Water Security Problems in Asia and Longer Term Implications for Australia

Gurudeo A. Tularam and Kadari K. Murali

Abstract This paper reports on water security issues in Asia that has long-term security implications for Australia. Asia's water problems are severe with one in five people not having access to safe drinking water. Water security is defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies. It is a function of access to adequate quantities and acceptable quality, for human and environmental users. This analysis shows many Asian countries will face greater challenges than present from population explosion, shifts of populations from rural to urban areas, pollution of water resources and over-abstraction of groundwater. These challenges will be compounded by the effects of climate change over the next 50 years. It is then necessary to mobilise technologies, techniques, skills and research to aid security issues in Asia now. Otherwise, population growth, rapid urbanisation and climate change issues will worsen placing strong demands on water resources, thus creating water refugees, and this will affect countries close to Asia such as Australia. Reducing water's destructive potential and increasing its productive potential is a central challenge and goal for the sake of future generations in Asia and Australia.

Keywords Water · Water security · Asian water security · Water threats · Governance of water · Climate change · Water pricing

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1 Introduction

Water is crucial to all life on earth, economical activities, and environmental and agricultural systems (Sadoff and Muller 2009; Tularam and Ilahee 2007; Tularam 2010). People require water to drink, produce food items and conduct other real-life activities (Beppu 2007; Tularam and Singh 2009; Tularam 2012; Tularam and Keeler 2006). It is one of the most fundamental requirements for survival of all life on earth (George et al. 2008) in that all earthly systems depend on the reliability and quality of water (Beppu 2007; Indraratna et al. 2001; Tularam and Ilahee 2007). The effects of global warming are drying out many regions making clean water supply precious (Jones 2009; Renner 2010); yet, interestingly, Biswas and Seetharam (2008) argued a fortunate position exits, in that a drier and more crowded world could still have enough water to meet the needs, if water supply is regulated nationally and internationally.

Water security can be defined as “the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production” (Sadoff and Muller 2009, p. 11). History shows that water problems have wiped out civilisations such as Mohenjo in India and others in the past (Tularam 2012). Indeed, there have been some boarder conflicts around the world arising because of water (Beppu 2007; Tellis 2008; Tindall and Campbell 2010). A mild border conflict of water rights and pumping from rivers presently exist in Australia. The potential for future conflicts arising from water security issues is real, and as such, it is important to consider water security concerns in Asia and examine possible consequences and implications for Australia (Wouters 2010; Tularam and Properjohn 2011).

Growing populations and economies including some fundamental changes in the hydrologic cycle have together increased demands on global water supply threatening biodiversity, food production and other everyday needs (Barnett 2003; Renner 2010). Increasing demands of water has led to water shortages, with more than one billion people being without adequate drinking water even when water is essential for maintaining adequate food supply and productive local environments (Smith and Gross 1999). The global water stress situation particularly in many parts of Africa and Asia demands higher level planning and strategies if we are to overcome major future water crises (Guthrie 2010; Smith and Gross 1999). In recent times, water security is gaining attention but governments need to act quickly as water is a strategic resource that can help achieve sustainable growth and progress (Sadoff and Muller 2009; Tookey 2007).

This paper specifically addresses water issues in countries close to Australia such as those in Asia. The critical analysis is conducted to consider reasons why flow of persons (so-called water refugees) may occur from Asia towards greener pastures such as Australian shores, thus considering longer term implications for Australian boarders. This is an issue that has had very little attention in the past but requires important strategic visionary planning for sustaining harmonious relationships with our neighbouring countries in future.

1.1 Water Security

The concept of water security is framed in terms of seven interconnected concerns that are relevant to water allocation in order to evaluate the overview of water security framework (Briscoe 2009; De Loe et al. 2007):

- Ecosystem protection;
- Economic production;
- Equity and participation;
- Integration of resource;
- Water conservation;
- Climate variability and change; and
- Trans-boundary sensitivity.

As noted, water security is a multi-dimensional concept that recognises that sufficient good-quality water is needed for social, economic and cultural uses as a whole. It seems that an effective, efficient and equitable water allocation system is critical in achieving water security (De Loe et al. 2007; Pigram 2006; Renner 2010). Essentially, water security involves protection of vulnerable water systems, protection against water-related hazards, sustainable development of water resources and actively safeguarding access to water functions and services (Biswas and Seetharam 2008; De Loe et al. 2007; Raj 2010). Adequate water is required to sustain human activities and enhance ecosystem functions as well as maintain border sensitiveness and security where rivers, for example, pass through boarders.

Figure 1 shows the Asiatic region and the position of Australia of in it. The high level of population growth in Asia compared with the rest of the world is one of the main reasons that water security could become a great global challenge not only for Asia but also for Australia (Wouters 2010). For example, the population increase in India and China has contributed to doubling of irrigated areas and tripling of water withdrawals from groundwater in the region (Raj 2010; Wouters 2010).

Figure 1 shows populated water stress Asian countries close to our region such as India and Pakistan, Nepal, China and Indonesia, for example. The impacts of climate change such as rising sea levels, extreme flooding and droughts and decline in agricultural productivity are occurring in Asian countries (Nuttall 2005; Vorosmarty et al. 2010). There already exists some tension within Asia concerning access to water, public health and global economic growth (Tellis 2008; Tindall and Campbell 2010). Therefore, it is important to critically analyse water resources, accessibility, capacity, quality and use in Asia (Biswas and Seetharam 2008; De Loe et al. 2007) if only to identify gaps in water security, and to address them to aid water security of the region (Briscoe 2009; Tellis et al. 2008).

The main aim of this paper was to identify water security issues in Asian countries to consider possible longer term implications for the Australian shores by “water refugees”. This is done by examining critically the water security issues of populated and water-stressed countries in Asia. Particular attention is paid to populated Asian countries that experiencing serious domestic water challenges and are

Fig. 1 Asian countries close to Australian borders (adapted from BugBog 2001) (http://www.bugbog.com/maps/asia/asia_map.html)

in proximity of Australia. Today, boat migrants are increasing daily but they are not water refugees, yet the complexities in the region need a closer examination in terms of water security problems to comprehend underlying issues that may cause flow of water refugees. A background of water is presented next that is followed by country-by-country analysis in terms of water stress. A critical analysis of the issues related to water security follows factors such as causal factors and solutions and their concerns, use of technology and so on. Some important questions are then posed, and possible solutions are explained. This is followed by the conclusion including some implications for water security in Asia and Australia.

2 Background

More than 97.5 % of the world's water is salt water in the oceans and seas, leaving 2.5 % as freshwater and much of it is contained in glaciers, deep aquifers or soil moisture (Fig. 2; UNEP 2010). Water is not uniformly distributed throughout the world (Nettle and Lamb 2010; UNEP 2010; Tularam and Keeler 2006), and as such, accessibility to water cannot be separated from notions of human rights (Pimentel et al. 2004; Renner 2010; Smith and Gross 1999). The security of supply for the next 50 years appears to be critical in overcoming water security problems in the region.

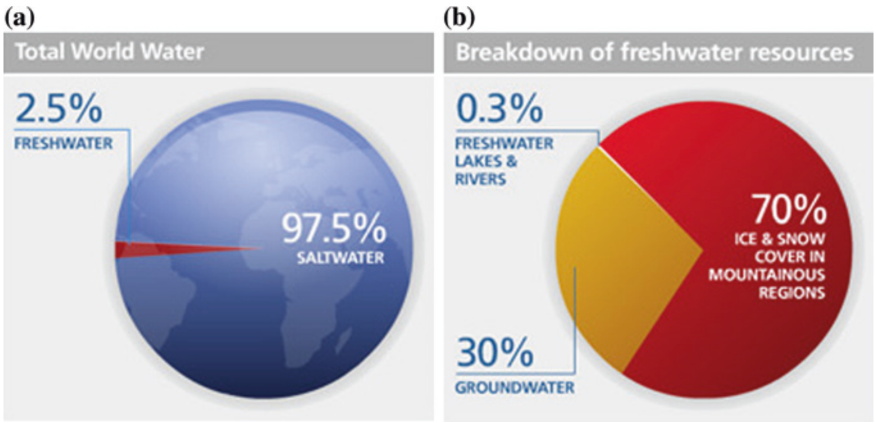


Fig. 2 **a**, **b** Total amount of world water (UNEP 2010)

Although dams constructed in water catchments, and rivers and streams are the main source of fresh potable water in most countries (Indraratna et al. 2001; Qadir et al. 2007), there has been a significant drop in water stored due to the lack of rainfall in many Asian countries over the past decades. Such countries then need to rely on alternative water resources to avoid restrictions and service interruptions to domestic water supply. Where the population density is high and water demand is increasing, desalination, rainwater harvesting, groundwater and surface water have all been considered (Aditi 2005; Guthrie 2010; Pigram 2006), but there are advantages and disadvantages in each case.

2.1 Desalination

Desalination is a process that converts sea water or highly brackish groundwater into good-quality freshwater and used where rain water, storm water supply or the supply of sea water remains abundant (Tularam and Ilahee 2007). In water-scarce environments, potable water can be obtained from desalination plants. There are some advantages such as low whole of life cycle cost and highly reliable water supply source (Pigram 2006; Raj 2010; Saliby et al. 2009). But equally, there are a number of disadvantages for it requires significant amount of energy primarily heat and electricity that can be expensive. There are negative environmental impacts such as air pollution mainly due to greenhouse gas emissions and sea water pollution caused by the production of highly concentrated brine solution (Pigram 2006; Raj 2010; Saliby et al. 2009; Tularam and Ilahee 2007).

2.2 Rainwater Harvesting

Rainwater harvesting involves collecting and storing of rainwater from rooftops, land surfaces or rock catchments using simple techniques (jars and pots) to highly engineered ones. It is an important water source where there is significant rainfall but the process usually lacks centralised supply system. It is an option where good-quality surface water or groundwater is lacking (Barron and Salas 2009; Qadir et al. 2007; Rezwan 2013). The advantages include the following: it acts as a supplement to other water sources and utility systems; it can be used in emergency or breakdown of the public water supply systems; and it can be used during natural disasters. Harvesting may help reduce storm drainage load and flooding in city streets, often reducing soil erosion; finally, harvesting technologies can be built to meet almost any requirements and maintenance are not labour intensive (Barron and Salas 2009; Qadir et al. 2007; Rezwan 2013). Harvesting has disadvantages such as supply contamination by bird/animal droppings on catchment surfaces and guttering structures; requires constant maintenance and cleaning/ flushing before use; contamination of water by algal growth; and finally invasion by insects, lizards and rodents—thus becoming possible breeding grounds for disease vectors (Barron and Salas 2009; Qadir et al. 2007).

Water can also be stored in an aquifer for use during dry periods and for storage reservoir during wet periods. The use of surface supplies is encouraged when surface water availability is plentiful especially in winter months and during wet years (Sadoff and Muller 2009; Tularam and Krishna 2009). As such, pumping of aquifers should be comparatively less during these wet periods, allowing them to refill naturally or through replenishment efforts such as aquifer storage and recovery (ASR). When stream flows are less (during dry periods), groundwater can be tapped to meet irrigation or urban demands. Thus, surface water can be used for low-demand periods, while groundwater maybe pumped at other times (Aditi 2005; Tularam and Krishna 2009).

Such conjunctive water management plays an important role in addressing sustainable water resource management issues. However, it is important to recognise both the strengths and the limitations of the water management in terms of water security (Aditi 2005; Aswathanarayana 2007). The advantages include the following: improved security of water access; flexibility of switching between more than one water source according to relative availability; capture and conserving of surplus water supplies when available; and delivery of water management and environmental targets (MacKenzie 2009). The main disadvantages are as follows: evaporation, sedimentation, environmental impact of surface reservoirs; flooding of agricultural land; and distribution of water from the reservoir is expensive (Aditi 2005; Renner 2010).

Figures 3 and 4 show groundwater withdrawal and consumption highlighting Asia and India as the greatest user of groundwater. Although the groundwater availability is high, the largest population on earth also lives in this region, thus placing much pressure on groundwater levels.

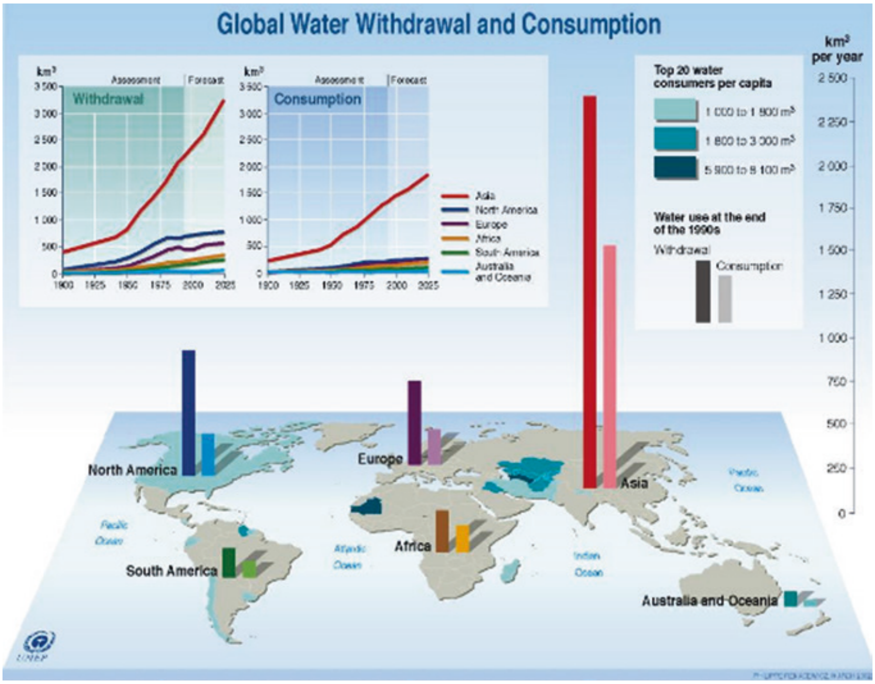
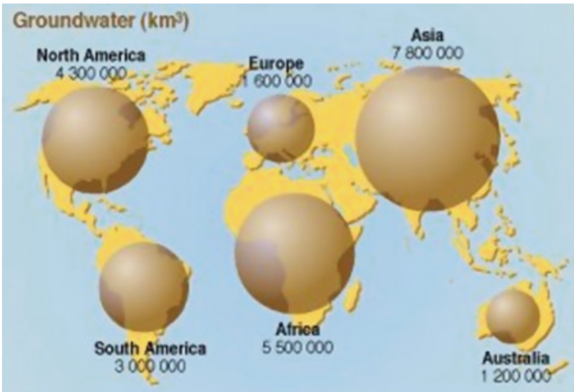


Fig. 3 Groundwater withdrawal and consumption (MacKenzie 2009)

Fig. 4 Freshwater resources (Groundwater in km^3; MacKenzie 2009)



3 Water Stress in Asia: Country-by-Country Analysis

As noted earlier, water security implies affordable access to clean water for agricultural, industrial and household usage, and access for such use is an important part of human security (Grey and Sadoff 2007). Increasing populations, poverty, industrialisation, urbanisation and negative effects of climate change together with inefficient water use have all added to water security problems in Asia. Increase in settlements, grazing and deforestation in Asian mountains appears to have all adversely affected even the rainfall patterns in nearby countries (Aswathanarayana 2007; Jones 2009; Nuttal 2005). Unsupervised withdrawal of water from the rivers or lakes solves problems in the short term but when rivers run dry, ecosystems such as wildlife habitats are critically affected, thus degrading not only the habitats but also land use. Therefore, monitoring rivers and lake waters appears critical if Asia is to avoid problems with water security in the future (Biswas and Seetharam 2008; Pimentel et al. 2004; Xia et al. 2007). To develop a balanced perspective, water security issues of seven different Asian countries are discussed in turn, namely India, Pakistan, China, Indonesia, Nepal, Bangladesh and Japan. The countries were chosen because of their very high populations and also close proximity of Australia. In the past few years, there have been thousands of boat people arrivals and most of them considered refugees. The majority are from the countries selected of analysis excepting Japan. Japan is a developed country; it will provide a balanced picture for it also has a number of water security issues.

3.1 India

Marked by inefficient use and lack of storage facilities, India's relationship with its water resources has always been unsteady (Walsh 2009). India's water utilisation rate is 59 %, already ahead of the 40 % mark that has been set as the standard. A utilisation rate above 40 % means that the natural mechanisms in place do not have the capacity to recharge adequately. That is, water is being used at a rate that is unsustainable (Aswathanarayana 2007; Raj 2010). Water security for India implies effective responses to changing water conditions in terms of quality, quantity and uneven distribution (George et al. 2008; Tellis et al. 2008).

India's water resources are a combination of groundwater resources and surface water resources. However, surface water resources are present in the country in much greater volume when compared to the groundwater resources (Qadir et al. 2007). While rivers form the means of support of most of the cities, towns and villages across the country, groundwater is vital to India's people (Tularam and Krishna 2009). As majority of the rivers in the country are not perennial, groundwater sustains much of the population during lean months (Aditi 2005; Walsh 2009).

Of the different types of surface water resources, rivers constitute the most valuable and huge part. The majority of India's rivers are rain-fed with the exception of those originating in the Himalayas. The Himalayan rivers are perennial owing to the glacier melt that feeds India's fortunes throughout the year. While other rivers in the country are seasonal in nature, due to their dependence on rainfall, the Himalayan rivers flow all year round (Aditi 2005; Shrestha 2009). It seems that Ganges and the Brahmaputra are the most important rivers in the country (Biswas and Seetharam 2008; Jones 2009; Pigram 2006).

3.2 Pakistan

Pakistan problems are initially related to overgrazing of their lands along road corridors in dry regions that have resulted in erosion and landslides as well as dust storms. Such erosion leads to degradation of land resources having a severe impact on agricultural land. The erosion in turn affects the available water resources including groundwater, thus causing water security problems (Grey and Sadoff 2007; Pimentel et al. 2004).

There have been long-term problems in the irrigation sector in Pakistan, which has been further complicated by trends in the upper reaches of the Indus River Basin. The deterioration of infrastructure has led to much seepage from irrigation canals, suggesting only 36 % of the water drawn for irrigation reaches crops. This loss of water makes the system highly inefficient, requiring large quantities of water to be withdrawn in order to grow crops (De Loe and Bjornlund 2008). An estimated 40 % of irrigated land has been affected by poor maintenance and naturally poor drainage, which has led to waterlogging and increased salinity of irrigation water (Sadoff and Muller 2009).

Human population pressures together with unchecked development that facilitates logging, for example, have impacted upon the biodiversity and the ability of water sheds to handle monsoon floods (Rezwan 2013). Some predictions state around 80 % of the productive land may become severely impacted by developments that are deemed to occur by 2030 (Nuttall 2005). Also, the water levels of its rivers in Pakistan may decrease by 30–40 % in future (Funabashi and Shimbun 2010).

In the dry, mountainous region of the upper basin, population growth appears to have caused rapid depletion of groundwater and deforestation that are both linked to more sediment downstream diminishing the quality of water stored in downstream reservoirs and irrigation canals. Sediment build-up has also reduced Indus River Basin reservoir storage capacity by about 20 % (Asia Society 2009).

3.3 China

China's massive population is expected to grow from 1.33 billion in 2010 to 1.42 billion by 2050, causing significant water resource challenges. The country's diverse landscape and large landmass make water problems distinct from the arid north to the more water-rich south (Briscoe 2009). Northern China is characterised primarily by desert and grasslands, but it is experiencing population growth that is accelerating the exploitation of scarce water resources. Severe desertification is further eating up land that once was used for agricultural production, thus choking the more heavily relied upon rivers (Xia et al. 2005). The North China Plain is home to almost 40 % of China's cultivated land area, but 40 % of the population holds only 7.6 % of the country's water resources. Yet agricultural and industrial water demands are growing by more than 10 % a year and are expected to increase by 40 % by 2020 (Xia et al. 2007). Officials have failed to curtail industrial dumping and sewage discharge into the plain's three major river basins, namely the Huai, Hai and Huang (Yellow) Rivers, severely polluting these rivers.

Water shortage in North China is a major issue facing the country due to overcommitted water resources. These include drying up of rivers, decline in groundwater levels and degradation of lakes and wetlands and water pollution (Xia et al. 2005). Its water scarcity is characterised by insufficient local water resources as well as reduced water quality due to increasing pollution both of which have caused serious impacts on society and the environment. Thus, the problem of water shortage in North China has become the significant limiting factor affecting sustainable development (Jianyun et al. 2009; Renner 2010; Xia et al. 2007).

Moreover, climate change effects have increased aridity in drought seasons and will further deteriorate the short water supply in the northern and northwestern parts of China (Ahmed 2009). The catchment management authorities (CMA's) statistics show the temperature in China has risen 0.4–0.5 °C during the past century, slightly lower than the global average increase of 0.6° (Henebry and Lioubimtseva 2009).

In southern China, meltwater from the Himalayan glaciers bordering the Tibetan Plateau feeds some of Asia's greatest water sources including the Yangtze, Yellow, Ganges, Brahmaputra and Mekong rivers. However, the quality and quantity of water from these rivers are threatened by pollution and overwithdrawal including the effects of climate change. Climate change is projected to decrease China's glacial coverage by 27 % by 2050, seriously diminishing water availability for communities throughout south-eastern China (Henebry and Lioubimtseva 2009). South-eastern China is a major site of global manufacturing, as well as agricultural and industrial pollution of its water. The pollution restricts access to good-quality water and creates threats to human health and fisheries, which has in past resulted in bans on Chinese fish exports (Xia et al. 2005).

The dense coastal population of south-east China is particularly vulnerable to forecasted sea-level rise. In north-west China, water access is becoming more salient as domestic, agricultural, and industrial usage. However, the rising sea level has caused salinity changes in the freshwater rivers that feed the ocean, affecting water access and quality, which could cause drying of rivers during non-rainy seasons. If urban infrastructure proves incapable of handling the encroaching sea, the epicentre of China's manufacturing region could be destroyed (Jianyun et al. 2009). As a whole, China is facing increasing water shortages as well as experiencing water resource overexploitation. The low water quality in many parts of China has the potential for serious environmental and socio-economic impacts (Tellis et al. 2008).

Table 1 shows that water demand in China has been rapidly increased compared to 1995 and 2030. These figures indicate that water consumption is going to increase in residential, industrial and agricultural sectors (Tellis et al. 2008). Meteorologists estimate that the western regions of China will lack about 20 billion cubic metres of water from 2010 to 2030, and in 2050, the regions would still

Table 1 Projected water demand in China (1995–2030 in billion tons)

	1995	2030
User type		
Residential	31	134
Industrial	52	269
Agricultural	400	665
Total	483	1,068

need 10 billion more cubic metres of water (Asia Society 2009). China will face a tougher challenge in its water security as global warming will further increase the evaporation of its seven major valleys, of which the annual natural run-off has kept falling as a whole during recent years (Moore 2009). Thus, responsibility needs to be taken to implement major water security measures to protect China's water supply and quality.

3.4 Indonesia

Although Indonesia enjoys around 21 % of the total freshwater available in the Asia Pacific region, many of the country's water security issues are tied to its rapid development, poor urban infrastructure and stretched institutional capacity (Arnell 2004; Bates 2008). The economic growth has not been accompanied by a corresponding expansion of infrastructure and institutional capacity. As a result, nearly one out of two Indonesians lacks access to safe water and more than 70 % of the nation's 220 million people rely on potentially contaminated sources (Wouters 2010). Significant land-use changes and a high level of deforestation have left many areas more vulnerable to extreme events such as monsoon floods (Jones 2009).

Urbanisation and economic development has made Indonesia a pollution hot spot (Asia Society 2009). Waste streams are evident due to growing industrial, domestic and agriculture sectors. Extractive industries account for much of the development, and waste from industrial and commercial processes has made its way into both surface water and groundwater supplies (IIIangasekare et al. 2009). Around 53 % of Indonesians obtain their water from sources that are contaminated by raw sewage for people living in urban slums lack wastewater treatment tools, and the basic sanitation infrastructure necessary to prevent human excrement from contaminating water supplies is virtually non-existent, thus greatly increasing human susceptibility to water-related diseases (Jones et al. 2007).

Large barren hillside areas and underlying soils, which are subjected to heavy precipitation, greatly increase the likelihood and severity of floods and landslides. When flooding occurs, urban infrastructure is quickly overwhelmed, leading to sewage spillover. The post-event clean up and repair costs can be immense, and thus, managing water scarcity is a critical challenge for Indonesia and for surrounding Southeast Asian Nations with similar climates (Barnett 2003; Renner 2010; Sadoff and Muller 2009).

Located along the equator, Indonesia is surrounded by warm waters that create relatively stable year-round temperatures and monsoons drive seasonal variations. Yet climate change threatens to disrupt the regular, alternating periods of rain and arid dryness. The dry season may become more arid, driving water demand, while the rainy season may condense higher precipitation levels into shorter periods, increasing the possibility of heavy flooding. This results in decreasing the ability to capture and store water (Benjamin et al. 2006).

Vulnerability to extreme events and water quality in the capital regions of Indonesia has deteriorated sharply because of sea water intrusion. Pollution and compromised sanitary conditions in much of the country may lead to epidemics and severe health problems, testing institutional capacities. The enormous challenge of environmental degradation directly feeds into many of Indonesia's water security problems (Guthrie 2010).

3.5 Nepal

Nepal lies in the middle of the Ganges and the Brahmaputra (South Asia's major river systems) and is one of the countries with the highest level of water resources. For many Nepalese who live in the hills, the water flowing in the large valleys below is out of reach (Asia Society 2009). Only half of all farmland is irrigated, and more than a third of the population has difficulties in obtaining water in this country (Renner 2010).

Shrestha (2009) noted that many of the rivers in the region have already been affected by deforestation and increased use of water for irrigation, which has been fuelled by existing infrastructure developments. Large areas of pristine wildlife habitats have been laid bare because the river has run dry as a result of demand for water for irrigation by growing settlements. These rivers are the lifeline for the people, but seasonal scarcity of water is an increasing problem as are floods, as a result of land-use changes such as deforestation and intensive agriculture (Henebry and Lioubimtseva 2009; Nuttall 2005).

The uncontrolled dumping of wastes into flowing streams has turned the Himalayan waters into giant sewers. It is said that 80 % of the country's illness is due to contaminated water. Every year, many children die from the waterborne diseases such as dysentery, hepatitis and even cholera which are very common throughout the country. In recent years, another danger has been added to the list of the water pollutants say arsenic (Prasai 2007).

Nepal faces acute shortage of water and remains one of the poorest countries in the world. Nepal has the poorest drinking water and sanitation coverage for its population in South Asia, and a large percentage of its drinking water contains faecal coli forms. Waterborne disease is transmitted through contaminated water, and several bacterial, protozoal and viral waterborne diseases have posed serious public health problem in Nepal. According to the Nepal Country Environmental Analysis, diarrhoea, intestinal worms, gastritis and jaundice are the top five waterborne diseases in Nepal (Prasai 2007).

3.6 Bangladesh

Bangladesh is recognised worldwide as one of the most vulnerable countries to the impacts of global warming and climate change. This is due to its unique geographic location, dominance of floodplains, low elevation from the sea, high population density, high levels of poverty and overwhelming dependence on nature, its resources and services (Arnell 2004; Nishat 2008). Water scarcity of drinking water in Bangladesh is mainly due to reduced precipitation, prolonged dry season and droughts. The available freshwater resources are contaminated with saline water in the coastal aquifer (Beppu 2007; Renner 2010; Sadoff and Muller 2009).

Already challenged by a confounding physical landscape, Bangladesh is faced with unique obstacles to growth and stability because of rising population, urbanisation and poverty (Roberts and Kanaley 2006). According to the United Nations Development Program, four out of five Bangladeshis live below the poverty line (less than US$2/day), and one out of three lives in extreme poverty (less than US$1/day). Despite improvements in health, mortality and poverty rates, significant portions of the population lack access to clean drinking water and sanitation. Clearly, the accelerating urbanisation of Bangladesh will perpetuate the water security challenges (Biswas and Seetharam 2008).

3.7 Japan

Although a water-rich country, Japan is a large importer of mineral water. Japanese culture and society were shaped in a diverse natural environment with a climate ranging from subtropical to subarctic, and Japanese cities are experiencing severe ground subsidence issues due to excessive groundwater abstraction during that period of rapid economic growth. Overabstraction results primarily from population growth and urbanisation (Funabashi and Shimbun 2010). The overabstraction of groundwater has become the major concern in water security (Tularam and Krishna 2009).

Japan depends on imports of many goods. The quantity of water that is necessary for the production of the food that Japan imports is said to be the equivalent of tens of billions of cubic metres of water per year. The processing of grains and meat imported by Japan requires vast quantities of water is as about the same amount as that is being used by 1.3 billion people in developing countries (Asia Society 2009).

Japan is also a high-risk nation in terms of water, vulnerable to drought and flooding, because it lies in the monsoon climate region (Barnett 2003). Japan failed to control water levels due to increased population, and also, water quality is deteriorated due to lack of treatment techniques. Failure to efficient water usage, reuse of sewage treated water has shown impact on use of water resources and thus leads to impact on ecosystems (Jones 2009).

Table 2 Population size and density of Asian countries selected

Country name	Population	Area (km^2)	Population density (person/km^2)
India	1,184,639,000	3,287,590.00	360.34
Pakistan	170,260,000	803,940.00	211.78
China	1,339,190,000	9,596,960.00	139.54
Indonesia	234,181,400	1,919,440.00	122.01
Nepal	29,853,000	140,800.00	212.02
Bangladesh	164,425,000	144,000.00	1,141.84
Japan	127,380,000	377,835.00	337.13

Table 3 Annual freshwater withdrawal for agriculture (%)

Country	Agriculture % of total freshwater withdrawal
India	86.46
Pakistan	96.02
China	67.72
Indonesia	91.33
Nepal	96.46
Bangladesh	96.16
Japan	62.46

3.8 Analysis: Population, Size, Density and Water Withdrawal in Asia

Essentially, water shortages are occurring in Asia due to the rapid population growth and economic development (Table 2). There are shortages of the water necessary to sustain daily life, leading to serious food shortages caused by negative effects on the ecosystems (Beppu 2007; Jones 2009). Water pollution caused by groundwater withdrawal (Table 3), lack of wastewater disposal facilities, increases in population in areas that are subject to dangerous flooding and climate-change-related coastal sea level rises causing pollution of coastal aquifers have altogether led to water security problems in the Asian countries studied (Nuttall 2005).

4 Factors that Influence Water Security: Between Countries Analysis

As noted, water security is emerging as an increasingly important and crucial issue for the Asia Pacific region. The simultaneous effect of agricultural growth, industrialisation and urbanisation is now beginning to show moderate-to-severe water shortages (Tookey 2007). Clearly, this will be compounded by the predicted effects of climate change that will produce even more erratic weather patterns (De Loe et al. 2007; Tindall and Campbell 2010). There are a number of factors that influence or are affected by water security, and these factors need more analysis such as agriculture, industrialisation, environmental factors, demographic factors, economy and livelihood, health security and conservation factors, including migration and conflict. In the following, these factors are briefly analysed.

4.1 Agriculture

One issue that is consistently emerged is the impact of growing food demand on global water supplies (Aswathanarayana 2007; Nettle and Lamb 2010). Renner (2010) stated that the need for irrigation water is likely to be greater than currently anticipated and also warns that the food production will likely be seriously constrained by freshwater shortages in the next century. In Asia, the growing demand for food is a significant factor that will determine the supply of available freshwater. About half of the water that is used for irrigation is lost due to seepage and evaporation. Hence, irrigation can be a powerful tool for expanding crop yields, but it can also be wasteful when mismanaged (Nelson 2009). For example, erosion, waterlogging and salinisation of the soil all make the soil less able to produce crops (Jianyun et al. 2009; Nuttall 2005; Sadoff and Muller 2009).

De Loe and Bjornlund (2008) argued that the irrigation is an important determinant of water security because of the volumes of water used. For example, in India, a change in water security has a direct and immediate impact on agriculture. A majority of India's population, almost 58 %, is employed either directly or indirectly by the agriculture sector. India's primary crops, rice, wheat and maize are all water-intensive crops, especially rice. Since most crops are directly dependent on the monsoon, often the weak and delayed monsoons have caused disorder to India's farming prospects, reducing yield significantly. Apart from the immediate impact of lack of water on crops, there is also the problem of growing desertification due to depleting groundwater resources (De Loe and Bjornlund 2008; Nelson 2009; Raj 2010; Tindall and Campbell 2010) (Fig. 5).

4.2 Industrialisation

Aside from agriculture, another factor that influences the status of water security is degree of industrialisation. Industrial activities in Asian countries require massive amounts of freshwater for such activities as boiling, cleaning, air conditioning, cooling, processing, transportation and energy production (George et al. 2008; Pigram 2006). Also, we see a migration from rural to urban areas and it is expected that by 2030 more than 85 % of the population of Asian Countries will

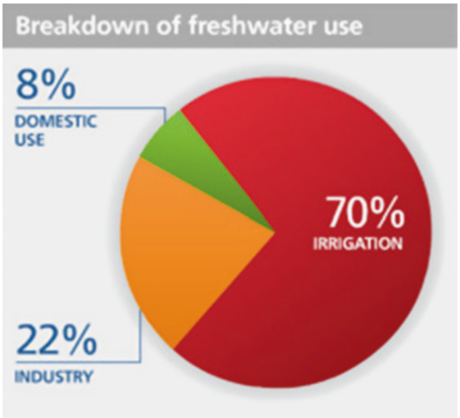


Fig. 5 Percentage of freshwater use for different activities

live in urban centres. In addition, we see a rapid increase in the standard of living as well (more domestic water demand). Due to this, the consumption per capita as well as the need for urban and industrial water supply will increase over time (Asia Society 2009; Renner 2010).

While domestic and industrial water supply can be provided at a substantially higher price than agricultural water supply, we often see in cases where competition develops that water is shifted from the agricultural sector to the urban and industrial sector (Guthrie 2010; Tookey 2007).

4.3 Environmental Factors

Many Asian countries routinely dump human and industrial waste into their rivers and lakes, in which roughly 90–95 % of all domestic sewage and 75 % of all industrial waste are discharged into surface waters without any treatment (Tindall and Campbell 2010; Vorosmarty et al. 2010). The development of provisions for sanitation lags behind the development of urban and industrial water supply, resulting in substantial discharges of untreated wastewater with numerous impacts for the water quality and waterborne diseases (Pimentel et al. 2004). For example, in South Korea, more than 300 factories along the Naktong River illegally discharged toxic wastes directly into the river, whereas, in China, nearly three-fourths of the nation's rivers are so badly polluted in such a way that they no longer support fish life. Meanwhile, all of India's 14 major rivers are polluted, because they transport 50 million cubic metres of untreated sewage into India's coastal waters every year (Jones 2009; Wouters 2010; Xia et al. 2007). New Delhi alone is responsible for dumping more than 200 million litres of raw sewage and 20 million litres of industrial wastes into the Yamuna River as it passes through the city on its way to the Ganges (Biswas and Seetharam 2008).

Another potential environmental threat to water security in Asia is global warming and climate change (Ahmed 2009; Barnett 2003). Changing weather

Table 4 Possible impacts of climate change (adapted from Bates 2008)

Direct impacts of climate change	Implications of climate change
Temperature	Floods
Precipitation and seasonal shifts	Droughts
Variable stream flow and run-off	Water quality
	Loss in power generation
	Agriculture
	Rise in sea level

patterns could result in droughts in areas accustomed to plentiful rainfall and vice versa, but Southeast Asian countries may end up with little rainfall due to unusual weather patterns (Benjamin et al. 2006; Henebry and Lioubimtseva 2009). Many areas of china are likely to have much water when they do not need it (i.e. flooding during the rainy season) and too little when they do (the dry summer months) (Jianyun et al. 2009; Pimentel 2004). Thus, its impact will be felt in terms of reduced rainfall and run-off, leading to increased heat stress, drought and desertification (Renner 2010). Climate change and increasing demands from population growth will cause a worsening of water stress over the coming decades (Beppu 2007; Moore 2009) (Table 4).

For example, in India, climate change is expected to impact the Himalayan Rivers in two distinct ways. The rising temperatures will affect the glaciers at the mouth of rivers such as the Ganges and the Brahmaputra, accelerating the rate at which they melt. Global warming will impact monsoon patterns in such a way that rainfall is more intense and heavy, but concentrated on fewer rainy days. These two factors have already started to impact the two rivers that sustain themselves on rainfall and glacial melt (Ahmed 2009; Guthrie 2010; Moore 2009).

Rainfall is also expected to become more intense and concentrated on fewer days, which will lead to adverse situations such as flash floods. Due to the fewer days of rain, adequate amounts of water will not percolate down to the groundwater tables (Barnett 2003; Henebry and Lioubimtseva 2009). Increased temperatures will also increase the movement of water from the soil and vegetation into atmosphere through evaporation and transpiration reducing the actual amount of water that is available for human use (Aswathanarayana 2007; Nelson 2009).

Around 80 % of the annual rainfall of Nepal falls between June and September, and many people in the hills have to survive on less than five litres of water per capita per day. Months of the year are marked by long spells of drought (Sadoff and Muller 2009; Tindall and Campbell 2010). Nepal depends heavily on rainwater for irrigation, and only 35 % of its arable land has irrigation facilities. Too much water and too little water pattern is likely to continue in Nepal, owing to the unfavourable monsoon with changing weather patterns, erratic monsoons and rising temperatures (Tularam 2010; Shrestha 2009).

Climatic changes in Bangladesh are not only affecting rivers and the waters but also underground water is being affected (Ahmed 2009). Jones (2009) stated that dams and barrages constructed upstream in India are drastically reducing the availability of water in Bangladesh. As precipitation becomes uncertain and as rivers dry up, underground water is not being replenished. Minerals such as arsenic that are extremely harmful to all living beings including plants, animals and humans have been oxidised found in groundwater (Henebry and Lioubimtseva 2009). As sea levels rise and rivers dry up, salinity intrusion has also occurred, affecting land and groundwater (Briscoe 2009). During dry seasons, withdrawal of waters from already silted up rivers will make Bangladesh a desert, and during the monsoons, release of excess waters will flood the whole of Bangladesh since silted up rivers will be unable to carry waters to the sea (Nishat 2008; Nuttall 2005; Walsh 2009).

Land degradation is another variable that will influence the availability of water. For example, in India, land degradation has resulted in reduced aquifer recharge, even in areas that receive large amounts of annual rainfall. Village authorities in high rainfall regions have placed a petition to the central government for drought relief. Similar trends can be seen in China (Biswas and Seetharam 2008; Raj 2010). Xia et al. (2007) noted that more than 100 Chinese cities in Northern and coastal regions have experienced severe water shortages. Renner (2010) said that overpumping and inefficient irrigation techniques have led to sharply declining groundwater levels, loss of wetlands and salinisation of agricultural lands.

Deforestation is yet another challenge, and it is currently extensive in Asia. Deforestation is a major factor in water security because tropical forests protect weak soils from temperature and rainfall extremes, but if trees are removed, it can create a cycle of flooding and drought that results in extreme soil erosion and, in the most extreme cases, desertification (Pimentel et al. 2004; Xia et al. 2007).

4.4 Demographic Factors

At the beginning of the twentieth century, the world's population was roughly 1.6 billion people, but by 1990, it had increased to around 5.3 billion. Currently, the world's population is 6.77 billion and is expected to reach 8.5 billion by the year 2025. Roughly half of this population will live in Asia, but only 16 % of the world's total land surface is occupied by Asian countries. Population growth in Asia is seen as a major challenge for water security in the region and is a fundamental driver of natural resource stress. Asia's increasing population is straining the ecological systems that provide water for drinking, agriculture and other life-sustaining services, while causing a rapid increase in land degradation (Wouters 2010; Jones 2009). Massive urbanisation in Asia will present a new set of water management challenges in the coming decades (Beppu 2007; De Loe et al. 2007; Roberts and Kanaley 2006). Water is required not only for direct consumption and industrial use, but also for any kind of food production activity. Among other things, urbanisation is expected to shift water out of agriculture for growing cities to supply drinking water (Grey and Sadoff 2007). China's growing industrialisation and urbanisation require increased amounts of water; this is the same water that would have gone to agriculture (Tellis et al. 2008; Tookey 2007). Thus, these countries should deploy water saving and water treatment technologies to overcome water security issues in future since the demand for water is rising so quickly.

4.5 Economy and Livelihood

The threat to food security due to water security issues will directly manifest itself in India's economy. The rate of farmer suicides is high and is likely to increase, placing an additional burden not only on the families of those farmers, but also on the community and state (Jones et al. 2007). Apart from agriculture, there will also be an impact on the fisheries and aquaculture sector in India (Nuttall 2005). The lack of future food security will have an immediate and irreversible impact on the economy of the nation. The livelihoods of hundreds of millions of workers, and their families, who depend wholly on the agriculture and fisheries sectors for their livelihood will be adversely affected (Aswathanarayana 2007; De Loe and Bjornlund 2008; Raj 2010). It is clear that Pakistan, Bangladesh, China, Indonesia and other Asian countries will also experience similar problems of an economic nature described above.

4.6 Health Security

In India, for example, polluted water sources are also a leading cause of water-related diseases. In the Ganges Basin, the poorest among the population often have no choice but to drink and cook with seriously polluted water, causing numerous diseases and stomach infections, such as diarrhoea and dysentery. Water shortages have devastating impact on human health, including malnutrition, pathogen or chemical loading, infectious diseases from water contamination and uncontrolled water reuse. Due to lack of safe drinking water, people could end up in using whatever water is available to them, including water tainted with sewage and agricultural run-off or even, contaminated water and end up with diseases (Jones 2009; Raj 2010). In India, hundreds of millions of Hindus revere the Ganges. They believe that bathing in the river purifies their souls. Unfortunately, the river is polluted with sewage. The concentration of pollutants is many times the permissible level. Serious diseases occur, and recurring problems of diarrhoea among the worshipers are common (Renner 2010). In a similar manner, other Asian countries such as Indonesia, Bangladesh and Pakistan also have a number of health-related issues due to lack of clean drinking water.

4.7 Conservation Factors

If the water was used more efficiently in agricultural, industrial and municipal settings, it could help assure water security. In many irrigation systems, as little as 37 % of the water used is actually absorbed by crops; the remainder is lost through evaporation, seepage or run-off. Water used for agricultural purposes could be saved if more efficient irrigation methods were utilised. Thus, the degree of wastage occurs is the key factor in water security (De Loe and Bjornlund 2008; Pigram 2006). The rapid industrialisation and urbanisation along with poor water resource management associated with a large population have severe impact on water security (Grey and Sadoff 2007). Water pollution in Asia resulting from factors such as population growth and greater demand from the agricultural and industrial sectors not only will contribute to increasing rates of food insecurity and land degradation, but also will have detrimental impacts on human health as noted earlier (Tindall and Campbell 2010).

4.8 Migration and Conflict

With parts of the country becoming increasingly water scarce, especially in North India, millions of people will be forced to move away from their homes in search of water supply. In the next two decades, many rural residents will be forced to abandon their hometowns due to the lack of water resources, and increased frequency of extreme weather events such as floods. Lack of job security in the agriculture sector due to water shortages will also force many farmers to leave their villages for a better life (Nettle and Lamb 2010; Raj 2010). With an increased number of people competing for scarce resources and jobs, an anti-outsider mentality will dominate creating a backlash against migrant workers. Inappropriate circumstances and negative external pushes can cause tension, and this could manifest into violence as has been noted in South Africa recently (Nettle and Lamb 2010; Raj 2010; Smith and Gross 1999; Walsh 2009).

The Himalayan River Basins (Ganges, Brahmaputra, Indus and Yangtze) in China, Nepal, India and Bangladesh are inhabited by around 1.3 billion people. These rivers were the lifelines of the ancient civilisations but presently the rivers are under threat. In the next two decades, the four countries in the Himalayan subregion will face the depletion of almost 275 billion cubic metres of annual renewable water, more than the total amount of water available in Nepal today (Bates 2008). Water availability is estimated to decline by 2030, compared to present level by 13.5 % in case of China, 28 % in India, 22 % in case of Bangladesh and 35 % in case of Nepal. The contributing factors are as follows (Bates 2008; Jones 2009):

(a) about 10–20 % of the Himalayan Rivers (https://mail.bag-mail.de/owa/Henrik.Scheller@bertelsmann-stiftung.de/redir.aspx?C=9442d565e87c48b99e78af220c0bdb8b&URL=http%3a%2f%2fblogs.ei.columbia.edu%2fwater%2f2010%2f07%2f19%2fthe-glaciers-disappear-the-startling-photos-of-david-breashears%2f) are fed by Himalayan glaciers, and studies say 70 % of these glaciers will be melted by the next century (https://mail.bag-mail.de/owa/Henrik.Scheller@bertelsmann-stiftung.de/redir.aspx?C=9442d565e87c48b99e78af220c0bdb8b&URL=http%3a%2f%2fblogs.ei.columbia.edu%2fwater%2f2010%2f07%2f19%2fthe-glaciers-disappear-the-startling-photos-of-david-breashears%2f) as a result of accelerating global climate change;

(b) glacial melting will eventually reduce river flow in the low season and increase in temperature in some areas leading to deforestation;
(c) disappearance of thousands of lakes;
(d) depletion of water resources due to pollution and natural reasons; and
(e) reduced river flows induce more deposit of silt in river bed lowering the depth of river, thus causing flooding.

Some implications of depletion of water resources are as follows: non-availability of water leading to less productivity and massive reduction in the production of rice, wheat, maize and availability of fish (Bates 2008; Nuttall 2005).

5 Ways to Overcome and Reduce Water Security Concerns

Water security is a critical factor in government planning in that the protection of adequate water supplies for food, fibre, industrial and residential needs for expanding populations is vital (Biswas and Seetharam 2008; De Loe et al. 2007). Maximising water-use efficiency, developing new supplies and protecting water reserves in event of scarcity are critical aspects of governance. A frequently proposed response to water scarcity is water pricing. To ensure efficient agricultural use, the price of water needs to be raised, but not to the point where it becomes too expensive for residents or farmers to use (Briscoe 2009). The only way that we can cut down the enormous amount of water wasted in farming is by applying more efficient agricultural practices such as drip irrigation and implementing regulations against the industrial pollution users (Walsh 2009). An effective water resource management can also help to protect vulnerability especially when water scarcity may be more severe in the future (Sadoff and Muller 2009; Walsh 2009). To improve drinking water quality, there are two important factors. Firstly, there should be a community-level participation in the management. Secondly, there should be appropriate protection of water sources and waterways and maintenance and protection of infrastructure (Nuttall 2005; Qadir et al. 2007). In the following, governance and regulation, cost of water and some questions that need to be answered are considered in turn.

5.1 Governance and Regulation

Water security is not only about a sufficiency of water but also about recognising the true value of water and managing it accordingly. There is a need for better governance and management at all levels, as well as at the catchment level in regard to water security (Beppu 2007). Where rivers cross national boundaries or lakes are shared between countries, a trans-boundary agreement for water allocation should be negotiated (Smith and Gross 1999). Importantly, when dealing with threats to global water security, negotiations should be sensitive to the individual country's political, social, economic, environmental, financial and cultural conditions (Raj 2010).

5.2 Cost of Water

Water has traditionally been regarded as a free resource. But any costs for it are usually associated with the cost of processing and delivering alone, rather than assigning any value to the resource. There is growing interest internationally in the use of water pricing to reduce demand as well as to generate revenue to cover the cost of providing water supplies and maintaining infrastructure (Pigram 2006; Roca and Tularam 2012; Sadoff and Muller 2009). The effectiveness of pricing in influencing demand depends on water users. For municipal water demand, pricing can be effective when combined with raising user awareness. In the case of water for irrigation, pricing is more complex because the amount of water consumed is difficult to measure and farmer behaviour may not be sensitive to price until the price of water is several times that of the cost of providing water. Large increases in the price of surface water may cause farmers to use groundwater instead, which is relatively unregulated by comparison (Sadoff and Muller 2009).

One of the central problems facing the construction and operation of water infrastructure is the price of water that is paid by the end user. In order to make water a universally accessible good, the National Development and Reform Commission (NDRC)'s Price Bureau has traditionally heavily subsidised and regulated the price of water for all users. However, low water tariffs often make it impossible for utilities and water companies to recover their capital expenditures through the collection of drinking and wastewater fees (Hu 2010). Within the sector, water tariffs differ based on use with industrial users typically subject to higher water prices than municipal or residential users, who pay still more than agricultural users. The first reason is economic in that the industrial wastewater can be more expensive to treat than municipal wastewater, while water used for irrigation is neither treated before being added back to the environment, nor requires as much treatment prior to use. The second reason is socio-economic, where the access to water is considered a basic right. Therefore, affordability remains central to residential prices and the problem is more acute in the agricultural sector, when small-scale subsistence farmers require large volumes of water for irrigation. Thus, water price reform can then have a direct and dramatic impact on livelihood and, in turn, on levels of social unrest (Asia Society 2009; Hu 2010).

Water is a social good, and so should be provided free of charge or at highly subsidised prices (Reza et al. 2013; Roca and Tularam 2012). In contrast, current studies indicate that without appropriate water pricing, the present vicious cycle of waste, inefficiency and lack of services to both the rich and the poor will continue. Lack of income of the utilities due to inadequate water pricing will ensure that the water systems are not properly maintained, and investment funds are not available for updating technology, improving management and technological capacities, expanding the networks and providing wastewater management. There is no question that the era when drinkable water could be provided to everyone free of charge or at highly subsidised rates on a long-term basis is now over (Hu 2010). The users pay for the services they want, the poor who cannot pay receive targeted subsidies, utilities provide water supply and wastewater management services efficiently and accountably, users cover the costs of the services, and public funds are used for public purposes. Of course, this does not mean that we now have all the answers on how water should be priced for different consumers and for different uses (Hu 2010; Tindall and Campbell 2010). There are a number of questions from the above analysis that are in line with those Biswas and Seetharam (2008) posed such as:

(a) How can it be ensured that the poor have adequate access to reliable water and sanitation services at affordable prices while the rich are not subsidised?
(b) How should water and sanitation services be managed in order to ensure the provision of reliable services, economic efficiency, universal access and maximisation of social welfare are met?
(c) What type of institutional frameworks and governance practices are needed to improve the delivery services?
(d) How quickly can all of the above be met allowing for regional social and political sensitivities?

The World Bank notes that many countries face a major challenge in developing and maintaining appropriate water systems infrastructure. Financial institutions are likely to play a key role in making up this shortfall. However, better information on likely costs and barriers to their implementation is needed. This may help to close the water supply–demand gap and help meet the Millennium Development Goals in the long run (Sadoff and Muller 2009).

6 New and Better Technologies, Techniques and Practices

Existing technologies need to be refined, developed and improved to address the challenges of research and development of water security issues. Also, an effort must be made to study the role that technology and the affect it may have on the ecosystem as well (Briscoe 2009; Guthrie 2010). In the following, managing variability, surface water storage, sustainable use of groundwater, water efficiency in agriculture and water efficiency in industry are discussed as possible ways of managing water security problems of Asia.

6.1 Managing Variability

High rainfall variability, high evapotranspiration rates, geographic separation of water resources and irrigation development together make the storage and delivery of water a major challenge to the Asian countries. However, water storage in rivers, lakes, reservoirs and aquifers provides a means of managing variability in water availability, allowing stored water to be used during dry periods. Historically, water resource development in Asian countries has taken a surface water focus, with the construction of large dams. There are opportunities in using aquifers as water banks in conjunction with surface water reservoirs to enable greater flexibility and efficiency in securing water supplies (De Loe et al. 2007; Nishat 2008). Enhancing recharge to aquifers during periods of above-average water availability provides a resource for access during droughts.

A conjunctive approach has benefits when compared with relying solely on large surface water storages. Using aquifers as storage is becoming a viable alternative considering the existing constraints of building new dams due to environmental concerns and general lack of suitable sites. Subsurface storage complements surface reservoirs, and while it may not replace large dams, it could be an alternative to expanding storage capacity using reservoirs alone (MacKenzie 2009; Tualram and Keeler 2006). The infrastructure costs are generally cheaper, and there is the potential that the aquifer material can filter and improve water quality. Although the concept appears simple, sustainable operations which protect groundwater quality require a sound understanding of the hydrological and biological processes involved, along with careful management. Thus, the storage in lakes and reservoirs can be managed to provide potential for the storage of excess flows during floods (Aditi 2005; Qadir et al. 2007).

6.2 Surface Water Storage and Sustainable Use of Groundwater

Surface water storage by means of dams can bring many benefits, but the benefits may come at social and environmental cost caused by the displacement of people or impacts on the ecosystem caused by changes in flow and continuity of rivers. There are many issues to be considered before the construction of a dam such as the need to gain public acceptance, address the impact of existing dams, sustain rivers and livelihood and share river resources for peace and development as well as security (Guthrie 2010). Storing and treating the river water in dams appears attractive. However, building dams in hills of Pakistan, Japan, Indian subcontinent or Indonesia, for example, may not be safe for the dam may sit in the seismically active zone. Moreover, steep gradients of the streams and siltation problems are challenging, and economic, social and environmental cost makes them unattractive (Shrestha 2009).

Another possibility is groundwater that is naturally replenished, or recharged, through rainfall and surface water. Excessive use of groundwater in Asia has been a major problem. Nonetheless, groundwater is an important supply of water for agricultural and domestic use. ASR is the process of storing excess water underground when it is available and recovering that water for use when supplies are short (Aditi 2005; Pigram 2006). This is a new technology but one that can be easily applied in most Asian countries.

6.3 Water Efficiency in Agriculture

It is our responsibility to manage the water use to meet the future needs. Measures such as mulching and conservation tillage will help in retaining soil moisture, especially to manage land cover if supported by soil conservation measures (Nettle and Lamb 2010). Small-scale rainwater harvesting helps to provide an additional source of water for crops. Improved surface irrigation methods such as level furrows, sprinkler and micro-irrigation methods, and the use of advanced techniques of irrigation scheduling and timing can help improve water management at farm level. By monitoring water intake and growth, farmers can achieve greater accuracy when necessary in water application and irrigating only. Remote-sensing schemes are beginning to allow farmers to detect their crops water taking into account meteorological data as well as soil moisture and biomass information (Aswathanarayana 2007; De Loe et al. 2007).

6.4 Water Efficiency in Industry

Water availability is becoming critical in the power industry for electricity generation. Water used for cooling by thermal and nuclear power plants is set to rise throughout the world as new power plants are commissioned. In some cases, it is not simply the availability of cooling water that is the issue, but that outflows from power stations can become warm enough to cause environmental damage on discharge. Water treatment and reuse on site can significantly reduce water abstraction (Tellis et al. 2008).

Achieving water security at the global, national, regional and local levels is a challenge the problem close to Australia must be recognised and met. The previous analysis of Asian countries allowed the identification of factors that influence water security. Factors that influence water security were studied, and new technologies and management issues were examined. Some questions posed regarding the issues that need addressing to achieve water security were posed; clearly, solving these will help build and manage the livelihoods of those who live in the region. A comprehensive and strategic plan to combat Asia's growing water scarcity and water quality problems must include commitment to the development of water infrastructure along with efficient water management guidelines, capacity and expertise. The analysis shows the key to mitigating the adverse impacts of climate change such as water scarcity and water-related disasters is increased understanding of the dimensions of water security infrastructure and management.

7 Conclusions and Recommendations

The analyses conducted in this paper show that population growth accompanied by increased water use will not only severely reduce water availability per person but also create stress on biodiversity in the entire global ecosystem. A fair allocation of water is a key factor while managing the water resources, considering the total agricultural, societal and environmental system, thus maintaining livelihoods of millions in Asia. It is clear that substantial withdrawal of water from lakes, rivers, groundwater and reservoirs to meet the needs of individuals, cities and industries has led to water stress in many parts of the Asia. The amount of water withdrawn from these resources (groundwater and stored water) both for use and for consumption in diverse human activities should be limited to be sustainable over time. Pumping of ground water in order to fulfil human requirements will lead to pollution of water resources and thus not only pose a threat to public and environmental health but also contribute to the high costs of water treatment. The rapid increase in freshwater withdrawals for agricultural irrigation and for other uses that have accompanied population growth has stimulated serious conflicts over water resources both within and between countries, and this has consequences such as creating water refugees. The best approach to conserve the world's water is to find the ways to facilitate the percolation of rainfall into the soil instead of allowing it to run off into streams and rivers. Such an approach will also help reduce flooding more generally during high rainfall periods.

Priorities to use water wisely in Asia could be as follows: (i) farmers should be the primary target for incentives to conserve water since agriculture consumes 70 % of the world's fresh water; (ii) farmers should implement water conserving irrigation techniques (such as drip irrigation to reduce waterwaste) and soil conservation practices (such as cover crops and crop rotations, to minimise rapid runoff); (iii) government and private industry should implement World Bank policies for the fair pricing of freshwater and should reduce or eliminate water subsides; and (iv) countries should develop better management guidelines, actions and policies to control water pollution and protect public health, agriculture and the environment.

The analysis shows that water security strategies depend upon pertinently developed and implemented water management plans and practices. The practices include plans for potable water sustainability, proper wastewater and waste disposal methods, distribution, water-use priorities and water resource development, to overcome water security issues in future. Water resource management must become economically more efficient, ecologically sustainable and also socially justifiable, especially in the regions of the world suffering from water crisis such as Asia. Clearly, the reliance on our rivers for water supplies should and the only way it may be achieved is by using storm water, recycling and desalination.

As noted in the paper, water security is the protection of adequate water supplies for food, industrial and residential needs for expanding populations. This requires maximising water-use efficiency, developing new supplies and protecting water reserves in event of scarcity due to natural, man-made or technological hazards. Thus, a major challenge for water-stressed Asian developing countries is the manner in which they coordinate all the concerned resource policies, legal and regulatory frameworks and institutions responsible for formulating and implementing these policies. For this to occur, there is a need to understand the dimensions of water security, namely household water, industrial and agricultural water, city water, healthy river, water disaster management and water governance.

Water security in Australia has become a major concern over the course of the late twentieth and early twenty-first century as a result of population growth, severe drought, fears of the effects of global warming on Australia, environmental degradation from reduced environmental flows, competition between competing interests such as grazing, irrigation and urban water supplies and competition between upstream and downstream users. Australia also has a major role to play in Asia in terms of aid, building infrastructure, providing capacity and technology transfer. It is in the interest of all Australians that the developing countries in close proximity to Australia have little or no water security issues soon, but for this to occur, a number of steps need to be taken. These steps will not only help here in Australia but also provide leadership in the region.

Australian should continue to recognise the water resource issues in Asia and should take steps to promote sustainable water use by implementing set of policy goals and prioritising the steps undertaken in managing the water resources in the region:

- Australia should establish policy objectives for water resource management, including strengthening river basin management, protecting drinking water sources, combating trans-boundary water pollution, enhancing water saving in agriculture and increasing the treatment rate of urban sewage by 2050;
- provide leadership in the promotion of efficient management of existing available water supplies for agricultural, urban and industrial purposes as well as utilising wastewater and recycling technology; and
- establish the need for public engagement, education and awareness in raising the subject of water security in the region.

Finally, there are a number of more specific water security considerations and concerns that need to be included in the framework such as ecosystem protection—monitoring and enforcement for protection; economic production—stable allocation rules, economically sound decisions, reallocate water between users, sectors and regions; equity and participation—issue of access and equity, stakeholder and public, development of rules to address conflicts, etc; integration of resource—integration of surface and groundwater, quality and quantity, land use and water allocation; water conservation—promotion of more efficient and less consumptive use, inclusion of conservation practices; climate variability and change—investments to understand effects of climate change, development and application of adaptive strategies; and finally trans-boundary sensitivity—coordination of water allocation systems across political and country boundaries, respecting state sovereignty and being sensitive to indigenous customs, etc.

Appendix

See Table 5.

Table 5 Water security concerns and impacts in Asia

Country	Element	Leads to	Impacts
INDIA	Desertification Dumping of unwanted waste into the rivers Excessive Population growth Climate change Land degradation	Depletion of water resources Badly polluted Water Stress Reduced rainfall, run-off and droughts Reduced aquifer recharge	Lack of water on crops Diseases Lack of access to clean water Severe water shortages
PAKISTAN	Erosion Landslides Duststorms Population growth	Agricultural Land and available water resources Rapid depletion of groundwater	Increased salinity issues and water logging problems
CHINA	Population growth Desertification Climate change	Scarce water resources Agricultural production Dimishing water availablity Sealevelrise Pollution Global Warming	Drying up of rivers Decline in groundwater levels Degradation of lakes and wetlands Salinity Issues Threats to human health and fisheries Floods and droughts
INDONESIA	Increase in Population Land use changes and deforstration Rapid urbanisation + Economic development Increased rainfall + flood conditions	Economic growth Floods Pollution Lack of access to clean water and sanitation	Lack of access to safe water Industries have polluted Water related diseases Spread of diseases
NEPAL	Unsustainable land use practices Climate change	Widespread landslides Flooding Uncontrolled dumping of waste into streams	Human lives and infrastrucure got damaged Water borne diseases
BANGLADESH	Climate change	Global warming Sea-level Rise Reduced precipitation and prolonged dry season	Impact on availiable resouces and services Indundation of coastal plains Increase in river and coastal erosion Increase in vector borne diseases Water scarcity
JAPAN	Rapid economic growth+ population growth+ urbanisation Heavy water demand	Excessive groundwater pumping	Groundwater subsidence Sewater Intrusion and sinking lands

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