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ASSESSING WATER SCARCITY SITUATION IN PAKISTAN: CAUSES, EFFECTS AND REMEDIAL MEASURES

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ABSTRACT

Pakistan is predominantly an arid and semiarid country. Almost 80% of its areas are inherently vulnerable to WS. Due to wide latitudinal extent from 23.5° N to 37° N and great altitudinal variations from sea level in south to 8611 m in north, the amount of rainfall and water distribution is highly uneven in the country. For most of water supplies, Pakistan is dependent upon single Indus River System. About 78% water of this river system is generated outside the boarders of Pakistan which is a constant threat to regulate the country's water supplies. Consequently, many agricultural and urban areas of the country are facing WS problem which has restricted farming activity and socio-economic development. Sensing the severity of this multifaceted issue, the study in point probes into its causes, effects and mitigation measures. Using descriptive approach, the study is largely grounded on secondary data acquired from various national, international and UN reports, surveys, researches and other writings. WS situation was assessed with the help of various indices, specifically applying Falkenmark's Indicator. Findings show that Pakistan falls into topmost water scarce countries of the world and almost 80% of its population face acute water shortage at least for one month of each year. The study concludes that WS is a reality in Pakistan, and with the delay of effective mitigation measures, the issue is becoming more serious over time. Besides harming aquatic and land ecosystems and biodiversity, water shortage is also impairing crop yields, livestock farming, human health, and socio-economic progress. It is thus suggested that public education and awareness campaigns about the conservative utilization of water should be initiated at all levels. Other key mitigation measures include population growth control, enhancement of water storage capacity, efficient use of water, waste water recycling for reuse, pollution control, and introduction of smart agriculture in water scarce areas. The study can also help to draw lessons for the future planning.

Key Words: Pakistan, remedial measures, water crisis, water scarcity, water stress.

1. INTRODUCTION

Pakistan contains world's fifth biggest population concentration. The huge water demands of its domestic, agricultural and industrial sectors are fulfilled from two sources, largely (2/3rd) from the surface water and partially (1/3rd) from the ground water. During the past few decades, water scarcity (WS) issue has cropped up mainly because of rapid population growth, climate change effects, lack of proper infrastructure, poor management and water wastage, and water pollution. Water is indeed the most crucial and a finite resource that plays a critical role in all phases of people's life from survival to earning wealth. It is one of the key products liable for life on the earth and essential for socio-economic advancement of the society. In view of that, accurate handling and conservation of water resources is necessary. Almost 43,000 km^3 of renewable freshwater is being supplied globally to streams, lakes and aquifers every year, of which about 11% is used by domestic, 19% by industry, and 70% by agriculture sector (Mehmood et al., 2022). However, the water accessible for any given use is becoming increasingly scarce and contaminated. WS is one of the extreme feared threats in Pakistan because streams are drying up and reservoirs do not have enough size to store ample water which can be used for decades (Akbar et al., 2021). The resulting situation has caused a big restriction to socio-economic progress and a menace to subsistence in numerous areas of the country. For this reason, from late 1980s onwards, research on WS has appealed much political and public attention. Since the dawn of 21st century, policy institutions and politicians have increasingly been speaking about a menacing water future of Pakistan. World predictions also indicate that Pakistan is an exceedingly WS vulnerable country with little ability to cope with water crises. For such reasons, the issue needs to be probed aptly. Based on causes of origin, WS can be classified into various types (Figure 1). Physical or absolute WS occurs when the demand of people surpasses the existing water resources of an area. This type of WS often prevails naturally in arid areas where availability of water is constrained by nature. Economic WS occurs when water is unobtainable due to the lack of economic resources needed to invest in water infrastructure (Rijsberman, 2006; Paulson, 2015). It is found quite often because most of the areas contain enough water to cope various needs, but do not have adequate means to supply it efficiently. Some professionals opine that Pakistan is suffering more from economic WS rather than physical WS which can be minimized with effective water management strategies (Ashraf, 2015; Maqbool, 2022; Wattoo, 2022). Managerial WS refers to inefficient management and poor maintenance of water resources such as losses along the supply systems and water contamination. This results from malfunctioning of water distribution networks and inability of the systems to meet demands. 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. Political WS refers to the situation when publics cannot access to water source due to political restrictions (Molle & Mollinga, 2003). However, physical and economic WS are usually taken into account and it's others forms are usually overlooked.

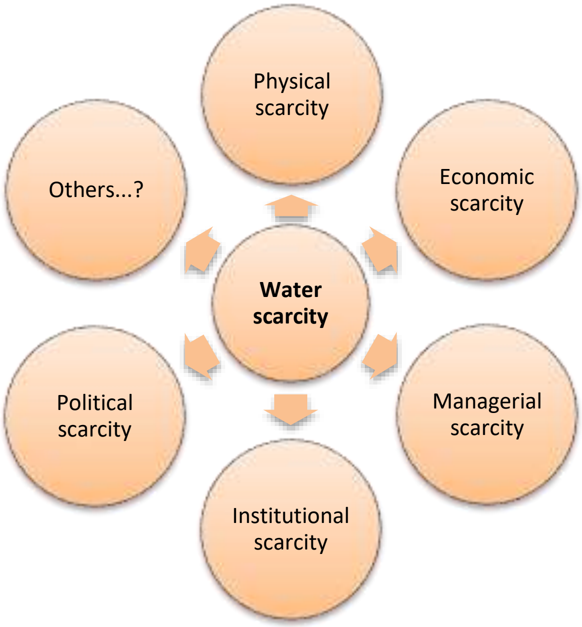

Figure 1: **Different types of WS**

The study in point was produced keeping in view the increasing severity of issue in the country. Its foremost objective was to appraise briefly the status of WS in Pakistan focusing on to its major causes and impacts, and also to suggest remedial measures. Applying descriptive approach, this baseline study sheds light on different aspects of the WS situation in Pakistan and seeks answers of the questions; is WS a reality in Pakistan? What are its causes and effects and most importantly, how to mitigate this problem?

2. MATERIAL AND METHODS

Except for some personal field observations, the study is largely based on secondary data obtained primarily from global water information system AQASTAT (FAO, 2021), national and international reports, surveys, researches, newspapers and other literature. It is intrinsically hard to estimate WS precisely because an all-encompassing and fully agreed upon scientific method for its calculation has not yet been developed (Manungufala, 2021). WS is typically assessed per person per annum renewable water provision (Rijsberman, 2006). During the last few decades, about 150 methods, varying from simple and to intricate and multidimensional, have been framed to quantify WS situation for decision making and policy devising, out of which few are in common use (Alcamo & Henrichs, 2002; Komnenic et al., 2009). The key elements of all these indices are water availability, population, and water usage (Liu et al., 2017). Due to data limitations and simplicity of calculation, following indices have been applied for the current study;

2.1 Falkenmark's indicator

Hydrologists usually judge WS by considering the population-water equation. Falkenmark's (1989) indicator measures water availability in cubic meter (m^3) per person per annum within the region. To him, a country is water stressed when its water supplies drop under 1,700 m^3/person/annum, water scarce when water provisions drop below 1,000 m^3/person/annum, and there is an absolute WS when water supplies fall below 500 m^3/capita/year. Involving just total population of the given region and the amount of water (called blue-water by him) accessible in the region, it was calculated as;

$$FI = \frac{SW}{P}$$

Where; FI = Falkenmark water stress indicator, SW = Total available surface water within the country, and P = Population of the concerned region.

2.2 Water resource vulnerability index (WRVI)

This method is also called as critical ratio index. After initiation in 1972, it was modified and used by several people. It is the ratio between overall water withdrawals (or consumption) and water availability (Manungufala, 2021). The index 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, agricultural and industrial water demand to water supply, and can be computed as;

$$WRVI = \frac{D + A + I}{WS}$$

Where; D = Domestic water demand, A = agricultural water demand, I = Industrial water demand, and WS = Water supply (in km^3/year). Estimated at national level, a country is called water stressed if yearly extractions 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).

2.3 International water management institute's indicator

Pakistan's WS problem was also assessed by using IWMI's physical and economic water stress indicator. This method considers the part of renewable water accessible to meet for people's needs, assured by present water infrastructure, with respect to key water supply source.

2.4 Water poverty index (WPI)

This mathematical data-driven method assesses the degree of water-related poverty in an area and tells weather people are water secure at domestic and community level or not. It measures water availability for people and environmental needs, water quality, percentage of people who can get safe water and time taken to get water, water management issues, and economic & social dimensions of poverty (Sullivan, 2002).

3. RESULTS AND DISCUSSION

3.1 Causes and status of water scarcity in Pakistan

WS is caused by a complex interplay of various natural and anthropogenic factors. In Pakistan, it is primarily caused by rapid population expansion accompanied with accelerated urbanization, climate change, inefficient infrastructure and lack of water storage capacity, poor management and wastage of water, overuse of groundwater, water pollution, and dominance of arid and semi-arid climate (Khan & Khan, 2022; Imran, 2022; Akbar et al., 2021). Although, the role of these factors vary in time and space, but all are conjointly dragging the country towards a situation of serious water crisis. Water intake has increased globally at a rate higher than twofold the rate of population growth during the past century (SDG, 2019). Resultantly, several countries are now threatened by WS (Figure 2).

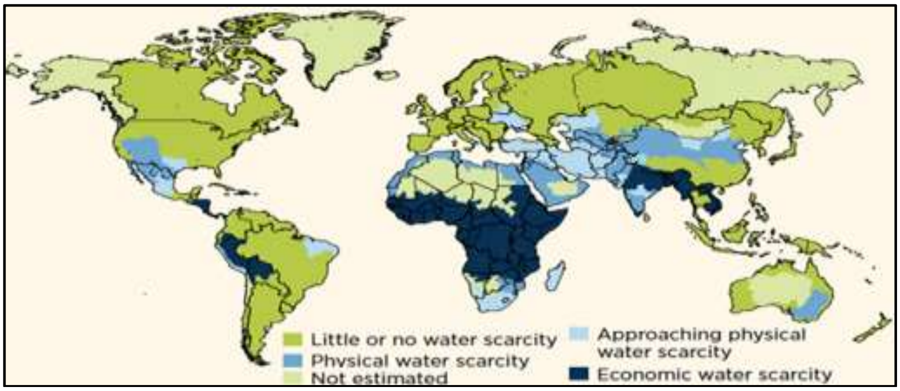

Figure 2: Pakistan's standing among World's physical and economic WS regions

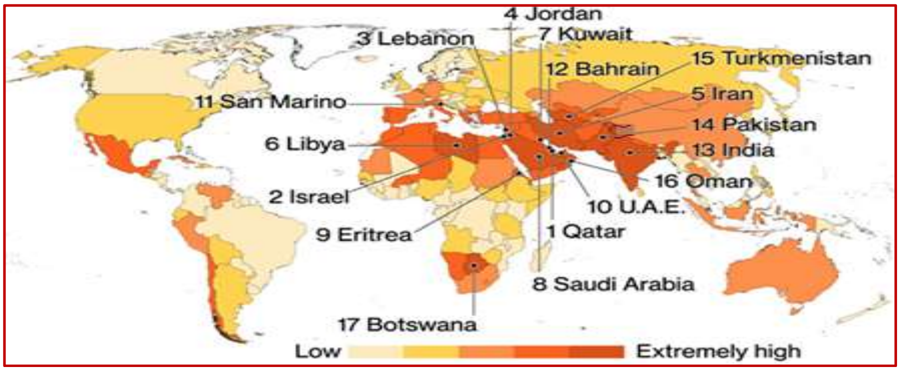

Figure 3: World regions of high water risk

According to CEOWORLD magazine (2019), Pakistan ranks 14th among 17 hot and dry states viz. Qatar, Israel, Lebanon, Iran, Jordan, Libya, Kuwait, KSA, Eritrea, UAE, San Marino, Bahrain, Hindustan, Pakistan, Turkmenistan, Oman, and Botswana (Figure 3). All these are world's 'extremely high water risk countries' facing baseline water stress. Interestingly, all are located in South and west Asia, and Africa where physical WS may be further intensified by human impacts (Manungufala, 2021).

3.1.1 Population growth and water scarcity

Pakistan's population augmented by over 3.84 times in 50 years from 61.4 million in 1972 to 235.8 million in 1922 lifting the country in ranking from 9th to 5th position among the world nations (World Population Review, 2022; PRB, 2022). During the same period, population of Bangladesh increased by almost 2.57 fold from 66.6 million to 171.2 million (Maqbool, 2022; PRB, 2022). Holding 2.85% of the world's inhabitants, Pakistan contains just 0.5% of the global 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).

Table 1: Population growth and increasing stress on water resources

Parameters	Situation in 1972	Situation in 2022	Annual change rate in %age
Population in millions	61.4	235.8	2.7
Aggregate water resources in billion m^3	246.8	246.8	0.0
Per head renewable water resources in m^3	4,021	1,046	-1.5
Overall water withdrawals in billion m^3	153.6*	200**	0.7

Note: *Data refer to 1977, **data refer to 2017. Source: PBR, 2022; FAO, 2021 & World Bank, 2021.

Table 1 reveals that overall water consumption has swollen by almost 0.7% per year between 1977 and 2017 (FAO, 2021; World Bank, 2021), while available water resources stayed fixed at 246.8 billion m^3 (Maqbool, 2022). Falkenmark's indicator shows that average per head water availability in the country has dropped from 5,229 m^3/year in 1962 to 3,478 m^3/year in

1972, 1,187 m^3/year in 2017, 1,117 m^3/year in 2020 (Figure 4), and now is at the verge of dropping below the threshold limit of 1,000 m^3/person/year (Qureshi & Ashraf, 2019; World Bank, 2021). The amount of available water may drop further by 20% in dry period (Habib, 2015). This situation has increased stress on water resources and pushed the country into the category of very high ratio of water withdrawal to supply (WRI, 2021). This is also evident from WRVI 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 better position from only 18 countries (WRI, 2021). Growing at current rate of 2% per year, Pakistan's population is estimated to become 367.8 million in 2050 (PRB, 2022). The proportion of urban residents is also estimated to rise from 37.2% in 2020 to 52.2% in 2050 (UN, 2021). Having water efficiency fixed at the current scale, water extraction-to-availability ratio may surpass 100% in approaching some years (Maqbool, 2022). The IWMI's physical and economic WS indicator tells that the countries which will be unable to meet their predicted water needs by 2025 are categorized as physically water scarce. According to this indicator, Pakistan is already facing WS (Figure 2). It has suffered from 11% water deficiency in 2004 which is projected to become 31% in 2025, making the country more water scarce (Ashraf, 2018). Dividing the total available water resources by total population, current per head water availability is 1,046 m^3/year, which is much lower than the global water poverty index (WPI) of 1,700 m^3/person/year (Figure 4).

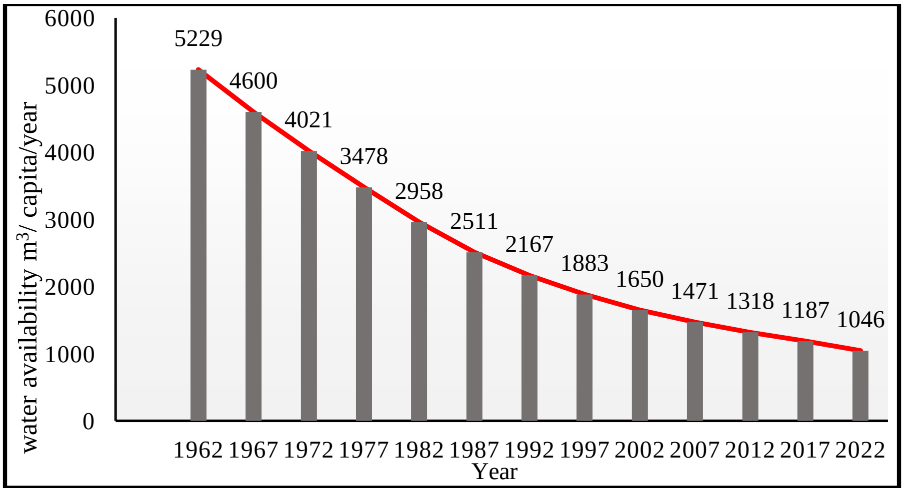

Figure 4: Declining per capita water availability in Pakistan (1962-2022) (Data source: FAO, 2021 & PRB, 2022).

According to some other data sources, Pakistan has already crossed the critical limit of WS 1,000 m^3/person/year (Figure 5). Figure 6 also shows a rise in population size and decline in per head water availability from 1951 to 2025. It reveals that water availability in Pakistan in 1951 was over 5,000 m^3 per person, which declined to water stress limit in 1990 and went down to WS limit in 2005. If such situation continues, the country with a predicted population of 250 million will come close to absolute WS limit by 2025 (Ashraf, 2018).

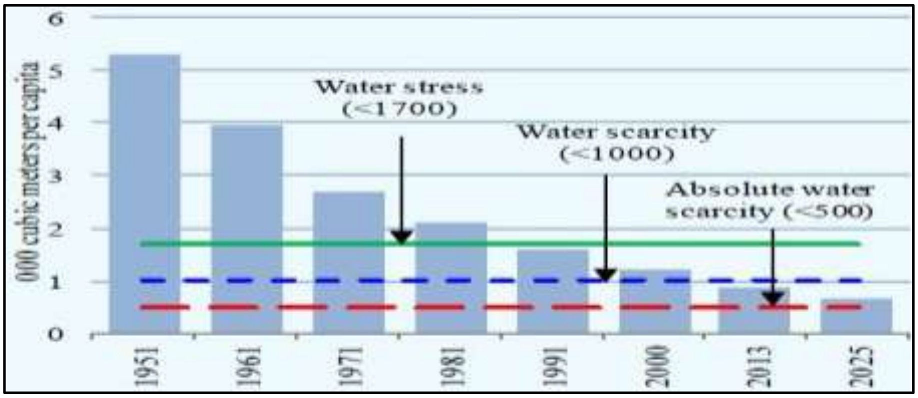

Figure 5: Water stress level in Pakistan
(Source: Draft National Water Policy (Mukhtar, A., 2021, Islamabad Policy Research Institute)

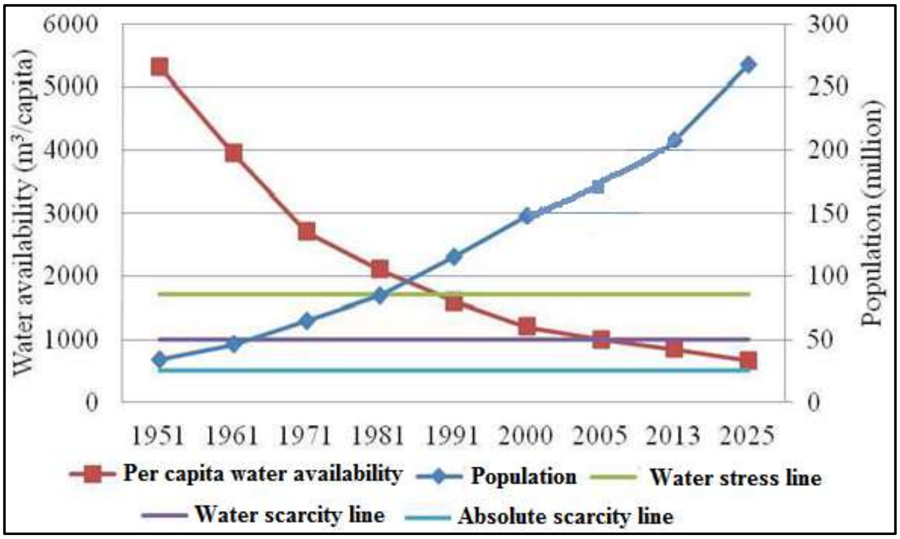

Figure 6: Population versus per capita water availability
(Source: Ashraf, M. 2015).

In brief, evaluated by Falkenmark indicator, WRVI, IWMI's indicator, and WPI, Pakistan fall in the group of water scarce countries (Ashraf, 2015). It is threatened by all forms of WS mentioned above and **o**ver 80% of its population suffers now from extreme WS for at least one month of every year (Maqbool, 2022). Table 2 summarizes the prevailing WS situation.

Table 2: Water scarcity situation in Pakistan

Indicator	Present situation	Remarks/results
Pakistan's share in global population	2.85%	World's 5th biggest 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, increasing rate of evapotranspiration & 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

Source: Computed from various sources mentioned in the text of this study

In sum, fast growth of population and accelerated urbanization accompanied with economic growth, especially industrialization and commercialization of agriculture, have led to an increase in freshwater demand and pollution of both the surface and the groundwater. There is a positive linear correlation between population size and water demand as well as between population size and WS regardless of geographical location (Manungufala, 2021). This means, with growing population, demand for water also rises resulting in an upsurge in pressure on freshwater resources. Not only Pakistan is suffering from water shortage, many other countries are also threatened by WS and it has become a global issue. Population of the world has doubled over the preceding 50 years and continues to grow rapidly. Resultantly, water demand for household, agricultural and industrial consumption has almost tripled. World's current population of over 8 billion is anticipated to boom in the next decades (PRB, 2022). Thus, water resources must be managed more proficiently, otherwise, problems of water shortage may intensify further.

3.1.2 Climate change and water scarcity

Climate change has influenced water cycle at global level and altered precipitation trends, patterns, timing, quantity, intensity and forms (Jian, 2012). Pakistan is world's one of the most susceptible countries to climate change (Figure 7). Ranked by climate risk index (28.83), it falls at 5th position in the world and already suffering from climate associated issues of water resources (Abbasi, 2022). The climate change impacts are evident from rising temperatures, change in monsoon and winter rainfall patterns, rapidly melting and receding glaciers, recurrence of floods and droughts. A clear warming trend of almost 0.57^{o}C in mean annual temperature was seen in Pakistan during the previous century, and the future rise in temperature is forecasted to be more than the world average (Chaudhary, 2017). Besides, uncertain rainfalls as occurred in previous some years, more intense rainfalls as occurred during July and August 2022, an increasing danger of glacier lake outbursts, flash floods, and growing salt water incursion in coastal areas are some of the aspects through which climate change is influencing hydrological cycle and water resources of the country. The Indus River System (IRS), which is the country's major water source, being reliant on glaciers, snowmelt and precipitation water supplies, is exceedingly sensitive to climate change (Janjua, et al., 2021). The two big effects of climate change are a decline in water flow of IRS and an upsurge in water demand for agriculture because of rise in temperature and evapotranspiration. Most of the predictions made for future also show a decreasing trend and increasing variability of river flows, and recurrence of droughts and famines (Khan, 2017; Bhutto, 2020). Climate change thus, may worsen the water crisis, specifically in the areas which are already under water stress. High temperature coupled with water shortage has made farming a tough and costly activity. Resultantly, the issues of food and drinking water shortage, and high food prices can further aggravate in future. The effect of climate change on farming includes shrinking of growing season length, high heat intensity at critical reproductive times, and enhanced water needs of crops. Such factors cause decline in crop yields, mainly in semi-arid and arid regions by almost 6 to 18%. It has been estimated that a change of 10% in the overall worth of agricultural produce causes 2.9% change in GDP in the same direction (Alrwis et al., 2021). The penalties imposed by climate change are irretrievable, but, the effects of prevailing issues can be minimized via effective planning and cautious management of available water resources (Abbasi, 2022).

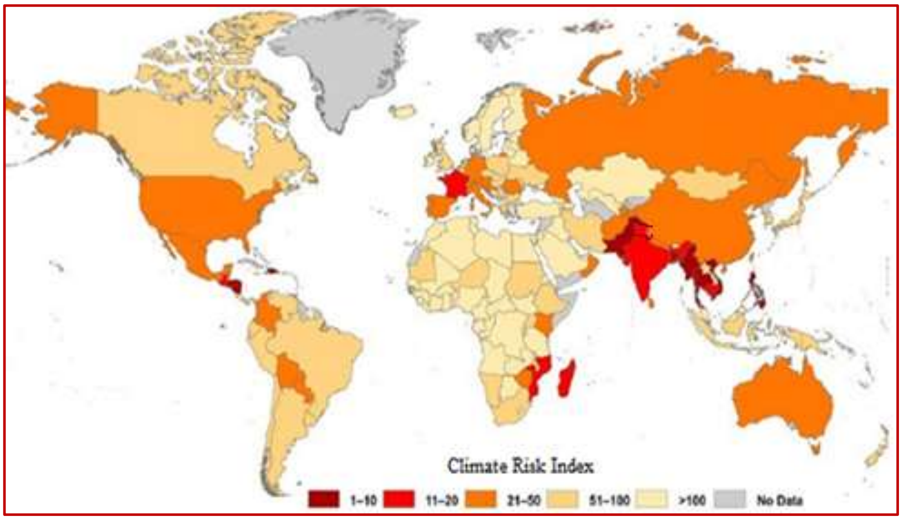

Figure 7: Climate risk index regions of the world (Source: Eckstein et al., 2021).

3.1.3 Inefficient infrastructure and lack of water storage capacity

Inefficiency of existing infrastructure and lack of storage capacity to allocate water according to the requirements at different times of the year is another leading factor to cause WS in Pakistan. The country receives more than 80% of its water in three monsoon months and less than 20% in other nine months of the year. The annual water storage capacity of Pakistan is about 159 m^3/capita, which is much lower than other countries. For instance, in USA and Australia it is over 5,000 m^3, in Egypt 2,300 m^3, in China 2,200 m^3, in Turkey 1,402 m^3, and in Iran 492 m^3/capita (Ashraf, 2020). Furthermore, Egypt's Aswan dam on Nile River can store water for 1,000 days, India for 320 days while Pakistan only for 30 day's needs (Qureshi, 2011). The existing water storage capacity of Pakistan's three main dams is just 9% of the average annual inflow. It means that country can conserve only about 9% of the water available in IRS round the year compared to the world average of 40% (UNDP Pakistan, 2016). Because of sedimentation, the storage capacity of existing reservoirs is being lost at a rate of 0.27 bm^3 per annum. Up to 2010, the dams had already lost almost 8.1 bm^3 of their water storage capacity (Iqbal et al., 2012). In 2004 the shortfall between demand and supply of water was 11% which is projected to reach 31% by 2025. This means there is an immediate need of 3 to 4 large size dams to store at least 20 maf water (Ashraf, 2020). Few years back, the IRSA advised the government to construct large dams for storing

22 maf water on urgent basis 'to put an end to the misery faced by the country'. Nonetheless, the matter was politicized instead of treating is earnestly (Habib, 2015). Our regimes have made no mentionable attempt in the last several decades to increase fresh water storage capacity. Resultantly, we annually lose almost 10 trillion gallons (30 maf) of water just because of the lack of water reservoirs (FPCCI, 2018). The proposal of Kala Bagh dam has virtually been shelved because of the mutual distrust between provinces. The work on Mohmand and Bhasha reservoirs is also still in early stage (Wattoo, 2022). This situation has made the country vulnerable to WS. Thus, construction of large dams and enhancement of the infrastructure efficiency is a life line for Pakistan's economy.

3.1.4 Poor management and wastage of water

Besides water storage issues, poor management and wastage of water is also a great concern of Pakistan. Mismanagement of water resources and profligate way of their usage, whether it be in household, agriculture, or industrial sector, causes wastage of the huge amount of water, leading to a serious stress on the amount of accessible water resources. At global level, agriculture is the leading water consumer, utilizing almost 70% of the world's available fresh water (Donnenfeld et al., 2018). Over 90% of the overall water intake in Pakistan is consumed by agriculture sector (Qureshi & Ashraf, 2019). Almost 80% of Pakistan's water resources are utilized by rice, wheat, cotton and sugarcane that share merely 5% to GDP (Young et al., 2019). Compared to worlds other significant agricultural economies, the yields of these crops are much lower in Pakistan (Table 3).

Table 3: Comparison of crop yields of Pakistan with some other major agricultural countries

Sr. No.	Country	Crops yield in 2019 (kg/ha)			
		Paddy rice	Wheat	Seed cotton	Sugarcane
1.	Pakistan	3,664	2,806	1,779	6,432
2.	India	4,058	3,533	1,157	8,010
3.	USA	8,374	3,475	2,712	7,840
4.	China	7,056	5,629	4,881	7,729
5.	Egypt	8,373	6,379	3,050	11,574

Source: FAO, 2021.

Irrigation water is exceedingly underpriced, recovering just about 20% of the annual maintenance and operational costs (*Abiana*) of canal water whereas the collection is 60% of the total receivables (Young et al., 2019). Even if, agriculture contributes $1/5^{th}$ of the country's GDP and employs about 50% of workforce, it shares under 0.1% to overall tax incomes, producing little amount of money for the upkeep of irrigation system (IMF, 2015). As a result, poor water distribution infrastructure causes massive water wastage. Because of ageing and improper maintenance, the overall effectiveness of country's irrigation system is just 39%. In other words, out of 143 bm^3 of water available at canal head-works, just 55 bm^3 (39%) is being utilized for the agriculture and 87 bm^3 (61%) is lost during supply via canals and watercourses, and use in the farms (Ashraf, 2018). Pakistan was rated 8th lowest in 2017 among the world nations in water productivity yielding just 1.4 US$/$m^3$ of water withdrawn compared to Turkey 13.6 US$/$m^3$, China 21.4 US$/m^3, and Malaysia 55 US$/$m^3$ (FAO, 2021).

3.1.5 Over-exploitation of groundwater

Groundwater is the second major source of freshwater in Pakistan for municipal, agricultural and industrial uses (Aslam et al., 2021). Its intake has increased several times over the last 70 years or so. Currently, Pakistan is 4th biggest consumer of overall groundwater, and 3rd biggest consumer of groundwater for irrigation in the world (Qureshi, 2020; Habib & Wahaj, 2021). Nearly 94% of the entire groundwater extraction is consumed by our agricultural sector (Margat & Van der Gun, 2013; UNESCO, 2022). The Punjab consumes over 90% of the total groundwater withdrawals. According to World Bank (2021), groundwater provides 70% of the overall national domestic water, 90% of the domestic water in rural areas, and about 50% of the agricultural water of Pakistan. It is playing a vital role in the development of irrigation farming and in managing the effects of variable supplies of canal water and rainfall. Over 60 bm^3 groundwater is extracted annually by an estimated number of more than 1.2 million private tube-wells, out of which 85% are working in Punjab, 6.4% in Sindh, 04.8% in Baluchistan, and 3.8% in KPK (Qureshi, 2020; GoP, 2022). Basically the Indus basin irrigation scheme was planned for an annual cropping intensity of 75% and water is being provided to the fields weekly on rotational basis locally known as '*warabandi*'. The farmers get their quota of water weekly for the duration concerned to their farms and cropping pattern. However, in the areas where groundwater was accessible, the farmers have enhanced cropping intensity to above 150%. As the country has no groundwater governing system, any individual can install any number of tube-wells anywhere at any depth and can withdraw any quantity of water at any time (Ashraf et al., 2012). Thus, the people started pumping groundwater ruthlessly. Certainly the intensive use of groundwater has aided agriculturalists to secure sustenance for growing populations and geared-up socio-economic development but at the same time has threatened the sustainability of this resource (Mehmood et al., 2022). The annual extraction rate of groundwater has already surpassed the recharge rate of 55 km^3/year (Watto, 2018). The unrestricted exploitation and excessive use of aquifers at a rate higher than the rate of their recharge is causing groundwater depletion and originating serious environmental concerns. The most alarming concerns are rapidly dropping levels and deteriorating quality of ground water, and increasing soil salinity in irrigated areas. The groundwater tables are dropping sharply in various parts of the country (Habib & Wahaj, 2021; Ashraf et al., 2022). It was pointed out years back that out of 43 canal commands, the water-table was dropping in 26 commands because of rapidly increasing groundwater pumping (Bhutta et al., 2000). In more than 50% irrigated areas of the Punjab, ground water-table has fallen below 6 meters resulting in an increase in pumping costs and degradation of water quality (Qureshi, 2020). The situation in Baluchistan is even more fearsome where in some river basins, the water-table is dropping at a rate of over three meters per annum. This is happening largely because of hyper arid climate and application of flat rate of electricity in the province (Ashraf, 2015). Due to over drafting of groundwater in freshwater regions, the aquifers are ultimately recharged with contaminated water and untreated wastes from agriculture, factories and households. As a result of unchecked usage of such type of polluted groundwater, land degradation and health issues are increasing day by day, some species of the local plants are waning, and agricultural yields are diminishing. Almost 21% of the irrigated lands are already damaged by various extents of salinity (Qureshi, 2020).

3.1.6 Water pollution

Degradation of water quality due to municipal and industrial wastes and agrochemical residues is another facet of WS being confronted by Pakistan (Habib & Wahaj, 2021). The deterioration of quality decreases the quantity of usable water and ultimately pushes the area into a state of WS. The insanitary drainage and poor water supply have given upsurge to contaminated water. Inadequate waste disposal, improper use of agro-chemicals, and soil depletion are the main factors damaging the quality of available fresh water resources. Huge amounts of untreated sewage and sullage of cities and towns are disposed-off into rivers and other surface water sources which have endangered aquatic and human life (Bhutta & Alam, 2006). In Pakistan, about 50% of the over two million tons per year produced wet human excreta is released into water bodies (GoP, 2016). For instance, huge amounts of untreated municipal and industrial wastes from Peshawar, Mardan, Charsadda and Nowshera are drained into the Kabul River (Imran, Bukhari, & Gul, 2018). Similarly, all kinds of liquid wastes from Lahore and some other cities are drained into Ravi making it world’s third most polluted river (Hassan et al., 2022; Sheikh, 2022). Increasing contamination is making water unfit for various uses and thereby is resulting in serious environmental and health consequences. A study conducted on Pakistan indicates that over 60 million inhabitants of

Indus Plains are threatened by high concentrations of arsenic in groundwater (Podgorski et al., 2017). The quality of available water is inadequate in majority of the areas and clean water dearth has damaged agriculture, livestock and fisheries specifically of coastal communities (Abbasi, 2022). The inadequate access to sanitation and clean water is giving birth to a number of health issues as well. Studies reveal that water borne diseases are one of the foremost causes of death in the country (Daud et al., 2017; Qamar et al., 2022). Such issues put a lot of stress on country's economy. For example, the monetary costs of poor water and hygiene, and droughts and floods to Pakistan are estimated to be around 4% of the GDP or almost US$ 12 billion per annum (Young et al., 2019).

3.2 Effects of water scarcity

WS is a mother cause of many problems. Its effects on physical and human environment are multifaceted. In case of Pakistan, it has evidently affected biodiversity, agriculture, human health, and socio-economic development.

3.2.1 Loss of biodiversity and ecosystem damages

Degradation of water resources is harming biodiversity and lessening the links within and amongst the ecosystems. WS has affected the physical environment of Pakistan threatening its various components like rivers, lakes, and other fresh water resources. It is damaging the environment through nutrient pollution, increased salinity, loss of floodplains, and wetlands deterioration. As a result, biodiversity is decreasing and ecosystem's instability is increasing. This is evident in several parts of the country, such as due to shortage of water in IRS, we have lost a considerable part of floodplains, wetlands, and fish production. In Cholistan and Thar we have lost several species of flora and fauna.

3.2.2 Pressure on agriculture and economy

Agriculture is being seriously influenced by climate change and associated WS. Predicted rises in temperatures, alterations in precipitation patterns and declines in water availability may decrease agricultural productivity (GoP, 2022). A lesser amount of water means lesser yields of agriculture which may increase dependence upon other countries to fulfill growing food needs. Orchards of the country earn an ample sum of foreign exchange that is impaired because of water dearth. Lesser agricultural earnings are compelling rural dwellers to seek jobs in cities. Resulting displacement of people from agriculture and their migration towards cities is increasing unemployment and stress on the economy.

3.2.3 Sanitation and health issues

WS compels people to use polluted water. In the areas where water is scarce, people store it at homes in different ways which increases the risk of contamination. Inadequate sanitation and use of contaminated water may lead to deadly diseases like cholera, diarrhea, typhoid, hepatitis, giardia etc. Due to dearth of water people cannot properly bath, wash their cloths and utensils, and clean their residences which results in poor health. Apart from this, use of waste water containing heavy amounts of trace elements and heavy metals has increased for irrigation purposes during the past few decades. The crops grown using polluted water contain toxic materials, which when enter in food chain are ultimately transferred into animal and human bodies. Vegetable crops like cabbage, lettuce, spinach, onion, potato, tomato, carrot, reddish etc. are highly sensitive to water pollutants. When such crops are consumed by humans, the toxins contained in them start bio-accumulating in human bodies and cause serious health problems.

3.2.4 Hunger, poverty and education

In numerous regions of the world like several African countries and in several areas of Pakistan like Cholistan, Thar, and parts of Baluchistan, starvation is one of the big issues. This is because, WS has a direct adverse impact on crop and livestock production, which may lead to food shortages and eventually hunger. In water scarce areas many people die every year just because of hunger and hunger related diseases. Water shortage takes a bigger toll on children and women as they are often responsible for water collection. Carrying water from far and wide areas is also a massive physical strain and can expose children to safety threats and abuse. When water is collected from far away locations, it needs more time to obtain, which usually means less time at school. Especially for girls, water shortage in schools effects student's enrolment, attendance and performance. In poorest societies, specifically of rural areas, many children cannot attend schools because they are either too sick or they have to walk a long distance for most of their time on daily basis to obtain water. Even when they attend schools, many of them cannot learn due to their fatigue, hefty liabilities and concerns for their families.

3.2.5 International and local tensions and conflicts

In present times, having access to water resources has turned into an influential global economic concern that could become one of the major reasons of international tensions. For example, the claim of right to access the water resources is one of the major reasons of tension between Pakistan and India. Local or regional conflicts are also triggered from time to time over scarce water resources that often result in big clashes. Water crisis in Pakistan is aggravating cross boarder and local tensions between the provinces. With the growing population and increasing needs, such kind of tensions could increase in future.

3.2.6 Water distribution issues among provinces

WS has become a basis of dispute between provinces on the sharing of available water resources in Pakistan. Canal water is divided between provinces according to 1991 Water Accord that is, a baseline water amount of 144.8 bm^3/year is distributed between the provinces, with almost 48% going to the Punjab, 42% to Sindh, 7% to KPK, and 3% to Baluchistan (Siddiqui, 2021). A method has been mentioned in the accord for the surplus water supply but no mechanism for apportionment during shortages is given. Less amount of water available during some dry months have increased tensions between provinces. Sindh charges the Punjab of upstream water theft whereas Baluchistan blames Sindh of not providing his quota from Guddu and Sukkur barrages (Maqbool, 2022).

3.3 Remedial measures against water scarcity

Based on the reasons, WS management involves several interventions. The factors responsible for WS are intricate and differ greatly across the regions. That is why context-specific measures are required to address the issue effectively. Pakistan needs to take a series of measures. All the stakeholders are required to understand water demands at national level and must ensure them to be reflected in national planning considerations (UNICEF, 2022). Some of the key measures are given here.

3.3.1 Taking ownership of the challenge

At the outset, all the stakeholders, especially the political leadership of Pakistan should accept the ownership of the challenge of water crisis. They should clearly state their intent to grab the issue. Merely pointing the finger at earlier governments, or charging India for the crisis cannot solve the problem (Baloch, 2018).

3.3.2 Education and awareness of masses

Although, every year, 22nd March is observed as World Water Day to highlight the importance of water conservation, but a lot of work is still to be done. In order to deal with WS in future, it is essential to thoroughly improve all forms of water use, from individual consumption to the supply chains of big establishments. Collaborative water conservation measures can prove fruitful. People should be educated to change their behaviors about water usage. An understanding of the worth of water protection among people needs to be promoted. Awareness oriented education of masses can play critical role in this regard. Another effective measure can be the establishment of institutes for farmers to learn how to cope with climate change adopting drought-resistant crop varieties, crop rotation systems, and sustainable techniques for livestock rearing.

3.3.3 Improvement of water use and agriculture efficiency

Evidently agriculture sector is the biggest water user in Pakistan. Wastage of water during irrigation is a big issue of the country. Around 50% water of the IRS never reaches agricultural fields. About 30% to 50% of the diverted water is wasted during the process of tail-end irrigation which tolls a lot to the country's economy. The existing rotation based irrigation system of Pakistan needs to be transformed into a modern demand oriented system. Use of advanced technologies for irrigation can help a lot to effectively apply and conserve the available water resources. Farmers can practice precision watering instead of inundating their crop farms. Drip irrigation is one of the beneficial advances of modern agriculture. In the regions where groundwater is pulled for agriculture, smart irrigation system can be more effective. Utilizing external information about weather and soil moisture this system monitors moisture-related conditions on the farm to determine frequency and length of water cycle and automatically adjusts watering to optimal level. Besides, water intensive crops like sugarcane and rice can be replaced with the crops having low water demands, especially in water deficient areas.

3.3.4 Improvement of water storage infrastructure

The two basic components of sustainable water management are its conservation and efficient use. Thus, improvement of water storages should be a priority of the concerned departments. Unluckily, Pakistan has poor water infrastructure, not improved over time according to the growing needs and no any mentionable new water storages were built. Resultantly, a huge amount of seasonally available water is wasted to the Arabian Sea each year. To save water and to control floods, construction of new water storages is an urgent need of the time. Construction of Chashma, Kalabagh, Mirani, and Gomalzam dams, and enhancement in the storage capacity of Mangla and other existing dams must be a top priority. Large dams indeed are a source of lifeline for Pakistan's water security. In addition to producing cheapest electricity, they can supply water for irrigation, control floods, regulate water flow from high to low flow seasons and from a wet to dry year, and can act as buffer against the impacts of climate change. If we mention the case of Kalabagh dam only, it has been pending since last over 40 years. Besides fulfilling other needs, it can produce 3,600 MW electricity (Valasai et al., 2017; Akbar et al., 2021). Although, building of small dams and management of water resources in every sector is necessary but this cannot be a substitute of large dams.

3.3.5 Use of reclaimed, recycled and desalinized sea water

Use of rain harvested and recycled wastewater for agricultural and other purposes can reduce the pressure on ground and surface water resources (Ricart et al., 2019). In Pakistan, about 70% of the rainwater is wasted due to poor or no storage arrangements. Our policy makers also need to promote wastewater recycling based on the idea of optimal pricing by involving private sector as is practiced in several countries. For example, Singapore was once a water scarce country, but now is satisfying 40% of its water requirements from recycled wastewater which are estimated to go up to 55% in future (The Korea Times, 2021). Another solution of the issue is desalinization of sea water (Ricart et al., 2019). This can help a lot to tackle the problem of WS, especially in the areas which are sited close to the coastlands and seriously deficient of fresh drinking water. For this purpose, solar desalinization technology may prove highly beneficial.

3.3.6 Improvement of sewage system and pollution control

Without proper handling and sanitation, water becomes contaminated, full of diseases and thus, unsafe for drinking and other uses. In many areas of Pakistan, residents do not have access to safe water. About 80% population of the country is compelled to utilize unclean water due to shortage of clean water. Therefore, addressing pollution and consistently checking and monitoring water quality is key to maintain its healthiness. Besides, improving the treatment and sewage systems is another practice to avoid contamination of water sources and check WS.

3.3.7 National water policy (NWP) and reforms

To overcome the issue of WS is the goal of many countries national policy including Pakistan. The first ever NWP of Pakistan was formulated in 2018 which reinforces drinking water and sanitation as top priority than all other uses. It urges the provinces to prepare their guidelines and plans for drinking water and sanitation (GoP, 2022). It was recognized for the first time that water is a limited resource and that Pakistan needs to recover at least the expenditures of irrigation system from users. The policy also mentions the upcoming effects of climate change on water resources and water pricing, and talks about the regional cooperation challenges. A number of provincial level steps have also been taken before and after NWP such as the Baluchistan Integrated Water Resource Management Policy 2006, KPK's Drinking Water Policy 2015 and Climate Change Policy 2016, Sindh's Agricultural Policy 2018, and the Punjab Water Act 2019. Nevertheless, there are numerous flaws in these documentations such as a lack of scientific grounds, the negligence of water quality concerns, the lack of setting goals, absence of strong and obvious reference to sustainable development goals (SDGs), and inclusion of gender (Maqbool, 2022). Such deficiencies are required to be removed in the execution stage, and it is essential to bridge the gap between policies, reforms and their execution by formulating a comprehensive execution strategy.

3.3.8 Improvement in governance and efficient use of water

Some experts proclaim that there is no water crisis, there is a failure of governance giving birth to water problems (Husain, 2017). It is essential for the government to introduce a big paradigm change that supports more sensible water usage. This includes improvement of water infrastructure, provision of technologies for water conservation, and increasing awareness. Besides this, political will, provision of monetary resources, clear timeline and capacity are essential requirements of the effective governance. Without further delay, government should make and strictly implement laws on water conservation like numerous western countries.

3.3.9 Measurement of water usage and price rationalization

Some researchers suggest that measurement of water quantity consumed should be made obligatory for all users from households to agriculture and industry (Ashraf, 2015; Akbar et al., 2021; Maqbool, 2022). When the quantity of usage is determined, it can help in effectively planning and managing available water resources. Our present pricing system offers little or no motivation to users for water conservation. Pricing can be related to income levels along with a number of other influential dimensions. Increase in the price of water usage will not only inspire users to consume water more carefully but also produce ample incomes for the up-keeping of infrastructures and water saving technologies.

4. CONCLUSION

The study concludes that Pakistan is rapidly heading towards a serious water crisis. Several interlinked natural and anthropogenic factors such as climate change, population growth, inefficient infrastructure, mishandling and pollution are responsible for the crisis. However, most of these factors are related to management side and can be handled by limiting population size, building new reservoirs, formulating and implementing groundwater regulatory principles, improving land and water productivities, and promoting arid land and climate resilient agriculture. All this needs a paradigm change and stakeholder’s commitment right from policy makers to water consumers. In future, population growth and climate change may further upsurge water demand and uncertainties in supply. The incidence of severe events is expected to rise. The severity and nature of water concerns will differ to a great extent within the country. It is thus, essential for Pakistan to learn about WS management, which needs all-inclusive, well assessed and revolutionary solutions in all water consumer sectors. In this regard, collective efforts and the consistency of scientific researches to further extend and improve the knowledge are vital. Managing WS indeed is a complex and intrinsically hard task that involves a unified approach consisting on the application of technology, capital, effective policies, capacity building, partnerships, monitoring, data, and accountability. At the outset, government should take the ownership of the issue and promote the effective and rewarding usage of existing water resources in all sectors. The steps like creating awareness among communities, managing water wastage, recycling and reusing wastewater, rainwater harvesting, and construction of small and large dams, can be taken to handle the issue. In Pakistan, farming is by far the leading water consumer and may provide the great possibilities for saving this resource. Saving merely a fraction in this sector can considerably reduce water stress in other sectors. Pakistan can produce almost 83 maf of additional water through an effective water management strategy and by building more reservoirs. In addition, application of sustainable water management techniques and production of crops which require a lesser amount of water should be promoted in arid areas. Water savings in other sectors such as industries, power production units, and household usage should also be encouraged. The execution of the recommendations of researchers and concerned departments may help Pakistan to meet the challenges and attain sustainability in developing and managing finite aquatic resources. Lastly, what we do, nature reacts accordingly. So, we must revisit our deeds and doings with the strong intension to eradicate maladies in handling water resources, otherwise with growing population, our problems will continue to increase and aggravate further pushing us towards a miserable situation. Our future lies in how effectually way outs are set for construction of more dams, up-gradation of infrastructure, and management and conservation of existing water resources.

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