Chapter 2

Recent Trends and Outlook for Water Resources in Agriculture

2.1. Trends in water resource use and management since 1990[1]

The key trends in OECD agriculture's use of water resources since 1990, include:

- Use of freshwater resources by agriculture and non-agricultural users has changed little;
- Agriculture accounts for the major share of total water use;
- The area irrigated has been increasing, while the total agricultural land area has decreased; and,
- Abstractions from groundwater resources by agriculture have been increasing.

Overall OECD agricultural and non-agricultural uses changed little between 1990-92 and 2002-04, although there has been considerable annual variability in water use in agriculture (Figure 2.1). The OECD trend in agriculture water use reflects significant growth in four countries (**Greece, Korea, New Zealand** and **Turkey**) mainly driven by an increase in the area irrigated (except **Korea**), but a substantial reduction in **Australia, Mexico** and most **European OECD countries**. For this latter group of countries the decrease in water use is due to a mix of factors varying between countries, but notably improvements in water use efficiency, drought, release of water to meet environmental needs, and contraction of the agricultural sector in **Europe**.

OECD agriculture accounted for 44% of OECD total water use overall in 2002-04, although for eight OECD countries where irrigated agriculture is important, the share is over 55% (Figure 2.1). Some of the water used by irrigated agriculture is reused by other downstream users or diverted to meet environmental needs, although there are also losses due to evapotranspiration; pollutant runoff from irrigated farming; and losses to groundwater sources which are no longer economic to pump. Even so, there are no cases of an overall national physical shortage of water, as the share of total water use in total availability of annual freshwater resources is low.

The supply and demand for water resources, however, varies greatly within most countries. As a result competition for water between agriculture, other users (*e.g.* industrial, urban) and the environment, especially in drier regions, is becoming a growing concern in many countries. In the **United States**, for example, the 17 western contiguous States are generally characterised as arid/semi-arid with seasonal periods of moisture deficits during the growing season. This region in 2002 accounted for 51% of US cropland, 76% of the US irrigated area. The rest of the US is generally characterised as more humid, where most irrigated agriculture is generally considered to be supplemental.[2]

In aggregate the OECD area irrigated rose by 8% compared to a reduction of 3% in the total agricultural area between 1990-92 and 2002-04, although while the area that is irrigable is normally greater than the actual area irrigated in any given year (Figure 2.1). For some countries where irrigation plays a key role in the agricultural sector and farming is also a major water user in the economy (**Greece** and **Turkey**), the growth in agricultural water use over the past decade has been substantially above that compared to other water users (Figure 2.1).

For a number of other countries where irrigation is important (**Australia, Korea, Mexico, Portugal** and **Spain**) the growth in agricultural water use has been below that compared to other water users (Figure 2.1). The value of production from irrigated agriculture has a high and growing share in total agricultural production value (in excess of 50%) and value of exports (more than 60%) in a number of OECD countries, *e.g.* **Italy, Mexico, Spain** and the **United States** (crop sales only).

Box 2.1. Water use terminology and water balance calculations

The term "agricultural water use" used in the text and figures in this chapter refers to "water abstractions" for irrigation and other agricultural uses (such as for livestock) from rivers, lakes, and groundwater, and "return flows" from irrigation but excludes precipitation directly onto agricultural land. "Water use" or in the technical literature "water withdrawals", is different from "water consumption" which relates to water depleted and not available for reuse. Canadian agriculture's use of water resources provides an illustrative numerical example of the use of these terms. Agriculture in Canada uses (withdraws from total available water sources) 7-9% of Canada's overall water use. Agriculture consumes (does not return to the water system) 70-80% of the water it withdraws to make it the leading user of water in Canada (about 70% of total consumption).

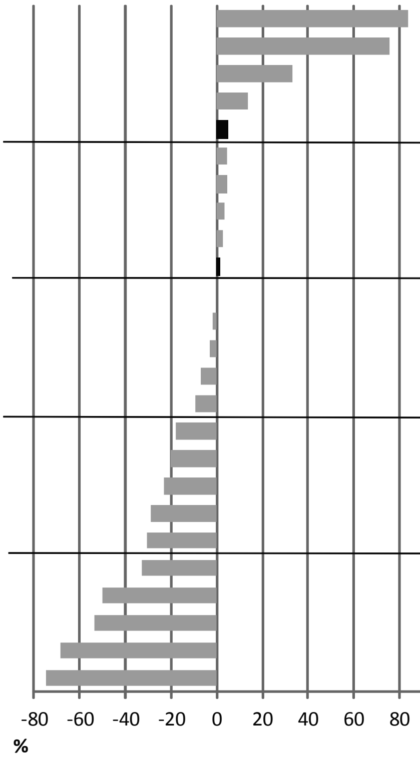
Calculations of water balances are complex (from which the data in Figures 2.1 to 2.4 are drawn), and not all OECD countries use the same data collection methods, which is a limitation in using the indicators, shown in the figures. A further limitation is that water use balances are usually not calculated annually, but derived from 5 or even 10-year surveys, and cover all uses of water across the economy, including agriculture. Moreover, the extent of groundwater reserves and their rate of depletion are also not easily measured, and cross country time series data are lacking. An additional complication is that under some systems, agriculture has the potential to recharge groundwater.

Cross border sources of water also need to be taken into account in establishing water balance calculations, for a considerable number of countries. While internal renewable water resources, represented by annual flow of rivers and recharge of aquifers generated from endogenous precipitation make-up the major part of a water balance, water generated outside the border of a country can also be important, such as natural inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers. Similarly, not all the water resources generated by endogenous precipitation in a particular country are available for that country. This is because, for example, a certain quantity of water must remain to maintain the natural flow of the river which ultimately leaves the nation's (nations') border. Thus, the water balance equation of a country also needs to include the external renewable water resources that naturally flow into that country and the amount of water generated by endogenous precipitation that naturally flows out of the country.

Source: OECD Secretariat, and the Canadian response to an OECD questionnaire at www.oecd.org/water.

Figure 2.1. Agricultural water use[1]

% Change in total agriculture water use
1990-92 to 2002-04



	Total agriculture water use[1]		Change in total agriculture water use	Change in total water use[2]	Share of agriculture in total water use[2]
	1990-92	2002-04	1990-92 to 2002-04	1990-92 to 2002-04	2002-04
	million m³	million m³	%	%	%
Turkey (3)	18 812	34 552	84	48	75
New Zealand (4)	1 281	2 254	76	56	57
Greece (5)	5 694	7 600	33	24	87
Korea (6)	14 100	16 032	14	42	55
EU15 (7)	43 625	45 557	4	-6	29
Spain (8)	23 700	24 701	4	4	60
United Kingdom (9)	1 347	1 402	4	14	10
France	4 901	5 067	3	-12	15
Canada (10)	3 991	4 104	3	-6	10
OECD (11)	414 385	419 883	1	1	44
Iceland (12)	70	70	0	-1	42
United States (13)	195 200	191 555	-2	2	40
Japan (14)	58 642	56 840	-3	-3	66
Portugal (15)	5 547	5 162	-7	2	59
Mexico	62 500	56 811	-9	1	77
Austria (16)	100	82	-18	-50	5
Sweden (17)	169	135	-20	-10	5
Australia (18)	13 384	10 310	-23	-6	55
Germany (19)	1 600	1 140	-29	-21	3
Poland	1 527	1 065	-30	-18	9
Hungary	968	651	-33	-8	11
Netherlands (20)	184	91	-50	27	1
Denmark (21)	383	177	-54	-39	27
Slovak Republic (22)	192	59	-69	-42	6
Czech Republic (23)	93	24	-75	-43	1
Italy (24)	..	20 865	..	0	50

1. Agricultural water use is defined as water for irrigation and other agricultural uses such as for livestock operations. It includes water abstracted from surface and groundwater, and return flows from irrigation, but excludes precipitation directly onto agricultural land.
2. Total water use is the total water abstractions for public water supply + irrigation + manufacturing industry except cooling + electrical cooling.
3. Data for irrigation are used because data for agricultural water use are not available. For Turkey, change in total agricultural water use is +84%.
4 Data for the periods 1990-92 and 2002-04 refer to the years 1999 and 2006.
5. Data for the period 1990-92 and 2002-04 refer to the year 1990 and 1997. Share of agriculture in total water use is for 1997.
6. Data for the periods 1990-92 and 2002-04 refer to the years 1990 and average 2002-03.
7. EU15 excludes: Belgium, Finland, Ireland, Italy and Luxembourg.
8. *Sources:* OECD and national data.
9. England and Wales only.
10. Data for the periods 1990-92 and 2002-04 refer to the years 1991 and 1996.
11. OECD excludes: Belgium, Finland, Ireland, Italy, Luxembourg, Norway, and Switzerland.
12. Data for the period 1990-92 refer to the year 1992. Data include water use for fish farming.
13. Data for the periods 1990-92 and 2002-04 refer to the years 1990 and 2000.
14. Data for the periods 1990-92 and 2002-04 refer to the years 1990 and 2001.
15. Data for the periods 1990-92 and 2002-04 refer to the years 1989 and 1999.
16. Data for the period 2002-04 refer to the year 2003. *Sources: Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management, Facts and Figures 2006* and *Austrian Water, Facts and Figures*.
17. Data include water use for fish farming.

(Notes continue on following page.)

(Notes to Figure 2.1 continued.)

18. Average 1990-92 = average 1993-95, Average 2002-04: data for irrigation are used because data for agricultural water use are not available. *Sources: irrigation in water use on Australian farms 2002-2003, 2003-2004, 2004-2005.*
19. Data for the period 2002-04 refer to the year 2001. Data for irrigation are used because data for agricultural water use are not available.
20. Data for the period 1990-92 refer to the year 1991.
21. Until 1999 abstraction for irrigation included abstraction for freshwater fish farms, accounting for approximately 40 million m^3/year.
22. For the Slovak Republic, the change in total agricultural water use is –69%.
23. For the Czech Republic, the change in total agricultural water use is –75%.
24. For 1990-92, data for agricultural water use are not available. Data for the period 2002-04 refer to the year 1998.

Source: Updated from OECD (2008a).

Irrigated agriculture provides a growing and major share of the value of farm production and exports for some OECD countries, and supports rural employment in a number of regions. As such irrigated agriculture accounts for most of agricultural water use, and will continue to play an important role in agricultural production growth in some countries.

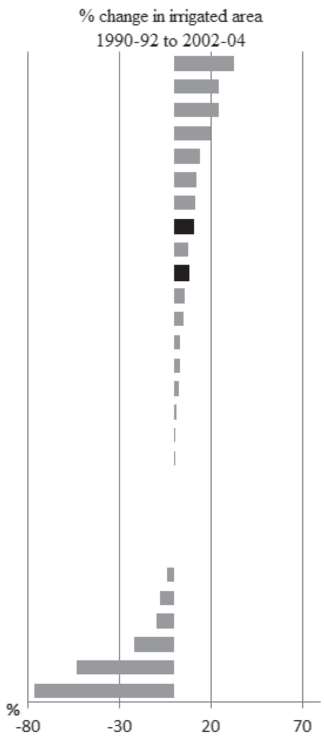
Increases in physical water productivity by agriculture, through better management and uptake of more efficient technologies, such as drip irrigation and adoption of other water saving farm practices, has contributed to higher farm production. Overall the OECD average water application rate per hectare irrigated decreased by 7% between 1990-92 and 2002-04, while in most cases the volume of agricultural production increased (Figure 2.2).

In the **United States,** for example, efficiency gains have been made in irrigation water use over the 1990s, with a decline in per hectare application rates by 7% (Figure 2.2, Hutson *et al.*, 2004). Reduction in water application rates per hectare irrigated have also been achieved in other countries where irrigated agriculture is important, notably in **Australia**, but also to a lesser extent in **France**, **Mexico**, **Spain** and the **United States** (Figure 2.2), but irrigation water use efficiency has deteriorated for others (**Greece** and **Turkey**) (Figure 2.2).

The adoption of drip irrigation, low-pressure sprinkler systems, and other water-saving technologies and practices, are becoming more widespread (Figure 2.3). The uptake of more efficient water management technologies (*i.e.* low-pressure sprinklers and drip emitters) in countries where irrigation is important covers over 25% of the total irrigated area for **Australia, France, Czech Republic**, **Greece, Italy, Spain** and the **United States** (Figure 2.3). In addition, water use efficiency in agriculture is being improved through replacing earthen irrigation channels with concrete linings to reduce losses, and upgrading flood irrigation systems (*e.g.* levelling of fields, neutron probes for soil moisture measurement, and scheduling of irrigation to plant needs).

The low uptake of water-conserving irrigation technologies, such as drip emitters, and the poor maintenance of irrigation infrastructure (*e.g.* canals) has for some countries, however, led to inefficiencies in water use and water losses through leakages leading to an increase in water withdrawal and application rates per hectare irrigated. Estimates for **Mexico**, for example, show that only 45% of water extracted reaches irrigated fields. Even so, overall the OECD average water application rate per hectare irrigated decreased by 12% between 1990-92 and 2002-04 (Figure 2.2).

Figure 2.2. Irrigated area, irrigation water use and irrigation water application rates



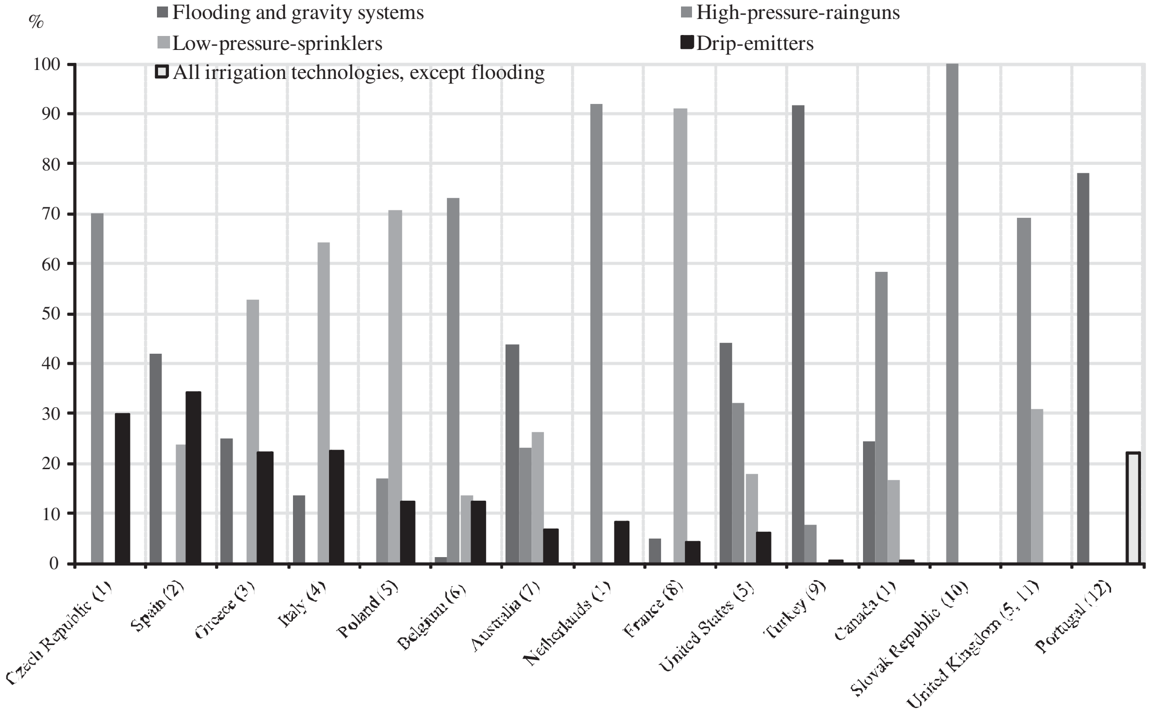
	Irrigated area (1)		Change in irrigated area		Change in total agricultural area	Share of irrigated area in total agricultural area	Share of irrigation water use in total agricultural water use	Irrigation water application rates		
	'000 hectares		'000 hectares	%	%	%	%	Megalitres per hectare of irrigated land		
	1990-92	2002-04	1990-92 to 2002-04	1990-92 to 2002-04	1990-92 to 2002-04	2002-04	2002-04	1990-92	2002-04	% change
Turkey	3 933	5 215	1 282	33	3	13	..	4.8	6.6	39
Greece	1 195	1 482	287	24	-3	16	..	4.8	5.1	8
France	2 107	2 611	505	24	-3	9	..	2.3	1.9	-17
Canada (2, 3)	900	1 076	176	20	-1	2	94	3.5	3.6	1
New Zealand (2)	250	285	35	14	-1	2	..	..	..	..
Spain	3 388	3 787	399	12	-3	9	98	7.0	6.4	-9
Sweden (2, 4)	48	54	6	12	-6	2	70	2.1	1.7	-19
EU-15 (5)	11 791	12 994	1 203	10	-3	10	..	3.6	3.4	-6
United States (2, 6)	20 900	22 543	1 643	8	-3	5	99	9.0	8.4	-7
OECD (7)	50 827	54 808	3 981	8	-3	4	..	8.0	7.5	-7
Belgium	24	25	1	6	2	2	..	0.5	1.5	189
Australia (2)	2 380	2 497	117	5	-4	1	99	7.5	4.1	-45
Denmark	433	448	15	3	-4	17	95	0.6	0.4	-35
United Kingdom	165	170	5	3	-6	1	7	1.0	0.6	-46
Mexico	6 170	6 313	143	2	1	6	97	9.9	8.7	-12
Netherlands	557	565	8	1	-8	29	..	0.3	0.2	-51
Germany	482	485	3	1	-2	3	..	3.3	2.4	-29
Poland	100	100	0	0	-12	1	8	3.7	0.9	-77
Austria	4	4	0	0	-4	0	..	12.5	20.5	64
Finland (2)	64	64	0	0	0	3	80	0.3	0.6	100
Switzerland	25	25	0	0	-3	2	..	..	..	..
Italy (8)	2 698	2 698	0	0	1	17	..	..	7.7	..
Portugal (2, 9)	626	601	-25	-4	-3	16	..	8.9	8.6	-3
Japan	2 846	2 624	-222	-8	-8	50	99	20.6	21.4	4
Korea	977	879	-98	-10	-11	46	95	14.3	17.4	22
Hungary	213	166	-47	-22	-8	3	26	2.3	1.0	-55
Czech Republic (2)	43	20	-23	-54	0	0	..	0.7	1.2	64
Slovak Republic (2)	299	70	-229	-76	0	3	80	0.5	0.7	31

. . : not available

1. Covers area irrigated and not irrigable area (*i.e.* area with irrigation infrastructure but not necessarily irrigated.) To be consistent, the years used for the average calculations are the same for irrigation water use and total agricultural water use, irrigated area and total agricultural area.
2. For some countries, data in brackets below are used to replace the average due to missing data: Australia: 1990-92 (1997), Canada: 1990-92 (1988), 2002-04 (2003). Czech Republic: 1990-92 (1994), 2002-04 (2003). Finland: 2002-04 (2001). New Zealand: 1990-92 (1985), 2002-04 (2003). Portugal: 1990-92 (1989), 2002-04 (1999). Slovak Republic: 1990-92 (1993), Sweden: 1990-92 (1985), 2002-04 (2003). United States: 1990-92 (1990), 2002-04 (2000).
3. For Canada, the source is the OECD questionnaire at www.oecd.org/water.
4. For Sweden, the source is the OECD questionnaire at www.oecd.org/water.
5. EU15 excludes Ireland and Luxembourg.
6. For the United States, the source is the *Census of Agriculture*.
7. OECD excludes: Iceland, Ireland, Luxembourg, Norway, Switzerland.
8. For Italy, share of irrigation water in total agriculture water use, for 1998.
9. For Portugal, the area irrigated is that equipped for irrigation and not the actual area irrigated which was 453 540 ha for 2002-04.

Source: Updated from OECD (2008a).

Figure 2.3. Share of irrigated land area using different irrigation technology systems: 2000-03



1. Data for 2003.

2. The data are for 2002-03 and represent the area for flooding, sprinklers and drip emitters that are irrigable but not necessarily irrigated.

3. Data for 1999, which show different irrigation technologies' share of total irrigation water use.

4. Data for 2000.

5. National data.

6. Data for Flanders refer to 2002. Flooding data include Wallonia and Flanders data, but for Flanders only ornamental plant cultivation in greenhouses is included; high-pressure raingun data refer only to Flanders; data for low-pressure sprinklers and drip emitters are the sum of Flanders and Wallonia data.

7. Data are taken from the Australian Bureau of Statistics (2005), *Irrigation Methods 2002-03;* flooding refers to surface; low-pressure sprinklers refers to microspray; drip-emitters refers to drip or trickle; and high-pressure rainguns refers to portable irrigators, hose irrigators, large mobile machines and solid set.

8. Values are an average of data for 2000 and 2003.

9. Data for 2000, values for high-pressure rainguns include area irrigated by low-pressure sprinklers.

10. Data for 2000-03.

11. Data for England.

12. 78% for flooding and 22% covers all others.

Source: Updated from OECD (2008a).

In **Turkey**, despite the increasing adoption of low-pressure sprinkler and drip irrigation systems, irrigation through flooding remains dominant, used on over 90% of irrigated land (Figure 2.3). Moreover, the water application rate per hectare irrigated in **Turkey** increased by 39% between 1990-92 and 2002-04 (Figure 2.2), partly explained by losses from the irrigation infrastructure and inefficiencies in managing irrigation systems due to lack of irrigator management skills and poor advisory services (OECD, 2008a). But water policy reforms in both **Mexico** and **Turkey** are beginning to address these deficiencies in managing the irrigation systems (Box 3.8).

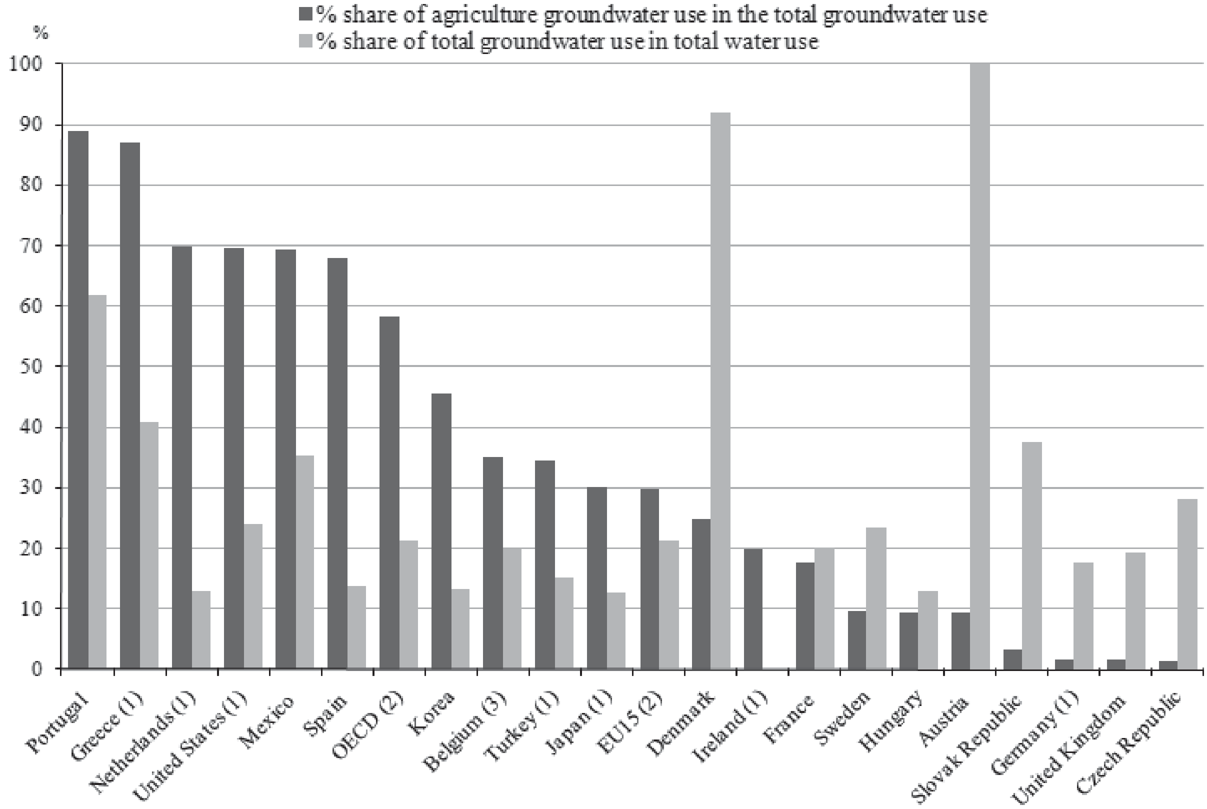
Agriculture abstracts an increasing share of its water supplies from groundwater. The sector's share in total groundwater utilisation, although data are limited, was above 30% in 12 OECD member countries in 2002, notably for **Greece, Japan, Korea, Mexico, Portugal, Spain, Turkey** and the **United States** (Figure 2.4). Although data are limited, farming is drawing an increasing share of its supplies from groundwater, and agriculture's share in total ***groundwater utilisation*** was above 30% in a third of OECD member countries in 2002 (Figure 2.4).

Over-exploitation of water resources by agriculture in certain areas is damaging ecosystems by reducing water flows below minimum flow (stock) levels in rivers, lakes and wetlands, which is also detrimental to recreational, fishing and cultural uses of these ecosystems. Groundwater use for irrigation above recharge rates in some regions (**Australia, Greece, Italy, Mexico** and the **United States)** is also undermining the economic viability of farming in affected areas. Also farming is now the major and growing source of groundwater pollution across many countries. This is of particular concern where groundwater provides a major share of drinking water supplies for both human and the farming sector (*e.g.* **Greece, Mexico, Portugal,** the **United States**) (Figure 2.4).

In those regions were growing water scarcity is an issue, greater use is being made of recycled wastewater and desalinated water from seawater and saline aquifers. These sources of water still remain marginal in most OECD countries, although they are important for agriculture in some localities within countries, especially near large population centres (recycled sewage wastewater) and coastal areas (desalinisation), such as beginning to emerge in some OECD Mediterranean countries, for example, Spain.

Changing cropping patterns is also being explored as means to alter virtual water trade flows. ***Virtual water trade*** is considered by some researchers as a way to make water savings in countries where water resources are under pressure from competing users. In brief, virtual water trade is importation by water scarce nations of their least water efficient crops from countries that have a lower opportunity cost of water and higher productivity (World Bank, 2006). But the policy recommendations that follow from virtual water trade analysis can be incorrect and misleading, as discussed in Box 2.2.

Figure 2.4. Share of agricultural groundwater use in total groundwater use, and total groundwater use in total water use: 2002



1. Data for 1994 are used to replace missing data of 2002 for: Ireland.
Data for 1995 are used to replace missing data of 2002 for: Netherlands.
Data for 1997 are used to replace missing data of 2002 for: Greece, Turkey.
Data for 1998 are used to replace missing data of 2002 for: Germany.
Data for 2000 are used to replace missing data of 2002 for: United States.
Data for 2001 are used to replace missing data of 2002 for: Japan.

2. The EU15 and OECD data must be interpreted with caution, as they consist of totals using different years across countries, and do not include all member countries. EU15 excludes: Finland, Italy and Luxembourg. OECD excludes: Australia, Canada, Finland, Italy, Luxembourg, New Zealand, Norway, Poland and Switzerland.

3. Data for Belgium only cover the Flanders region.

Source: Updated from OECD (2008a).

Box 2.2. Economic analysis of the virtual water and water footprint concept related to agriculture

The term "virtual water" began appearing in the water resources literature in the mid-1990s. Professor Tony Allan of London University chose the term to describe the water used to produce crops traded in international markets. During the 15 years since its inception, the virtual water concept (or metaphor, symbol) has been very helpful in gaining the attention of public officials and policy makers responsible for encouraging wise use of limited water resources.

Several authors have conducted empirical analyses of "virtual water flows" between countries, by comparing the water requirements of crops and livestock products involved in international trade, concluding that some countries are "net importers of virtual water," while others are "net exporters." They also suggest that, based on the virtual water concept, water-short countries should import water intensive goods and services, while water-abundant countries should export water intensive products. This line of reasoning, while simple, is not based on a legitimate conceptual framework. Hence, the policy recommendations that follow from this form of virtual water analysis can be incorrect and misleading.

The fundamental shortcoming of the virtual water concept that prevents it from serving as a valid policy prescriptive tool is the lack of an underlying conceptual framework. Some researchers have incorrectly described virtual water as analogous to, or consistent with the economic theory of comparative advantage. The virtual water concept is applied most often when discussing or comparing water-short and water-abundant countries. By focusing on the water resource endowment, alone, virtual water represents an application of absolute advantage, rather than comparative advantage. For this reason, policy prescriptions that arise from virtual water discussions are not those that will maximise the net benefits of engaging in international trade. Comparative advantage is the pertinent economic concept, and virtual water considers only absolute advantage.

Recent empirical analyses of international trade data generally confirm the lack of consistency between virtual water prescriptions and actual trade patterns. A number of authors have begun describing the important role of non-water factors in determining optimal production and trading strategies, such as the importance of considering population densities, historical production trends, national food security goals, poverty reduction targets, and the availability of complementary inputs when determining whether to transfer water from one region to another, or to achieve desired outcomes alternatively by transporting or trading agricultural commodities.

The notion of water footprints describes the volume of water required to support production and consumption in selected regions or countries, and to assess whether a region or country is consuming resources in a sustainable or unsustainable fashion, from a global perspective. Water is one of many inputs in those activities. Hence, estimated water footprints are somewhat one-dimensional, as they depict the use of only one resource. In addition, water footprints do not describe the implications of water use. Rather, they consider only the amounts of water used in production and consumption activities. Hence, ecological water footprint analysis is not sufficient for determining optimal policy alternatives, as it does not account of the net benefits generated as resources are consumed.

The costs and benefits of water use depend largely on the opportunity (scarcity) costs of water resources and the ways in which water is combined with other inputs in production and consumption. Water footprints enable one to compare estimated water use, per person or in aggregate across countries, but they are inadequate for evaluating the incremental costs, benefits, or environmental impacts of water use. For this reason, empirical estimates of water footprints do not provide sufficient information for assessing environmental implications or determining policy goals and strategies pertaining to water resources. Like the virtual water concept, water footprints bring helpful attention to important policy issues, but they lack the conceptual foundation and breadth required to support policy analysis.

Some researchers have described ***the "green" and "blue" components of virtual water and water footprints***. "Green water" is used to denote effective rainfall or soil moisture that is used directly by plants, while "blue water" denotes water in rivers, lakes, aquifers, or reservoirs. "Blue water" generally refers to water that can be delivered for irrigation or made available for alternative uses, while "green water" must be used directly from the soil profile.

Like virtual water, the blue-green concept has helped increase public awareness of an important dimension of water resource management. The terms "green water" and "blue water" generate easily recallable images of soil moisture and stored surface water in a manner that is likely to be helpful to many public officials and agency staff members.

Yet the notions of green and blue water do not establish a new conceptual framework that can be used alone to guide policy decisions. Some authors have suggested that the opportunity cost of "green water" is generally smaller than that of "blue water". They propose trading "green water" for "blue water", when possible, to generate meaningful water savings. The perspective regarding opportunity costs is not accurate and the recommendation is not based on a legitimate conceptual framework.

In summary, the virtual water, water footprint, and blue-green concepts have brought much-needed attention to important issues regarding water resources, within countries and around the world. These concepts serve well in gaining the attention of public officials and policy makers. Current patterns of water allocation and use often reflect underlying market failures that can be corrected with appropriate policy interventions. In this context the concepts are helpful in bringing attention to these market failures, particularly among members of the media, public officials, and the general public.

Yet none of these concepts is based on an established, underlying conceptual framework, and none is a sufficient criterion for determining optimal policy decisions. Farmers, traders, and public officials must consider many economic and social issues when determining optimal strategies. Virtual water, water footprints, and the blue-green concepts will be helpful in starting policy discussions in many settings. But they will not be sufficient for determining the optimal outcomes of those discussions and establishing economically efficient and environmentally effective policy alternatives.

Source: Adapted from Wichelns (2010a).

2.2. Outlook for water resources in agriculture

2.2.1. OECD Environmental Outlook baseline scenario projections

Projections of agriculture's use of water resources up to 2050 from the OECD (2008b) *Environmental Outlook*, highlight a number of new developments of concern to water users and consumers, as well as policy makers.[3] The OECD baseline scenario results provided in the *Environmental Outlook* and shown in Figures 2.6 to 2.9 in this chapter are policy-neutral, as they project current policies into the future to show what the world could be like in 2050 if current policies are maintained. Also the baseline scenario does not include any climate change impacts. The main baseline projections relevant to water and agricultural linkages included in the *Environmental Outlook* are summarised below.

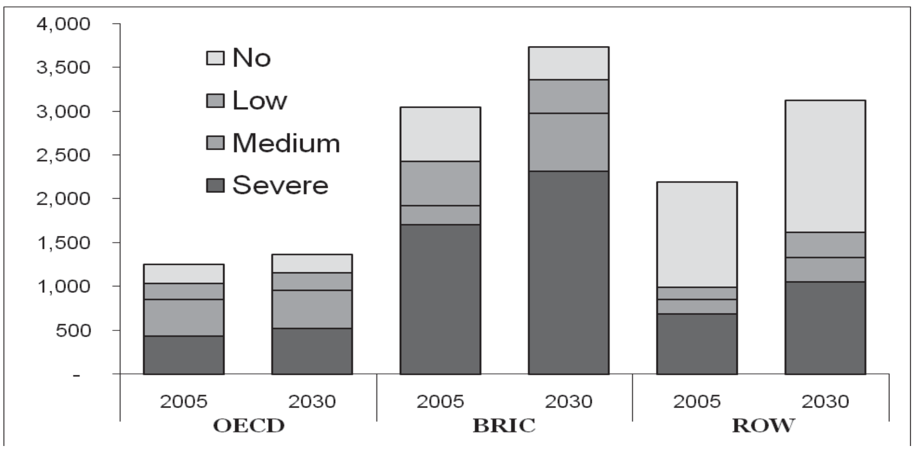
- Overall water scarcity is an increasing threat in many regions within countries, as water pollution and overuse are damaging to water sources, while populations grow and competition between different uses increases (Box 2.3). Currently, 1.4 billion people live in water basins where the water usage rates exceed recharge rates. In 2005, 35% of the population of the OECD was living in areas characterised by severe water stress, compared with 44% worldwide. By 2030, the number of people living under severe water stress is expected to increase by 1 billion from the 2005 baseline to an estimated 3.9 billion people (47% of the world population), mostly in non-OECD countries.

- Water withdrawals are projected to increase at a much higher pace in developing relative to OECD countries, and for non-agricultural compared to agricultural uses (Figures 2.6, 2.7). As a result global and regional quantities and shares of water withdrawals by agriculture decline (Figures 2.8, 2.9). Around a half of the projected increase in total water withdrawals would be used by the power generation industry, although a major share of water used for power generation is returned into the water system (OECD, 2008b). Even though, the baseline scenario suggests that developing countries will need to expand their supply of water resources to meet the expected growth in consumer demand and to secure environmental needs.
- At the same time as water use by agriculture declines, global food and non-food demand will continue to increase mainly as a result of the growth in incomes, population, urbanisation and industrialisation. This will chiefly be driven by developing countries, but agricultural production in many of these countries will be much more constrained by pressures on the natural resource base, including land and water, notably in China and India.
- The global decrease in agricultural water withdrawals is dominated by developments in irrigation, as this is assumed to account for 99% of agricultural water withdrawals (the remainder is accounted for by livestock), and, in particular, by China and India as the volumes involved in these countries are so large. The OECD *Environment Outlook* under the baseline scenario projects that for both these countries there will be a steady decline in the physical volume (and share) of water withdrawals by agriculture up to 2050 (Figures 2.6 and 2.9).

Box 2.3. Water stress

Figure 2.5. People living in areas of water stress

Projections, by stress level (millions)

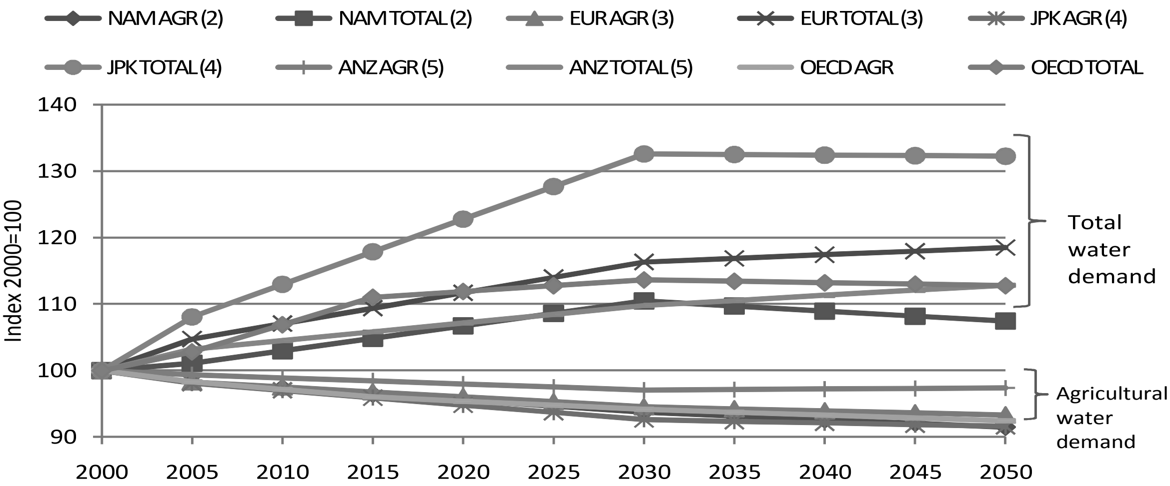


BRIC: Brazil, Russia, India, China. ROW: Rest of World. Projections are the OECD *Environmental Outlook* baseline scenario which assumes no new policies and does not include climate change impacts.

OECD's indicator for water stress, is based on the ratio of water withdrawal to annual water availability, which uses the following thresholds: below 10% water stress **low**; the 10-20% range indicates **moderate** stress, *i.e.* "water availability is becoming a constraint on development and that significant investments are needed to provide adequate supplies"; above 20% stress is **medium** and "both supply and demand will need to be managed and conflicts among competing uses will need to be resolved"; while above 40% stress is **severe.**

Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.6. Projected total and agricultural water withdrawals in OECD countries: 2000-50

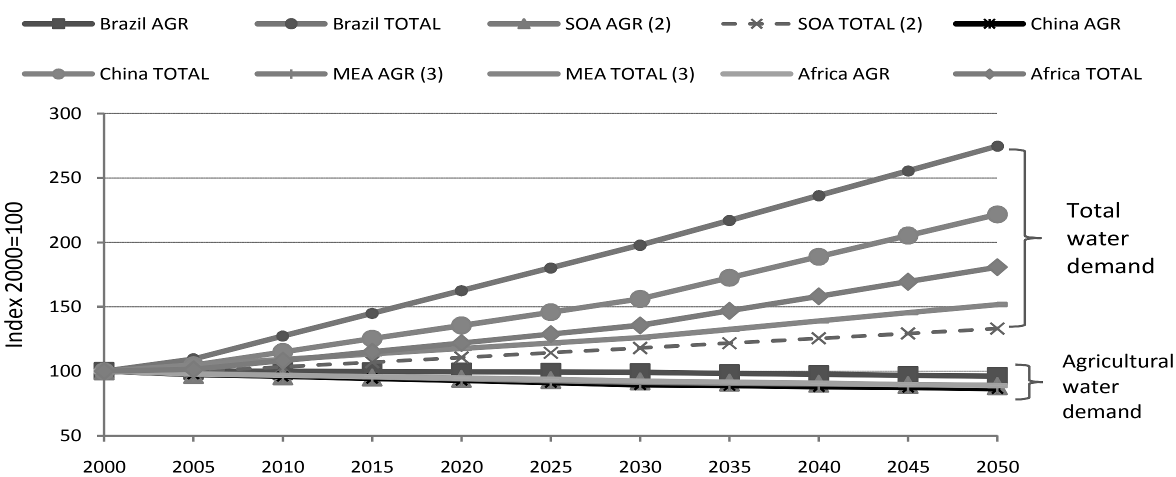


Projections are the OECD *Environmental Outlook* baseline scenario which assumes no new policies and does not include climate change impacts.

1. Water quantity demand in agriculture includes water for irrigation and water for livestock.
2. NAM includes: Canada, United States and Mexico.
3. EUR includes: all OECD European countries, including Iceland and Turkey.
4. JPK includes: Japan, Korea and North Korea.
5. ANZ includes Australia and New Zealand.

Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.7. Projected total and agricultural water withdrawals in selected non-OECD countries/regions: 2000-50

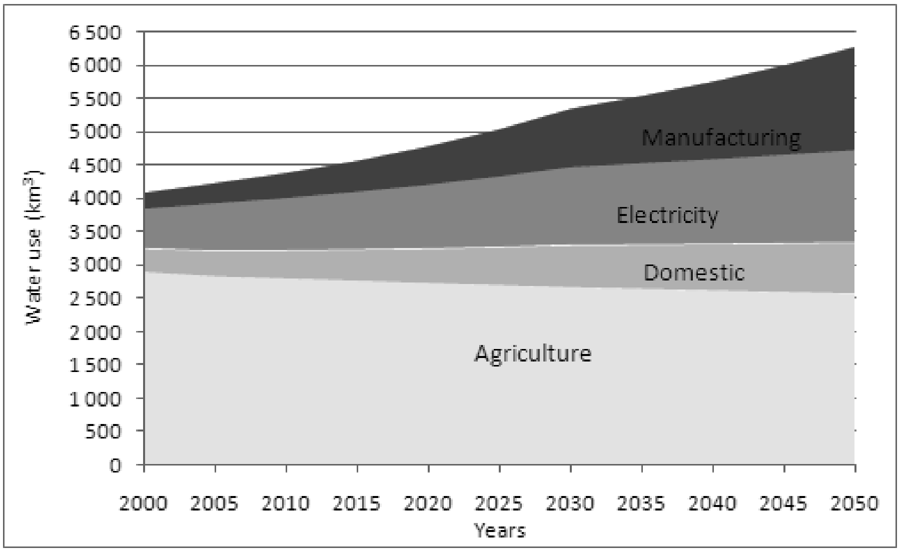


Projections are the OECD *Environmental Outlook* baseline scenario which assumes no new policies and does not include climate change impacts.

1. Water quantity demand in agriculture includes water for irrigation and water for livestock.
2. SOA includes India and South Asia.
3. MEA includes the Middle East.

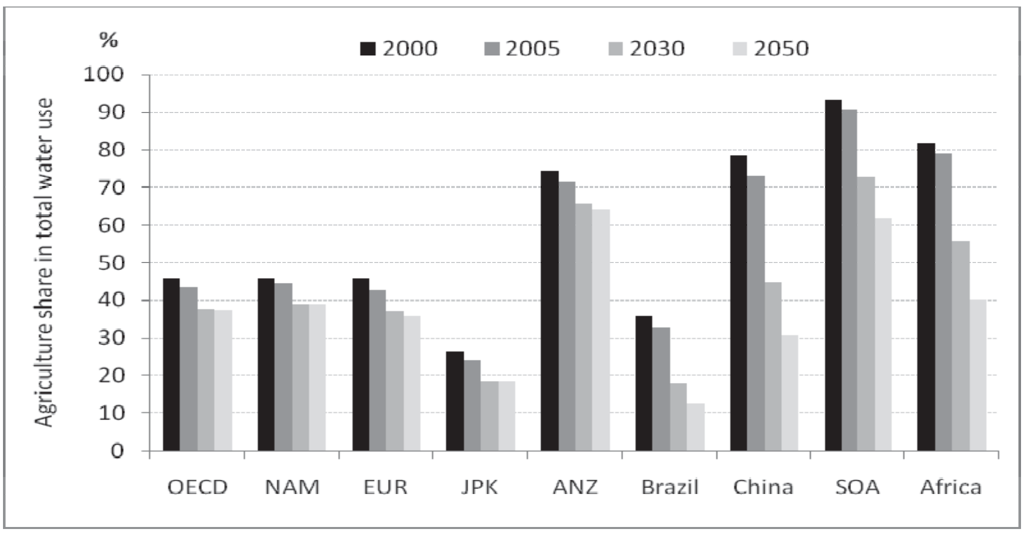
Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.8. Projected world water withdrawals by sector: 2000-50



Source: OECD (2008b), *Environmental Outlook* baseline.

Figure 2.9. Projected share of agriculture in total water withdrawals: 2000-50



Projections are the OECD *Environmental Outlook* baseline scenario, which assumes no new policies and does not include climate change impacts.
For definitions of country groupings, see Figures 2.6 and 2.7.
Source: OECD (2008b), *Environmental Outlook* baseline.

- Consistent with the expectation in the International Water Management Institute Report (IWMI, 2007), it is assumed that the global irrigated area changes little under the baseline scenario. Hence, there is much need for improvement in the physical efficiency of water use in agriculture in all irrigated regions of the world, to help toward meeting the projected global increase in agricultural commodity production, and also to release water for other uses. Some of this improvement is included in the *Environment Outlook* baseline scenario projections.
- OECD agricultural exporting countries are expected to be a continuing and expanding source of food and non-food agricultural commodity exports, mainly to Asian, African, and Middle Eastern countries (some developing countries will also continue as major agricultural exporters, especially in Latin America). Such an expansion in OECD agricultural production and exports will necessitate improving water use efficiency in agriculture, both in largely rain-fed and also irrigated farming systems, if the overall use and pressures on water resources in agriculture are to be reduced.
- It is important to emphasise that these highly aggregated projections for the demand for water, both by agriculture and other water users, mask significant variations within countries in the overall directions and causes of changes in the water situation over the coming decades.

It is pertinent to review the OECD *Environmental Outlook* projections against other studies of future global irrigation water withdrawals (Table 2.1). While the OECD *Environmental Outlook* projections expect a reduction in global irrigation water withdrawals, this compares to a projected increase by most other studies. The OECD results, however, concur with the more recent projections of Alcamo *et al.* (2007), and the descriptive conclusions of the IPCC (Bates *et al.,* 2008; and Tables 2.2 to 2.4).

Table 2.1. A selection of global projections for irrigation water withdrawals

Source	2000 Cubic kilometres	2025 Cubic kilometres	Change 2000-25 %
OECD (2008b)	2 874	2 631[1]	–8
Shen *et al.* (2008)	2 658	3 388 – 3 665[2]	+27 to +38
IWMI (2007)	2 630	2 800 – 3 400[2]	+6 to +29
Alcamo *et al.* (2007)	2 498	2 341 – 2 366[4]	–5 to –6
Shiklomanov (2000)	2 488[3]	3 097	+24
Seckler *et al.* (2000)	2 469[3]	2 915	+18
Alcamo *et al.* (2000)	2 465[3, 4]	2 292 – 2 559[2]	–7 to +4

1. Projection year is 2030 instead of 2025. Projections are the OECD *Environmental Outlook* baseline scenario, which assumes no new policies and does not include climate change impacts.
2. Projections show data for a range of different scenarios.
3. Base year is 1995 instead of 2000.
4. Projections include total agricultural water withdrawals (*i.e.* including water for livestock).

Sources: OECD, adapted from IWMI (2007) and other sources.

Projections of global irrigation water withdrawals differ for a number of reasons including, for example, varying use of data (note the differences in the base year – 2000 – estimates of global irrigation withdrawals in Table 2.1); and differences in the underlying model structures and expert assumptions. For example, researchers have used different definitions of irrigation water use (*e.g.* some define this as total withdrawals others as crop depletion); and make assumptions and judgments regarding irrigation water use efficiency, as well as irrigated versus irrigable area (IWMI, 2007). This highlights the need to improve the underlying water resource related data in projection models and refine model specifications (Chapter 3.6).

2.2.2. Climate change, climate variability, agriculture and water resources

The Intergovernmental Panel on Climate Change (IPCC) report on climate change and water (Bates *et al.,* 2008), concludes that "observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies." Climate change's main water-related impacts with regard to agriculture are expected by the IPCC to be felt in terms of shifting and more variable hydrological regimes, as summarised in Box 2.4.

IPCC also projects a decline in the melt water from major Asian mountain ranges where more than one-sixth of the world's population currently live (Table 2.2). Climate change is expected to affect the function and operation of existing water infrastructure (*e.g.* irrigation systems) as well as water management. Moreover, current water management practices may not be robust enough to cope with the impacts of climate change on, for example, water supply reliability, flood risk, agriculture and ecosystems. Specifically concerning agriculture, the IPCC projects that changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation (Table 2.3).

Climate change can also have a dual effect on irrigated agriculture. This may occur through both higher water demand by agriculture and an expansion of the area irrigated. These developments are due to both general climate change (higher temperatures and lower precipitation) and climate variability leading to an increase in extreme events, especially the frequency of droughts.

Climate variability is also a concern in terms of changes in the seasonality of precipitation, which is of particular importance for agriculture as it affects the timing of annual rainfall patterns or periods of snow pack melt, necessitating the restructuring of irrigation storage systems. Better understanding of climate variability and extension of risk management approaches in agriculture to existing climate variability, can help build a more solid foundation for addressing climate change in the future.

Many other reports from OECD government agencies have reinforced the IPCC view on climate change (*e.g.* **Australia**, Commonwealth Scientific and Industrial Research Organisation [CSIRO], 2008; **Canada**, Lemmen *et al.,* 2007; **EU**, European Parliament, 2008 and Portuguese Ministry of Environment, 2007; **United States**, United States Environmental Protection Agency [USEPA], 2008). Overall these reports have indicated that in terms of the linkages between climate change, water resources and agriculture, farming systems are increasingly vulnerable to changes in water availability and temperature, requiring high levels of adaptive responses. Projections also expect there to be significant regional variation within and across countries as a result of climate change (Table 2.4).

In some situations climate change will also lead to beneficial opportunities for agriculture, as research is already suggesting in some countries (*e.g.* **Finland** – see the OECD questionnaire at www.oecd.org/water), and as projections reveal in terms of the increase in wheat yield potential in Northern Europe and overall crop yields in North America (Table 2.4).

This report reveals that the incidence and severity of flood and droughts has been increasing for the majority of OECD countries, which has put increasing pressure on irrigated farming in drier and semi-arid areas. In many cases this trend is associated with greater risks associated with climate change (Figure 1.2; Chapter 3.5; and the OECD questionnaire at www.oecd.org/water). Many of these countries also project that with climate change the incidence and severity of flood and drought events may continue to increase, while other researchers also support the view of an ongoing intensification of the hydrologic cycle (Huntington, 2006; Bates *et al.,* 2008).

2.2.3. Agriculture, water, energy and renewable energy

The outset of the new millennium has seen significant increases in ***energy prices and growing concern about climate change***. Energy price increases can affect rain-fed agriculture by raising the cost of transporting agricultural commodities to market and by increasing the cost of agricultural inputs, like fertilisers and pesticides. Because water conveyance and irrigation systems require energy, irrigated agriculture faces the additional burden of increasing water costs as energy costs increase.

***Recent increases in energy prices have also led to a growing interest in expanding bioenergy production in many OECD countries*.** This development has included using agricultural feedstocks for the production of biofuel and bioenergy which can have implications for agricultural water use (Box 2.5). The overall impacts on water balances of supporting agricultural feedstocks to produce biofuels and bioenergy, however, is complex and remains unclear. It is a largely empirical question and needs to be assessed in a way that compares the effects of alternative uses of resources.

Research suggests, however, that the quantity of water needed to produce each unit of energy from second generation biofuel feedstocks (*e.g.* lignocellulosic harvest residues and forestry) is much lower than the water required to produce ethanol from first generation feedstocks (such as from maize, sugar cane, and rapeseed) (Box 2.5). But this can vary according to the location and practices adopted.

Box 2.4. Intergovernmental Panel on Climate Change: Climate change and water

This Box provides the key conclusions from the IPCC's recent report (2008) on climate change and water. The main conclusions, of particular relevance to water resources and agriculture, are listed below.

- Observed warming over several decades has been linked to changes in the large-scale hydrological cycle.
- Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (*likely/very likely*).
- By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics (*high confidence*).
- Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas *(likely/very likely*).
- Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution (*high confidence*).
- Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (*high confidence*).
- Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation.
- Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defences, drainage and irrigation systems – as well as water management practices (*high/very high confidence*).
- Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems *(very high confidence*).
- Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions (*very likely*).
- Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies.
- Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.
- Water resources management clearly impacts on many other policy areas, *e.g.*, energy, health, food security and nature conservation.
- Several gaps in knowledge exist in terms of observations and research needs related to climate change and water.

Source: IPCC (2008).

Table 2.2. Key conclusions from the 2007 IPCC 4th Assessment Report on Climate Change and Water

	Quantitative Assessment		Expert Judgment	
	Chance of finding correct:		*Probability of occurrence:*	
	Very high confidence: 9 out of 10	High confidence: 8 out of 10	Very likely >90%	Likely >66%
Global	Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation	Shifts in the amplitude and timing of runoff in glacier- and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed. Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress.	Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions	The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas Globally the area of land classified as very dry has more than doubled since the 1970s.
Regional		Many semi-arid and arid areas (*e.g.* the Mediterranean Basin, western US, southern Africa and north-eastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change. Water supplies stored in glaciers and snow cover are projected to decline in the course of the century in regions supplied by melt water from major mountain ranges, where more than one-sixth of the world's population currently lives	Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes.	Climate model simulations for the 21st century are consistent in projecting precipitation increases in parts of the tropics, and decreases in some sub-tropical and lower mid-latitude regions.
Floods and droughts			The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) will increase over most areas during the 21st century, with consequences for the risk of rain-generated floods.	The proportion of land surface in extreme drought at any one time is projected to increase.

(Table 2.2 continued)

	Quantitative Assessment		**Expert Judgment**	
	Chance of finding correct:		*Probability of occurrence*	
	Very high confidence: 9 out of 10	High confidence: 8 out of 10	Very likely >90%	Likely >66%
Agriculture		Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected. Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems.		

These conclusions are based on the quantitative projections across a range of emission scenarios used by the IPCC, while adaptation to climate change is not included in these estimations. For the full documentation on the methodologies and scenarios used by the IPCC see the source below.

Source: Adapted from Bates *et al.* (2008).

Table 2.3. Summary of key 2007 IPCC 4th Assessment conclusions by warming increments for agriculture

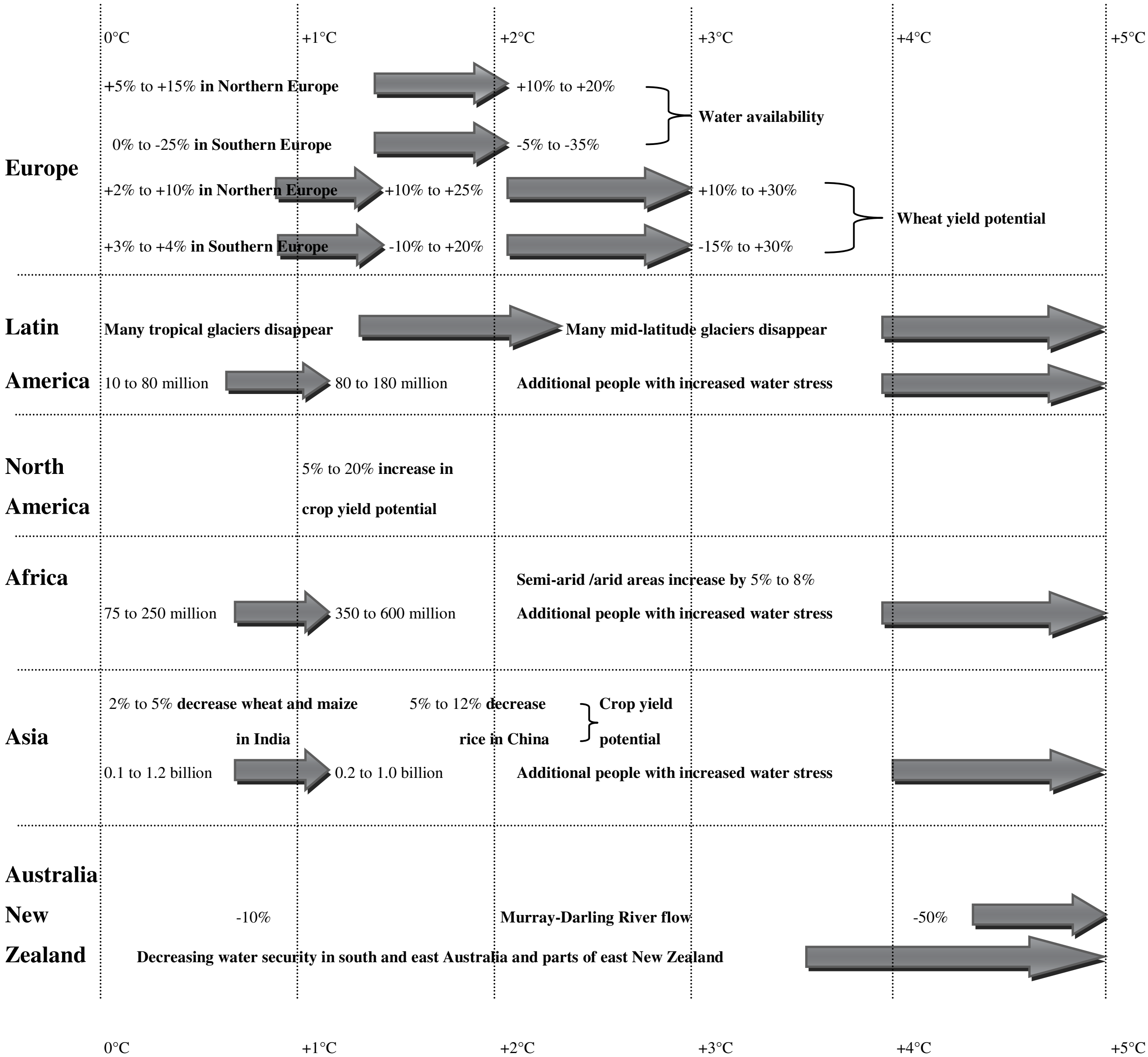
Global mean annual temperature change relative to the 1980-99 (°C) baseline

Sub-sector	Region	+1°C to +2°C	+2°C to +3°C	+3°C to +5°C
Food crops	Global		550 ppm CO_2 (approx. equal to +2°C) increases crop yield by 17%; this increase is offset by temperature increase of 2° C assuming no adaptation and 3° C with adaptation	
	Mid- to high latitudes	Cold limitation alleviated for all crops Adaptation of maize and wheat increases yield 10% to 15%; rice yield no change; regional variation is high	Adaptation increases all crops above baseline yield	
	Low latitudes	Wheat and maize yields reduced below baseline levels; rice is unchanged Adaptation of maize, wheat, rice, maintains yields at current levels	Adaptation maintains yields of all crops above baseline; yields drop below baseline for all crops without adaptation	Adaptation maintains yields of all crops above baseline; yield drops below baseline for all crops without adaptation Maize and wheat yields reduced below baseline regardless of adaptation, but adaptation maintains rice yield at baseline levels
Pastures and Livestock	Temperate	Cold limitation alleviated for pastures; seasonal increased frequency of heat stress for livestock	Moderate production loss in swine and confined cattle	
	Semi-arid	No increase in net primary productivity; seasonal increased frequency of heat stress for livestock	Reduction in animal weight and pasture production, and increased heat stress for livestock	
	Tropical			Strong production loss for pigs and confined cattle
Fibre	Temperate		Yields decrease by 9%	
Real Agricultural Prices and Trade	Global	Real agricultural prices: –10% to –30%	Real agricultural prices: –10 to +30%	Real agricultural prices: +10 to +40% Cereal imports of developing countries to increase by 10-40%

These conclusions are based on the quantitative projections across a range of emission scenarios used by the IPCC, while adaptation to climate change is not included in these estimations. For the full documentation on the methodologies and scenarios used by the IPCC, see the source below.

Source: Adapted from Easterling *et al.* (2007).

Table 2.4. Regional impacts of global annual temperature change as they relate to water and agriculture relative to 1980-99 (°C)



Edges of boxes and placing of text indicate the range of temperature change to which the impact relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. These conclusions are based on the projections across a range of emission scenarios used by the IPCC, while adaptation to climate change is not included in these estimations. For the full documentation on the methodologies and scenarios used in this figure by the IPCC, see the source below.

Source: Adapted from IPCC (2008).

Box 2.5. Agriculture, biofuels and water resources

The rapid growth of biofuel production from agricultural feedstocks over the past decade has implications for the demand on water resources. This has raised concerns that further expansion of biofuel production from agricultural feedstocks could increase pressure on water resources in regions where competition for water resources is an issue.

The extent to which biofuel production draws on the need for irrigation varies by region (Table 2.5). Rain-fed rapeseed in Europe requires virtually no irrigation. Maize in the United States is largely rain-fed, and only 3% of national irrigation water withdrawals are devoted to biofuel crops. Globally only 2% of water withdrawn for irrigation is estimated to be applied to biofuel crops, and on average an estimated 2 500 litres of evapotranspiration (ET) and 820 litres (L) of irrigation water are needed to produce one litre of biofuel, although regional variation is large.

Table 2.5. Biofuels, land and water use, 2005

	Ethanol	Main feed-stock	Feed-stock used	Area planted to biofuel crops	% Total crop area grown for fuel	Crop water ET	% Total ET used for biofuel	Irrigation with-drawals for biofuel	% Total irrigation with-drawals for biofuel
	(mill. L)		(mill. t)	(mill. ha)		(km^3)		(km^3)	
Brazil	15 098	Sugarcane	167.8	2.4	5.0	46.02	10.7	131	3.5
US	12 907	Corn	33.1	3.8	3.5	22.39	4.0	5.44	2.7
Canada	231	Wheat	0.6	0.3	1.1	1.07	1.1	0.08	1.4
France	829	Sugarbeet	11.1	0.2	1.2	0.90	1.8	--	0.0
Italy	151	Wheat	0.4	0.1	1.7	0.60	1.7	--	0.0
UK	401	Sugarbeet	5.3	0.1	2.4	0.44	2.5	--	0.0
China	3 649	Corn	9.4	1.9	1.1	14.35	1.5	9.43	2.2
India	1 749	Sugarcane	19.4	0.3	0.2	5.33	0.5	6.48	1.2
Indonesia	167	Sugarcane	1.9	0.0	0.1	0.64	0.3	0.91	1.2
S. Africa	416	Sugarcane	4.6	0.1	1.1	0.94	2.8	1.08	9.8
World	36 800			10.0	0.8	98.0	1.4	30.6	2.0
Biodiesel	1 980			1.2		4.7			0.0

Source: Adapted from de Fraiture *et al.* (2008).

The amount of water needed to produce each unit of energy from second generation biofuel feedstocks (*e.g.* lignocellulosic harvest residues and forestry) is three to seven times lower than the water required to produce ethanol from first generation feedstocks (*e.g.* from maize, sugar cane, rapeseed) (Table 2.6). Hence, production of first generation feedstocks could increase demand for water and raise prices. Second generation biofuels, however, can be expected to reduce demand for water for energy crop production as less water-intensive crops replace maize and sugar as the principal feedstocks for ethanol.

Feedstocks such as tree plantations, for example, can capture a greater share of annual rainfall in areas where much of the rainfall occurs outside the normal crop growing season, and also help to reduce soil erosion and bring flood control benefits. While second generation feedstocks offer the potential for reducing water demand, it is not necessarily a clear outcome, as this may depend on the types of feedstocks grown, the location of production and the reference first generation feedstocks. Moreover, new pressures on water systems may arise in some areas where second generation feedstocks are established, while some of these feedstocks (*e.g.* forestry) may require irrigation during establishment and to achieve high yields, hence, the final impact on water balances are uncertain.

Table 2.6. Water intensity of biofuel feedstocks

Biofuel / Feedstock	Water use efficiency[1,2] (kg. DM ha^{-1} mm^{-1} ET)	Energy crop evapotranspiration	
		Mg GJ^{-1} feedstock	Mg GJ^{-1} gross bioenergy
Rapeseed (biodiesel)	9-12	48-81	100-175
Sugarcane ethanol	17-33	23-124	37-155
Sugar beet ethanol	9-24	57-151	71-188
Maize ethanol	7-21	37-190	73-346
Cellulosic ethanol	10-95	7-68	11-171

1. The water-use efficiency is given as kg above-ground DMmm_1 evapotranspiration (ET). The depth of water supply is often given in mm, where 1mm corresponds to 10 Mg water ha_1. 50kgDMmm_1 is equivalent to a water loss as ET of 200 g per g DM produced.

2. Lower range numbers refer to systems where: (i) harvest residues from non-lignocellulosic crops (50% of total) are used for power production (at 45% efficiency); or (ii) higher efficiencies in processing lignocellulosic crops are achieved. When ethanol is produced from sugarcane or lignocellulosic feedstocks, process by-products (bagasse and lignin, respectively) are used for internal heat and electricity. Here, lower range numbers refer to system designs allowing for export of electricity in excess of internal requirements.

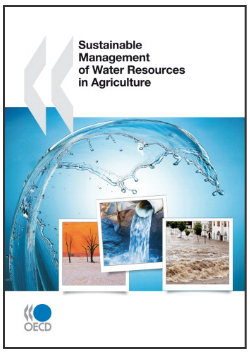
Source: Adapted from Berndes and Borjesson (2001).

Projections estimate that an additional 30 million hectares (ha) of cropland may be needed to meet world food and biofuel demand in 2030 using first-generation feedstocks, such as maize, sugar, and rapeseed. This would require 170 km^3 of additional evapotranspiration and 180 km^3 of additional irrigation. Given that increasing global demand for food crops will require 1 400 million ha of land and 2 980 km^3 of irrigation withdrawals, the biofuel-induced demand seems modest. At the regional level within countries, however, the increased demand for water resources may be difficult to achieve.

Sources: OECD Secretariat, drawing on Berndes (2008); Berndes and Borjesson (2001); European Environment Agency (2008); de Fraiture *et al.* (2008); Hellegers *et al.* (2008); Liao *et al.* (2007); National Research Council (2008); Varis (2007).

Notes

1. This chapter is largely drawn from OECD, 2008a. Also, for the terminology relevant to this chapter see Box 2.1.
2. The information on the US was taken from the US response to an OECD questionnaire at www.oecd.org/water.
3. The OECD projections described here are outlined in OECD (2008b), but for full documentation of the OECD *Environmental Outlook* model and underlying assumptions, see the OECD website at www.oecd.org/environment/outlookto2030.



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