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Chapter 4: 'Water' - Resource Efficiency in Asia and the Pacific

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Abstract
Water is essential to life, supplying human needs and maintaining ecosystems for all living species. Water resources are important to socio-economic development, providing material input into production and consumption activities and acting as sinks for waste material. Consequently, water resource systems are closely linked to the economic use of resources. This section of the report investigates water resource and water use patterns, trends in water use, and resultant stress on water systems across the Asia-Pacific region.

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Chapter 4: **Water**

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Main messages

- The Asia-Pacific region has increased total water withdrawals over the 15 year period (1985–2000) by 329,160 GL, representing an approximate 25% increase. All other subregions have increased withdrawals, except Central Asia, which has maintained a constant withdrawal.

- Many countries have been extracting water in an unsustainable manner by withdrawing more water per year than is available from renewable sources. The situation is serious in Central Asia, particularly in Uzbekistan, Turkmenistan, and Tajikistan. These countries are already withdrawing more water per year than is available from renewable sources. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia large volumes of withdrawals indicate that China has also been extracting water rapidly.

- Central Asia withdraws significantly more water per capita, and as a whole, than other subregions (1998–2002). Australia and New Zealand have the second highest water withdrawal per capita, though significantly less than Central Asia.

- Over 81% of annual water withdrawals in the Asia-Pacific region in the recent past (1998–2002) have been used for agriculture. Although the percentage of water withdrawn for agriculture may be high, the actual volume used varies widely between countries.

- Water intensity increased, indicating that water productivity decreased, in the Asia-Pacific region in 1985–2000. In Central Asia, water use intensity increased significantly, indicating less GDP has been generated while using the same amount of water.

- Central Asia had the largest water intensity value for agricultural use at 18,315 L/$US, and has the lowest productivity. The subregion was using 63% of total renewable water resources, more than double the extraction of the other subregions (1998–2002).

- The predictions of future water withdrawals will be a decline in developed nations and rising withdrawals in developing nations, thereby further increasing pressure on water resources. Accordingly, many river basins will be under severe stress, complicated by strong competition for scarce water resources between households, industry, and agriculture.

- By 2025, agriculture is expected to increase requirements for water withdrawal by 1.3 times, industry by 1.5 times, and the domestic supply by 1.8 times. Future scenarios suggest that many of the region's transboundary river basins will be stressed or highly stressed, and the competition for these resources will cause ongoing tension between nations.

Water resources – general world overview

Water is essential to life, supplying human needs and maintaining ecosystems for all living species. Water resources are important to socio-economic development, providing material input into production and consumption activities and acting as sinks for waste material. Consequently, water resource systems are closely linked to the economic use of resources. This section of the report investigates water resource and water use patterns, trends in water use, and resultant stress on water systems across the Asia-Pacific region.

Changing climatic conditions, rapidly increasing populations, and persistent over-use of available resources have generated concerns of a pending 'global water crisis'. In many regions of the world, socio-economic activities are rapidly changing water use patterns, which have implications for future water resources, water policy, and water planning. The challenge of managing and developing water resources to sustain communities continues to grow in the face of the pressures of economic growth, major population increases, and climate change (UN-WATER/WWAP 2006).

While the distribution of global water resources is highly variable, water issues are inherently localized and interdependent, and almost fully reliant on the interaction between social systems and their socio-technical environments. Global water resources are increasingly in demand for purposes such as drinking, hygiene, and the production of food, energy, and industrial goods, as well as for the maintenance of natural ecosystems. The construction of dams and diversions are influencing river regimes in many regions. The impact on communities can be highly significant, as in several cases in North-East Asia and South-East Asia, or more localized, as with small dams in hillside terrace systems. The removal, destruction, or impairment of natural ecosystems, has the greatest critical impact on the sustainability of natural water resources (UN-WATER/WWAP 2006)

Groundwater is by far the most abundant and readily available source of fresh water, followed by lakes, reservoirs, rivers, and wetlands. Currently, there are high levels of exploitation of groundwater, with extraction rates often more than 50% of the rate of recharge in many countries in the Middle East, Africa, Asia, and Europe (UN-WATER/WWAP 2006). In many developing countries, groundwater assessment and monitoring activities are minimal or ineffective. Consequently, there is a limited knowledge of groundwater resources and aquifer systems.

Water is often used in the production of commodities, particularly food, and there are flows of virtual water through international trade. In some instances, water-scarce countries import virtual water (through import of water-intensive products), thus relieving the pressure on the domestic water resources (Water Footprint Network 2010). However, continued economic development will lead to decreased water availability and water quality. Poor water quality, low water availability per person, high dependence on water use for agriculture, and the impacts of climate change mean that many countries will be vulnerable to long-term water scarcity (UNESCAP 2005).

More than half of the world's major rivers are seriously depleted and polluted, leading to the degradation and poisoning of surrounding ecosystems, health consequences, and reduced livelihoods (World Commission on Water 1999). Most water bodies are now heavily polluted with domestic sewage, industrial effluents, chemicals, and solid wastes (UNEP 2002; UNESCAP 2005). Globally,

eutrophication is the most prevalent water quality problem resulting from high-nutrient loads (mainly phosphorus and nitrogen), which substantially impairs beneficial uses of water (UN-WATER/WWAP 2009). Consequently, water availability is also linked to the quality of available water. Box 4.1 provides an example of the complex issues facing water courses in the Asia-Pacific region.

Box 4.1. Serious water issues in Panay Island, Philippines

The port city of Iloilo, Panay Island, Western Visaya, Philippines, has a population of 300,000, and is the commercial, cultural, and intellectual hub of the island. The city sources water from the Tigum Aganan Watershed and residents have been subject to poor water quality, lack of sanitation, increasing siltation, decreasing water availability, groundwater contamination, the threat of saltwater intrusion into the aquifer, and catastrophic floods and droughts. The productivity of the river has been compromised by headwater surges, pollution from mining activities, riverbank erosion, reduced fish habitat, and the relentless impacts of urban migration. A severe typhoon in 2008 damaged regional infrastructure and ecosystems. Natural hazards such as landslides and erosion are exacerbated by heavy rains in the uplands, threatening the lives and livelihoods of village communities. Over-exploitation of resources, social injustices, indigenous welfare, problematic governance, and rural poverty are embedded issues in the management of the watershed.

FIGURE 4.1.
Headwaters of the Tigum Aganan Watershed, Panay Island, Philippines. (Source: Alexander et al. *2010)*

Water resources – Asia and the Pacific region

The Asia-Pacific region is characterized by a range of climates, and therefore experiences a variety of hydrological regimes. The hydrology of the region is dominated by the typical monsoon climate, which induces large inter-seasonal variations of river flows (FAO 2009). In the humid areas, water management concerns have been largely related to flood control because flooding is a common

problem in the Mekong, Brahmaputra, and Ganges basins. In the arid areas, such as in central China, where water is scarce, hydrological studies have been oriented much more towards water resources assessment (FAO 2009). Withdrawals in upstream countries (e.g. India), are known to significantly affect the volumes of water available to downstream countries (e.g. Bangladesh). Where there are shared river basins, as in South and South-East Asia, the computation of water resources becomes relatively complex and transboundary issues often occur. The futures of rivers dependent on glacier melt are expected to be affected by the rate of glacial retreat and precipitation (WWF 2010).

The Asia-Pacific region contains 60% of the world's population and agricultural land and is the largest consumer of water, with withdrawal rates of 2,268,726 GL/year (Table 4.1), which is far more than the consumption of the rest of the world according to UNESCAP (2009). The average annual total withdrawal for agriculture was approximately 81.5% of total water use (1995–2002) in the region. Total withdrawal for industrial purposes was 11.4%, with 7.1% used for domestic purposes during this period (UNESCAP 2009).

While the Asian and Pacific region experiences further economic growth, the region faces some major development challenges in the coming decades. Population growth, changing water regimes and climate, and rising demand for energy, water, and other basic needs are likely to intensify over the next few decades. The important factors that have an impact on water resources in the Asia-Pacific region include (UNESCAP 2006):

- **Natural resource endowment:** Water is a vital component of the natural resource endowment of a region. The natural resource endowment per capita is much lower in Asia and the Pacific than global averages, because the region has a population density of 1.5 times the global average with the lowest freshwater availability per capita of all global regions.
- **Pollution:** Several highly polluting industries are growing more rapidly in regional developing countries than in developed countries, with consequences for the quality of available water.
- **Increased use of water:** Increasingly more water is used for agricultural and industrial processes. The majority of water is used for agricultural production, which tends to be highly chemically, energy, and water intensive.
- **Changing consumption patterns:** As incomes increase, consumption patterns are changing. Growing supply of consumer goods is increasing the amount of water needed for industrial processes.
- **Water extraction rates:** Extraction rates are already unsustainably high in the majority of countries in the Asia-Pacific region. Irrigation systems, the largest user of water, are highly inefficient and poorly maintained in most countries, resulting in wastage. Some countries with the least available water also have the poorest water quality, and experience disruption to industrial production from water shortages.
- **Ecological efficiency of water use:** The ecological efficiency of water use is highly variable in the industrial sector, and does not necessarily reflect the availability of water. Some water-

stressed countries have highly developed industrial sectors that use much more water to produce one dollar of GDP than do water-rich countries.

- **Long-term sustainability of the water supply:** The water supply is further threatened by climate change, which may increase the severity and incidence of drought and cause long-term reductions in water flows in freshwater systems, particularly those dependent on glacier melt.

Water use patterns

Continued economic growth that increasingly demands more energy, water and other basic inputs, population increases, changing water regimes and climate change are challenging abilities to manage global water resources. Many countries of the Asia-Pacific region are highly vulnerable to long-term water scarcity and experience poor water quality, low water availability and have a high dependence on water used for agriculture. In the Asia-Pacific region, water withdrawal per capita has been increasing and shows an ongoing upward trend. Many countries have been extracting water in an unsustainable manner. The situation is serious in Central Asia, where several countries are already withdrawing more water per year than is available from renewable sources. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, high withdrawals indicate that China has also been extracting water rapidly. Countries in the Asia-Pacific region have increasingly used their water resources and, by 2025, assuming current consumption patterns continue, a significant proportion of the population in the region will live in water-stressed river basins. By 2025, many transboundary river basins will be stressed or highly stressed, and the competition for these resources may cause ongoing tension between nations.

Regional water withdrawals

Table 4.1 shows the annual water withdrawals for the Asia-Pacific region by subregion (Australia and New Zealand; Central Asia; North-East Asia; South Asia; South-East Asia and the Pacific) for the period 1998–2002. Water withdrawal data has been compiled to allow comparisons between agricultural use (irrigation and livestock), community use (municipal or domestic water), and industrial use.[1]

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1 Although national data on water withdrawal is often available for some years, large uncertainties remain about the computation methods used to develop the statistics. In this report, water data has been derived from FAO Aquastat data, which deals with a series of 5-year time intervals, where the value given for any interval may come from any single year within it. Here, either the full interval is quoted, such as 1998–2002, or the midpoint of the time interval is given. For example, where the year 2000 is quoted, the value may actually have been recorded for any year within the period 1998–2002. This latter convention is important mainly where an intensity such as water withdrawals per $US GDP is given, as the GDP data is for the exact year nominated.

Because many countries do not have recorded data for many years in the FAO Aquastat database, for this review of water resources it was not possible to simultaneously retain a large sample of the countries within each subregion, and also make comparisons between years. As a result, variable bases have been used here. For single interval (1998–2002) graphs, the largest and most representative sample of countries within a subregion was retained by including all countries for simple totals, such as total withdrawals, or by excluding only those countries that do not have a value for either the numerator or denominator, such as when calculating withdrawals per capita. Where a comparison was to be made between two different years (e.g. 1985 and 2000), to achieve meaningful results, it was necessary to also exclude countries where a record for either year was missing. Unfortunately, this reduces the size of the sample, in the case of Central Asia and the Pacific sometimes to zero. As a result, values for quantities that might be expected to be identical will sometimes not be. This is why, for example, sectoral water intensities for 1998–2002 (Figure 4.3) do not match the water intensities given for 2000 in the comparison between 1985 and 2000 (Figure 4.8).

Trends in water withdrawal for Asia and the Pacific between 1985 and 2000

Figure 4.2 shows the change in total water withdrawals for subregions during the 15-year time period between 1985 and 2000.[2]

The Asia-Pacific region increased total water withdrawals over the 15 years, by 329,160 GL, representing an approximate 25% increase in water withdrawal. Central Asia maintained roughly constant withdrawals, while all other subregions increased withdrawals. In 1985, the total for those countries included in this sample for South Asia and North-East Asia had similar withdrawals of approximately 500,000 GL, and similar levels of increase over the period to 646,000 GL and 630,000 GL, respectively, or approximately 30% over the 15 year period.

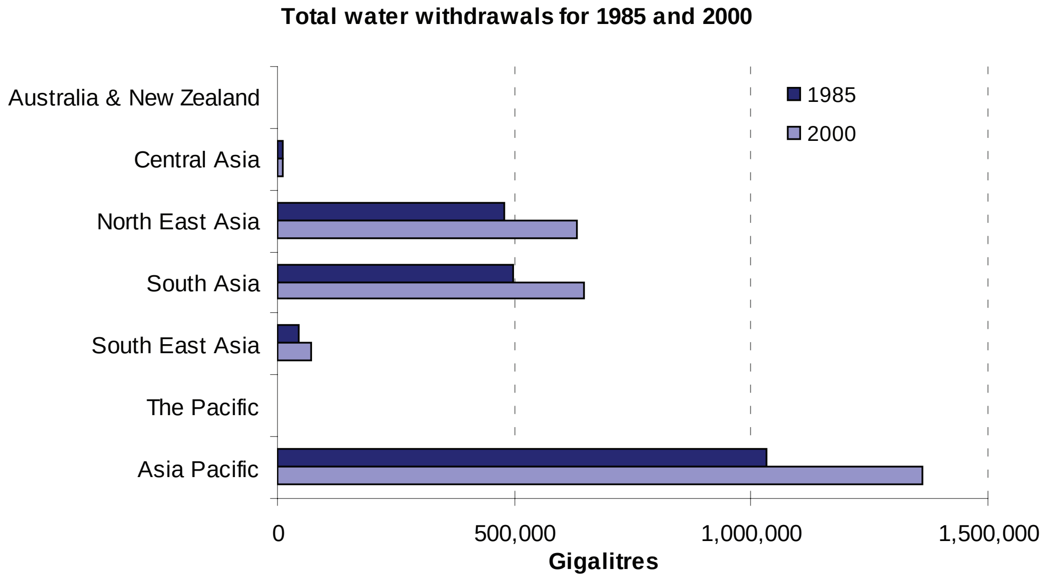

FIGURE 4.2.
Total water withdrawals for 1985 and 2000

Figure 4.3 shows that per capita water withdrawals for the Asia-Pacific region increased by some 0.04 ML per capita, or around 6%, during the 1985–2000 period. Values for Central Asia were not calculated due to insufficient data, while the figure for Australia and New Zealand is in reality only for New Zealand, where water use per capita decreased. Of far greater significance is the 5% decrease in water withdrawals per capita in South Asia. However, this improvement was not sufficient to offset the increases in North-East Asia and South-East Asia, where usage per capita increased by some 12% in both subregions.

The volume of water withdrawn per unit of land area in the Asia-Pacific region was 64 ML/km^2 while in South Asia it was 150 ML/km^2, as shown in Figure 4.4. This is indicative of widespread, high-intensity agricultural activities, with a high reliance on irrigation. At the other end of the spectrum, on a per unit area basis, withdrawals in Australia and New Zealand are over an order of magnitude lower, at less

2 Data are available for Australia and New Zealand and the Pacific, but values are not of sufficient size to be visible at the scale required here. Also note that data for 2000 here may not match that displayed in single time interval graphs and tables, as discussed earlier.

than 4 ML/km^2. This low rate reflects both the limited availability of water within much of Australia (which dominates the subregion in terms of land area), and the low intensity of agricultural activities and restricted extent of irrigation over the majority of the area.

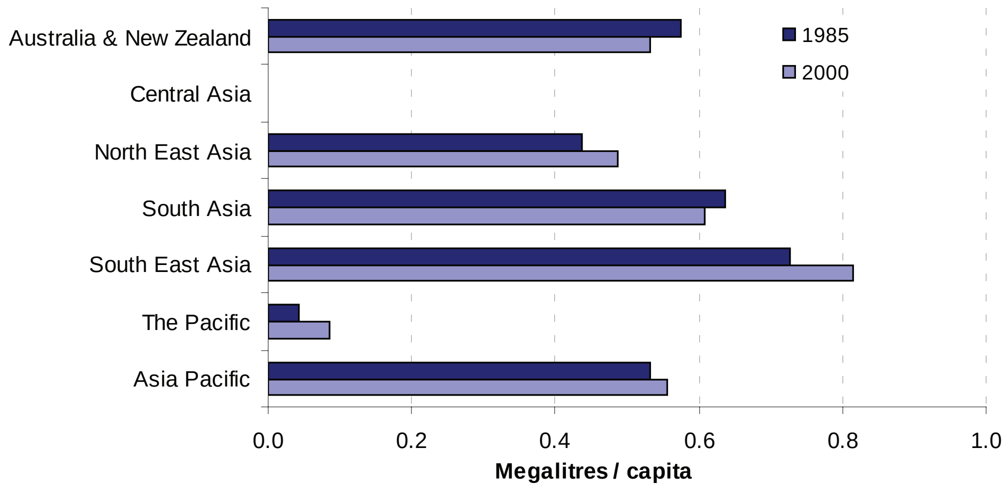

FIGURE 4.3.

Per capita withdrawals for 1985 and 2000 (note that data shown for 'Australia and NZ' in this case only includes New Zealand)

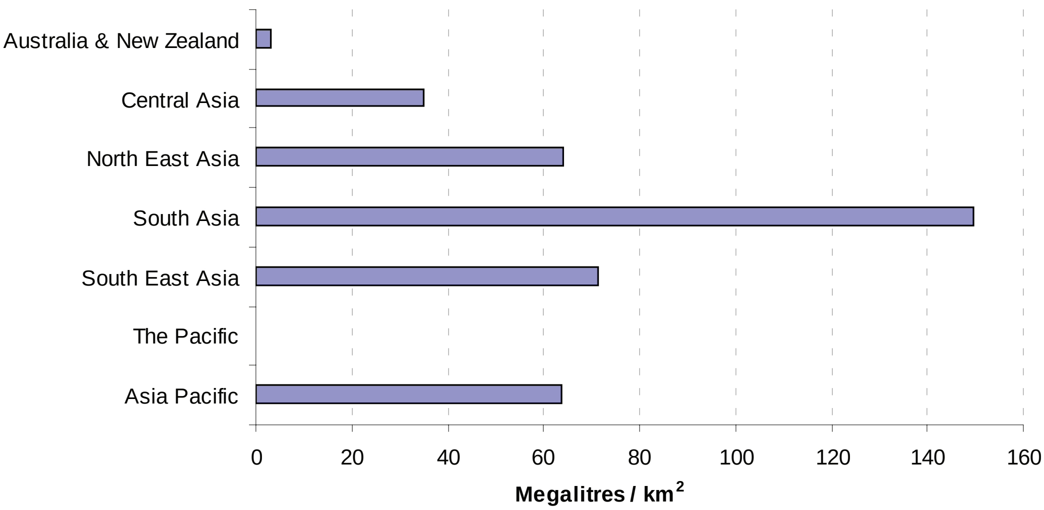

FIGURE 4.4.

Water withdrawals per km^2 land area for 1998–2002

Figure 4.5 indicates that water intensity decreased, and hence water productivity increased, in the Asia-Pacific region between 1985 and 2000, but these trends mask important subregional differences. In Central Asia an already high water use intensity more than doubled, indicating much less GDP was generated using the same amount of water. However, in this sample Central Asia is represented only by Tajikistan, so the overall subregional performance may be much better than this. Water intensity also increased in the Pacific (not visible at this scale), while all other subregions decreased their water intensities. These improvements included major decreases in the all important subregions of North-East Asia and South Asia, of over 66% and 52%, respectively, with similar levels of improvement in South-East Asia. The net result for the region as a whole (or at least the sample available for cross time interval comparisons) is that water intensity decreased by over 57% between 1985 and 2000. This is an encouraging development, and shows that water efficiency trends are generally heading in the right direction in the most important subregions. However, due to the ongoing increase in total water withdrawals shown in Figure 4.2, it has clearly not been enough to prevent increasing pressure on water resources.

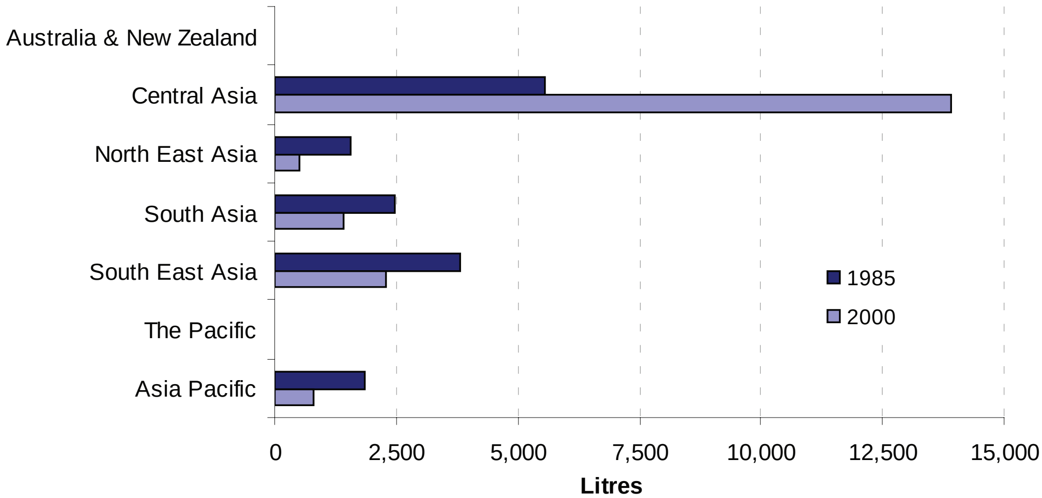

FIGURE 4.5.
Water intensity, litres per $US for 1985 and 2000

Sectoral water withdrawals

Over 80% of annual water withdrawals in the Asia-Pacific region in the recent past (1998–2002) have been used for agricultural purposes, representing 1,848,041 GL (Table .1). During that time, 11.4% of water or 259,385 GL/year was withdrawn for industry, slightly more than for municipal use. Although heavily populated, the Asia- Pacific region withdrew only a small fraction of water (7.1%) for municipal/ domestic use, with an overall volume of water withdrawn of 161,260 GL. Although withdrawals for domestic use were lower in the poorest countries, many countries have seen a rapid trend of increasing domestic water use over the last decade (UNESCAP 2009).

Table 4.1. Annual water withdrawals by sector for 1998–2002

Subregion	Agriculture (GL)	Percentage of total withdrawals	Industry (GL)	Percentage of total withdrawals	Municipal (GL)	Percentage of total withdrawals	Total withdrawals (GL)
Australia and NZ	18,900	72.6%	2,600	10.0%	4,540	17.4%	26,040
Central Asia	127,450	91.0%	8,040	5.7%	4,540	3.2%	140,030
North-East Asia	503,120	66.7%	183,240	24.3%	67,370	8.9%	753,760
South Asia	925,510	89.9%	40,575	3.9%	63,580	6.2%	1,029,675
South-East Asia	273,010	85.6%	24,890	7.8%	21,180	6.6%	319,080
The Pacific	51	36.2%	40	28.4%	50	35.5%	141
Asia-Pacific	**1,848,041**	**81.5%**	**259,385**	**11.4%**	**161,260**	**7.1%**	**2,268,726**

Source: FAO Aquastat (2009)

According to Table 4.1, during 1998–2002, the highest percentage withdrawal per sector was in Central Asia for agricultural use, at 91%, the least in the Pacific at 36.2%. The Asian subregions had larger water withdrawals for agriculture than did the Pacific. Australia and New Zealand's' withdrawals for agricultural at 18,900 GL are just over 2% of those for South Asia alone, and 1% of regional withdrawals. In terms of actual volumes of water withdrawn, agriculture in South Asia consumed the most at 925,510 GL, while in the Pacific only 51 GL were withdrawn. This indicates that, while the percentage of water withdrawn for agriculture may be high, the actual volume used varies widely

between countries and subregions, in keeping with the large disparities in population. Furthermore, water withdrawal figures fail to account for the water used in rain-fed agricultural practices.

Withdrawals for industry was greatest as a proportion of total subregional withdrawals for the Pacific (28.4%), followed by North-East Asia (24.3%), while for all other subregions it constituted less than 10% of water used. The greatest total volume of water used for industry was by North-East Asia, with 183,240 GL, which is over four times greater than the next largest user, South Asia. Across the Asia-Pacific region, many economies were using more water for industry. China and Viet Nam have significantly increased their industrial water withdrawal over the last decade (UNESCAP (2009). Figure 4.6 depicts the water withdrawals by sector for 1998–2002. Note that in some of the following graphs the disparities between some subregions are so large that values for the smaller subregions are not actually discernable, such as any of the Pacific's water withdrawals, or Australia and New Zealand's municipal or industry withdrawals.

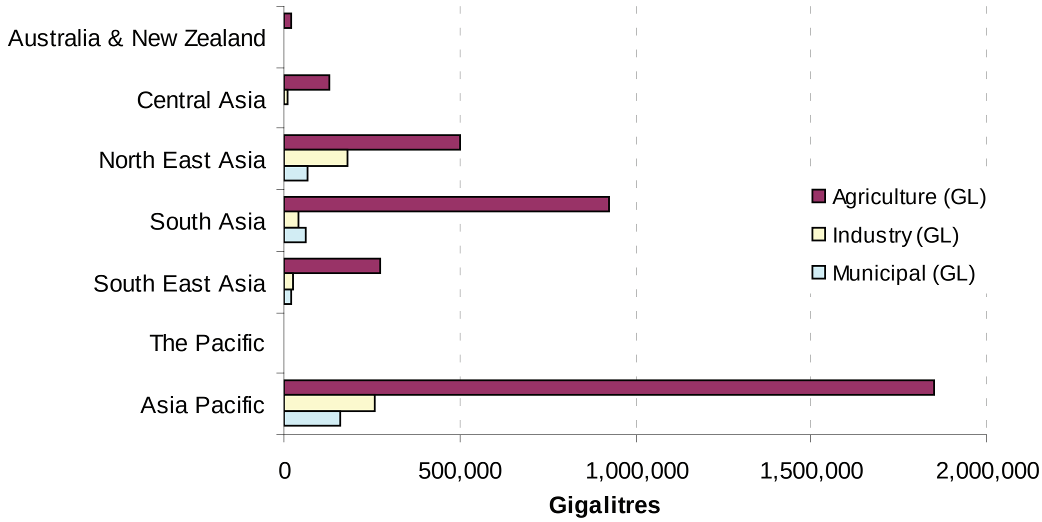

FIGURE 4.6.
Water withdrawals by sector for 1998–2002

Water withdrawals in megalitres (ML) per capita for each subregion during 1998–2002, are represented in Figure 4.7. Central Asia withdrew almost 2.5 ML/capita, which is significantly more than other subregions. Australia and New Zealand had the second highest water withdrawals per capita, though less than 50% those of Central Asia. The Pacific used very little water per head of population. As could be anticipated, the effects of these sparsely populated subregions on consumption in the region as a whole is insignificant, with overall consumption per capita at 0.63 ML/capita being intermediate between the region's most populous subregions South Asia (0.68 ML/capita) and North-East Asia (0.5 ML/capita).

It should be noted that some countries of the Pacific are highly water stressed because of limited access to water resources: in particular, Tuvalu, Nauru, Kiribati, and the Marshall Islands. Consequently, water intensity rates fail to account for under-developed water management systems, reliance on rain-fed agriculture, and threatened freshwater resources (Burns 2000).

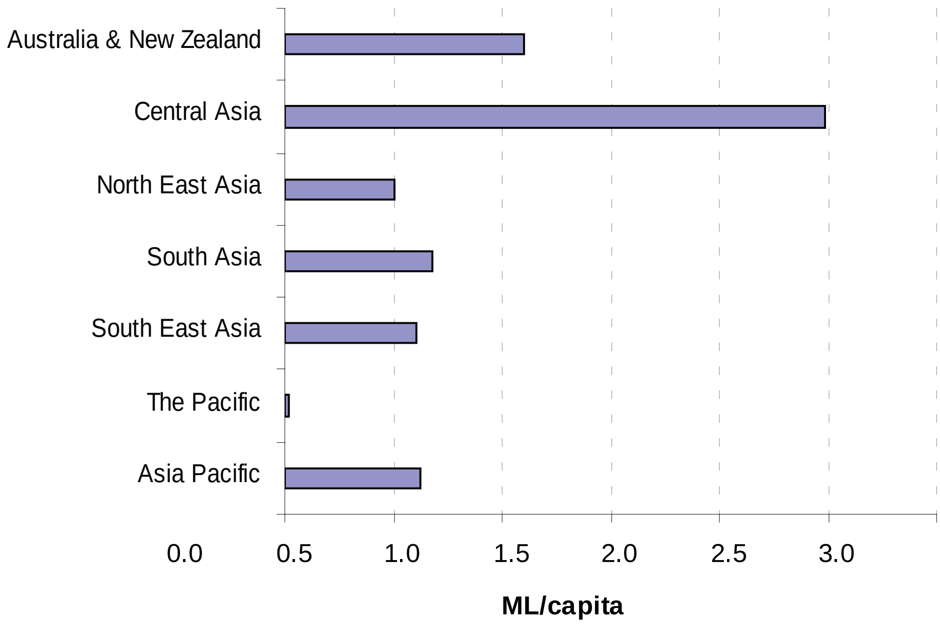

FIGURE 4.7.
Water withdrawals in Asia-Pacific in ML/capita

Water productivity and water intensity

Water productivity is the quantity of produce (crops and other goods) that can be obtained per unit of water used (Molden and Sakthivadivel 1999). Consequently, water productivity can be increased through improved agronomic practices, such as crop varieties, and improved supply and demand management, regionally and at farm scale. In other words, increasing water productivity is achieved by increasing the technical efficiency of production (Billi *et al.* 2004). According to FAO (2003), increases in crop yields between 1961 and 2001 improved the productivity of water used in agriculture by 100%. At the same time, irrigated rice yields doubled and rain-fed wheat yields rose by 160%, with little variation in water consumption per kilogram of output. Globally, FAO (2003) estimates that water needs for food per capita halved between 1961 and 2001; a significant saving and a significant gain for other water users. However, it must be noted that there are many other uses of water; for the production of timber, firewood, and fiber, aquaculture and animal husbandry, domestic consumption and environmental servicing, which should also be considered when assessing and valuing water resources (FAO 2003).

In practice, estimating comprehensive measures of water productivity across an economy from physical outputs of crops, materials, and so on, is generally not practical because of the lack of sufficiently disaggregated data on water use and the individual product categories. More generally achievable measures of water efficiency can be obtained by using measures of value added or expenditures within a broad sector, such as agriculture or industry, which can be matched to correspondingly broad categories in water use accounts, to calculate water intensities. The overall water intensity of an economy refers to the total water consumed in that economy, divided by economic output per dollar (US) of GDP. Sectoral water intensities refer to the water used by that sector per dollar of value added by that sector, such as water withdrawals for agriculture/ value added from agriculture. Water intensity is simply the inverse of water productivity, so lesser values for water intensity reflect higher water productivity.

Figure 4.8 shows the Asia-Pacific region to have had an overall water intensity for agriculture of 3,454 L/$US. Central Asia had the highest water intensity for agriculture at 18,315 L/$US, which was the lowest water productivity for any subregion and sector. The all sectors average depicted in Figure 4.8 for Central Asia was 3,766 L/$US after the high water intensity for agriculture was combined with 694 L/$US for industry and 104 L/$US for municipal/domestic use. Australia and New Zealand had a value of 1,093 L/$US for agriculture, a relatively low intensity for this sector and less than a third of the regional average. For the region as a whole, the average all sector water intensity of 273 L/$US is again intermediate between that of North-East Asia and South Asia. The third most populous subregion, South-East Asia, is also intermediate in its water intensity (579 L/$US) between North-East Asia and South Asia, as it was for per capita withdrawals.

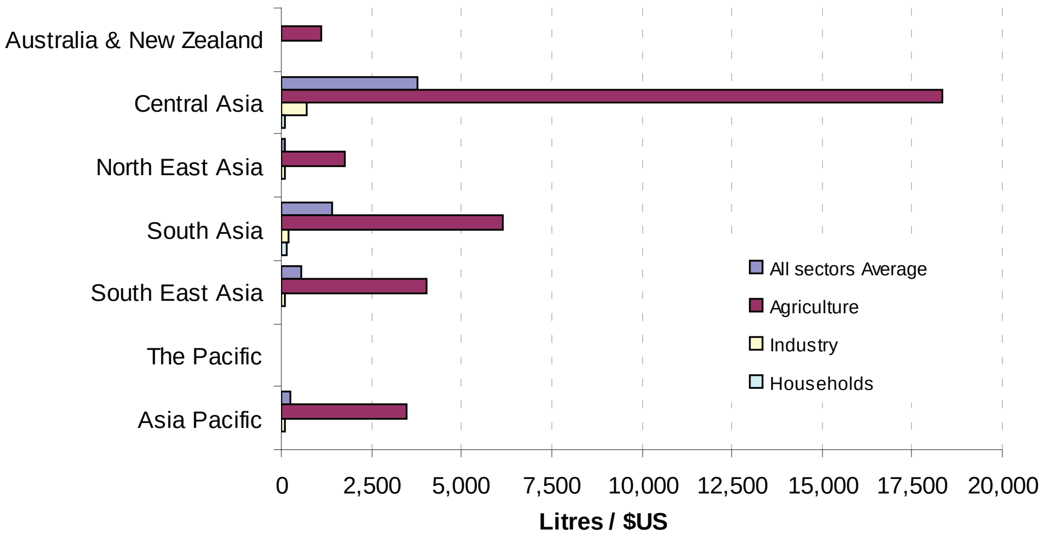

FIGURE 4.8.
Water intensity per $US, by sector, for 1998–2002

Figure 4.9 maps the water intensity per $US, for countries in the Asia-Pacific Region, for 1998–2002. Central Asia shows the highest water intensity values, with countries around the Himalayas, particularly Pakistan, also yielding high water intensity values. The Mekong river area in South-East Asia also displays high water intensities. These subregions and river basins support major food production through intensive agricultural activity. The associated countries are characterized by large populations, many of which are expected to grow rapidly over the next few decades, so reducing water intensity will be important to improve food security in the future.

Water abstraction rates and water stress

The difficulties in meeting water resource needs from available freshwater resources are often exacerbated by limited water availability and poor-quality water supplies. Further challenges are experienced by countries highly dependent on external water resources. This is particularly apparent for countries dependent on river flows sustained by glacier melt, especially the Ganges, Indus, Brahmaputra, Mekong, Thanlwin, Yangtze, and Yellow Rivers, as well as the Amu Darya and Syr Darya rivers. India, the Islamic Republic of Iran, Uzbekistan, and Pakistan are among the most vulnerable countries in this regard (UNESCAP 2005).

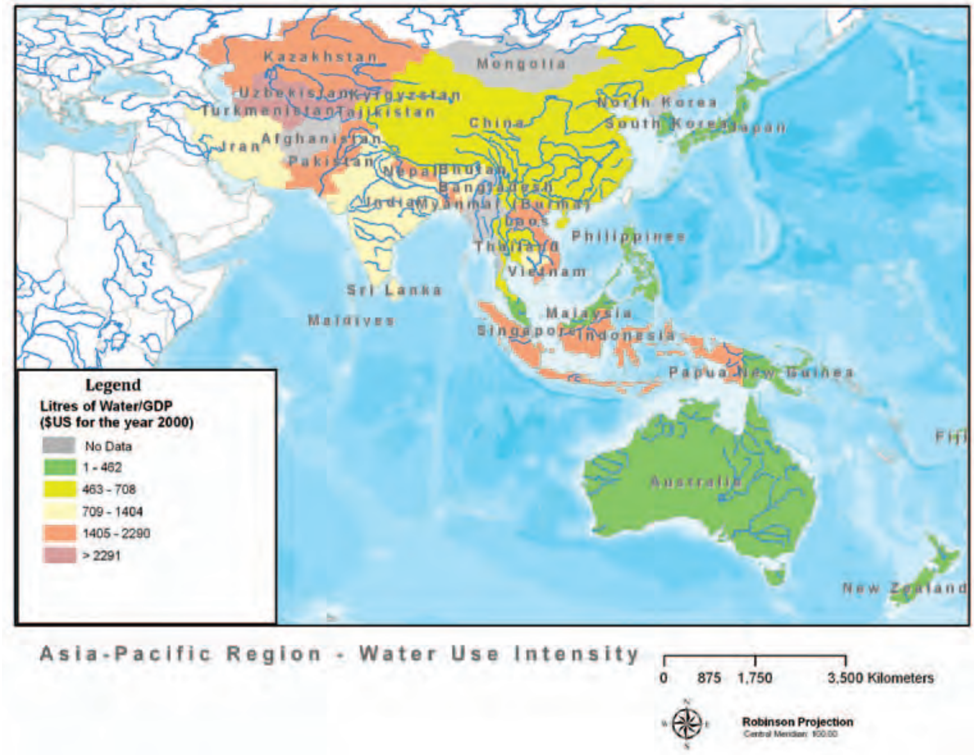

FIGURE 4.9.
Water intensity per $US, in Asia and the Pacific, for 1998–2002

Water abstraction is the portion of available freshwater resource used and is an indication of pressures on water resources. Countries with high abstraction rates in relation to renewable resources are prone to water stress. Water abstraction rates are unsustainably high in many countries in the Asia-Pacific region (UN-WATER/WWAP 2006). The situation is serious in Central Asia, particularly in Uzbekistan, Turkmenistan, and Tajikistan. These countries are already withdrawing more water per year than is available from renewable sources. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, high withdrawals indicate that China has also been extracting water rapidly.

Total water withdrawal as a percentage of total renewable resources during 1998–2002 is shown in Figure 4.10. The Asia-Pacific region used 14% of total renewable resources, while Central Asia accessed 63% of total renewable water resources, more than double the extraction of the next subregion. South Asia and North-East Asia, with values of 27% and 22%, respectively, had higher extraction rates than South-East Asia (4.5%) and Australia and New Zealand (3.2%), while there was insufficient data to calculate values for the Pacific.

Water stress is considered to occur when per capita water supply drops below 1,700 m³/year and then frequently disruptive water shortages occur (World Resources Institute 2003). When annual water supplies drop below 1,000 m³ per person per year, severe consequences can include disruption to food production and economic development unless the region is wealthy enough to apply new technologies for water use, conservation, or reuse. Globally, a quarter of the terrestrial surface (excluding Greenland and Antarctica) is under severe water stress. In Asia and Pacific countries, the highly and severely water stressed areas are in the large basins in China (including the Yellow River), the Krishma in India, and much of Central Asia (Alcamo *et al.* 2000).

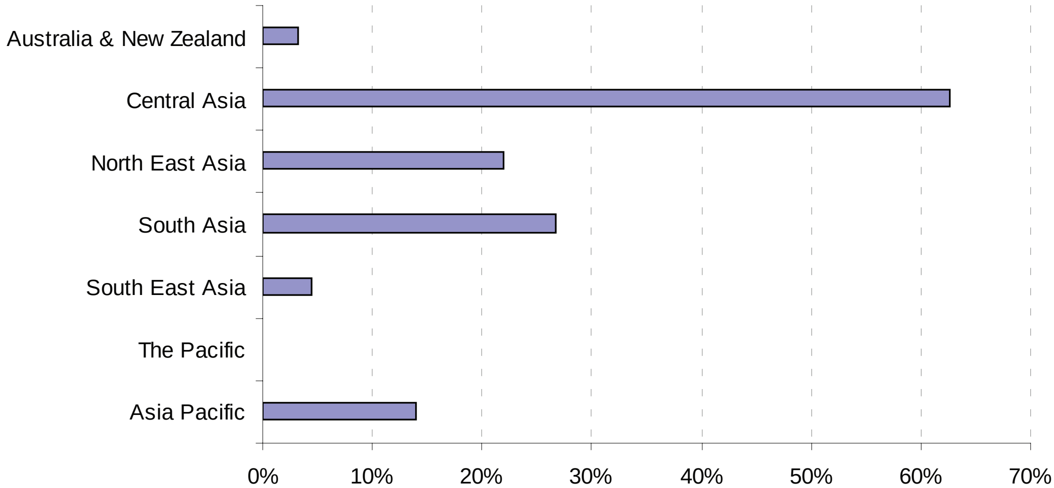

FIGURE 4.10.
Total water withdrawal as a percentage of total renewable water resource for 1998–2002

Figure 4.11 compares water stress for various countries in the Asia-Pacific region using the Water Exploitation Index, calculated by dividing the national mean annual total abstraction of fresh water with the mean annual total renewable freshwater resource, expressed in percentage terms. The index shows available water resources in a country compared with the amount of water used. An index of over 20% usually indicates water scarcity, relative to the amount required. Accordingly, countries between 20 and 40% are considered stressed, while those with a Water Exploitation Index above 40% are considered to be under severe stress.

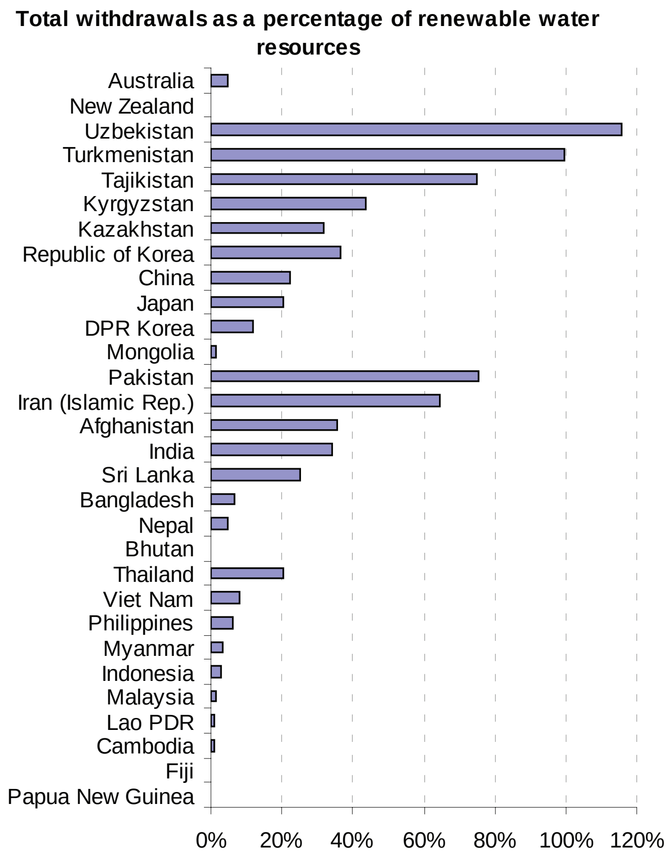

FIGURE 4.11.
Water Exploitation Index – indicator of the sustainability of withdrawals and resultant water stress.

Box 4.2 details how climate change is projected to affect one of Australia's major river basins.

Box 4.2: Key findings of the CSIRO Sustainable Yields Project for the Murray-Darling Basin, Australia

The CSIRO Murray–Darling Basin Sustainable Yields Project assessed 18 regions of the Murray–Darling Basin, which collectively are considered to make up Australia's 'food bowl'. The key findings are summarized as:

- Water resource development has caused major changes in the flooding regimes that support nationally and internationally important floodplain wetland systems in the Murray–Darling Basin (MDB). Integrating the flow impacts down through the connected rivers of the Basin shows that total flow at the Murray mouth has been reduced by 61%; the river now ceases to flow through the mouth 40% of the time compared with 1% of the time in the absence of water resource development.

- The south of the MDB was in severe drought from 1997 to 2006 and the catchment runoff in the southernmost parts of the MDB was the lowest on record. This event would occur once in more than 300 years without climate change. Such conditions will become increasingly common. The drought conditions in the south of the MDB further worsened in 2007 and 2008.

- The impacts of climate change by 2030 are uncertain; however, surface water availability across the entire MDB is more likely to decline than to increase. A decline in the south of the MDB is more likely than in the north. In the south of the MDB, a very substantial decline is possible. In the north of the MDB, significant increases are possible. The median decline for the entire MDB is 11%: 9% in the north of the MDB and 13% in the south of the MDB.

- The median water availability decline would reduce total surface water use by 4% under current water sharing arrangements, but would further reduce flow at the Murray mouth by 24% to be 30% of the total without-development outflow. In volumetric terms, the majority of the impact of climate change would be borne by the environment rather than by consumptive water users.

- The relative impact of climate change on surface water use would be much greater in dry years. Under the median 2030 climate, diversions in driest years would fall by more than 10% in most New South Wales regions, around 20% in the Murrumbidgee and Murray regions and from around 35 to over 50% in the Victorian regions. Under the dry extreme 2030 climate, diversions in driest years would fall by over 20% in the Condamine-Balonne, around 40 to 50% in New South Wales regions (except the Lachlan), over 70% in the Murray and 80 to 90% in the major Victorian regions.

- Groundwater currently represents 16% of total water use in the MDB, but under current water sharing arrangements groundwater use could increase by 2030 to be over one-

quarter of total water use. One-quarter of current groundwater use will eventually be sourced directly from surface water diversions. Current groundwater use is unsustainable in seven of the twenty high-use groundwater areas in the MDB and will lead to major drawdowns in groundwater levels in the absence of management intervention.

- Expansion of commercial forestry plantations and increases in the total capacity of farm dams could occur by 2030. 'Best estimate' projections of these developments indicate only very minor impacts on the total runoff reaching rivers across the MDB. However, the volumes of surface water used by these developments, and the within-subcatchment streamflow impacts, may be significant.

(Source: CSIRO 2008)

Future trends in water use, withdrawal and consumption

Between 2000 and 2050, the world's population is projected to grow from 6 billion to 9 billion, and demand for food and other goods will increase significantly (UN-WATER/WWAP 2009). Alcamo *et al.* (2000) explore future water usage under several scenarios based on assumptions designated as (1) Business as usual (BAU), (2) Technology, Economics and the Private sector (TEC – in which the free market system and new technologies are assumed to reduce water demand) and (3) Values and Lifestyle (VAL – in which commitment and human values avert a water crisis). These were used to explore the consequences to water use of continuing current trends in populations, economy, technology, and human behaviour up to 2025. The findings indicate that water withdrawals will decline in developed nations and rise in developing nations, thereby further increasing pressure on water resources. Accordingly, many river basins will be under severe stress, complicated by strong competition for scarce water resources between households, industry, and agriculture. Many of the world's transboundary river basins will be stressed or highly stressed, and the competition for these resources may cause ongoing tension between nations.

Under the three future scenarios (BAU, TEC, and VAL), Alcamo *et al.* (2000, p. 39) suggest outcomes for the Asia-Pacific region which indicate rapid population growth. In addition, urban populations are likely to increase by 60% before 2025, significantly increasing pressures on available water supplies (UN-WATER/WWAP 2006).

Structural change in the domestic sector will increase water use per capita while technical change will decrease water use slightly, with a net overall increase. Strong economic growth will lead to more material wealth and greater water use in households, increasing overall domestic water withdrawals. Meanwhile, industrial water intensity will decrease through efforts to improve water efficiency, but larger quantities of water will be used and water withdrawals will increase.

In the agricultural sector, irrigated areas in the region will remain at current levels, with some expansion in India, while irrigation efficiency is expected to improve. Investment in irrigation will reduce and there will be losses of irrigated areas to salt intrusion and waterlogging. Future predictions indicate the role of agriculture will slightly decrease with intensive growth of other water uses, primarily industrial

and public water withdrawal. By 2025, agriculture is expected to increase requirements for water withdrawal by 1.3 times, industry by 1.5 times, and the public supply by 1.8 times (Shiklomanov 2000, p.23).

The overall predicted trend for water use to 2025 for the BAU scenario is an increase in total water withdrawals and increasing pressure on water resources, causing water stress (Alcamo *et al.* 2000). In the TEC scenario, withdrawals will not grow as rapidly because of structural changes, though a net increase is predicted. In the VAL scenario, total water withdrawals are predicted to decrease because of a decline in water intensity in the industrial sector and as irrigated efficiency improvements override the small expansion in irrigated land.

Conclusion

Water withdrawal per capita in the Asia-Pacific region is increasing, with an ongoing upward trend, and many countries are extracting water in an unsustainable manner. In Central Asia, the situation requires immediate attention and appropriate policies and international agreements to dampen cross-boundary tensions. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, high withdrawals indicate that China has also been extracting water rapidly. In the Pacific, coral islands are threatened by reduced precipitation, increasingly variable rainfall patterns and rising sea levels, storms, and tsunamis that can have an impact on the shallow freshwater lenses that form to provide and protect groundwater (Moglia *et al.* 2008). Saline intrusion may infiltrate the aquifers. This would be a significant threat to islands reliant on freshwater aquifers and decrease their ability to maintain water quality fit for drinking and agricultural purposes. IWRM techniques are essential to protect vital water resources in the Pacific region (SOPAC 2009).

Data limitations on water resources have been overcome by exploring trends in water withdrawals in various sectors in the past and predicting future trends. An unsustainable trend is emerging in the Asia-Pacific region, with increasing water withdrawals leading to over-extraction. The situation is serious in Central Asia, South Asia and increasingly so for North-East Asia. Notably, Central Asia is experiencing serious water extraction issues, with the highest extraction for agriculture in the region and the highest per capita extraction, and the lowest water productivity for the region.

Scenarios of future water withdrawals indicated a decline in developed nations and rising withdrawals in developing nations, and that many river basins will be under severe stress, complicated by strong competition for scant water resources between households, industry, and agriculture. Under the *Business as usual* future, a significant proportion of the population in Asia-Pacific region will live in water-stressed river basins, which will heighten the need for policies supporting water use efficiencies and water demand strategies to provide a basis for future economic growth and to provide water resources for burgeoning populations. Improved water productivity of regions more dependent on irrigated agriculture and an increase in water efficiency is needed. Additionally, technologies and infrastructure supporting alternative water sources, recycled water, eco-city development, and dampened water demands while tackling industrial and urban pollution at point of source, may allow for water savings and protect the quality and quantity of water available for consumptive use. All

sectors are expected to increase requirements for water withdrawal in the future and consequently many of the world's transboundary river basins will be stressed or highly stressed, and the competition for these resources may threaten harmony between nations.

International assistance in developing effective IWRM policies and transboundary agreements for riparian areas will be needed to ensure access to a sustainable water supply. Monitoring of groundwater levels and managing of surface to groundwater connectivity and provision of environmental flows will be necessary to ensure biodiversity and ecosystem services outcomes and sustainable water supplies into the future.

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