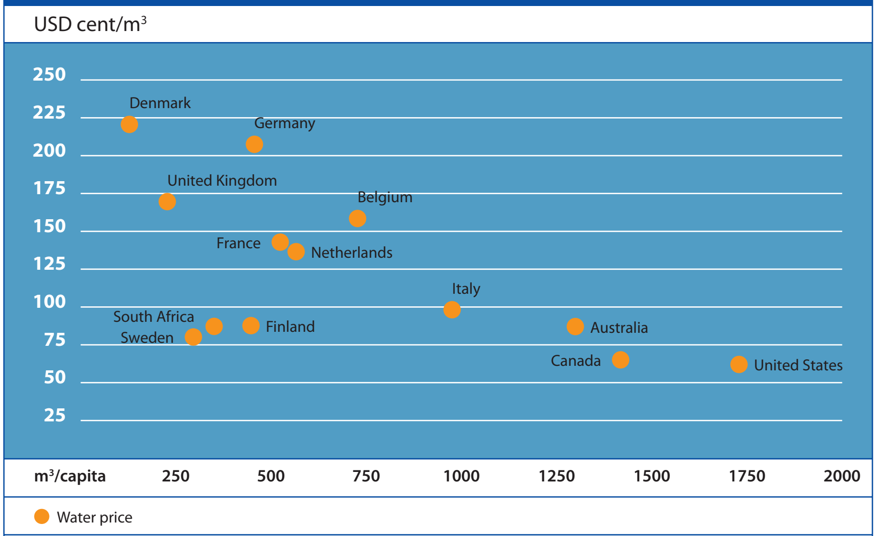
For an economically efficient allocation of scarce water between agriculture, industry and municipalities, irrigation-water prices would have to more accurately reflect the economic opportunity cost, i.e., the value of the water in its 'best alternative' use.

While true in theory, this is unlikely to be implemented in practice, in cases where the need for irrigation cost recovery is more likely to drive water prices to a level that 'merely' includes the financial cost of producing, transporting and treating water.

Considerations of economic efficiency require that water prices must convey the notion of water as a scarce natural resource. Higher water prices are a prerequisite for a more sustainable use of irrigation water as they provide farmers and investors with the necessary financial incentive to economise on their water consumption and/or increase their investments in water efficient technologies.

Whether farmers will reduce their irrigation-water use in response to price rises (i.e., the demand elasticity) depends on the cost of irrigation water as a portion of their total and variable production costs, as well as on the availability of water-efficient technologies or alternatives. Figure 4.7 below shows the relation between high (municipal) water prices and low water use.

Figure 4.7 Water use and water prices



Source: Credit Suisse [108], 2007

Raising irrigation-water prices is politically sensitive. Participation by farmers and full transparency in tariff setting is necessary but not sufficient. Where farmers have water rights and responsibilities in managing the irrigation service, there is a better chance that resistance to higher water prices can be overcome.[109] Another strategy is to allow for a transition period during which water prices can follow (rather than precede) improvements in water deliveries. Also, price increases can be accompanied by targetted subsidies - not on water but on water saving equipment, for example - to help manage irrigation-water demands, as in Israel and California.

Box 13 Raising Water Prices in Israel and California

In 1951 Israel recognised that its water resources were not sufficient to irrigate all of its arable land. The Ministry of Agriculture drove a variety of measures to increase crop water productivity. Farms were given fixed allocations based on area cultivated and crops grown. Irrigation water was metered and priced by an increasing block structure. Low interest loans were given to farmers to install more efficient irrigation systems. This integrated approach helped to increase the area under irrigation, and reduced water use per hectare by more than 37%. Crop yields improved more than threefold and crop values tenfold.

The Broadview Water District of California developed a two-tiered water price structure in which the first 90 % of water use was charged the standard rate and any water after that was priced at a 250% premium. The water board also offered low interest loans to farmers to encourage better water management. The programme was successful, water use efficiency increased and the water use dropped by half. The simple structure, fair pricing and transparency helped all stakeholders to be satisfied with the programme.

Source: Worldwatch Institute [110], 1999; World Bank [111], 2006

In countries where farmer incomes are the main concern when raising water prices, governments might consider switching from subsidies on scarce inputs - like irrigation water but also energy - to direct income support. Thus they would end incentives for overuse, while shielding farmers from the impact of higher water prices.

Improving cost recovery

The opportunity to recover costs and make profits is ultimately what will attract investments to the irrigation sector and water-efficient technologies. Governments, as in Egypt, are increasingly prepared to create those opportunities and raising water prices are an obvious and necessary (albeit not sufficient) first step.[112]

Cost recovery would require water prices to reflect the financial cost of supply, i.e., production, distribution and treatment of irrigation water. Irrigators are increasingly required to pay towards costs of system operation and maintenance and - in the longer run - capital charges and depreciation.

As higher water prices boost the revenue of the irrigation service organisations, they can reduce their dependency on government subvention (and interference that tends to come with it), while improving the quality of the irrigation service as organisations become more accountable to their client irrigators. Higher water prices can thus help to move from the low-level equilibrium to a high-level equilibrium of higher prices and better service.

Defining water rights

Water resource management can be broadly defined, but usually includes the allocation of water among different uses on the basis of economic, social and environmental criteria. In situations of water scarcity, farmers can be confronted with uncertainties as to the availability and delivery of irrigation water. Minimising such uncertainties may increase farmers' willingness to invest in efficiency improvements.

For higher irrigation-water use efficiencies, it is important that farmers' water rights are clearly defined, that they can be enforced within a clear legal framework and, possibly, that they can be traded between farmers and with industrial and urban users. The latter will lead agricultural water prices to reflect their economic value in alternative uses, and may provide incentives for efficiency improvements as farmers have the opportunity to sell or lease to other farmers or sectors the irrigation water they save. Box 14 shows that that is the case in Chile.

Box 14 Water Rights in Peru and Water Markets in Chile

The government of Peru has launched a massive effort to formalise traditional water rights to ensure that water user organisations have legal security on the use of irrigation, thus creating incentives to private investment, to operation and maintenance of schemes, and to water conservation. To this end a water rights registry has been set up, employing satellite images, and licenses and permits are being issued. In a year's time, the programme had formalised 250,000 water rights.

The National Water Law of Chile created markets for the trade of water rights. As a result, irrigation efficiency improved by 22% to 26%, freeing up water for expanding the irrigated area with 264,000 hectares. The markets and associated efficiency gains also saved the equivalent of USD 400 million dollars in energy costs over 17 years. The water markets also drove other sectors to reduce their water use: the pulp industry increased its efficiency by 70%.

Source: UNPD [113], 2006; World Bank [114], 2006

In Australia, water rights market has developed into certain maturity. Water has its own title, and value to land and morgages can be taken over water licences to advance funding.

Reducing risks

Irrigation system development and performance can be improved by drawing on private sector management expertise and investment capital. While the benefits may be understood, the costs often are not. Policies designed to attract private investors into irrigation infrastructure or management improvements must specifically reduce a variety of risks:

- country-specific risks such as political interference in system management, currency fluctuations, limitations regarding the liquidation of assets and expatriation of profits;
- commercial and financial risks such as insolvency of clients (farmers), difficulty of recovering payments, social unrest;
- specific risks such as water availability and demand uncertainties, and risks inherent in design and construction of complex projects.

The World Bank listed a number of ways to minimise these risks in Figure 4.8.

Figure 4.8 Risks and Mitigants in Private Sector Investments in Irrigation Development

Risks	General mitigants	Financing options
Project profile & cash flow	Financing structure to match project profile and cash flow	Sufficient grant & equity; Adequate loan tenor; Partial credit guarantees to cover later servicing
Production, client & credit	Credit risk assessment by experienced institution; Use of local financial intermediary	Credit risk insurance (e.g., partial credit guarantee); Collective security schemes; Liquidity & refinance facilities
Market	Governments provide market intelligence; Investment in supporting infrastructure (e.g., acess roads, storage facilities)	Adequate capitalisation of borrowers
Environmental	Investigation, due diligence, consultation, option appraisal; Appropriate risk allocation & retention by public sector	
Climatic	Diversify water sources; choice of drought-resistant crops	Weather insurance & exotic derivaties
Foreign Exchange	Use local capital markets for funds	Credit enhancement of local bonds & guarantees to local bank; MFIs raise funds locally, & on-lend in local currency
Sub-sovereign	Institutional reforms to ensure financial autonomy & save cash flow	External guarantees; Agreements with sub-sovereign institution & sponsor
Political, regulatory & contractual	Shareholder consultations in the decision-making process	Political risk insurance; Partial risk guarantees; Breach of contract cover; Participations (B loans) to confer preferred creditor status

Source: World Bank [115]

One of the first public-private partnerships in irrigation that has successfully established and mitigated the key sources of risk for private investments is the Guerdane project in Morocco as described in Box 15.

Box 15 Public Private Participation in Morocco

In 2004, the Guerdane Irrigation Project in Morocco was the first public-private partnership in irrigation in the world. The Moroccan government co-financed the USD 85 million project, consisting of a 100 km-long main from a reservoir, and 300 km of distribution pipes, combined serving 600 citrus farmers on 10,000 hectares of land.

Two private companies were prepared to invest USD 35 million and bid for the concession contract as, with assistance from IFC, the main risks were identified and properly addressed.

A detailed geohydrological survey, for example, mitigated supply uncertainties. Demand risks were covered by requiring farmers to pay upfront for their connection to the network, and obliging them to buy a minimum volume of water. The risk of drought was shared between government, concessionaire and farmers.

Owing to the way risks were structured and apportioned, the winning concessionaire was able to offer a water tariff that was actually lower than what farmers used to pay for unsustainable groundwater irrigation.

Source: IFC [116], 2004

Expanding market access

Investments in irrigation-water use efficiency require that farmers have access to markets for agricultural inputs and produce, as well as to markets for irrigation materials and services and finance. Some of these markets are local, others international. Market access does not just refer to the necessary physical infrastructure and transport facilities, but also to trade rules and regulations, and to information and communication linkages.

The willingness and ability of farmers, in developing countries in particular, to invest in water-efficient irrigation technologies can be increased by relaxing domestic and international trade restrictions on agriculture and/or agricultural products. Drip irrigation in Jordan took off because of direct access to markets for high-value crops.

Similarly, improving access to financial services can strengthen farmer's ability to invest in water-efficient irrigation technologies.

Extending information

On-farm adoption of water-efficient irrigation technologies often relies on information as much as on incentives for investment. One example is in-field water conservation, which is a matter of irrigation strategy rather than irrigation equipment. Wastewater irrigation is another technology which requires programmes to inform farmers about the costs, benefits and risks.

There are technologies such as low-pressure drip irrigation that potentially pay for themselves over relatively short periods of time. Their expansion could benefit from massive farmer-extension programmes, backed up by companies that can supply, install and maintain these systems.

The same may be true for supplemental irrigation, the idea that in the face of water scarcity and/or high water prices, it may be better to optimise income rather than maximise yields. Farmer information and demonstration is crucial too in the selection of crops or crop varieties and irrigation techniques that allow the use of inferior, brackish water.

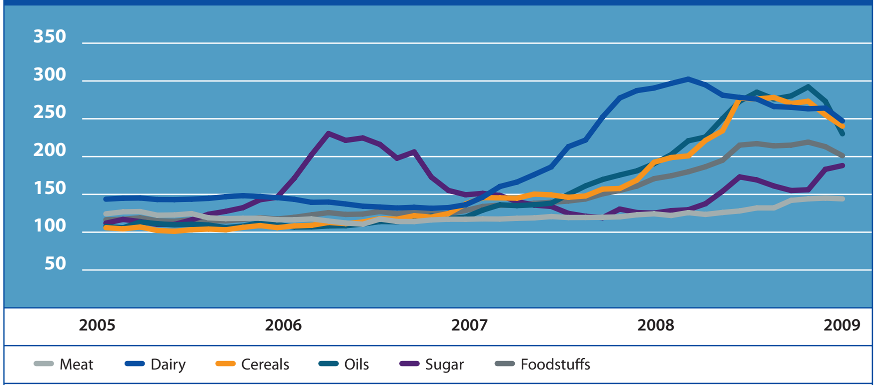
4.4 Market Signals for Private Investment in Irrigation Water Use Efficiency

While afore mentioned policy changes provide farmers and investors with information to reduce risks, and also incentives to invest in efficient irrigation technologies, markets are signalling more favourable conditions for such investments to be viable. Just like policies, these market signals differ in strength from one place to another.

Higher food and commodity prices

Reversing a decade-long decline, food and commodity prices have been increasing for a number of years, mostly driven by growing demands. Although they have fallen from record levels reached earlier this year (2008), prices are projected to increase by another 30% over the next ten years.[117] The fact that grain stocks are at historical lows may support that projection.[118]

Figure 4.9 Food Commodity Prices (Index)



Source: FAO[119], 2008

Higher food and commodity prices partly explain the 47% income gain US farmers have enjoyed in 2007. The current year is expected to be even better with farmer incomes 51% higher than the 10 year average.[120] Higher prices have been captured by the rising values of cropland and, in some parts the US, water rights.[121]

Higher incomes and asset prices are likely to increase farmers' willingness and ability to invest in crop water productivity and water-use efficiency improvements, where and when water is scarce. This is for instance illustrated by the reported strong and growing sales and profits of one US manufacturer of irrigation equipment.[122]

Higher input prices

Irrigation-water prices are rising around the world, including northern China and Tunisia where prices have increased fourfold over a decade.[123] Municipal water prices are also rising: over the past five years they have been up by 27% in the US, 45% in Australia, and 50% in South Africa.[124] Higher prices entice irrigators to reduce their water consumption and invest in water-efficient technologies, especially when accompanied by higher incomes and investment budgets.

Some of these technologies - for example, drip irrigation - have secondary benefits as they allow farmers to reduce pumping costs, and optimise the use of fertiliser and herbicides. As the prices of energy (fuel and electricity) and fertiliser have been going up even faster than water prices, the resultant cost savings may provide farmers with an even stronger incentive to invest in water-use efficiency improvements.

As fuel prices have soared by 400% since 2002 and fertiliser went up by 20% in 2007, these items have become even more prominent in farming cost structures. 47% of US farmers demonstrate this as they are engaged in energy saving projects, including reductions in water use in pump-irrigated areas.[125, 126]

Intensifying competition for water

With increasing water scarcity, the competition between agricultural (70%), industrial (20%), municipal (10%) and environmental uses is set to intensify. That competition is heavily regulated almost everywhere, and transfers to other sectors will be limited, at least as a percentage of agricultural water consumption. The competition for scarce water resources is, however, not without consequences as it may drive water prices up.

Irrigated agriculture is at a disadvantage in this competition for water because of the relatively low economic value it adds to a unit of water, compared to urban water uses that can and will pay much higher prices. However, this will not mean an unlimited sell-out of irrigated agriculture as other objectives such as food security, poverty alleviation and rural development are important considerations in the allocation of scarce water.

The intensifying competition for water and the higher water prices this will entail, presents farmers and irrigation boards with strong incentives to invest in water-efficient technologies, especially where they can sell or lease the rights to the volume of water saved. Farmers in Australia and California are, for example, finding it more profitable to sell or lease their water to municipalities rather than grow crops with it.[127]

Increasing investor awareness

Investors are increasingly aware of the risks and opportunities associated with water scarcity. These risks, which may affect farms, production plants and supply chains, can be material.

This growing awareness of the risks has created new opportunities for companies developing and/or producing (new) water technologies. Recent reports by major banks and investment funds demonstrate their keen interest in the themes of water scarcity and pollution, and in the solutions as offered by the water industry. Some have even started pondering the impact of water scarcity on other industries (including food & beverage), and coming out for more relevant disclosure on water-related risks.[128] Within the Rabobank Group, there are two dedicated water funds, those of SAM and Sarasin.

Emerging investment opportunities in agriculture originate from irrigation technologies that allow for higher water-use efficiencies (and thus mitigate water -related risks). For example, the drip irrigation market has been growing at a rate of 15% a year[129] and desalinisation capacity (mostly for municipal water production) has been expanding at a rate of 16.7% a year since 1997.[130] Companies that make and install water-efficient irrigation equipment are reporting mounting sales and profits.[131] Manufacturers of water meters are experiencing strong demand and expanding their offerings to include improved metering as well as entire systems technologies.[132]

5 Contributions by Rabobank

In the previous chapters we have argued that there is both the necessity and the opportunity to increase private investments in water-saving technologies to raise crop-water productivity and to meet the future demands for food, feed, fibre and fuel. As better policies combine with more favourable market signals, the irrigation sector may be able to break a history of low levels of investment. Before turning into Rabobank's role in attracting private investments, we first would like to introduce Rabobank to show that our involvement in and the attention for water is not a coincidence, but follows naturally and inevitably from our profile and values.[133]

5.1 Rabobank's Profile

Rabobank Group is a full-range financial services provider founded on cooperative principles. Its origins lie in the local loan cooperatives that where founded in the Netherlands nearly 110 years ago by enterprising farmers who had virtually no access to the capital market. Over the years, Rabobank has grown from a collective of small, cooperative rural banks into the largest all-finance concern in the Netherlands, and into the world's leading food & agri bank and a globally respected AAA player. Despite these enormous changes, Rabobank is still a cooperative, and local banks are the owners and 'shareholders', holding the same values and principles that typified the bank at its establishment.

Rabobank's roots lie in agriculture and this is our core competence. Our strategic framework profiles the Rabobank as a leading international food & agri bank with a strong presence in the world's major food & agriculture countries. Although our roots are in the Netherlands, this strategy also implies a continued expansion abroad.

At Rabobank, we are convinced that a healthy balance should exist between the economic, social and ecological effects of our activities and we aim to make a positive contribution to sustainable development in the countries where we operate. Rabobank's ambition is high and we want to remain one of the world's five most sustainable banks. Corporate Social Responsibility (CSR) is focal point in the bank's activities and we increasingly apply CSR aspects in our lending activities. On the basis of its Code of Conduct, Rabobank has formulated internal guidelines, such as a human rights policy. Rabobank has also signed, and is committed to, external guidelines, such as the OECD guidelines, the Global Compact on just and socially-responsible globalisation, the Equator Principles on social and environmental guidelines for project financing, and the Convention of the United Nations Environment Programme. In addition, Rabobank has processed principles and action programmes on important issues in food & agri, such as the necessity to safeguard food security and to ensure responsible management of land and (careful) use of water. In its credit-lending procedures Rabobank has chosen for an integral CSR approach. Potential clients and credit applications are reviewed in view of 10 CSR-aspects (Box 16).

Box 16 Ten Key CSR Aspects (Categories)

1. Corruption and/or bribery
2. Poor labour conditions
3. Forced labour
4. Child labour
5. Discrimination
6. Pollution
7. Depletion of scarce natural resources
8. Cruelty to animals
9. Poor treatment of indigenous people
10. Products/services imposing health or safety risk to consumers

For sectors in which Rabobank has a strong presence and that face serious sustainability issues, we have also defined more specific policies, such as our Soy Supply Chain Policy and Palm Oil Supply Chain Policy. These guidelines and policies on specific issues materialise in the operational lending and investment programmes. In addition, Rabobank is a board and founding member of, for example, the Round Table for Sustainable Palm Oil. These examples show Rabobank's strong commitment to CSR and sustainable development.

As water is a major input in agriculture, and while agriculture is the major user of water, issues related to irrigation water and technologies to increase water efficiency are of great importance for us as a food & agri bank. The water theme also impeccably fits our sustainability agenda. Water is thus a natural focal point for Rabobank's activities and perfectly fits with our values and principles.

The previous chapters of this report stipulated that water is becoming increasingly scarce and that water will be the limiting factor for agricultural production to accommodate the ever-growing need for food, feed, fibre and fuel. So far, private investments in water-saving technologies to raise crop-water productivity have been too low, mainly because of the high risks perceived by private investors, in combination with wrong market incentives and a lack of knowledge on appropriateness of techniques. We also argued that the irrigation sector may be able to break a history of low levels of investment, as better policies combine with more favourable market signals. Rabobank could assist in lowering risks and increasing incentives in order to raise investment levels in three ways:

- improving dissemination of knowledge;
- enhancing access to markets;
- stimulating private financing.

This is very much in line with what the former MD of the IMF and member of the UN Secretary General Advisory Board on Water and Sanitation, Mr Camdessus, stipulated: it is the channelling of finance that causes problems, more than the availability of finance.[134] It is precisely here that we think we, as Rabobank, could play a role.

Before we elaborate on Rabobank's role in these fields, it is worth stressing that Rabobank is already engaged in many ways in financing irrigation systems for many clients in Australia, Chile, Brazil and the US, for example. However, more needs to be done - in different countries, with different clients and with different crops. Focus should be on farmers that do not yet have access to irrigation techniques and equipment to increase water efficiency. This is the challenge to deal with.

5.2 Improving Dissemination of Knowledge on Water Issues

Improving knowledge

Rabobank has an extensive network in many countries throughout the world and has established relations with many important organisations active in, or dealing with, the food and agribusiness sector at the grass-root level as well as within the local, provincial/regional and central government. Rabobank also has an extensive network of local banks or local representations. Rabobank intends to employ these relations to increase awareness on water scarcity, water use and associated investment risks and opportunities.

Water risks for the agricultural sector range from worsening water shortages and their direct effect on crop yields, to government interventions to contain irrigation water demands through rationing and water pricing.

Increasing scarcity will lead to more emphasis on water metering, which would allow water prices to be based on the amount and timing of water use. Water scarcity, pollution and the regulatory response (often prompted by stakeholder concerns) are expected to drive up agricultural production costs that may or may not be passed up along the supply chain, or on to the customers. However, as illustrated throughout this report, this could lead to investments in more efficient water use. In the end, farmers may experience improved economic performance as the case studies reveal.

Rabobank aims to contribute to greater awareness of water scarcity and will learn about possible solutions - i.e., technologies and innovative strategies to increase water-use efficiency - through its clients. These ideas will be shared within our global network of shareholders. The present report is just one example of Rabobank's commitment to sharing ideas amongst its clients and partners in different countries.

A water lable for companies?

The starting point for raising water-use efficiency is measuring how much water is being used in the production of agricultural products, such as food and beverages. Recent research has focused on the 'water footprint' of various goods and services, which broadens water use to also include the water used in the supply chain, i.e., the water 'embedded' in various inputs.[135] Direct water use in the production of food and beverages is usually a mere fraction of the total water used in the agricultural supply chain.

Trading agricultural products is effectively trading 'virtual water', i.e., the water embedded in their production. Linking the water footprint of specific food and beverage products to local water availability can shed some light on the sustainability of water-intensive production of agricultural goods.

If water was priced in accordance with its scarcity value, a more sustainable geographical distribution of food production might emerge, where some of the most water-stressed regions (e.g., Australia) would no longer export highly water-intensive commodities (e.g., rice).

In acknowledging the carbon footprint, the development and adoption of a corporate standard to measure the direct and indirect water use might also be a useful concept with a value add to the already existing water hallmarks. If applied, water use could also be an aspect to be considered in loan requests or investments for a bank's clients. Such a 'water lable' would increase the visibility of the issue, assist benchmarking and comparisons between companies and encourage water savings.

Rabobank is one of the many companies that already measure their own direct water usage. Rabobank's efforts are highlighted in Box 17. It must be noted, however, that Rabobank's water use is limited compared to sectors that use water in their production processes.

Box 17 Measuring Water Use within Rabobank

For some years Rabobank has been monitoring the energy consumption of its member banks, not only to track actual consumption levels per employee, but also to target measures to improve energy efficiency. Benchmarking and comparisons between participating banks provide triggers for continuous improvements. Similarly, from 2007 water use per member bank and employee is being monitored and reported.

Next to a possible company-level water lable, it would also be of interest to link the water use associated with the main inputs procured by a company (commodities and intermediate goods and services) to the water scarcity in the regions of their production. A percentage use in relation to the volume of water available would be preferable as it would give more insight in usage rather than absolute figures. In practice, it may now be difficult to realise, as in many countries information on the exact volume of water - available in aquifers - is lacking, but GPS and satellite technologies may soon also be more broadly applied for this purpose.

5.3 Enhancing Access to Markets

Developing local capital markets

Water-service revenues are nearly always in local currencies, so investment capital that is raised abroad exposes foreign investors to an exchange risk. On the other hand, in many countries local capital markets are too small and immature to offer loans of sufficient duration for larger investments in irrigation systems.

In addition, individual farmers often do not have access to local credit markets even where they exist, which obviously forms an impediment to invest in more efficient in-field irrigation technologies.

Rabobank contributes to developing a range of (long-term) financial instruments and improving farmers' access to credit markets through its assistance to local banks.[136] Rabobank is participating in or having strategic alliances or representations with local banks in Africa, Asia and Latin America with the aim of professionalising credit and banking services. It is also engaged in efforts to tap into domestic savings and attract local pension funds and institutional investors to the agricultural sector.

Supporting micro-finance institutions

Next to support to local banks, Rabobank has gained much experience in establishing micro-finance institutions (MFI). MFIs are considered an important step for individual farmers or groups of farmers to obtain credits from such institutions (Box 18). They can also present the irrigation sector with lessons learned from other sectors where individual clients organise themselves to assume a collective responsibility for the repayment of loans.

What Rabobank aims to achieve is that both clients and MFIs mature over time. Smallholders could start with micro credits, followed by larger, more commercial credits when production increases and, in due course, they might eventually need bigger loans from a formal bank. Based on increasing financial and banking experiences, MFIs could also develop themselves into full-fledged banks.

Box 18 Micro-finance in Uganda

Since 2002, farmer organisations in three western districts in Uganda have established MFI's which initially provided limited savings and credit facilities, based on farmer contributions. With intensive technical assistance and financial support of Kabarole Research Centre and the Rabobank Foundation, some of them have evolved into independent, financially sound organisations offering credits on more commercial terms to (groups of) farmers.

Box 19 highlights an interesting example from the textiles sector that could be emulated in irrigation systems to help address the problems experienced in participatory irrigation management and irrigation management transfer to farmer organisations.

Box 19 Producer Organisations and Ownership

Kuyichi produces natural cotton clothing. It obtains its inputs from producer organisations it has helped to establish, and which own shares in the mother company. Thus, producer organisations are committed to the Kuyichi success (which is used in marketing the brand). Participatory irrigation management has been not been successful so far. Maybe lessons could be retrieved from cases - such as that of Kuyichi. Irrigators could establish organisations for adequate representation in the irrigation board or even for taking ownership in the irrigation service.

Improving Access to Physical Markets

Just as farmers need access to credit, they need access to domestic and international markets for their production. Rabobank is putting much of effort into developing farmer cooperatives and organising supply chains to link small farmers to big markets. As an agribusiness bank and cooperative with a local presence in many countries, Rabobank is well-placed to organise farmers and facilitate their access to markets.

An interesting example of farmers being linked to the market through the production of sustainable products, is the 'pro' initiatives on different agricultural products (Box 20).

Box 20 Linking Farmers to Sustainable Production

Rabobank has been engaged in several initiatives to improve the sustainability of farmers' production processes of to and link them with traders or end-producers to ensure a steady off-take of their produce. Sustainability is not only related to production but also to the other aspects of 'people, planet & profit', such as labour conditions. Rabobank identifies with end producers' preparedness to engage in sustainable production and to assists farmers in their transformation to sustainable production. Initiatives for coffee (Foundation 'Progreso'©), cocoa ('procacao') and fruits ('profruta') have been up and running for years now, while that for cotton ('pro cotton') is being established.

5.4 Stimulating Private Financing

Designing Innovative Finance

To overcome the 'innate' investment risks of the water sector and, more specifically, to attract the private sector to investing in water infrastructure and water use efficiency improvements, financing innovations are called for.

One example of an innovative form of public-private partnership is the Sino Dutch Water Fund in which Rabobank played an important role (Box 21).

Box 21 Sino Dutch Water Fund

The Sino Dutch Water Fund was initiated by a number of Dutch investors, Rabobank and the Chinese Greentech Engineering Co Ltd. The fund developed a new PPP model for a contract awarded in Yuanping. Apart from the government of China and the investors mentioned it also involves a third party, the industrial client. In this model, private investors build and operate the waste-water treatment plant, with revenues coming mainly from selling the treated water to the industrial partner. The innovation is that the company waives the fee it would otherwise charge the domestic users for treating the water, but it will retain the income it generates from selling the treated water to the industrial user to whom the water is provided (a more secure income stream). The government will in its turn collect the fee charged to the municipal clients for the wastewater treatment and use this to pay for the upkeep of the sewerage network which it continues to own and maintain. In this way, the 'polluters pay' principle can still be applied.

Rabobank is also involved in a public-private partnership (PPP) in the Netherlands (Box 22). Although this also involves waste-water treatment, it demonstrates the efficiency gains that can be realised by drawing on private-sector experience to run a public service.

Box 22 PPP with Rabobank for Wastewater Treatment in the Netherlands

The new wastewater-treatment installation, Harnaschpolder, the Netherlands, is one of Europe's biggest. It was realised as a partnership between the (public) water board of Delfland and the (private) consortium Delfluent, consisting of the water companies Violia and Evides, the construction companies Strukton and Heijmans, and Rabobank. Delfluent will be responsible for the design, the construction, the financing and the management of the installations for 30 years. The public-private partnership, the first in Dutch water management, achieved a cost saving of 17% on the contract sum.

Through the financing of innovations, it is possible to mobilise new investments that would or may otherwise have been financed at higher costs - or not at all. Morocco, for example, attracted private investment by adequately mitigating and sharing investment risks between public and private partners. The country has already signed three water and electricity concessions, and is preparing for three more. Another example is India, where an urban development fund has been established to raise funds from the local bond market for a group of municipalities.[137]

Augmenting Development Finance

Rabobank is a considerable contributor to development, through grant-making by the Rabobank Foundation, but also through regular banking activities as it supports a cooperative approach to rural development as discussed above. The Rabobank can apply its activities effectively through its proximity to small farmers and agribusiness clients in developing and emerging countries in Africa, Asia and Latin America.

Rabobank Foundation contributes to sustainable development, supporting microfinance institutions, producer organisations and other supply-chain initiatives. Development financing could often be used to support commercial finance. Development finance could be used to finance non-commercial elements in projects that are nevertheless essential to setting a right framework for commercial finance. Through a grant by its Foundation, Rabobank for instance helps farmers in Mozambique to gain access to commercial funding (Box 23).

Box 23 The Illovo Group Holding

The Illovo Group Holding is one of the leading producers of sugar and related products in southern Africa. Plans are being made to rehabilitate and expand Illovo Sugar Maragra Acucar Ltd in Mozambique, a plantation and sugar factory that was ravaged by the war.

Presently, the land is owned by small and some larger farmers organised in three small and rather weak farmer associations. Rabobank Foundation is supporting the establishment of larger, more powerful farmer associations to increase efficiency in sugar production, to improve relations between sugar farmers and Maragra, and to facilitate payments. Grant funding is made available to improve the irrigation and drainage system and land use.

Rabobank is also partner in Banco Terra, a new agricultural bank that provides credits to farmer associations once they have matured and become bankable.

In response to a call from the Dutch government, Rabobank initiated the Sustainable Agriculture Guarantee Fund (SAGF). The fund aims to enhance the access of small- and medium-sized producers of sustainable agricultural products to working capital.

Besides new initiatives and new donours, there are also new financing structures. One of the very recent examples of innovation in financing and a new way of working is the development of 'peer to peer' platforms establishing a direct link between individuals in developed and less developed countries to stimulate development without complete intervention of banks or development organisations. While the initiative is till in its early stages, Rabobank is reflecting on the idea to facilitate financial transactions between individuals and thus save the cost of intermediaries and fulfill the needs of the customers themselves, as well as to restore the direct contact and accountability between the provider of capital looking for specific returns and the user of capital realising those returns.

One could imagine that this model could also be applied to water, for example by water consumers in rich countries sponsoring/paying directly for the improvement of water services in developing countries.

Above financing innovations are best seen as examples to stimulate thinking about ways to increase development and water finance and attract private investors to investments in improving water-use efficiency and crop-water productivity.

Financing new technologies

Rabobank is investing directly in companies that are involved in the production of new water technologies. In the Netherlands venture capital could be provided to individual companies that have developed new, promising techniques. So far, the focus has been foremost on renewable energy and biofuels and less on water-saving technologies in irrigation and wastewater treatment. In the future this may change, however.

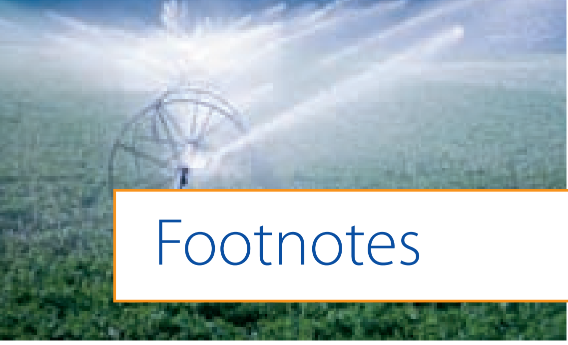
In addition to the venture capital vehicles within Rabobank, there are also two sustainable investment funds within the Rabobank Group that invest in water specifically: the SAM Sustainable Water Fund and the Sarasin Water Fund. These funds invest worldwide in companies that promote sustainable water management. The investments cover water supply and wastewater, as well as all the technologies and services relevant to water.

5.5 Agenda for the Future

Rabobank acknowledges that there is an urgent need to increase private investments in technologies increasing water-use efficiency to raise crop-water productivity. In the above paragraphs, we have stipulated which role the bank could play in overcoming the hurdles for private investments, and also in triggering these investments.

Rabobank would also like to extend lending to or investing in the irrigation sector to companies that do not yet have access to these technologies. Opportunities may rise in the field of irrigation techniques, water-saving technologies, reuse of wastewater, desalinisation technologies and other technologies aimed at increasing water-use efficiency or at augmenting available water resources.

We, as Rabobank, will take a flexible attitude and use our imagination and innovative capacity to try to find solutions. Together with our clients, Rabobank will seek for good opportunities that contribute to raising water efficiency for irrigation. There is too much at stake to justify a lukewarm attitude: water is scarce, it is an essential ingredient to life, and there are no alternatives to water.



Footnotes

1 The technical solutions presented in this report are broader than only technologies to increase water-use efficiency as we also deal with other technologies aimed at water conservation, such as using drought and salt-tolerant crop varieties or deficit irrigation, or techniques to increase water availability such as (waste) water reuse, automated monitoring and measurement of water flows & distribution devices and desalinisation techniques. We have comprised all these techniques under the heading 'water use efficiency' so as not to dilute the main message of this report: water is becoming increasingly scarce and the efficiency of water has to increase drastically.

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