Pakistan Geographical Review, Vol.77, No. 2, December. 2022, PP 234-260

UNDERSTANDING WATER SCARCITY RISKS OF PAKISTAN: A SPATIO-TEMPORAL VIEW

KINZA KHAN[1] • ASAD ALI KHAN[2]*

[1]Department of Microbiology, Faculty of Veterinary Sciences, BZU, Multan
[2]Department of Geography, The Islamia University of Bahawalpur, Pakistan

*Corresponding author: asadkhaniub@yahoo.com

ABSTRACT

Water scarcity (WS) refers to the dearth of sufficient accessible water resources to fulfil the needs of an area. As a result of population growth and climate change, WS problem is rapidly mounting in many parts of the world. Pakistan is an exceedingly WS vulnerable country with little capability to cope with water crises. Water shortage is a big restriction to socio-economic progress and a menace to livelihood in the country. This study sheds light on various aspects of the current situation of WS issue in Pakistan and suggests some remedial measures. The prime objective of this study was to present a spatio-temporal view of the WS risks of Pakistan focusing on to its major reasons, effects and remedies. This was an assessment study mainly based on secondary data sources. The information was primarily obtained from various national and international reports, surveys, researches and other literature. Some of the widely recognized indices, specifically Falkenmark's indicator, water resources vulnerability index (WRVI), IWMI's water stress indicator, and water poverty index (WPI) were applied to assess the WS situation in Pakistan. Selected aspects of WS were also compared with some other countries. Results show that demands for water are increasing and per head water availability is decreasing. WS indices values clearly indicate that Pakistan is a water scarce country. Estimates of the global organizations like FAO, IWMI, IMF, and UNICEF also indicate that Pakistan is a highly vulnerable country to water crisis. The study concludes that WS is a reality in the country and population growth, climate change, inefficient infrastructure, mismanagement and pollution are its main causes. The key remedial measures include masses awareness, enhancement of water storage capacity, and efficient use of water resources. As regards policy implications, this study may help to draw some lessons for the future planning.

KEYWORDS: Economic water scarcity, indicators, Pakistan, physical water scarcity, water scarcity risks, water scarcity measurement.

1. INTRODUCTION

Although, almost 71% surface of the earth is capped by aquatic-bodies, water is highly unevenly distributed spatially as well as temporally across the landmasses. This is the most vital commodity for human life from all angles, from survival to an enhancement in prosperity, and for which people are prepared to perish and be killed. The Greater Darfur region's conflict in Sudan is an example (Smith, 2017). Presently, the global water budget is under stress which is indicated by a 20% decrease in per head renewable internal water resources at world level between 2000 and 2018 (FAO, 2022). It is a widely held view that 'water wars' can break in near future to get hold on water resources if the global community did not pay attention to overcome the problem of water scarcity (WS). Alike the previous century which was the 'century of oil', current century can be the 'century of water', but unalike oil, there is no alternate for water. Views exist that globally influential powers of current century would be the countries containing plentiful water resources like Brazil, Canada, China, Russia and USA (Wattoo, 2022). Population augmentation, economic advancement, and nutritional shift from plant products towards animal foods have led to ever growing water demands and subsequent pressure on water resources. Globally, numerous areas such as India, Pakistan, Middle Eastern and several African countries are now suffering from the issue of WS, the situation in which water demand by all sectors cannot be fulfilled satisfactorily (Alcamo et al., 2000; Vorosmarty et al., 2000; Falkenmark et al., 1989). In broader sense, the term implies scarceness in obtainability associated with physical dearth, or scarceness in access because of inefficiency of the concerned departments to guarantee a consistent supply or because of the absence of appropriate infrastructure. Deterioration of water quality also leads to WS (Rijsberman, 2006). When demand exceeds supply and people of a region cannot get clean and affordable water to meet municipal (or household), agricultural and industrial requirements for a considerable time, that dominion is called water scarce (Damkjaer & Taylor, 2017). Indeed, WS instigates from the point wherein the combined effect of all consumers interrupts the water provision or quality under prevalent formal arrangements to the level that the demand by all sectors, including the environment, cannot be met satisfactorily (UN-Water, 2006). WS is thus, a relative conception and may arise at any stage of demand or supply. It may be a social create (a creation of prosperity, hopes and routine behavior) or the result of changed supply patterns instigating from climate change (UN, 2014). The term is now commonly used in government reports, in academic literature, and in the reports of international organizations like UNO and OECD, media and NGOs to identify the regions where water resources are under stress. In current era, water crises are not infrequent even in countries with plentiful water resources and occur due to several reasons like physical shortage, institutional failure and absence of appropriate infrastructure. The poor access to satisfactory amount of water has an immense impact on the environment and socio-economic development. It threatens the physical environment and humans in a number of ways upsetting all facets of human development including health, education, agriculture, livestock rearing, economics and even peace and stability

(Manungufala, 2021). Meanwhile, the influence of climate change has increased the threat of droughts as well. At present, about 2.4 billion individuals are inhabiting in high water stressed countries and their number will continue to grow (Water Scarcity Clock, 2022). This is why the issue needs to be probed aptly.

WS essentially implicates water stress, water deficits, and water crisis. The idea of water stress is comparatively recent and concerned with the difficulties of accessing sources of freshwater for utilization over a span of time. It may arise due to more decline of obtainable water resources. Water deficits can occur as a result of enlarged population demands, climate change associated with changed weather patterns causing droughts or floods, overuse of freshwater, and enhanced contamination. Water crisis refers to a situation in which available clean water in an area is lesser than its needs. In terms of severity, WS is a stage next to water crisis and arises as a result of two uniting phenomena, increasing freshwater usage and decline of available freshwater resources. Based on reasons, Molle and Mollinga (2003) mentioned following five types of WS;

1. Physical or absolute WS most often prevails naturally in arid areas where availability of water is constrained by nature, but at times, may originate artificially because of imperfectly managing and distributing existing water resources, (Giordano et al., 2019).
2. Economic or human induced WS originates when water cannot be used due to the deficiency of economic resources and lack of ability to pay for the access to water resources (Paulson, 2015).
3. Managerial WS refers to inefficient management and poor maintenance of water resources such as losses along the supply systems and water contamination. All this results from malfunctioning of water distribution networks and inability of the systems to meet demands.
4. Institutional WS results from the incompetence of institutions to forecast and manage the variations in demand and supply of water and to arrange proper technologies.
5. Political WS refers to the situation when publics cannot access to water source due to political restrictions (Molle & Mollinga, 2003).

In brief, from late 1980s onwards, research on WS has appealed much political and public attention. Many researchers and experts, hitherto, have made efforts to develop methods and guidelines to delimit water scarce areas, to identify root causes of WS, and to manage water resources efficiently. The study in point is produced keeping in view the increasing severity of issue in the country. It attempts to seek the answers of some basic questions; is WS **a** reality in Pakistan? How risky WS is for the socio-economic advancement of the country? And what are the possible remedial measures?

2. MATERIALS AND METHODS

Though, some personal field observations are also included, the study is primarily based on the data acquired from secondary sources. The information are chiefly collected from AQASTAT, national and international reports, surveys, researches, newspapers and various other kinds of literature. From 2005 onwards, the Land and Water Division of FAO prepared a global water information system known as AQUASTAT which compiles data acquires from the public sectors of individual countries (FAO, 2010). As regards WS measurement, it is a hard task because an all-encompassing and fully agreed upon scientific method for its estimation has not yet been developed (Manungufala, 2021). However, it is usually measured per person per annum renewable water supply (Brown & Matlock, 2011; Rijsberman, 2006; Falkenmark et al., 1989).

During the last few decades, dozens of WS measuring tools have been developed to quantify WS situation for decision making and policy devising for tackling the issue. Table 1 mentions just few of the over 150 identified indicators (WWAP, 2003; Vorosmarty et al., 2005). Varying from simple and straightforward to intricate and multidimensional, all these have their merits and demerits and are in common practice (Liu et al., 2017; Wang et al., 2012; Komnenic, Ahlers & Van der Zaag, 2009; Alcamo & Henrichs, 2002). The key elements of these indices are population size, availability and usage of water (Liu et al., 2017).

Hydrologists characteristically judge scarcity by considering the population-water equation (UN, 2014). Falkenmark's (1989) physical water stress indicator that had been used by the UN for the international comparison of water availability in individual countries was applied for this study. According to him, a country is called water stressed when its water supplies reduce under 1,700 m^3/person/annum, water scarce when water provisions fall below 1,000 m^3/person/annum, and there is an absolute WS when water supplies fall under 500 m^3/capita/year (Table 2). Due to simplicity of calculation, his index is widely used to estimate WS. Involving just total population of the given region and the amount of water (called blue water by him) accessible within the region it is calculated as;

$$FI = \frac{\text{Surface Runoff (in m}^3\text{)}}{\text{Population}}$$

Table 1: Some selected indices commonly used for water scarcity assessment

WS indices	Developed by	Definition
Falkenmark Indicator (FI)	Falkenmark, 1986 & 1989	Measures water availability in m³ per person per annum within the region (FI = Available Water/Population).
Basic Human Need Index (BHNI)	Gleick, 1996	Measures the water consumed to fulfil the basic needs of people like drinking, cooking and washing
Water Resources Vulnerability Index (WRVI)	Raskin et al., 1997	Estimates WS as a ratio of total per year water consumption to total water resources available in the region or country. If use is between 20 & 40%, the country is classed as water scarce. When use surpasses 40%, the country is called as sternly water scarce.
International Water Management Institute (IWMI) Indicator	Seckler, et al., 1998	Considers the portion of renewable water resources available for human needs, guaranteed by present water infrastructure, with respect to main water supply. This indicator estimates physical and economic WS.
Social Water Stress Index (SWSI)	Ohlsson, 2000	Estimates the capability of people to adjust to water stress situations using technological, economic or other methods.
Environmental Performance Index (EPI)	World Economic Forum (WEF), 2002	This index deals WS as a function of water availability and water uses, and tells water overuse in a region. It is computed by 'subtracting the recommended use fraction (0.4) from the ratio of total fresh water withdrawals (including both renewable and fossil ground water) to total renewable water resources' (EPI, 2022).
Water Poverty Index (WPI)	Sullivan,2002; Sullivan, et al., 2003	This index assesses weather people are water secure at domestic and community level or not. It measures physical water availability for people and environmental needs, water quality, percentage of people having access to clean water and time taken by the persons to collect water, issues of water management, and economic & social dimensions of poverty.
Water Stress Indicator (WSI)	Smakhtin et al., 2005	Tells water stress level using WSI=Water withdrawals/Mean annual runoff (MAR)-Environmental water needs (EWN). Environment needs certain amount of water for maintenance (EWN), and not all water (measured as MAR) can be treated available for human use. Index value ranges from 0 to 1 that moving towards 1 indicates high water stress and vice versa.
Watershed Sustainability Index (WSI)	Chaves & Alipaz, 2007	Index is watershed specific and used to estimate water sustainability within a maximum area of 2500 km². Bigger areas are divided into smaller units to gage WSI. It considers hydrology, environment, life, and policy. Each factor has equal weightage with fixed scores of 0.25, 0.50, 0.75, and

		1.0.
Agricultural Water Poverty Index (AWPI)	Forouzani & Karami, 2011	It evaluates the agricultural water concerns by combining various elements of agricultural water system. Index considers five key components and several sub-components.
Water Self-Sufficiency (WSS)	Aldaya et al., 2010	It measures WS in terms of water demand for the production of goods and services. Ability of a country to supply for the requirements of its regular activities is estimated. The ratio of internal water footprint to the total water footprint is calculated and stated in percentage. Value towards 100% indicates that demanded water is available within the region and towards zero indicates heavy reliance on imported water.

Note: Indicators used for the estimation of WS for current study are given in bold.

Another simple method used for current study is known as critical ratio index or water resources vulnerability index (WRVI). This index was originally initiated by Szesztay (1972), later improved by Raskin et al. (1997), and then modified and used by several others (Brauman et al., 2016). The index states the association amongst overall water withdrawals (or consumption) and water availability (Manungufala, 2021). It tells what percentage of available water is being obtained for use which is called as 'withdrawal-to-availability ratio' (WTAR) or 'use-to-availability ratio'. It is thus, a ratio of the sum of domestic water demand, industrial water demand and agricultural water demand to water supply, and can be calculated as;

$$\text{WTAR} = \frac{\text{DWD} + \text{IWD} + \text{AWD}}{\text{WS}}$$

Where;

WTAR = Withdrawal-to-availability ratio, DWD = Domestic water demand (km^3/year), IWD = Industrial water demand (km^3/year), AWD = Agricultural water demand (km^3/year), and WS = Water supply (km^3/year). Estimated at national level, a country is called water stressed if yearly withdrawals are between 0.2 and 0.4 (20-40%) of yearly freshwater supply, and sternly stressed if ratio surpasses 0.4 (40%) (Damkjaer & Taylor, 2017). Besides, Pakistan's WS problem was judged by using IWMI's physical and economic water stress indicator and WPI (Table 1).

Table 2: Falkenmark water stress index

Sr. No.	Index (m^3/capita/year)	Category
1.	>1,700	No Stress
2.	1,000-1,700	Stress
3.	500-1,000	Scarcity
4.	<500	Absolute scarcity

In short, most of the advancement made in WS measurement methods during preceding some decades is related to water obtainability and utilization quantification by using spatially explicit models. Nonetheless, the challenges continue on proper integration of soil moisture (green water), quality of water, environmental flow needs, globalization (worldwide developments), and virtual water trade in WS appraisal. Meantime, intra and inter annum variations in water availability and consumption also require assessment of the temporal aspect of WS. All this needs combined efforts of geographers, hydrologists, economists, environmentalists and social scientists to frame unified approach to apprehend the multifarious nature of WS.

3. RESULTS

Worldwide, several places are persistently facing WS issue because water consumption at the global level has increased at a rate higher than double the rate of population growth over the previous century (Zabarenko, 2011; SDG, 2019). It is now a growing concern of many nations all over the globe including Pakistan (Figure 1). According to CEOWORLD magazine (2019), seventeen hot and dry countries namely Qatar, Israel, Lebanon, Iran, Jordan, Libya, Kuwait, KSA, Eritrea, UAE, San Marino, Bahrain, India, Pakistan, Turkmenistan, Oman and Botswana are 'extremely high water risk countries' of the world facing baseline water stress. Pakistan ranks 14 among these countries, suffering from extremely high water stress. Though WS is the outcome of a multifarious interplay of several natural and human factors, in Pakistan it is mainly caused by rapid population expansion and accelerated urbanization, climate change, inefficient infrastructure and lack of water storage capacity, poor management and wastage of water, overuse of groundwater, and water pollution. However, the biggest constraints on the Pakistan's water resources are ever increasing population and most widely prevalent arid and semi-arid climate (Imran, 2022).

Pakistan's population increased by 3.6 times between 1972 and 1920 elevating the country in ranking from 9th to 5th position among the global nations (World Population Review, 2022). During the same period, population of Bangladesh increased by almost 2.5 fold from 66.6 million to 164.7 million (Maqbool, 2022). The National Institute of Population Studies (NIPS) estimated that Pakistan had a population of 224.78 million in 2021 (GoP, 2022), while according to World Population Data Sheet, growing at a rate of 2% per annum, its current population is 235.8 million (PRB, 2022). Containing 2.85% of the global population, the country holds just 0.5% of the world's renewable water resources. Globally, it ranks 36th in overall renewable water resources compared to Bangladesh 12th and India 8th in 2017 (FAO, 2021). As a consequence of population expansion, pressure on country's both surface and ground water resources has increased significantly. The past trends indicate increasing overall and per capita demands in all sectors and consistently decreasing per capita availability of water (SDG, 2019). Overall water usage has inflated by almost 0.7% per annum between 1977 and 2017 (FAO, 2021; World Bank, 2021), while available water resources stayed fixed at 246.8 billion m^3 (Table 3).

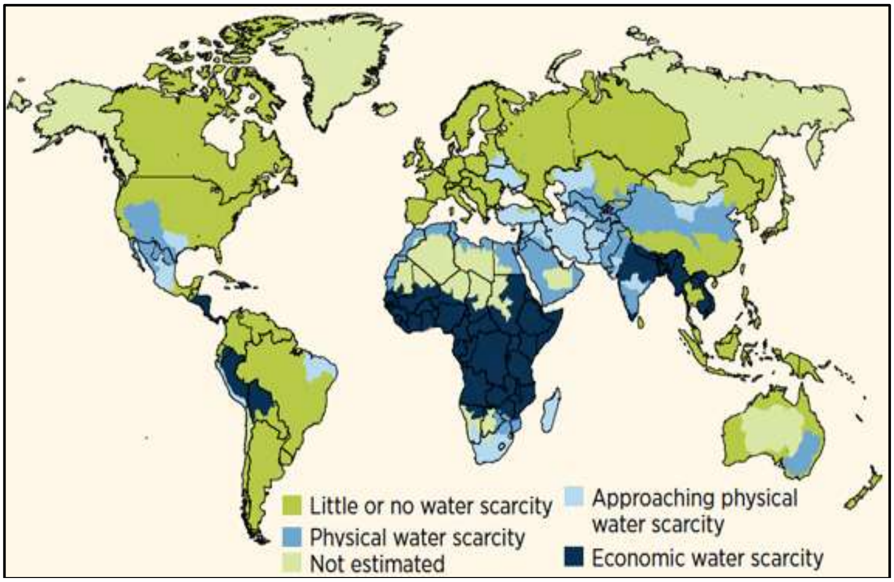

Figure 1: Pakistan's position among World's physical and economic WS regions

Source: WWAP, World Water Development Report 4, March 2012.

Table 3: Increase in population and stress on water resources

Parameters	Situation in 1972	Situation in 2020	Annual change rate in %age
Population in millions	61.4	221	2.7
Aggregate water resources in billion m^3	246.8	246.8	0.0
Per capita renewable water resources in m^3	3,478	1,117	-2.3
Total water withdrawals in billion m^3	153.6*	200**	0.7

Note: *Data refer to 1977, **data refer to 2017. Source: FAO, 2021 & World Bank, 2021.

Figure 2 indicates that according to Falkenmark's indicator, average per head water availability in the country has dropped from 5,229 m3/year in

1962 to 3,478 m3/year in 1972, 1,187 m3/year in 2017, 1,117 m3/year in 2020, and now is at the verge of falling below the threshold limit of 1,000 m3/person/year (Qureshi & Ashraf, 2019; FAO, 2021; world Bank, 2021). The amount of available water can further fall by 20% during the dry period (Habib, 2015). This situation has caused an upsurge in the stress on water resources and placed the country in the category of extremely high ratio of water withdrawal to supply (WRI, 2021). This is evidently mirrored by WTAR that has increased from 62% in 1977 to 82% in 2017 (FAO, 2021). Pakistan was ranked 160th among the world nations in the percentage of water extractions to total fresh water resources in 2017 and attained improved position from only 18 countries (WRI, 2021). Further, growing at current rate, Pakistan's population is projected to reach 367. 8 million in 2050 (PRB, 2022). The proportion of people residing in cities is also estimated to rise from 37.2% in 2020 to 52.2% in 2050 (UN, 2021). Considering water efficiency fixed at the present level, the water withdrawal-to-availability ratio might surpass 100% in coming few decades (Maqbool, 2022). According to IWMI's physical and economic water scarcity indicator, the countries that would not be capable to fulfill their projected water demands by 2025 are grouped as physically water scarce. According to this index, Pakistan is already facing WS (Figure 1). It has suffered from 11% water shortage in 2004 which is predicted to reach 31% in 2025, pushing the country further to physical and economic WS (Ashraf, 2018). Current per head water availability is also much lower than the global water poverty index (WPI) of 1,700 m3/person/year (Figure 2 & 3).

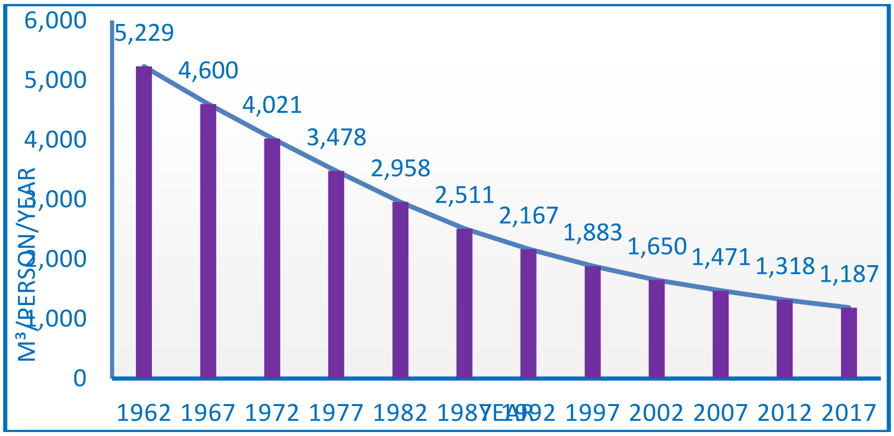

Figure 2: Changing per capita water availability trends in Pakistan (1962-2017)
Source: FAO, 2021.

In sum, assessed by the tools given in Table 1, especially by Falkenmark indicator, WRVI, IWMI's indicator, and WPI, Pakistan fall in water scarce countries (Ashraf, 2015). It is threatened by all forms of WS mentioned above and over 80% of its population suffers now from extreme WS for at least one month of every year (Maqbool, 2022). Table 4 summarizes the prevailing WS situation in Pakistan.

Table 4: WS situation in Pakistan

Indicator	Present situation	Remarks/results
Pakistan's share in global population	2.85%	Contain big population
Pakistan's share of global fresh water resources	0.5%	Limited water resources
Population having access to safe drinking water	36%	Indication of WS
Waste water treatment ratio	01%	Lowest in the world
Average annual increase in temperature during past century	Almost 0.57°C	Indication of climate change & high water demands
Future predicted temperature rise	Above world average	High vulnerability to climate change
Pakistan's ranking by global climate risk index	5th position	Highly vulnerable to climate change
Population suffering from WS	80% (High proportion)	Indication of WS
Predicted water shortage by 2025	31%	Indication of WS
Falkenmark's indicator (FI)	Below 1,117 m^3/capita/year	At the verge of WS
WTAR/WRVI	82%	Indication of WS
World ranking by WTAR	160th position	Poor water resources
IWMI'S indicator	Facing water shortage	Indication of WS
WPI	Less than 1,700 m3/person/year	Indication of WS
IMF's ranking of Pakistan among water scarce countries	3rd position	Indication of WS

Climate change is another global phenomenon which is influencing the water resources of almost every country. It has affected the hydrological cycle and altered rainfall patterns in terms of timing, severity, quantity and type (Jian, 2012). Its two big impacts are a fall in water flow of Indus River System and a rise in water demand for agriculture due to increase in temperature and evapotranspiration. Pakistan is world's one of the highly susceptible countries to climate change as it ranks 5th according to global climate risk index **(**Abbasi, 2022). The effects of climate change are obvious from increasing temperatures, change in monsoon and winter precipitation patterns, quickly melting and retreating glaciers, recurrence of floods and droughts, and declining river flows. WS in Pakistan has been accompanied by increasing temperatures. A marked warming trend of almost 0.57**°**C in annual mean temperature was witnessed in Pakistan in the previous century, and the future predicted temperature rise is expected to be more than the world average (Chaudhary, 2017). Consequently, water demands will increase and water resources will squeeze further. The most marked impact will be on river flows. Predictions also indicate a decreasing trend and increasing variability of the river flows in future (Khan, 2017). The Indus River system, being reliant on glaciers and snowmelt water supply, and precipitation is very sensitive to climate change and may be influenced more. If the situation aggravates further, it will be highly alarming for the country. Inefficient infrastructure and shortage of storage capacity to stock and distribute water according to the requirements at different times of the year is one of the big problems leading to WS in the country. Pakistan is wasting 10 trillion gallons of water yearly due to the deficiency of water reservoirs (FPCCI, 2018). Per head storage of water in the country is much lower compared to other countries (Table 5).

Table 5: Comparison of Pakistan's water storage capacity with selected countries

Country	water storage capacity (m^3/capita/year)
Australia	Over 5.000
USA	Over 5,000
Egypt	2,300
China	2,200
Turkey	1,402
Iran	492
Pakistan	159

Source: Ashraf, 2020.

Pakistan has the ability to store water for only 30 days needs which is far behind the rest of the world (Qureshi, 2011). When compared to other countries, India can store water for 190 days, over six times greater than Pakistan despite having needs five to six times higher than ours (Rafique, 2018). Egypt's Aswan dam on Nile River can store water for 1,000 days, and China for the needs of years (Table 6). Even the African country Ethiopia, which has been facing serious famine for years, has secured its water by constructing a millennium reservoir on the Blue Nile, though primarily it will be utilized for hydro-electricity production (Wattoo, 2022).

Table 6: Formulation of water policy and capacity to store water

Country	Formulation of 1st water policy	Capacity to store water for
Pakistan	2018 (40 years after India)	30 days
India	1978	190 days
USA	1948 amended in 1972	900 days
Egypt	1975	1,000 days
China	1988	Several years

Source: Rafique, 2018 & Qureshi, 2011.

The existing water storage capacity of Pakistan's three main dams is just 9% of the average yearly inflow compared to the world average of 40% (Ashraf, 2020). Because of sedimentation, the storage capacity of existing dams is being lost at a rate of 0.27 BCM per annum. Up to 2010, the water storages had already lost almost 8.1 BCM of their storage capacity (Iqbal et al., 2012). It means in addition to small dams, there is an immediate need of 3 to 4 large size dams to store at least 20 maf water (Ashraf, 2020). Up to 1980s, the country had a relatively plentiful amount of water. However, it became water stressed in 2000 and now is threatened by WS (FAO, 2021). The COVID-19 crisis has also slowed down the improvements in the projects of potable water supply systems. Presently, both surface and ground water resources are extensively exploited. According to FAO (2021), about 94% of the total annual water obtained from both resources is used by agriculture, 5.3% by domestic and 0.8% by industrial sector. The average annual inflow of Indus River System is 146 maf, of which almost 106 maf is diverted into world's one of the biggest but inefficient canal irrigation system and leftover is lost to Arabian Sea (GoP, 2013). Pakistan receives about 50% to 80% of the overall average river flows from snow or glacial melt and rest from monsoon rains (GoP, 2013; Yu et al., 2013). About 97% of the river water is consumed by agriculture and remaining 3% is used by manufacturing and domestic sectors. Out of 106 maf diverted into irrigation system, over 50% is lost during the diversion and farm applications before reaching to crop's root zone (Yu et al., 2013).

Additionally, over 50 maf ground water is extracted annually by an estimated number of 1.2 million tube-wells in the country (GoP, 2022). Due to excessive pumping, Pakistan's groundwater annual extraction rate has already surpassed the recharge rate of 55 km^3/year (Watto, 2018). Resultantly, groundwater tables are also dropping quickly in various parts of the country (Ashraf et al., 2022). For instance, in more than 50% irrigated areas of the Punjab, ground water levels have lowered below 6 meters (Qureshi, 2020).

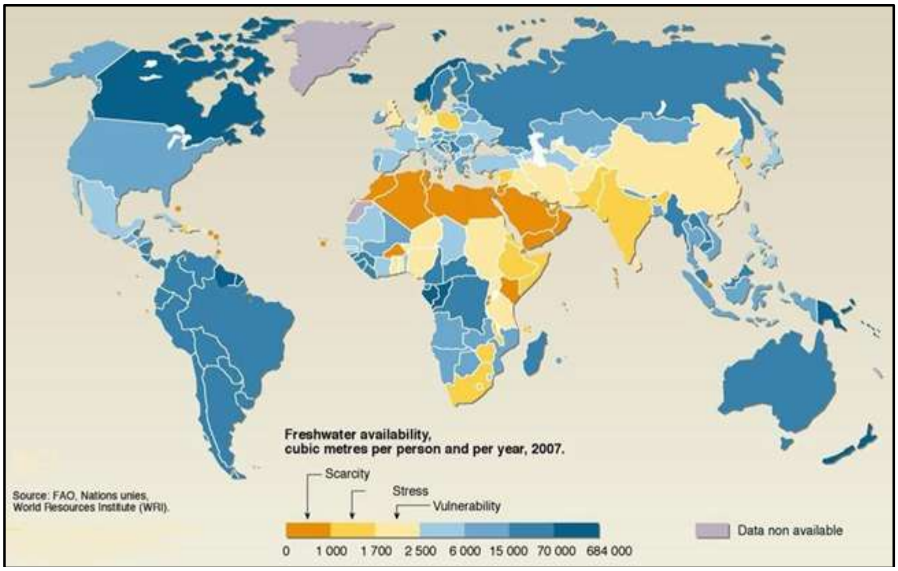

Figure 3: Fresh water availability (m^3/capita/year) and WS status of Pakistan among the global nations during first decade of the current century

Source: FAO, 2021.

Besides, water pollution has become a big threat to the availability of clean and healthy water for usage in current times (Krishnamurti et al., 2012). Population expansion and intensification of economic activities are not only resulting in a decline but also degradation of existing water resources. Increasing contamination is making water unfit for use and thereby is resulting in serious environmental and health consequences. The water quality degradation reduces the amount of usable water resources and causes WS. Inadequate waste disposal, improper use of agro-chemicals, and soil depletion are the main factors harming our available fresh water resources. In Pakistan, about 50% of the over two million tons per year produced wet human excreta is released in to water sources (GoP, 2016). The quality of available water in most of the areas is poor which has damaged agriculture, livestock and fisheries, especially of the coastal communities (Abbasi, 2022).

Further, urbanization in Pakistan is also at an accelerated stage and apart from dropping groundwater levels, many cities are facing the issues of irregular supply of clean water (Hifza et al., 2021). WPI tells that even though water is accessible but if it is of inadequate quality, the country is water scarce. According to Drinking Water Quality Monitoring Program of PCRWR accomplished from 2002 to 2006 in 24 cities of Pakistan, 80% samples were found contaminated and unsafe for human use (Ashraf, 2015). At present, Pakistan fall in the category of low access to clean drinking water as only about 36% of its inhabitants have access to healthy water (UN, 2021a).

As regards waste water treatment, above 63% of the worldwide produced water is collected. Out of this collected water, 52% is treated and 48% is released untreated, and only 11% is reused (Jones et al., 2021). Among the world countries, Pakistan ranks lowest in waste water treatment ratio, treating just 1% of the collected water (Wendling et al., 2020).

Above findings reflect that much of the available water is unsustainably managed, wasted, and polluted. As a result, several areas of the country are facing water crisis. PCRWR has already warned that if the government did not take serious steps, the country will run out of water by 2025 (Kundi, 2017). IMF has also ranked Pakistan third among the water scarce countries (Zang et al., 2020). Due to the prevalence of such kind situation, Pakistan is seen as one of the world's highly water intensive countries (Akbar et al., 2021).

4. DISCUSSION

Undeniably, water is one of the most crucial products for life on the earth and essential for socio-economic development of the society. However, as a consequence of population growth and climate change, the water accessible for any given use is becoming increasingly scarce in many parts of Pakistan (Table 4). This has caused a big restriction to socio-economic progress and a menace to livelihood. Since the dawn of 21st century, policy institutions and politicians have increasingly been speaking about a threatening water future of Pakistan. World predictions are also indicating Pakistan as an exceedingly WS vulnerable country with little capability to cope with water crises. During the previous some decades, Pakistan has been radically converted from being a water-rich to a water-stressed country (Figure 2 & 3). Water shortage has influenced almost every aspect of natural and human environment. Loss of biodiversity, loss of floodplains and wetlands, increase in salinity, pressure on agriculture and economy, rise in poverty and hunger, increase in sanitation issues and diseases, increase in internal and external tensions, and water distribution issues among provinces are some of the major outcomes of WS in Pakistan. It reveals that highly risky factor for Pakistan is its dependence upon single river system for most of water needs. The Indus River system provides 95.8% of the country's overall renewable water resources (Young et al., 2019). The situation is strategically more complex because Pakistan is lower riparian country to India and most of its water inflows from therein. The surface water originating from outside of Pakistan accounts for 78% of the country's total water resources putting it in a constant danger (FAO, 2021). Domestic arrangements make the situation further alarming as just two-third of obtainable water is being used and one-third is either lost or flows to Arabian Sea (GoP, 2019). Such kind of internal and external situation makes the country more vulnerable to WS. Besides surface water, country's aquifers are also seriously overdrawn, primarily to provide water for irrigation, drinking and industrial use (Ashraf, 2018). The Indus basin aquifer has been ranked second highest over-strained underground water reserve in the world (NASA, 2015).

In the global perspective, Pakistan is certainly facing the multifaceted issue of water shortage. Simply a 10% growth in population will place the country in constant WS and make it world's one of 'water crowed regions' according to another indicator of Falkenmark (Habib, 2015). Additionally, due to great economic dependence on water resources and little investment and deficiency of available management choices to satisfy the demands, Pakistan suffers from economic WS also (Habib, 2015). In national perspective, Pakistan is evidently confronting with a widening gap between demand and supply in all water consuming sectors, reducing capability to regulate surface flows, great uncertainty resulting from extreme events, deterioration of groundwater resources, less benefits from existing water resources, and water pollution. A continuing decline in manageable water amounts is the foremost governing issue. The formal data indicates a fall of nearly 10 maf in the amount of water diverted to the provinces after 1999. Three topmost government organizations, the ministry of water and power, the planning commission, and the Indus River System Authority admit a fall of 10 maf in stream inflows and canal diversions. This results in a deficit of 14 maf in the promised water supply to the provinces, almost 100 maf provided against 114 maf assured (Habib, 2015). The usual seasonal water disparity is also great in Pakistan. Streams get about 75% of the water in four summer months and about 25% during rest of the year, while water demand in summer is 60% and in winter is 40%. Presently, almost 13 maf water is transferred from shorter water surplus period to the lengthier water stressed period (Habib, 2015). Some years ago, the Indus River System Authority (IRSA) urged the government to build large dams for storing 22 maf water on war footing 'to put an end to the misery faced by the country'. However, the matter was politicized instead of dealing it seriously. IRSA also professes an upsurge in river losses from 9 maf in the 1980s to 20 maf in the previous decade. This is indeed, a serious regulatory failure (Habib, 2015). It is a common perception in our country that India has diverted the waters of our rivers in its enmity with Pakistan. This is a fact that Indus and all its eastern tributaries flowing in to our country originate from India, but it is also a reality that India framed its first water policy in 1978 and China in 1988 (Table 6), while in Pakistan this wonder come about 40 years later from India in 2018 (Wattoo, 2022). Despite the reality that agriculture is backbone of our economy, we have been in a situation of dreams for so long that the world has moved far away from here on the path of advancement. One of our big challenges is how to achieve the goal of self-sufficiency in agriculture and how to sustain agricultural output with less water. In addition, unluckily, Pakistan has not established its trans-border case for the present conditions of climate change, over withdrawals of groundwater, upstream aquifer recharge situation, watershed management, and necessary downstream environmental requirements. The decisions of Kishan-Ganga and Bagliar dams against Pakistan show our technical and legal flaws even in the execution of the Indus Water Treaty (Habib, 2015).

Moreover, the recommendations of international organizations tell that a country should have the capacity to stock up to 40% of its whole water received from rainfall or snow, whereas in Pakistan this capability has not touched 10% mark so far (Table 7). In such a situation, how we will be able to cope our requirements in the times of water shortage? We get over 80% of our water in three monsoon months and less than 20% during the remaining nine months of the year. Our governments have made no significant efforts in the last several decades to enhance storage capacity for saving fresh water. The proposal of Kala Bagh reservoir has more or less been shelved because of the mutual distrust between provinces. The work on Mohmand and Bhasha dams is also still in initial stage (Wattoo, 2022). On the other side, every year almost half of the water stored in dams is wasted ruthlessly. Over 90% of our total water consumption is taken by agriculture sector (Qureshi and Ashraf, 2019). According to some other studies, about 97% of Pakistan's fresh water is consumed by this sector (Rizvi, 2022; Salman, 2021). Out of this, nearly 50% of the water is wasted before reaching to the crops because of inefficient irrigation system (Table 7). In fact, we are struggling to achieve the targets with an old irrigation system in the era when the world has shifted to the high efficiency irrigation system. Even smart agriculture and micro-irrigation has now reached the peak wherein the discrete requirements of every plant are digitally dripped in a calculable manner (Wattoo, 2022).

Table 7: Present status of the selected water management parameters in Pakistan

Parameters	Existing situation
Capacity to store volume of water received from rain and snow*	Less than 10%
Proportion of water Pakistan receives from rain during the three months of monsoon season	80%
Wastage of water stored in dams	50%
Proportion of total water needs used for agriculture	90%
Wastage of water supplied for agriculture during distribution given at Sr. No. 4	Almost 50%

*Guidelines of international organizations tell that a country must have the capability to stock up to 40% of the whole amount of water received from rain & snow.
Information source, Zafar Iqbal Wattoo (2022).

Apart from this, ground water consumption has also increased several times over the last 70 years or so. Nearly 94% of the total groundwater extraction is consumed by agriculture sector (UNESCO, 2022; Margat & Van der Gun, 2013). We are not only wasting our stored surface water but also mistreating ground water. Resultantly, levels of groundwater in the country are dropping sharply. The condition is even more alarming in urban areas. Quetta is struggling for its survival and experts opine that mass-migration of people may instigate from this city in near future. Almost alike situation is found in Karachi. The cities of Rawalpindi-Islamabad, Lahore and Peshawar are rapidly moving towards this situation. In the walled city of Lahore, groundwater level has dropped to over 500 feet. According to the author's personal observation, in 1990, ground water in the city of Bahawalpur, which is situated on the eastern bank of Sutlej River and where agricultural land is predominantly irrigated by canal water, was obtainable from the depth of 40 to 50 feet which has now dropped to over 100 feet. The citizens who curse the governments at every occasion, are also equally responsible for this wrongdoing. Unlawful usage of water in factories and discharge of polluted water in streams and sewerage systems without any treatment is a malicious act that has led to several health issues. For instance, due to such acts the ground water resources of Sialkot and Kasur have been deteriorated to hazardous level. Summarily, our economy cannot cope with the growing needs of population without fulfilling the water requirements of its pivotal sectors like agriculture. It is thus crucial time to take some practical measures. Indeed, managing WS is a complex and tough work because factors responsible for the issue are intricate and greatly differ temporally and spatially across the regions. That is why a series of context-specific measures is required to be taken to effectively address the issue. Water management should be implemented at homes, factories, offices and at all other places where it is consumed. To make all this fruitful, water governance should be improved which involves several interventions. An integrated approach consisting of the use of technology, capital, effective policies, capacity building, partnerships, monitoring, data, and accountability can be rewarding. New water resources are required to be identified applying different techniques and technologies including field studies and geophysical and remote sensing surveys. Efficiency of existing water resources also requires to be enhanced by upgrading the water distribution networks and treatment systems to control water seepage and pollution. Groundwater resources need to be protected by encouraging water storage through small scale retention structures, managing aquifer recharge, rainwater harvesting, storing rainwater in urban areas and recycling of wastewater. All the used blue water should be recycled for reuse in agriculture. The concerned departments need to build facilities at all levels and in all regions to store water. People also need to be educated to change their behaviors about water consumption. This can be done by promoting an understanding of the worth of water and the significance of its protection among people at community and school level. All the stakeholders are required to understand water needs at national level and they must ensure that this should be reflected in national planning considerations (UNICEF, 2022).

5. CONCLUSION

Recent study on WS risks of Pakistan has provided an understanding of the issue. Findings suggest that WS is a reality in Pakistan. It has evidently come out that country’s water needs are increasing while per capita water availability is continuously decreasing over time. Several interlinked natural and anthropogenic factors are responsible for the situation. However, most of these factors are related to management issues which can be solved by adopting both hard and soft paths. Hard path includes population size control, building of new reservoirs, formulating and implementing groundwater regulatory principles and soft path includes improvement of land and water productivities, and encouragement of arid lands farming and climate resilient agriculture. All this needs a paradigm change and stakeholders commitment right from policy makers to water users. In future, population growth and climate change may further upsurge water demands and instabilities in provision. The incidence of extreme events is likely to rise. The severity and nature of water concerns will differ to a great extent within the country. It is, therefore, necessary for Pakistan to learn about WS management, which needs all-inclusive, well assessed and out-of the-box solutions in all water consumer sectors. In this regard, collaborative efforts and the continuation of scientific studies to further develop and improve knowledge are vital. At the outset, it is deeply required that the government and all other stakeholders take political ownership of the challenge. It is also earnestly needed to save the water by promoting the efficient use of existing water resources in all sectors. Being leading water user, agriculture sector provides big opportunities for saving water. Saving only a fraction might considerably reduce water stress on other sectors. Pakistan can generate about 83 maf of more water through an effective water management strategy and by constructing more reservoirs. Application of sustainable water management techniques and cultivation of crops that require less water can be promoted in arid areas. Water savings in other sectors such as industries, power production units, and household usage should also be encouraged. The implementation of the recommendations of researchers and concerned departments may facilitate Pakistan to cope with the challenges and achieve the goals of unified, effective, environmentally and economically sustainable development and management of limited water resources. Not least of all, let us first make ourselves accountable for each drop of water used on ourselves.

REFERENCES

Abbasi, J. (2022). The looming ‘water crisis’ in Pakistan needs due attention. *Daily Islamabad*

Post, 13 July 2022. https://islamabadpost.com.pk/the-looming-water-crisis-in-pakistan-needs-due-attention/

Akbar, M., Khan, S. A., Dilawar, S. & Hassan, M. T. (2021). Water crisis in Pakistan: Prospects and implication. *PalArch’s Journal of Archaeology of Egypt/Egyptology (PJAEE)*, 18(1), 4884-4892. https://archives.palarch.nl/index.php/jae/article/view/8948/8316

Alcamo, J., Henrichs, T. & Rösch, T. (2000). World water in 2025-global modeling and scenario analysis for the World Commission on Water for the 21st Century, *Kassel World Water Series,* University of Kassel, Kassel, Germany. https://www.coursehero.com/file/32496938/World-water-in-2025-global-modeling-scenariospdf/

Alcamo, J. & Henrichs, T. (2002). Critical Regions: A Model-Based Estimation of World Water Resources Sensitive to Global Changes. *Aquatic Sciences,* 64, 352-362. https://doi.org/10.1007/PL00012591

Aldaya, M. M., Martinez-Santos, P. & Llamas, M. R. (2010). Incorporating the Water Footprint and Virtual Water into Policy: Reflections from the

Mancha Occidental Region, Spain. *Water Resources Management,* 24(5), 941-958. https://doi.org/10.1007/s11269-009-9480-8

Ashraf, M. (2020). Ensuring Pakistan's Water Security: A Case for Large Dams. *Hilal,* 13 July 2020. https://www.hilal.gov.pk/eng-author/dr.-muhammad-ashraf/MjU=.html

Ashraf, M. (2018). Water Scarcity in Pakistan: Issues and Options.

http://pcrwr.gov.pk/wp-content/uploads/2021/07/Water-Scarcity-in-Pakistan-Issues-and-Options-May-18.pdf.

Ashraf, M. (2015). Managing Water Scarcity in Pakistan: Moving Beyond Rhetoric. PCRWR, Islamabad, Pakistan. https://pcrwr.gov.pk/wp-content/uploads/2021/08/Managing-Water-Scarcity-in-Pakistan-2015.pdf

Ashraf, S., Ali, M., Shrestha, S., Hafeez, M. A., Moiz, A. & Sheikh, Z. A. (2022). Impacts of climate and land-use change on groundwater recharge in the semi-arid lower Ravi River basin, Pakistan. *Groundwater for Sustainable Development,* 17(9): 100743, Elsevier. https://doi.org/10.1016/j.gsd.2022.100743

Brauman, K. A., Richter, B. D., Postel, S., Malsy, M., & Florke, M. (2016). Water depletion: An improved metric for incorporating seasonal and dry-year water scarcity into water risk assessments. *Elementa: Science of the Anthropocene,* 4, 83. https://doi.org/10.12952/journal.elementa.000083

Brown, A. and Matlock, M. D. (2011). A review of water scarcity indices and methodologies, White Paper 106. The Sustainability Consortium, Tempe, AZ. https://www.sustainabilityconsortium.org/downloads/a-review-of-water-scarcity-indices-and-methodologies/

CEOWORLD magazine (2019). Most Water-Stressed Countries in the World for 2019, https://ceoworld.biz/2019/08/08/most-water-stressed-countries-in-the-world-for-2019/

Chaudhary, Q. U. Z. (2017). Climate Change Profile of Pakistan. Asian Development Bank (ADB). https://www.adb.org/sites/default/files/publication/357876/climate-change-profile-pakistan.pdf

Chaves, H. M. L. & Alipaz, S. (2007). An Integrated Indicator Based on Basin Hydrology, Environment, Life, and Policy: The Watershed Sustainability Index. *Water Resource Management,* 21, 883-895. https://doi.org/10.1007/s11269-006-9107-2

Damkjaer, S. & Taylor, R. (2017). The Measurement of Water Scarcity: Defining a Meaningful Indicator. *Ambio,* 46(5), 513-531. https://doi.org/10.1007/s13280-017-0912-z

Falkenmark, M. (1986). Fresh Water: Time for a Modified Approach. *Ambio*, 15(4), 192-200. http://www.jstor.org/stable/4313251

Falkenmark, M. (1989). The massive water scarcity now threatening Africa: why isn't it being addressed? *Ambio,* 18(2), 112-118. https://agris.fao.org/agris-search/search.do? recordID=SE9000184

Falkenmark, M., Lundquist, J. & Widstrand, C. (1989). Macro-scale water scarcity requires micro-scale approaches: Aspects of vulnerability in semi-arid development. *Natural Resources Forum,* 13(4), 258-267. https://hal.archives-ouvertes.fr/hal-00930457/document

FAO (Food and Agriculture Organization of the UN). (2010). Evaluation of FAO's role and work related to water, Final Report. https://www.alnap.org/system/files/content/resource/files/main/water-evaluation-final-report.pdf

FAO. (2021). *AQUASTAT*. https://www.fao.org/aquastat.

FAO. (2022). *The State of the World's Land and Water Resources for Food and Agriculture 2021-Systems at breaking point. Main report.* Rome. https://doi.org/10.4060/cb9910en

Forouzani, M. & Karami, E. (2011). Agricultural water poverty index and sustainability. *Agronomy for Sustainable Development,* Shiraz University, Iran, 31(2), 415-432. https://pubag.nal.usda.gov/catalog/2343538

FPCCI (The Federation of Pakistan Chamber of Commerce and Industry). (2018). Pakistan wasting ten trillion gallons of water annually, The Nation, 9 July 2018. https://www.nation.com.pk/09-Jul-2018/pakistan-wasting-10-trillion-gallons-of-water-annually

Giordano, M., Barron, J. & Ünver, O. (2019). Water Scarcity and Challenges for Smallholder Agriculture in Campanhola, C. and Pandey, S. (eds) Sustainable Food and Agriculture. *Academic Press,* 75-94. https://doi.org/10.1016/B978-0-12-812134-4.00005-4

Gleick, P. H. (1996). Basic Water Requirements for Human Activities: Meeting Basic Needs, *Water International*, 21(2), 83-92. http://dx.doi.org/10.1080/02508069608686494

GoP (2013). 11th Five Year Plan 2013-2018 Pakistan. Planning Commission, Ministry of Planning, Development and Reform, Office of the Economic

Advisor, Islamabad. http://111.68.102.42:8080/xmlui/handle/123456789/16042

GoP (2022). Pakistan Economic Survey 2021-22, Finance Division Government of Pakistan, Islamabad.

Habib, Z. (2015). Water Worries of Pakistan. The Friday Times, 24 April 2015. http://www.thefridaytimes.com/tft/water-worries/

Hifza, R., Fauzia. A., Kiran, A. & Ashraf, M. (2021). Drinking Water Quality in Pakistan:

Current Status and Challenges. Pakistan Council of Research in Water Resources (PCRWR), Islamabad. https://pcrwr.gov.pk/wp-content/uploads/2021/10/Drinking-Water-Quality-in-Pakistan-2021.pdf

Imran, K. (2022). Examining Water Crisis in Pakistan. *Paradigm Shift*. https://www.paradigmshift.com.pk/water-crisis-of-pakistan/

Iqbql, M. N. et al. (2012). Natural Resources Degradation: Assessment and options for improvement. T. Oweis and M. Ashraf (eds.) in *Assessment and options for improved productivity and sustainability of natural resources in Dhrabi watershed Pakistan,* Int. Center for Agricultural Research in Dry Areas (ICARDA), Aleppo, Syria, 27-60.

Jian, S. K. (2012). Sustainable water management in India considering likely climate and other changes. Current Science, 102(2), 177-188.

Jones, E. R., Van Vliet, M. T. H., Qadir, M. & Bierkens, M. F. P. (2021). Country-level and Gridded

Estimates of Wastewater Production, Collection, Treatment and Reuse. *Earth System Science Data* 13(2), 237-254. https://inweh.unu.edu/country-level-and-gridded-estimates-of-wastewater-production-collection-treatment-and-reuse/

Khan, S. (2017). How Climate Change is Exacerbating Pakistan's Water Crisis. *DW.COM*, 9 November 2017. https://www.dw.com/en/how-climate-change-is-aggravating-pakistans-water-crisis/a-41315151

Komnenic, V., Ahlers, R., & Van der Zaag, P. (2009). Assessing the usefulness of the water poverty index by applying it to a special case: Can one be water poor with high levels of access? *Physics and Chemistry of the Earth,* 34(4-5), 219-224. DOI: 10.1016/j.pce.2008.03.005

Krishnamurti, R., Biswas, S. K. & Wang, T. H. (2012). Modeling Water Use for Sustainable Urban Design. In: Arisona, S.M., Aschwanden, G., Halatsch, J., Wonka, P. (eds) Digital Urban Modeling and Simulation. Communications in Computer and Information Science, vol 242. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-29758-8_8

Kundi, B. (2017). *Pakistan's water crisis: Why a national water policy is needed*. Asia Foundation.

Liu, J. et al. (2017). Water scarcity assessments in the past, present, and future, *Earth's Future,* 5, 545-559. https://doi.org/10.1002/2016EF000518

Manungufala, T. E. (2021). Water Scarcity: Classification, Measurement and Management.

Filho, W. L. et al., (eds.) in Clean Water and Sanitation, Encyclopedia of the UN Sustainable Development Goals, *Springer Nature,* Switzerland AG 2021. https://doi.org/10.1007/978-3-319-70061-8_7-1

Maqbool, N. (2022). Water Crisis in Pakistan: Manifestation, Causes and the Way Forward, *PIDE*

Knowledge Brief, 60, 04 March 2022. Pakistan Institute of Development Economics, Islamabad. https://pide.org.pk/research/water-crisis-in-pakistan-manifestation-causes-and-the-way-forward/

Margat, J. & Van der Gun, J. (2013). Groundwater around the World: A Geographic Synopsis, *Taylor & Francis,* CRC Press. https://doi.org/10.1201/b13977

Molle, F. & Mollinga, P. (2003). Water Poverty Indicators: Conceptual Problems and Policy Issues. *Water Policy,* 5(5-6), 529-544. https://doi.org/10.2166/wp.2003.0034

NASA. (2015). Study: Third of Big Groundwater Basins in Distress, *Water*. https://www.nasa.gov/jpl/grace/study-third-of-big-groundwater-basins-in-distress.

Ohlsson, L. (2000). Water conflicts and social resource scarcity, *Physics and Chemistry of the*

Earth, Part B: Hydrology, Oceans and Atmosphere, 25(3), 213-220. https://doi.org/10.1016/S1464-1909(00)00006-X

Paulson, L. D. (2015). What is Water Scarcity? RWL Water, 5(2), 1-7. PMID: 25220873. https://www.rwlwater.com/what-is-water-scarcity/.

PRB (Population Reference Bureau). (2022). World Population Data Sheet 2022.

https://2022-wpds.prb.org/wp-content/uploads/2022/09/2022-World-Population-Data-Sheet-Booklet.pdf

Qureshi, A. S. (2020). Groundwater Governance in Pakistan: From Colossal Development to

Neglected Management. *Water 2020, 12*(11), 3017. https://doi.org/10.3390/w12113017

Qureshi, A. S. (2011). Water Management in the Indus Basin in Pakistan: Challenges and Opportunities. *Mountain Research and Development,* 31(3), 252-260. https://doi.org/10.1659/MRD-JOURNAL-D-11-00019.1

Qureshi, R. H. & Ashraf, M. (2019). Water Security Issues of Agriculture in Pakistan. *Pakistan*

Academy of Sciences (PAS), Islamabad, Pakistan. https://www.paspk.org/wp-content/uploads/2019/06/PAS-Water-Security-Issues.pdf

Rafique, T. (2018). Water usage, *Daily Times, 25 October 2018. https://dailytimes.com.pk/314233/water-usage/*

Raskin, P., Gleick, P. Kirshen, P., Pontius, G. & Strzepek, K. (1997), Water Futures: Assessment of Long-range Patterns and Prospects, Stockholm Environment Institute (SEI), Sweden. https://mediamanager.sei.org/documents/Publications/SEI-Report-WaterFutures-AssessmentOfLongRangePatternsAndProblems-1997.pdf

Rijsberman, F. R. (2006). Water Scarcity: Fact or Fiction? *Agricultural Water Management*, 80, 5-22. https://doi.org/10.1016/j.agwat.2005.07.001

Rizvi, O. (2022). Pakistan’s Water Crisis. The Diplomat, 8 June 2022. https://thediplomat.com/2022/06/pakistans-water-crisis/

Sahi, A. (2013). Environment: A Dirty Job. *The News*, 27 October 2013.

Salman, A. (2021). Pakistan's looming water crisis. *East Asia Forum,* https://www.eastasiaforum.org/2021/11/13/pakistans-looming-water-crisis/

Seckler, D. Amarasinghe, U., Molden, D., de Silva, R. & Barker, R. (1998), World Water Demand and Supply, 1990 to 2025: Scenarios and Issues, International Water Management Institute (IWMI) Research Report 19, IWMI, Colombo, Sri Lanka. https://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB019/REPORT19.PDF

SDG (Sustainable Development Goals). (2019). Ensure availability and sustainable management of water and sanitation for all. https://unstats.un.org/sdgs/report/2019/goal-06/

Smakhtin, V., Revenga, C. & Döll, P. (2005). Taking into Account Environmental Water

Requirements in Global-scale Water Resources Assessments, Vol. 2. International Water Management Institute (IWMI). https://core.ac.uk/download/pdf/6405183.pd

Smith, R. (2017). The Water Scarcity-Conflict Nexus: The Case of Darfur. Master of Arts Thesis,

Faculty of Arts and Social Science, Stellenbosch University. https://core.ac.uk/download/pdf/188221553.pdf

Sullivan, C. A., Meigh, J. R. & Giacomello, A. M. (2003), the Water Poverty Index: Development and Application at the Community Scale, *Natural Resources Forum,* 27, 189-199. https://doi.org/10.1111/1477-8947.00054

Sullivan, C. A. (2002), Calculating a Water Poverty Index. *World Development*, Elsevier, 30(7), 1195-1210. https://www.ircwash.org/sites/default/files/Sullivan-2002-Water_0.pdf

Szesztay, K. (1972). The Hydrosphere and the Human Environment: An introduction to some hydrological aspects of international research programmes on problems of the human environment in Results of research on representative and experimental basins. In International Association of Hydrological Sciences (IAHS) (eds.), *Proceedings of the Wellington Symposium December 1970,* 455-467, Paris: IAHS UNESCO.

UN (United Nations). (2021). World Urbanization Prospects 2018. https://population.un.org.

UN (2021a). “SDG Indicators Database.” https://unstats.un.org/sdgs/unsdg.

UN. (2014). International Decade for Action ‘WATER FOR LIFE’ 2005-2015. United Nations

Department of Economic and Social Affairs (UNDESA). https://www.un.org/waterforlifedecade/scarcity.shtml

UN-Water. (2006). The United Nations World Water Development Report 2: Water, a Shared

Responsibility. *World Water Assessment Programme* (WWAP). Doc. No. UNWATER/WWAP/2006/3. UNESCO/Berghahn Books, New York. http://unesdoc.unesco.org/images/0014/001444/144409e.pdf.

UNESCO (2022). Groundwater: Making the Invisible Visible. *The UN World Water Development*

Report 2022. https://www.unwater.org/publications/un-world-water-development-report-2022/

Vorosmarty, C. J., Green, P. A., Salisbury, J. and Lammers, R. B. (2000), Global water resources: Vulnerability from climate change and population growth, *Science,* 28, 284-288. https://doi.org/10.1126/science.289.5477.284.

Vorosmarty, C. J., Douglas, E. M., Green, P. A. and Revenga, C. (2005). Geospatial indicators of emerging water stress: An application to Africa. *Ambio,* 34, 230-236.

Wanga, X., Maa, F. B., and Lib, J. Y. (2012). Water Resources Vulnerability Assessment based on the Parametric-system Method: A Case Study of the Zhangjiakou Region of Guanting Reservoir Basin, North China. *Procedia Environmental Sciences,* Esevier, 13, 1204-1212.

Water Scarcity Clock. (2022). https://worldwater.io/

Wattoo, Z. I. (2022). Water Scarcity could be killing our Economy, Rehman Habib Consultants Pvt. Ltd. https://www.linkedin.com/pulse/water-scarcity-could-killing-our-economy-zafar-iqbal-wattoo?trk=public_profile_article_view

Watto, M. A. (2018). Groundwater-one of the most neglected resources. *Dawn,* 15 January 2018. https://www.dawn.com/news/1382878

Wendling, Z. A., Emerson, J. W., Esty, D. C., Levy, M. A. and de Sherbinin, A. (2020). *2020*

Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy. DOI: 10.13140/RG.2.2.21182.51529

World Bank. (2021). WDI Online Database. databank.worldbank.org.

WWAP (World Water Assessment Programme). (2012). The United Nations World Water Development Report 4, March 2012. http://www.zaragoza.es/ciudad/medioambiente/onu/en/detallePer_Onu?id=71

WWAP. (2003). The United Nations World Water Development Report: Water for People, Water for Life. United Nations World Water Assessment Programme, Paris, UNESCO.

Young, W. J. et al. (2019). Pakistan: Getting More from Water. World Bank, Washington DC. https://openknowledge.worldbank.org/handle/10986/31160

Yu, W., Y. C. Yang, A. Savitsky, D. Alford, C. Brown, J. Wescoat and D. Debowicz. (2013).

The Indus Basin of Pakistan: The Impacts of Climate Risks on Water and Agriculture. Washington, DC, World Bank.

Zabarenko, D. (2011). Water use rising faster than world population. *Environment,* Reuters. https://www.reuters.com/article/us-population-water-idUSTRE79O3WO20111025

Zhang, D., Sial, M., Ahmad, N., Filipe, J. A., Thu, P. A., Zia-Ud-Din, M., & Caleiro, A. B. (2020).

Water scarcity and sustainability in an emerging economy: A management perspective for future. *Multidisciplinary Digital Publishing Institute*, 10.