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# Water Scarcity in Pakistan: Implications To Regional Security and Peace

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## Abstract

The supreme interest of any state is to strengthen her control over natural resources and maximize security in her national interest. Water is the key to every production process and hence to economic growth. The rising global water demand, declining freshwater availability and trans-boundary water conflicts have created water stress and scarcity issues. Looming fears of water disputes and conflicts may stimulate existing tensions with adverse effects to security, stability and peace of the region. It is predicted that the next war(s) would be fought over water and South Asian Region is ready for it. Keeping in view the arising water scarcity in the region, particularly in Pakistan, this study is planned to assess the status of water scarcity in Pakistan using various well-defined water indices for year 1972-73 to 2022-23. ARIMA model was used to forecast water scarcity in Pakistan. The implication of arising water scarcity in Pakistan to regional security and peace is also examined. Pakistan, once water abundant country is now a water scarce country both in terms of physical and social scarcity. Pakistan is found to fall in the category of absolute water scarce countries in near future either in terms of declining per capita freshwater availability, increased withdrawals to availability ratio, high environmental water scarcity or reduced social adaptive capacity. Effective and acceptable measures must be taken to address the problem of absolute water scarcity in Pakistan. It is high time regional forces must initiate dialogues and cooperative measures upto the optimal use of available freshwater resources to bring peace and stability in the region.

**Keywords:** Water scarcity, Regional security and peace, Pakistan, ARIMA
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## 1. Introduction

"Every living being is made from water" (*Al–Quran Sura Al Ambia Aayat* No. 30). Thus water is a basic ingredient of life and helps in maintaining a healthy ecosystem. Water is used in almost all production processes, vital for providing food, eradicating poverty and enhancing economic growth and development. The total amount of water is approximately 1.454 billion $km^3$ in this hydrosphere. Almost 2.5 percent of this amount is considered freshwater, while the rest 97.5 percent is highly saline ocean water. About 2/3 of the freshwater is found in polar ice caps, glaciers and permafrost, while remaining 1/3 is in liquid form. About less than one percent of the total water in this hydrosphere is in liquid form, which is available in lakes, aquifers, and rivers (Malik, 2011).

Water scarcity arises when the demand for water exceeds from available supply of water. This type of water scarcity is known as 'physical' or 'first-order' water scarcity. The second type of scarcity known as 'socio-economic' or 'second-order' water scarcity, arises when water is present, but it is not available to all because of a lack of investment and political will.

The arising scarcity of water has warned the world. The UN World Water Development Report 2020 has stated that the use of water for households, industry, and irrigation has increased by double the rate of population during the last century. The worldwide demand for water has increased drastically as a result of growing population, rapid urbanization, unfavorable climatic conditions, changing patterns of water consumption, industrial development, and excessive water withdrawals *etc.* The global water demand is expected to increase manifold in the next two decades, resulting in scarcity of water in many areas of the world (Brown, Mahat & Ramirez, 2019; Zenko & Menga, 2019). Due to limited availability of water, the agriculture sector is not able to feed the swelling world population and as a result will face rise in food prices. During the $21^{st}$ century, water related disasters such as drought and floods have caused a loss of US$ 600 billion at the global level (Lee, Perera, Glickman & Taing, 2020). The ecosystem which yields almost US$ 75 billion of goods and services is also under the threat of increased scarcity of water (Guppy & Anderson, 2017).

Almost 60 percent of the global population is living in South Asia and Middle East regions but these regions have access to only eight percent of the world's freshwater resources. In South Asia "the per capita availability in 1995 was 2265 $m^3$ against the whole world avarage availability of 7000 $m^3$ per capita" (Siddiqui & Tahir-Kheli, 2004, p. 7). The most volatile imbalance between available water resources and population is seen in Bangladesh, China, India, Iran and Pakistan, where irrigation is the life-line of their agricultural and industrial products. While discussing water scarcity issue in South Asian region, Tripathi (2011) witnessed scarceness of water due to enormous growth of population along with increasing water consumption in Bangladesh, China, India and Pakistan. The average freshwater per capita withdrawals in Pakistan are very high which are almost 885 $m^3$ as compared to its neighboring countries of India with 600 $m^3$ and China with 420 $m^3$ (Zahra & Khan, 2019). "South Asia is predicted to lose nearly 2% of its Gross Domestic Product by 2050 if no action is taken to mitigate the impacts of climate change" (ADB, 2017, p.34).

Freshwater resources in Pakistan are deteriorating day by day. Water availability per capita has declined in Pakistan from, on average, 5000 $m^3$ in 1950s to 2899 $m^3$, 1698 $m^3$, 1546 $m^3$, 844 $m^3$, 686 and below 600 $m^3$ in 1970s, 1980s, 1990s, 2000s, 2010s, during year 2020 to 2023 respectively. The per capita freshwater availability which was on average, 5000 $m^3$ in 1950s has persistently declined below the international standard of 1000 $m^3$ per person. The per capita freshwater availability in Pakistan, on average, was 5000 $m^3$ in 1950s which declined below 1000 $m^3$; an international threshold of the scarcity of water (Begum, 2018). According to Asian Development Bank (ADB), per capita water availability in Pakistan has decreased by 70 percent since 1950. "Pakistan is one of the world's most water stressed countries" (ADB, 2013).

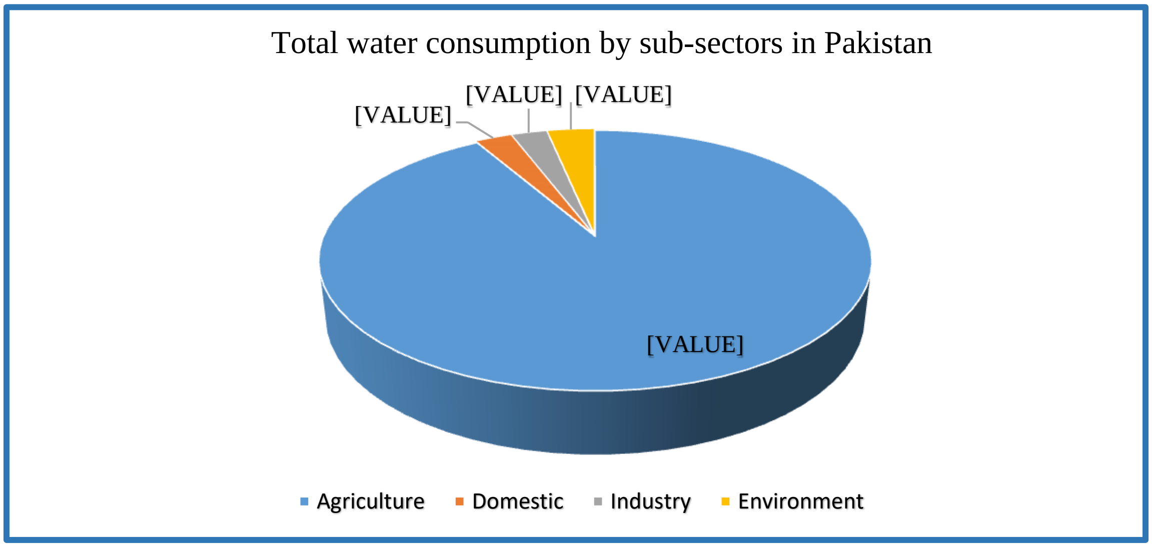
The Indus basin is a primary and largest source of freshwater in Pakistan. The tributaries of Indus River are Chenab, Jhelum, Ravi and Sutlej. The Indus and its western and eastern rivers supply almost 138 million acre feet (maf) freshwater every year to Pakistan from which 65 percent, 19 percent, and 17 percent of total water comes from Indus and its rivers of Chenab and Jhelum, respectively (Zahra & Khan, 2019).

Water has been a basic source of the Pakistan's socio-economic growth. The agricultural sector which is considered as a backbone of the country's economy uses 91.6 percent of the total freshwater and contributes nearly US$ 22 billion to her GDP (19-20% of GDP). Around 38 percent of Pakistan labour force is directly or indirectly linked to her agriculture sector. Similarly, the industrial sector that consumes 2.5 percent of total freshwater makes up 86 percent of the GDP. The remaining proportion of water i.e., 5.9 percent is used for domestic purposes (2.6 percent) and environment (3.3 percent) as shown by Figure 1 (Young, et al., 2019).

Therefore, the significance of water for the economy of Pakistan cannot be ignored. Pakistan must ensure efficient use of water in her agriculture sector to boost the economy.

Figure 1 Share of Pakistan's sub-sectors in total freshwater consumption

*Source: Adapted from "Pakistan: Getting more from water" by J. W. Young et al., 2019, Washington DC: The World Bank Group.*




Water scarcity in Pakistan will affect her agricultural sector by reducing its productivity first, overexploitation of groundwater that led to rapid depletion of aquifers, increasing costs of farming and economic losses, crop failures and food insecurity (particularly in drought-prone areas of province Sindh and Balochistan), forcefully cropping patterns shifting, migration burden from rural to urban areas, more conflicts over water among four provinces, fluctuation in river flows due to climate change impacts and, last but not least, reducing exports of agricultural products.

Pakistan ranks 5$^{th}$ among the most climate-vulnerable countries in the Global Climate Risk Index Report 2020. These changes in climatic conditions have adversely affected the water resources and food security of Pakistan. From 1999-2018, almost 152 life-threatening weather events have resulted in 10,000 deaths and an economic loss of US$76 billion to Pakistan (Yasin, 2020).

Pakistan is a water scarce country (Khan & Khan, 2022; Sleet, 2019; Young, et al., 2019; Zahra and Khan, 2019; Begum, 2018). In 2019, The World Resources Institute ranked Pakistan among 22 countries listed in the category of High (40-80%) base line water stress country.

The same Institute ranked India, Iran and Pakistan amongest 17 countries listed in the category of suffering from Extremely High (>80%) baseline water stress country in 2023.

The water storage capacity is also deteriorating. According to the Indus River System Authority (IRSA), Pakistan can store water for 30 days only, while India has enough capacity to store its water for 320 days. Pakistan is expected to be the country with the greatest water stress in future (ADB, 2019). The persistently growing population and unprecedented urbanization to be one of the drivers of water stress and water scarcity in Pakistan (Khoso, Wagan, Tunio & Ansari, 2015; Kugelman & Hathaway, 2009; Mustafa, Akhter & Nasrallah,2013; Naseer, 2014).

Besides these internal factors, one of the most external factors which are causing water scarcity in Pakistan is its water sharing of the Indus Basin with India (Begum, 2018). According to the Indus Water Treaty (IWT) of 1960, India has predominant control over Ravi, Bias, and Sutlej as a result they are flowing with less water in Pakistan, especially in growing seasons. India violated IWT by building dams on Jehlum and Chenab Rivers. Thus triggered a conflict on water issue between India and Pakistan. Water conflicts in South Asian region are looming. All South Asian countries must recognize the need for an interstate solution to this threatening issue of water shortage. The United Nations SDG 6.4 is also underlying this arising water scarcity challenge as: "To markedly reduce the number of people that are suffering from scarcity of water until 2030". Thus, forecasting water scarcity and its implication to regional security has become the focus of this study.

Assessing the status of water scarcity in Pakistan, using various well-defined water indices for year 1972-73 to 2022-23 and its implication to regional security is the main objective of the study. After descriptive analysis of depleting water resources of Pakistan, this study is designed firstly to measure existing level of water stress and scarcity and then forecast it using ARIMA model.

This study has its own significance in the respect that it helps policymakers to determine to what extent water would be a limited resource for Pakistan in the future. The forecasted water scarcity results may help government ministries in prioritizing investment decisions for the construction of water reservoirs, decisions concerning water allocation and management on sustainable basis. This study may help regional forces to initiate regional trans-boundary dialogues and cooperative measures to maintain peace, prosperity and economic integration in the South Asian region. This study will provide the basis for further studies to highlight looming water conflicts in South Asian region that, inturn, helps all South Asian nations to recognize the need for an interstate solution of arising threatening water shortage and scarcity issues.

Various water indices have been developed by researchers to assess the status of water scracity. The indices such as 'Falkenmark Indicator (FI)', 'Water Resource Vulnerability Index (WRVI)', 'Environmental Water Scarcity Index (EWSI)' and 'Social Water Scarcity Index (SWSI)' *etc.*, were used to measure water scarcity in different parts of the world. These indices are different from each other on the basis of complexity, accessibility of data, and their objectives. Based on WRVI, Pakistan ranks $14^{th}$ in highly water scarce global countries.

In this study, water means 'freshwater' that is found in lakes, rivers, and streams. Water losses (due to leakages or evaporation & due to the distribution process) are not included in water withdrawals as data on these water losses are not easily available. Due to the non-availability of data on other water scarcity indices, this study is also restricted to measure the scarcity of water in Pakistan through FI, WRVI, EWSI and SWSI indices. Furthermore, The status of availability of water in India is examined only on the basis of review of litreure as timeseries reliable data on water availability for India is not easily accessible .

## 2. Literature Review

### Literature Review Based Upon Descriptive Studies on arising Water Stress and Scarcity

Since 1950s, supply of freshwater resources has declined at a rapid pace due to rising water demand. Hanjra and Qureshi (2010) have observed that almost one-half of world's population lived in water stressed regions. Cosgrove and Loucks (2015) studied the present and future water challenges at global level and concludes that if these situations remain the same, two-third of world population is going to be affected by water scarcity in couple of decades. Examining water scarcity sitution and its rising impacts in both developed and developing nations, Guarino (2017) found uneven water distribution, increased population, overexploitation of water, and increasing drought are possible causes of water scarcity worldwide. Gleick (2000) suggested effective water management policies around the world to feed this rapidly growing population.

Callister, et al. (2019) found ballooning demand for water, increasing population, and climatic changes as primary reasons for worldwide water scarcity. This study predicts that almost 33 countries of the world comprising 15 countries of Middle East, Northern Africa, Turkey, Pakistan, Spain and Afghanistan will face extreme water stress by the year 2040. Other countries like Southern Africa, Australia, USA, India, and China will be in the zone of high water stressed countries in coming years. More or less five billion population of the world will be under severe water scarcity in 2050. According to Islam and Susskind (2015), Africa and Middle East are extreme water stressed world regions. Naik (2017) also found Africa a highly water stressed areas. Marshall (2011) found serious water scarcity in Kenya.

Pegram (2010) explores that resources of water around the world are diminishing speedily due to rapid economic growth, climatic changes, and intensifying population, especially in developing countries. South Asia's water resources are overexploited because of the highly growing population, variability of climate, immense enlargement of the hydropower sector, and poor governance of water. There is a dire need for proper management and governance of water resources as the risk of water scarcity will not go away and is expected to increase in the future.

Like other global countries, India has limited resources of water which are reducing continuously as a result of the growing population, rapid industrialization, and urbanization hence causing water scarcity in India (Goswami & Bisht, 2017). Chakraborti, Kaur, & Kaur (2019) concludes that India must take strict measures with the collaboration of its international partners and neighboring countries to tackle the negative effects of natural and human factors which are causing water scarcity.

Kahlown and Majeed (2002) propose some short to long-term policies to combat the water crisis in Pakistan. Public information campaigns and changes in cropping patterns are short-term suggestions to tackle this hostile issue of water. Construction of more small dams, installment of new tube wells in viable areas, and construction of gigantic capacity dams are medium and long-term strategies given by the researchers. Khalid and Khan (2016) recommends more water reservoirs in Pakistan so that the mounting water demand by all sectors of Pakistan can be satisfied.

Ahmed, Iftikhar and Chaudhry (2007) contend that consumption patterns of water in Pakistan are not according to its available water resources. Per capita availability of water which was 5,300 $m^3$ in 1951 has been declined to 1,200 $m^3$ per person in 2000 as a result of high population growth and increasing demand for water in the country. Construction of dams, effective water governance and management policies are dire needs of Pakistan. Khan and Javed (2007) found inverse linkages between population growth and per capita availability of water in Pakistan.

Pakistan, once a water abundant country, is now water stressed country with a per capita availability of 1,000 $m^3$. India's intention is to construct more dams on Pakistan's river, will cause low inflow at Mangla Dam and resultantly acute shortage of water, especially in winter season's crops in Pakistan. Pakistan should have to raise this issue internationally and policymakers should also make effective policies for proper management of water to prevent water wastage within the boundaries of country (Iqbal, 2010). Pakistan crossed threshold of water stress with 1,000 $m^3$ per capita water availability in 2007 (Ahmad, 2011).

Pakistan is the most vulnerable country effected from negative climatic changes. The worsening climatic change along with the life-threatening patterns of weather, water security problems, economic issues, and population have worsened the water crisis in Pakistan. Pakistan is among the top 14 countries which are facing acute scarcity of water in 2023. Being an agrarian country, its lifeline can be secured from integrated management of the Indus River Basin (Kamal, Amir & Mohtadullah, 2012).

In 2018, Ministry of Water Resources of Pakistan expressed that Pakistan is moving towards severe water shortage due to its swelling population, increasing water demand, unpredictable rains, and recurring droughts. Per capita availability of water in 2016 decreased to 1,000 $m^3$ which was 5, 260 $m^3$ in 1951. It will be around 860 $m^3$ in 2028-29, hence making Pakistan ‘‘a water scarce country’’. Sleet (2019) endorsed the above finding in that Pakistan is on the verge of acute scarcity due to excessive ground and surface water withdrawals as her per capita availability of water shows a declining trend in the country with 5,260 $m^3$ in 1951 and below 1,000 $m^3$ in 2016.

*In conclusion*, water is now under acute pressure of scarcity due to swelling population, swift urban development, industrialization, rising water demands, increased withdrawals for satisfying the agricultural, domestic, and industrial needs, uneven water distribution, climatic change, water pollution, global warming, and poor water management governance. About Five billion (about 2/3) people in the world will live in areas of severe water scarcity by the end of 2050 (Callister, et al. 2019). It can also be deduced from above literature that due to rapidly growing population, and exorbitant water withdrawals, *etc.*, Pakistan is facing the problem of water scarcity now-a-days. Per person water availability in Pakistan has declined below 1,000 $m^3$ and this situation is going to be worse more and may lead to absolute water scarcity in next decade.

## Review Of Literature Related to Empirical Studies on Arising Water Stress and Scarcity

Numerous empirical studies have introduced and applied various water indices by incorporating major drivers of water scarcity as given below:

## Falkenmark Indicator (FI)

Although FI does not consider other drivers of water scarcity such as lifestyles, water management, and varying water demand, this index has been highly assimilated and adopted for indication of water scarcity in global literature until now. According to Rijsberman (2006), FI is a most widely used indicator to measure water scarcity as compared to other complex indicators. Rijsberman measured per capita water availability in West and Central Asia and North Africa and concludes that these regions are water scarce with less than 1,000 $m^3$ per capita water availability. Falkenmark (1989) empirically analyzed the massive threat of water scarcity in the African region and found two-thirds of the African population facing water scarcity.

According to World Water Development Report, 2021, almost 50 percent world population do not have access to basic water needs as the world water security is increasing at alarming rate, especially in developing countries including Pakistan. Fischer and Heilig (1997) observe that in 1995 regions such as South Africa, North Africa, and West Asia have experienced water stress with per capita water availability ranges from 500 $m^3$ to 1,500 $m^3$. In 2030, due to rising population, three more regions of Eastern Asia, Eastern Africa, and South Central Asia will also be in the category of water scarcity with forecasted per capita water availability of less than 1000 $m^3$. Moreover, Western Africa will be among the highly water scarce regions up to 2050.

Wallace and Gregory (2002) found almost seven percent of the global population live in water stressed areas at present. India, and some areas in China and the Far East, currently water abundant, will also suffer from the shortage of water in near future. Fahimi, Creel, and Souza (2012) found acute water scarcity with less than 250 $m^3$ per capita freshwater availability per year in Jordan, Bahrain, Libya, Qatar, Yemen, United Arab Emirates, and Saudi Arabia.

Jiang (2009) observes that per capita water availability in Northern part of the China (in Hai, Huang, and Huai rivers) ranges from 314 $m^3$ to 672 $m^3$. This absolute water scarcity has caused conflicts among limited resources of water and infinite water demand at the local and national levels in China. Economic development coupled with overpopulation, mounting consumption of water, and poor management of water sources have worsened the issue of water scarcity in China. Cheng, Fang, and Wu (2017) depict that North China is facing extreme water scarcity with a per capita availability of 283 $m^3$ in 2016.

*In conclusion,* the growing population is putting severe pressure on the world's water resources, especially in Pakistan. On average per capita freshwater avaliabilty has declined below 1,000 $m^3$ hence leading  Pakistan towards 'absolute water scarcity'.

**Water Resource Vulnerability Index (WRVI)**

As FI measured the status of water scarcity on a national level only by assuming fixed water availability and human water demand.  Raskin, et al. (1997) tried to overcome this limitation of FI. To assess the impact of population, consumption patterns, and technological changes on global water resources, the authors have used a ratio of water withdrawals to water availability. WRVI was used to measure water scarcity at national and international levels. By using country level data of 1995 for this ratio, the study finds that countries that have annual withdrawals between 20 to 40 percent of their renewable water supply are facing a threat of water scarcity.

Computing water scarcity through the WRVI, Wada, et al. (2011) found more than 40 percent of people suffering from the threat of water scarcity.  United States, India, Northern China, and Spain are the regions of water scarcity as a result of increased water withdrawals. Florke, Barlund, Wimmer and Alcamo (2013) finds that domestic withdrawals on global level have increased due to burgeoning population and prosperity which has put more stress on water resources.

Pakistan's water withdrawals as a portion of its available water resources are quite high as compared to other countries of the world. Young, et al. (2019) concludes that Pakistan's water renewable resources are chronically water scarce as the water withdrawal to availability ratio is greater than 59 percent. Main reasons for this severe pressure on water resources are inordinate water withdrawals by the escalating population in the country.

*In conclusion,* water resources around the world and especially in Pakistan are under severe pressure due to excessive withdrawals of water as compared to decreasing freshwater availability.

**Environmental Water Scarcity Index (EWSI)**

Overuse of freshwater may not only result in scarcity of water but also endangered the ability of basins to maintain their ecosystem health and resilience. Since all above discussed scarcity indices incorporate ‘Environmental Water Requirements (EWR)’ implicitly during the measurement of water scarcity. Smakhtin, Revenga, and Doll (2004) are the pioneers who considered aquatic systems requirements explicitly in water scarcity analysis. The authors expressed estimated EWR as a percentage of annual mean river runoff in the WRVI. This water scarcity index was used in their global assessment of water resources. The study finds that more global rivers are now environmentally water stressed as the indicator’s value is greater than 1 for Southern Africa’s Orange River, Murray Darling river of Australia, and Yellow river of China. Areas with Monsoon-Driven variability should have to maintain 20 to 30 percent EWR to sustain a fair condition of their freshwater ecosystem.

Nilsalab and Gheewala (2018) observed that EWR should be explicitly taken in the withdrawals to availability ratio. The researchers have separately calculated two WRVI: one in which EWR are implicitly taken in total water demand and one in which EWR were explicitly taken. The authors explore that during the dry season (December to February) an increased human demand reduced water inflows in watersheds of Thailand. Furthermore, explicit incorporation of EWR shows that the water stress situation is extreme in the dry season as compared to WRVI which shows severe water stress levels in the country. The authors are of the view that reduced amount of rainfall and water withdrawals of finite resources in the dry season has made it impossible to satisfy environmental and human water demands at a time.

The Food and Agriculture Organization of the United Nations in 2018 calculated water scarcity through EWSI for 166 countries of the world. Pakistan is found facing environmental water scarcity with a score of 1.83 on this index, while EWR have been estimated as 27 percent of total freshwater resources. This means that Pakistan is currently lacking the ability to satisfy both human and environmental water needs with its limited water resources.

In conclusion, growing human water demand has resulted in a reduced flow of basins. Regions with Monsoon variability of river flows should have to maintain 20 to 30 percent average flow of total availability of water. When these environmental water demands are explicitly included in water scarcity analysis, countries that were severely watered scarce now fall in the category of extreme water scarcity and henceforth indicate the significance of water management policies on an elementary basis.

## Social Water Scarcity Index (SWSI)

Ohlsson (2000) states that many people in the world are also facing another type of water scarcity because of political and socio-economic factors. FI just measures physical scarcity of water only and does not take into account the society's adaptive capacity to alleviate this scarcity. Participation in politics, opportunities to get education, and distribution of wealth are good indicators to show whether a society has the adaptive capability to combat difficult challenges or not. Human Development Index (HDI) was used as a proxy to account for these societal factors in this index. This HDI as a weighted measure of FI has been utilized by the researchers to account world's ability to adjust with water stress.

Gundaa, Benneyworth and Burchfield (2015) computed water scarcity by SWSI for Sri Lanka and Bangladesh. Both countries are found to have more capacity to fight with the emerging threat of water shortage. However, Sri Lanka is more sufficient to fight with water issues because it has more educated people, high per capita income, and high expectancy of life than Bangladesh.

Measuring water scarcity through SWSI, Khan (2020) observes that with the passage of time Pakistan loss its adaptive capacity to fight with the issue of water scarcity as SWSI has a declining value of 239 $m^3$ per person by the year 2018 as compared to 1073 $m^3$ per person in 1980. This threatening scarcity is negatively affecting the country's economic growth both in the short and long run.

From above literature, it can be observed that second-order scarcity of water can be reduced with high adaptive capacity. A country that has a high value of HDI has more capacity to tackle the issue of scarcity. Pakistan, being a developing country, has a lower adaptive capacity to fight with the worsening situation of this scarcity.

In literature, there are some studies that measured scarcity using more than one water indices. Using various water indices such as FI, Water Resource Vulnerability and Water Poverty Index, Liu, et al. (2010) observe that water scarcity has become a major obstruction for social and economic development in different parts of the world. As global population reaches its peak by 2050, a big number of people than today will live in areas that are directly exposed to scarcity of water.

Holland, et al. (2015) applied two indies *i.e.*, FI and SWSI. Rivers of China, Pakistan, India and the United States are found in the category of severe scarcity due to increased water consumption in the energy sector. The study concludes that Pakistan, China, parts of the Middle East, and India are facing high water stress because of high water consumption for the energy sector. Ruess (2015) finds that USA and France are in the category of water stress due to their unsustainable withdrawals of water at present. While Australia and Argentina are going to be more vulnerable to water stresses in the world.

Hanasaki, Yoshikawa, Pokhrel and Kanae (2018) have empirically shown that the thresholds of FI and WRVI can signify the adequacy of renewable and local sources of water at a global scale. The results of study show that grid cells where the fraction of water withdrawals to availability ratio is greater than 20 percent and per inhabitant availability of water is below than 1,000 $m^3$, the renewable and local water sources are insufficient to meet water requirements.

Begum (2018) assessed the status of water scarcity by calculating FI, WRVI, and SWSI in case of Pakistan and finds reduction in per capita freshwater availability well below the Falkenmark threshold of water scarcity of 1,000 $m^3$ in 2017. According to WRVI, Pakistan is a severely water scarce country over the whole period of study. While taking the adaptive capacity of society, this study states that Pakistan has become water scarce country since 1990s.

The Food and Agriculture Organization of United Nations (2019) has measured per capita total renewable water availability and water withdrawal to availability ratio for all world's countries for the year of 1997, 2007 and 2017. The study explores that due to the growing population, per person water availability has declined to 1253 $m^3$ which was 1912 $m^3$ and 1539 $m^3$ in 1997 and 2007, respectively. While the percentage of total freshwater withdrawal to renewable water resources has raised to 74.4 percent in Pakistan which is a state of severe water scarcity. UN says "5 billion people will face water shortage by 2050".

The above *literature* shows that water 'once an abundant resource' is now depleting day by day due to the increasing population and exuberant water abstraction in case of Pakistan. The whole world is now moving towards a severe water scarcity level and has faced extensive pressure on its natural water resources.

**Literature Review on Regional Security and Peace arising from Water Stress and Scarcity**

According to Richard Lawford, "The survival of every human, every region, and every society depends on having access to a share of the world's water through the global water cycle". The most important issue between India and Pakistan is the issue of water which is of gigantic nature that it may lead to conflicts and wars. Declining amount of freshwater in Pakistan, and India's intentions being an upper riparian to divert the flow of Western Rivers, water has become a security threat to Pakistan.

India's water dispute with Pakistan and other neighboring countries like Bangladesh, Nepal and China have a full prospect of a big threat to regional peace and security. Mehta (2000) states that the 21st century will have conflicts and wars on water resources which will, in turn, have intense effects on health, food security, and human wellbeing.

According to Adhikari (2014; 2015), India's unilateral behavior, highhandedness and hegemonic design are the key causes in creating water disputes with Bangladesh, Nepal and Pakistan. Iqbal (2010a) finds that India's violation of IWT is not only affecting Pakistan's economic and security concerns, but also has a serious implications to regional security.

Potential for conflict over water issue can easily be perceived if one looks at year 2050 when there would be acute water scarcity in both India and Pakistan (Bhalla, July 25, 2012). The situation would be much horrible as both India and Pakistan are now nuclear states, having the capability of long range ballistic missile (Siddiqui, 2010). With at least 100 nuclear in each other arsenal, South Asia casts a dark shadow on the security of entire region (ADB, 2013). The population of India and Pakistan is growing rapidly with high food needs. Water will become the cause of conflict by the year 2050 when there would be acute water scarcity in both countries (Bangali, 2009). The hope of peace in South Asia could not be achieved without addressing the basic causes of water.

The countries using water as a weapon against other riparian tend to aggravate tensions, deepen political divides, threaten regional security and stability, and even go to conflicts and war (Alam, 2002; Gleick, 1992; Iqbal, 2010a; Jamwal, 2013; Khattak, 2008; Lowi, 1995; Romshoo, 2012; Wolf, 1998). Studies such as Arif (2010), Gleick (1993), Malik (2011), Nosheen and Begum (2011), Pak (2016), Rahaman (2012), Serageldin (2009), Shahzad (2016) and Wirsing (2006) are of the opinion that perceived fears of losing control over shared river waters among riparian will lead towards water war(s) in 21st century. The future water related conflicts appeared to be inevitable. The long lasting tensions over sharing river resources will result in violent, inter-state conflicts and regional instability.

The rapidly changing issues regarding water quality and its access to meet basic human needs have posed a new way to global security discussions (Levy & Sidel, 2008). Competition over limited freshwater resources may lead to political and/or military conflicts and even to water war (Butts, 1997; Westing, 1986; Gleick, 1993; Homer-Dixon, 1994; Remans, 1995).

Samson and Charrier (1997) expresses that many a freshwater resource conflicts are already apparent. The authors also predicted looming growing conflicts ahead.

Based on empirical evidence, Gleick (2009) also emphasized the emergence of water sharing conflict potential among riparians in the basin, even though the riparians have arrived at formal cooperative water agreements. The author has also maintained a conflict chronology data base that involved 203 events since 3000 BC. Six type of conflicts such as control over water resources, political tool, terrorism, military tool, military target, and development disputes were also identified by the author.

In conclusion, unprecedented rise in heatwaves, torrential rains, more floods and droughts, are expected in South Asian region. Current availability of freshwater poses a major challenge for the security of the region and intensifying by climatic changes. As a result, it may lead to further conflicts and violence in the region. South Asian nations are also prone to have climate related conflicts in future too.

**Summary**

The scarcity of water is now arising in various part of the world, including Pakistan due to rapidly growing population, rapid urbanization, more industrialization, economic growth, increased water demand, transboundary water conflicts, extensive water withdrawals, environmental degradation, harsh climatic condition, poor and bad water governance and management (Falkenmark, 1989; Uitto & Duda, 2002; Falkenmark & Lannerstad, 2005; Watson & Davies, 2011; Fencl, et al., 2012; Mancosu, Snyder, Kyriakakis & Spano, 2015; Doungmanee, 2016; Engelke & Passell, 2017; Cousin, Kawamura & Rosegrant, 2019; Griffin, 2012; Ashton, 2002; Vorosmarty, Douglas, Green & Revenga, 2005; Feitelson & Fischhendler, 2009; Tielborger, Fleischer, Menzel, Metz & Sternberg, 2010; Alankar, 2013; Merten et al., 2016; Liu, Cao, Li & Yu, 2018; Asim, Vains, Youaf & Ramzan, 2012; Amin, Iqbal, Asghar & Ribbe, 2018; Yasin, 2020).

Studies such as Bangali (2009), Callister, et al. (2019), Fischer and Heilig (1997), Hanjra and Qureshi (2010), Wallace and Gregory (2002) including UN forecasts severe water scarcity in major regions of the world by 2050. South Asian region countries must find an interstate solution to the threatening issue of water shortage.

It can easily be inferred from privious literature that Pakistan's water profile has changed from 'water abundance' to 'water scarce'. Most of the studies in literature have measured water scarcity level in Pakistan by using water scarcity indices. Moreover, there is a dearth of prior studies that have forecasted water scarcity in Pakistan by using time series econometric techniques. Hence, this paper measured the scarcity of water by applying FI, WRVI, EWSI, and SWSI. This study also applied ARIMA times series econometric model to forecast water scarcity of Pakistan for 2023-24 to 2029-30. After empirical analysis of Pakistan's freshwater availability, the implications of water scarcity to security of the region would also be analyzed in section IV of the study.

## 3. Data Sources and Research Methodology

### Data Sources

Annual time series data for 1972-73 to 2022-23 on total amount of freshwater availability, freshwater withdrawal, and population were taken from Punjab Irrigation Department of Pakistan, and various issues of Pakistan Economic Survey. A series of data on HDI from 1972-73 to 2018-19 was generated using UNDP Methodology 2010.

### Description of Variables

#### Total Amount of Freshwater Availability

The total amount of freshwater availability in million cubic meter ($m^3$) refers to the water that is available in the river, lakes, streams *etc.*, of the country. This variable was used by Rijsberman (2006), Fahimi, Creel, and Souza (2012), and Cheng, Fang, and Wu (2017) for the measurement of water scarcity. This variable was also used in the calculation of FI, WRVI, EWSI and SWSI.

#### Total Amount of Freshwater Withdrawals

Annual freshwater withdrawals in $m^3$ are the total amount of withdrawals that are abstracted for irrigation, domestic and industrial purposes on annual basis. Evaporation losses are not included in these withdrawals. Alcamo, et al. (2003), Wada, et al. (2011), and Florke, Barlund, Wimmer, and Alcamo (2013) used this variable to calculate WRVI and EWSI.

#### Total Population

The total population in millions include all those residents who are living in Pakistan. Total population was used in calculating FI and SWSI.

#### HDI

HDI assesses the progress of human development and ranges between 0 to 1 (0 indicates zero percent human development and 1 indicates 100 percent human development). UNDP's calculated HDI was used to capture the adaptive capacity of Pakistan in SWSI[2]. Bagolin and Comim (2008), Begum (2018), Grubaugh (2015), and Khan (2020) used HDI as a proxy of the social development of a society.

**Environmental Water Requirements (EWR)**

EWR are the amount of water that is necessary to maintain ecosystem. This variable indicates the amount of water that should be remained for freshwater habitats and population for their existence. Thirty percent (30%) of total freshwater availability has been taken as EWR in this study (Falkenmar, 2003). Tharme (2003), Vanham, et al. (2018), Ma, et al. (2020), Salik, Hashmi, Ishfaq, and Zahdi (2016) assessed these EWR of rivers that are necessary for their flow.

**Water Scarcity Measurement Tools**

A number of 'Water Scarcity Indices' both simple as well as complex have been developed by researchers to measure water scarcity and widely used for policymaking while addressing the problem of water scarcity. Since there are many simple and complexed water scarcity indices, the scope of this study is limited to only those which include the availability of water for the satisfaction of human needs and the environment.

**Water Scarcity Indices**

**First-Order/Physical Water Scarcity Indices**

According to first-order water scarcity indices, water scarcity occurs physically due to mounting population and increasing water demand which, in turn, has resulted in a low level of water flow in the world's river basins. On the basis of literature review, three first-order water scarcity indices such as 'FI', 'WRVI' and 'EWSI' were used in this paper.

**Second-Order/Socio-Economic Water Scarcity Indices**

Second-Order water scarcity emerges when a society lacks the adaptive capacity to manage its water shortages. All above defined physical indicators disregard the two most important aspects of sustainability *i.e.,* economic and social aspects. These domains are encompassed in a new index developed by Ohlsson (2000) which is known as 'Social Water Scarcity Index'.

**Falkenmark Indicator (FI)**

[2] HDI data has been calculated according to UNDP's 2010 methodology.

One of the most widely used measures of water scarcity, also known as 'Water Crowding Indicator' or 'Water Stress Index' is FI, developed by Falkenmark in 1989. This indicator is a fraction of annual total freshwater availability that is available for human purposes. FI, therefore, measures the per capita freshwater availability within a country during one year.

'FI' estimates per capita freshwater availability to satisfy agricultural, industrial and domestic needs. According to 'FI', a person needs 1700 cubic meter ($m^3$) of water annually. Water stress occurs when annual water supply falls below 1700 $m^3$ per person. Below 1000 $m^3$ per person annual supply of water is an indication of the scarcity of water resources. Water barrier differentiation proposed by Falkenmark (1989) is given below.

Falkenmark Water Scarcity Index

| Per capita annual supply of water in $m^3$ | Category/Condition |
|---|---|
| Greater than 1700 | No stress |
| Between 1000 and 1700 | Stress |
| Between 500 and 1000 | Scarcity |
| Less than 500 | Absolute scarcity |

The Food and Agriculture Organization of the United Nations (2019) has used these thresholds to measure water scarcity for all countries of the world. Regardless of stated advantages, this indicator also has some limitations as given below:

- FI shows that water is sufficiently available but does not take into account the water quality in a region or country (Rijseberman, 2006).
- This indicator includes natural freshwater availability and disregards non-natural man made water resources such as desalination plants which also increases the availability of water (Rijseberman, 2006).

Moreover, this indicator also ignores the difference in water demand between the countries that are determined by culture and climate *etc.*.

**Water Resource Vulnerability Index (WRSI)**

WRVI which is also known as 'Water Withdrawal to Availability Ratio Index' was developed by Raskin, et al. (1997) and is defined as a ratio of annual total water withdrawals to annual available water resources. Instead of taking water demand, this index took water withdrawals as demand varies between cultures, regions, and societies and its use might result in inaccurate water scarcity assessments. The term ‘water withdrawals’ is referred to that water which is taken for human need from rivers, and lakes *etc*. WRVI has also been used in Millennium Development Goals as its 7.5 indicators to measure water scarcity. According to this index, water scarcity can be calculated as:

$$\text{WRVI} = \frac{\text{Total amount of annual freshwater withdrawals}}{\text{Total amount of annual available freshwater resources}} X\ 100$$

According to WRVI, a country will face water scarcity if its annual water withdrawals range between 20 percent and 40 percent to its total water availability. Severe water scarcity occurs if this ratio exceeds 40 percent. Like FI, this method is easily computable due to the availability of data but it has some limitations too:

- Like FI, this index does not consider artificial man-made water resources which can increase water availability in a country.
- Moreover, this index does not take into account EWR explicitly as a key parameter of freshwater availability.
- WRVI neglects recycled and reused water withdrawals especially in the case of industrialized countries that used recycled water many times in their production process (Vorosmarty, Green, Salisbury & Lammers, 2000).

It also omits country’s ability to adjust to water scarcity by assuming no change in technologies or infrastructure.

**Environmental Water Scarcity Index (EWSI)**

The countries with insufficient resources of water usually have to face a tradeoff among water withdrawals to fulfill human requirements and water reservation for a healthy aquatic system. In 1992, the adoption of Dublin Principles for effective water management acknowledged the water needs of the environment. In order to know the extent of these environmental water requirements (EWR) for the maintenance of freshwater habitats and populations, Smakhtin, et al. (2004) proposed a new water scarcity index which is known as ‘EWSI’. Unlike the WRVI, this index explicitly measures the pressure on a country’s freshwater resources because of increased human water demand. Environmental water scarcity is calculated as:

$$\text{EWSI} = \frac{\text{Total amount of annual freshwater withdrawals}}{\text{Total amount of annual freshwater availability - Environmental Water Requirements}}$$

Here, EWR had been taken as a percentage of freshwater availability that should be held for the sustenance of freshwater ecosystem. According to EWSI, a country is said to face moderate environmental water scarcity (40 to 70 percent of exploitable water is still present in a basin before EWR can conflict with other uses) if the value of EWSI ranges between 0.3 to 0.6. Range of 0.6 to 1.0 indicates high environmental water stressed situation (0 to 40 percent of utilizable water is available in the basin before EWR can clash with other water uses). If EWSI exceeds the range of 1 (existing use of water is tapping into EWR), then a country is said to be environmentally water scarce and have negative effects on natural resource sustainability.

According to Smakhtin, et al. (2004), almost 20-50 percent EWR of total freshwater availability are required in different river basins. While areas such as India and Pakistan that faced Monsoon driven variability in their rivers should have 20-33 percent EWR of the total amount of freshwater availability to preserve their aquatic biota. This index has also been incorporated in Sustainable Development Goals (SDGs) as its 6.4.2 indicator to measure the level of water scarcity. The present study used 30 percent of annual freshwater availability as EWR that should be necessary for ecological needs (Falkenmark, 2003). Even though this index was adopted as SDGs 6.4.2 indicator, this index has also some limitations as:

- Like FI, EWSI does not consider the water quality and suitability for human and environmental use. It just required a minimum amount of water flows for the preservation of aquatic ecosystem.
- Lack of accurate and up to date data is a big hurdle in the computation of this index

**Social Water Stress Index (SWSI)**

The SWSI was proposed by Ohlsson in 2000 to integrate society's adaptive capacity. Ohlsson (2000) divided the per capita freshwater availability (measured through FI) by HDI and then divides the resulting value by a scale of 2. According to Ohlsson (2000), the capability of a society to combat difficult situations depends on its distribution of wealth, educational access, and political participation. UNDP HDI is widely used to evaluate the above said societal variables. Societies that have a low adaptive capacity as measured by HDI are found to be water stressed when Ohlsson (2000) used this SWSI. The formula of SWSI is as:

$$\mathrm{SWSI} = \left\lfloor \frac{\text{Falkenmark Indicator}}{\text{HDI}} \right\rfloor / 2$$

Although SWSI considers society's adaptive capacity through HDI, this index also suffers from certain limitations as:

- The HDI focused on economic and social indicators only and does not incorporate ecological factors that is why SWSI also suffers from this shortcoming (Tekken, 2012).
- Moreover, HDI used country data only so it does not describe intra national differences (Tekken, 2012).

As all of these indices have certain limitations so it is not appropriate to use only one index for the measurement of water scarcity. In order to get applicable and reliable results, this study used all of the above four indices to measure water scarcity in Pakistan.

**Autoregressive Integrated Moving Average (ARIMA) Time Series Model**

Many a researchers such as Afzal, Rehman and Butt (2002), Zakria and Muhammad (2009), Ahmed, Shah, Raza and Saboor (2011), and Amin, Amanullah and Akbar (2014), Manoj and Madhu (2014), Mondal, Shit and Goswami (2014), Din (2016), Fattah, Ezzine, Aman, Moussami, and Lachhab (2016), Farhath, Arputhamary and Arockiam (2016), Baser, Bozoglu, Eroglu and Topuz (2018), Abonazel and Elftah (2019), Alsharif, Younes and kim (2019), have used Univariate Non-Seasonal ARIMA models for forecasting purpose in their studies because these models are flexible and simple to implement as ARIMA models only need historical values of the underlying variable for empirical analysis. These ARIMA models are also suitable for short term forecasting of time series. Moreover, these models also elevate the accuracy of the forecast by keeping the Principle of Parsimony i.e., the number of parameter should be minimum. Box and Jenkins (1976; 2016) argued that parsimonious ARIMA models give better forecasts than over parametrized models. Forecasting power of ARIMA model was observed better than the regression model for future decision-making in case of Pakistan (Afzal, Rehman & Butt, 2002). Kumar, P., Shah, S., F., Uqaili, M., A., Kumar, L., Zafar, R., F. (2021) suggests that ARIMA models can be effectively used in drought forecasting which can be helpful for policy makers of water resources.

## 4. Empirical Results and Their Analysis

**Tabulated and Graphical Analysis of Pakistan's Water Scarcity**

To fulfill the first objective of the study, first-order and second-order scarcity of water in Pakistan were measured through FI, WRVI, EWSI, and SWSI, respectively, and their results are presented in Table 3.

**Table 3**

Assessment of water scarcity in Pakistan from 1972-73 to 2022-23 using First-Order and Second-Order Water Scarcity Indices

| Years | First-Order Water Scarcity | | | Second-Order Water Scarcity |
|---|---|---|---|---|
| | Falkenmark Indicator (FI) in $m^3$ | Water Resource Vulnerability Index (WRVI) in % | Environmental Water Scarcity Index (EWSI) | Social Water Scarcity Index (SWSI) in $m^3$ |
| 1972-73 | 3872.21 | 49.17 | 0.70 | 7077.48 |
| 1975-76 | 2991.36 | 56.90 | 0.81 | 4823.64 |
| 1980-81 | 1887.51 | 84.34 | 1.20 | 2653.69 |
| 1985-86 | 1391.42 | 90.04 | 1.29 | 1931.54 |
| 1990-91 | 1688.35 | 72.53 | 1.04 | 2089.70 |
| 1995-96 | 1659.43 | 62.50 | 0.89 | 2042.07 |
| 2000-01 | 759.88 | 99.15 | 1.42 | 862.37 |
| 2005-06 | 1024.36 | 80.99 | 1.16 | 1010.43 |
| 2010-11 | 1021.26 | 62.83 | 0.90 | 959.36 |
| 2015-16 | 865.09 | 73.74 | 1.05 | 786.45 |
| 2019-20 | 622.47 | 88.62 | 1.27 | 558.77 |
| 2020-21 | 604.42 | 86.15 | 1.23 | 539.66 |
| 2021-22 | 526.44 | 97.70 | 1.40 | 483.86 |
| 2022-23 | 579.45 | 92.34 | 1.32 | 520.33 |

Source: Authors’ calculation based on the data of World Development Indicators, Pakistan Economic Surveys, Punjab Irrigation Department of Pakistan, and Begum (2018).

Table 3 shows the status of water scarcity in Pakistan. The 2nd column in Table 3 indicates that Pakistan was a water abundant country with 3872 $m^3$ per capita freshwater availability as indicated by FI in 1972-73. At the start of 21st century, this per capita freshwater availability declined to 759 $m^3$ and has further reduced to 622.47 $m^3$ at the end of second decade of this century. This has reduced further to 579.45 $m^3$ in 2022-23. This threatening condition has caused Pakistan to be a water scarce country. However, according to WRVI (in 3rd column), Pakistan is facing severe water scarcity since 1972-73 as its water withdrawals to availability ratio exceeded 40 percent throughout the study period. This study found even 99 percent of this withdrawal to availability during some year of the study because of excessive water withdrawals.

EWSI in 3rd column of Table 3 reveals that Pakistan is at the edge of high environmental water stress with a value of one in most of the years of the study. This indicates that freshwater is under acute pressure due to increased water withdrawals for human purposes. Couple with this, Pakistan has also lacked its adaptive capacity to manage its water resources with a declining value of SWSI at the end of second decade in 21st century as shown in 5th column of Table 3.

The graphical representation of above four indices is presented in Figure 2, 3, 4, and 5. Figure 2 shows that Pakistan is moving towards 'absolute water scarcity' in terms of reduced per person freshwater availability. Figure 3 shows that Pakistan is facing a severe threat of water scarcity since 1972-73 because its water withdrawals are more than its limited water supply. Pakistan is also on the verge of high environmental water scarcity as shown by Figure 4. Figure 5 reveals Pakistan as water scarce country in South Asian region.

**Figure 2**

**FI for Pakistan from 1972-73 to 2022-23**

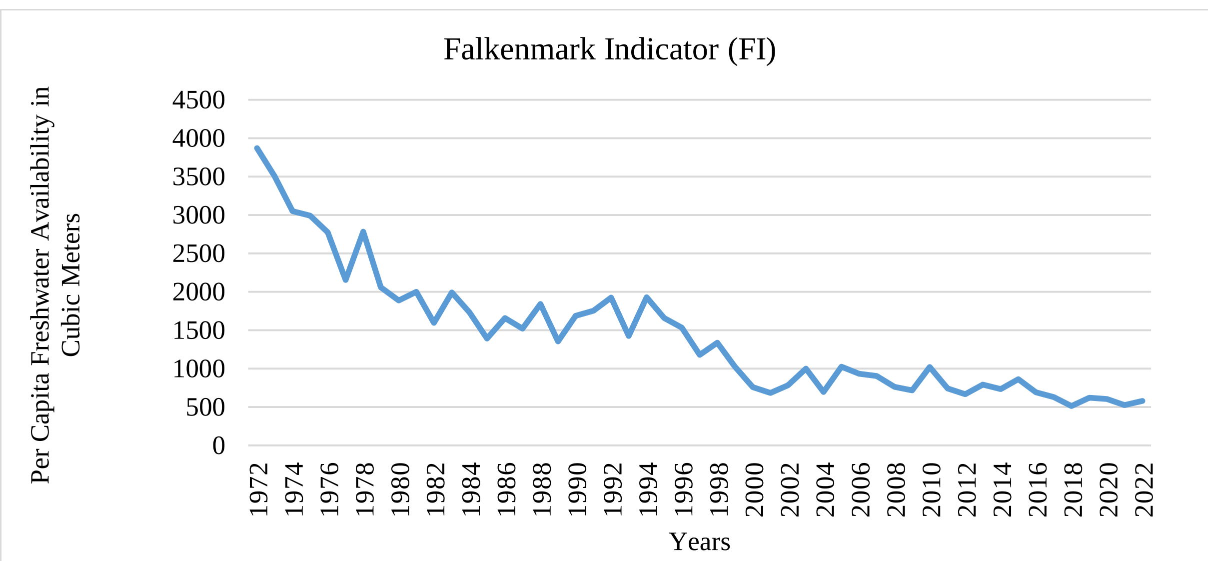


**Figure 3**

**Water Withdrawal to Availability Ratio of Pakistan from 1972-73 to 2022-23**

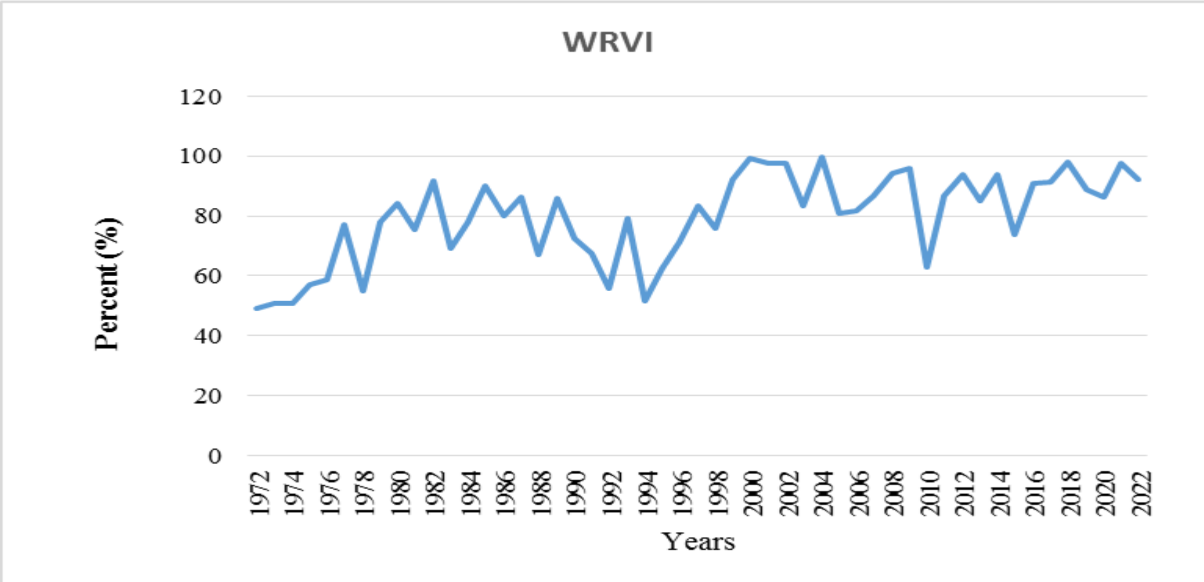



**Figure 4**

**EWSI for Pakistan from 1972-73 to 2022-23**

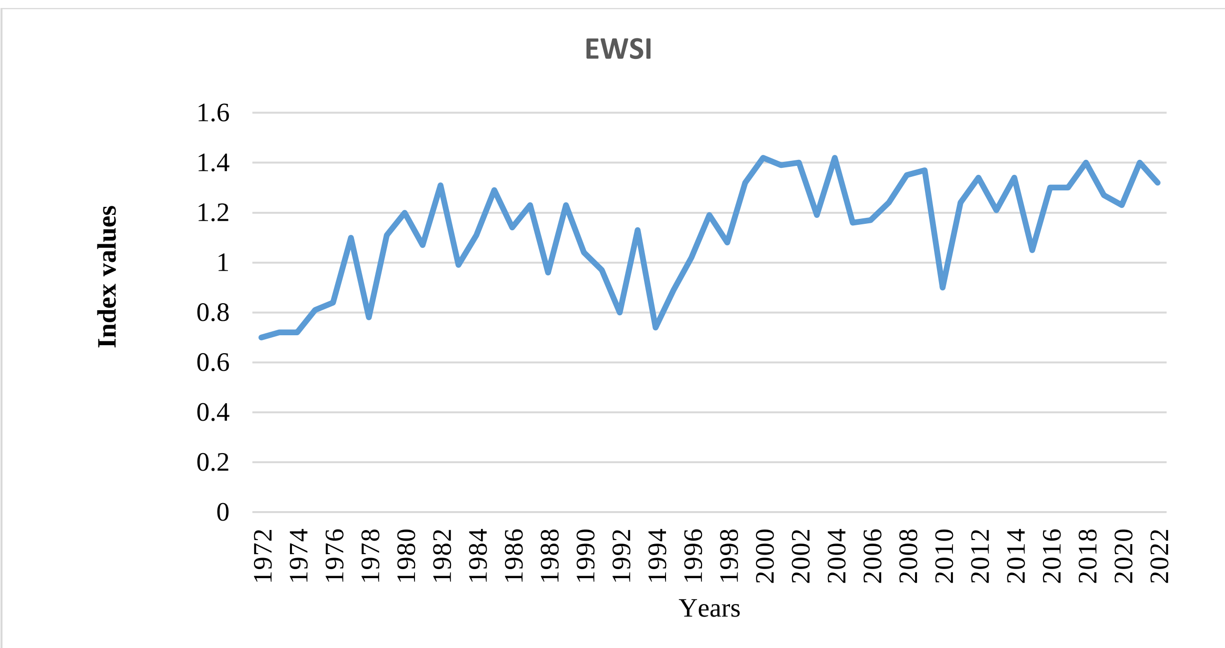
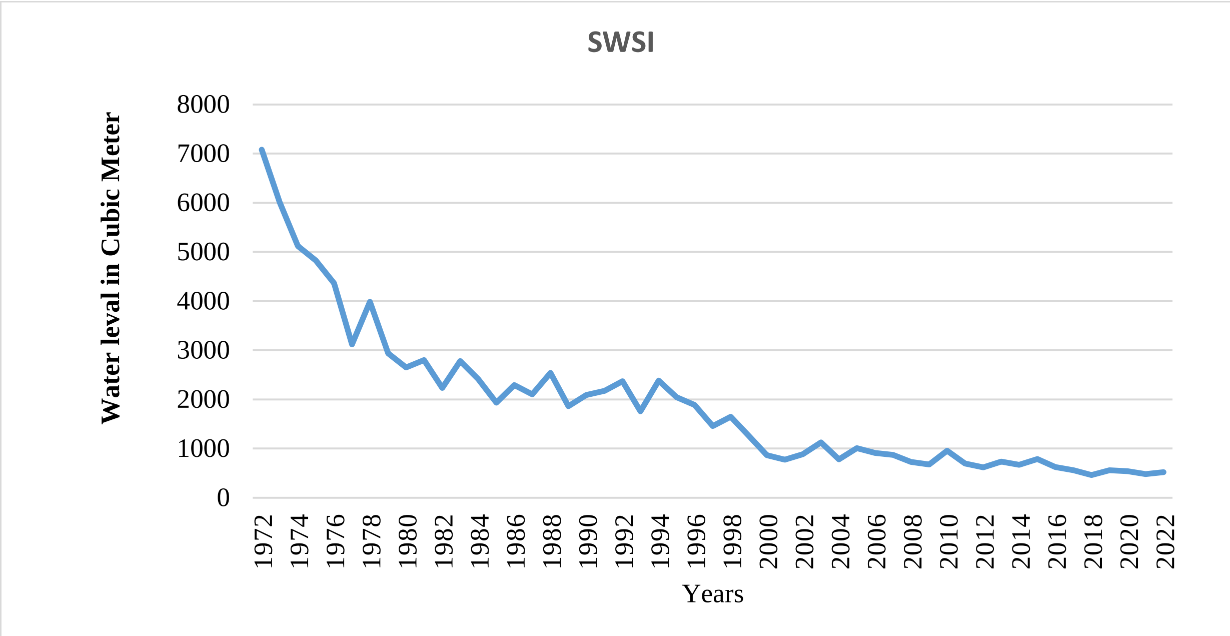


**Figure 5**

**SWSI for Pakistan from 1972-73 to 2022-23**




From tabulated and graphical analysis, it can be concluded that Pakistan's water resources have dwindled during the period of 1972-73 to 2022-23. Pakistan, a water rich country, is now a water scarce country in terms of both physical and social scarcity either because of reducing per capita freshwater availability, extravagant water withdrawals, or lower societal adaptive capacity. Furthermore, increased human water demand has induced severe pressure on the country's freshwater natural resources.

**Empirical Results of ARIMA Model and their Interpretation**

This section presents empirical results as found by the automatic ARIMA forecasting technique given in Eviews 10 in order to achieve the second objective of the study. ARMA Maximum Likelihood (BFGS) was used in the estimation.

**ARIMA (*p, d, q*) Models of First-Order Water Scarcity**

**Falkenmark Indicator (FI)**

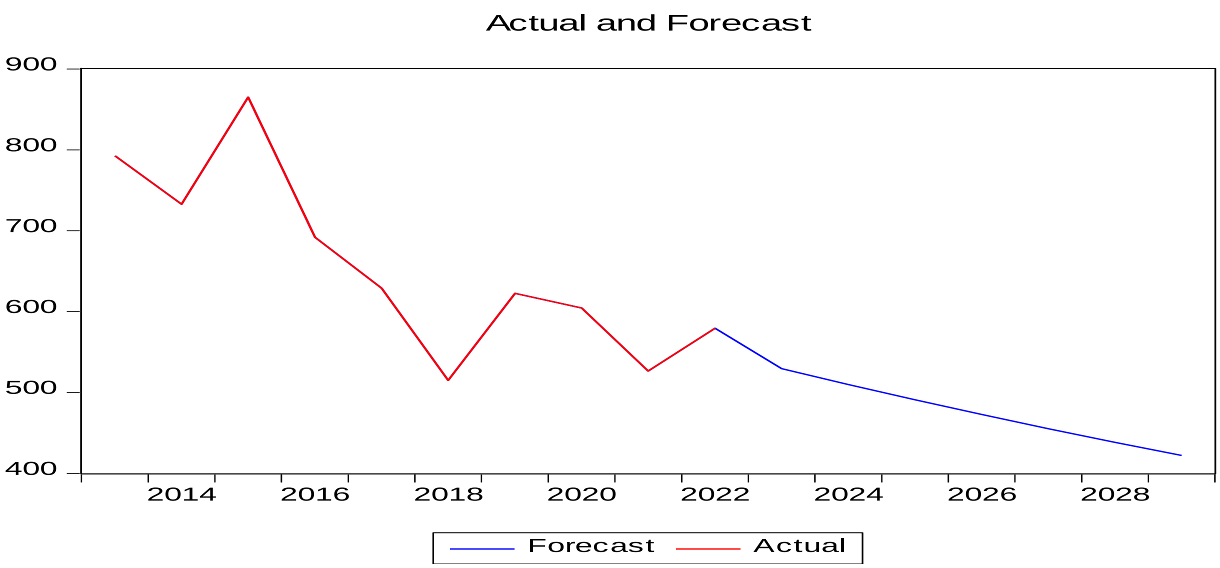
The estimated results of ARIMA(0,1,1) for FI are presented in Table 4. The estimated coefficient of MA (1) in Table 4 is significant. The plot of actual and forecasted FI for Pakistan is presented in Figure 6.

**Table 4**

| **Estimated Coefficients of ARIMA (0,1,1) Model for FI** | | | |
|---|---|---|---|
| Variable | Coefficient | p. value | |
| C | -0.038 | 0.0039 | |
| MA(1) | -0.526 | 0.0004 | |
| SIGMASQ | 0.029 | 0.0004 | |
| Adj. $R^2$ | 0.220 | | |
| F-Stat | 7.904 | Akaike Info Criter. | -0.581 |
| Prob(F-Stat) | 0.001 | Schwarz Criter. | -0.466 |
| Inverted MA Roots | 0.530 | DW Stat | 2.1 |

**Figure 6**

**Actual and Forecasted FI**




The declining trend of the blue line in Figure 6 shows that Pakistan will face absolute water scarcity with expected per capita freshwater availability of less than 400 $m^3$ in near future. This means that if the problem of water scarcity is not undertaken seriously, Pakistan will be an absolute water scarce country in next decade. The Pakistan's forecasted FI from 2022-23 to 2029-30 are given in Table 5.

**Table 5**

**Pakistan's Forecasted FI for Year 2022-23 to 2029-30**

| Year | 2023-24 | 2024-25 | 2025-26 | 2026-27 | 2027-28 | 2028-29 | 2029-30 |
|---|---|---|---|---|---|---|---|
| Forecasted FI ($m^3$) | 529.40 | 509.81 | 490.94 | 472.77 | 455.27 | 438.42 | 422.19 |

## Water Resource Vulnerability Index (WRVI)

Estimation results of the ARIMA (2, 1, 3) model for WRVI are presented in Table 6. ARIMA (2,1,3) has three significant terms (AR(1), AR(2) and constant). The line plot of actual and forecasted WRVI ARIMA(2,1,3) for Pakistan is presented in Figure 7.

**Table 6**

| **Estimation Results of the ARIMA (2,1,3) Model for WRVI** | | | |
|---|---|---|---|
| Variable | Coefficient | p. value | |
| C | 0.651 | 0.0419 | |
| AR(1) | 1.391 | 0.0000 | |
| AR(2) | -0.674 | 0.0011 | |
| MA(1) | -2.413 | 0.9952 | |
| MA(2) | 2.413 | 0.9960 | |
| MA(3) | -1.000 | 0.9978 | |
| SIGMASQ | 86.449 | 0.9958 | |
| Adj. $R^2$ | 0.485 | Akaike Info Criter. | 7.729 |
| F-Stat | 8.69 | Schwarz Criter. | 7.996 |
| Prob(F-Stat) | 0.000 | DW Stat | 2.0 |
| Inverted AR Roots | 0.70 - 0.44i | 0.70 + 0.44i | |
| Inverted MA Roots | 1.00 | 0.71+.71i | 0.71 - 0.71i |

**Figure 7**

**Aactual and Forecasted WRVI of Pakistan**

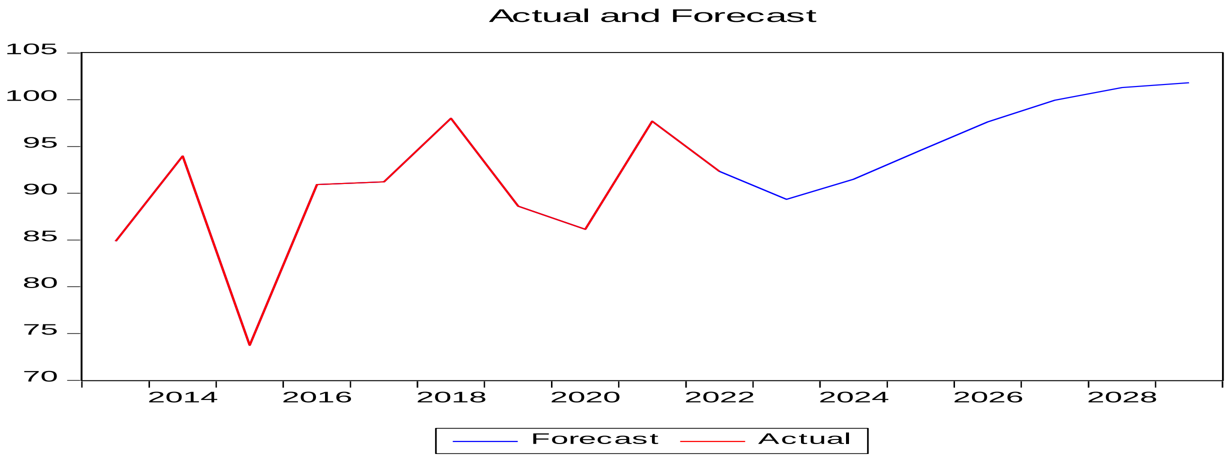



**Table 7**

**Forecasts of WRVI for Pakistan for Year 2023-24 to 2029-30**

| Year | 2023-24 | 2024-25 | 2025-26 | 2026-27 | 2027-28 | 2028-29 | 2029-30 |
|---|---|---|---|---|---|---|---|
| Forecasted Values of WRVI (%) | 89.34 | 91.50 | 94.60 | 97.63 | 99.95 | 101.31 | 101.83 |

Forecasted WRVI (%) values in Table 7 for the years 2028-29 and 2029-30 depicts that water withdrawal to water resources ratio exceeds100 percent. This is consistent with the finding of Khetran (2023) in Issue Brief on the topic “Pakistan’s Water Security Issus”. Pakistan should use her water resources more efficiently and intelligently.

**Environmental Water Scarcity Index (EWSI)**

Estimation results of the ARIMA (0, 1, 2) model for EWSI are presented in Table 8. ARIMA (0,1,2) has two significant terms (MA(1) and MA(2)). The plot of actual and forecasted Environmental Water Scarcity of Pakistan is presented in Figure 8.

The time plot of actual and forecasted values of EWSI Figure 8 show that the forecasted values are shown by blue line. EWSI followed an increasing trend from 2023-24 to 2029-30. Pakistan will face Environmental Water Scarcity as EWSI has crossed the range of 1 (see Table 9). This means that water in the rivers of Pakistan will be under severe pressure because of increased human water withdrawals and in turn, harms the economic development of the country.

**Table 8**

| **Estimation Results of the ARIMA (0,1,2) Model for EWSI** | | | |
|---|---|---|---|
| Variable | Coefficient | p. value | |
| C | 0.013 | 0.3170 | |
| MA(1) | -0.787 | 0.0000 | |
| MA(2) | 0.3256 | 0.0691 | |
| SIGMASQ | 0.024 | 0.0001 | |
| Adj. $R^2$ | 0.339 | Akaike Info Criter. | -0.7148 |
| F-Stat | 9.38 | Schwarz Criter. | -0.5618 |
| Prob(F-Stat) | 0.000 | DW Stat | 1.9 |
| Inverted MA Roots | 0.39 + 0.41i | 0.39 - 0.41i | |

Figure 8

Actual and Forecasted Environmental Water Scarcity of Pakistan

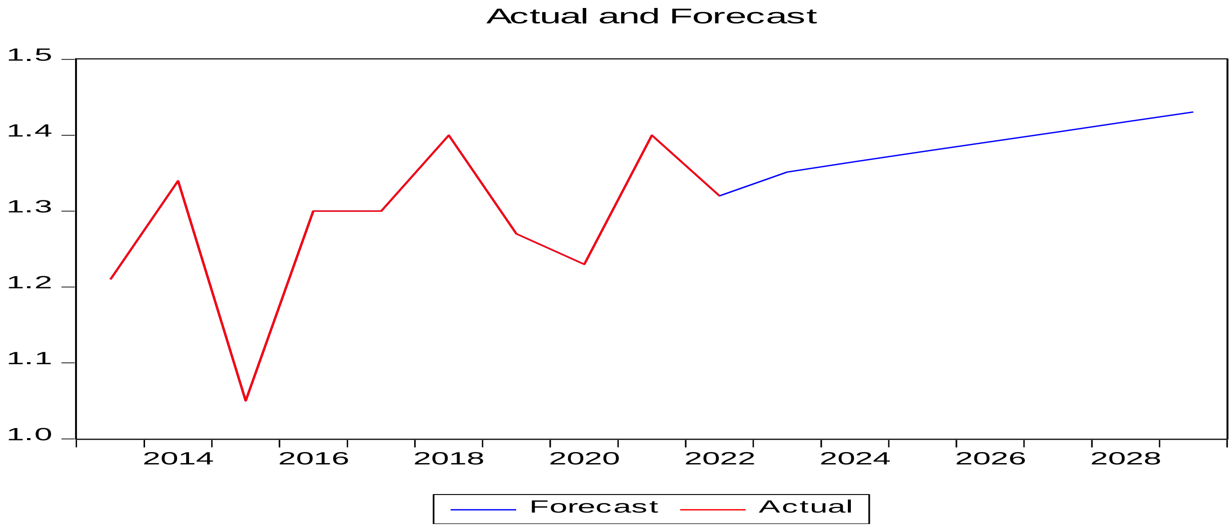



**Table 9**

| Years | 2023-24 | 2024-25 | 2025-26 | 2026-27 | 2027-28 | 2028-29 | 2029-30 |
|---|---|---|---|---|---|---|---|
| Forcasted Values of EWSI | 1.35 | 1.37 | 1.38 | 1.39 | 1.40 | 1.42 | 1.43 |

Forecasts of EWSI for Year 2023-24 to 2029-30

The forecasting values of FI, WRVI, and EWSI show that Pakistan would fall in Physically Water Scarce country by the year 2029-30. The per capita freshwater availability will be approximately 422.19 $m^3$ - a situation of 'absolute water scarcity', while the water withdrawals to availability ratio will increase beyond the level of severe water scarcity. In terms of Environmental Water Scarcity, Pakistan will also face a tradeoff of water between the human and aquatic systems.

**ARIMA (*p, d, q*) Model for Second-Order Water Scarcity**

**Social Water Scarcity Index (SWSI)**

**Table 10**

| **Estimation Results of the ARIMA (1,1,0) Model for SWSI** | | | |
|---|---|---|---|
| Variable | Coefficient | p. value | |
| C | -0.052 | 0.0004 | |
| MA(1) | -0.498 | 0.0015 | |
| SIGMASQ | 0.029 | 0.0001 | |
| Adj. $R^2$ | 0.188 | Akaike Info Criter. | -0.5686 |
| F-Stat | 6.663 | Schwarz Criter. | -0.4539 |
| Prob(F-Stat) | 0.003 | DW Stat | 2.1 |
| Inverted MA Roots | 0.50 | | |

The estimation results of ARIMA (1, 1, 0) for SWSI are shown in Table 10. The coefficient of MA(1) is significant and statistically different from zero. The declining trend of forecasted values of SWSI shown in Figure 9 by the blue line during the period of 2023-24 to 2029-30 provides evidence that Pakistan will face second-order water scarcity along with physical water scarcity. The Social Adaptive Capacity in Pakistan is expected to be diminishing as SWSI is passing below the level of absolute scarcity. Forecasted values of SWSI of Pakistan are given in Table 11.

Figure 9

Actual and Forecasted SWSI of Pakistan

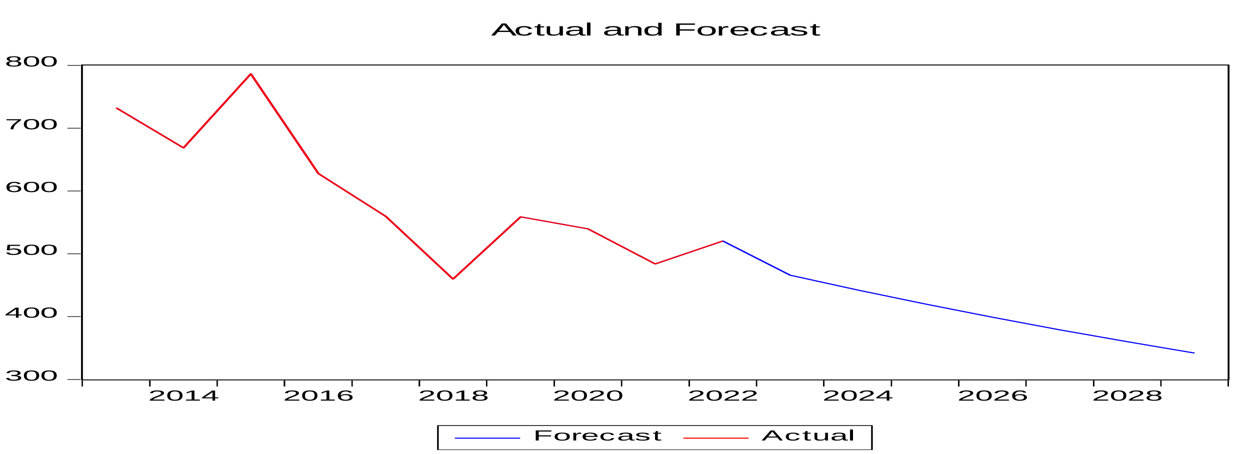


**Table 11**

**Forecasts of SWSI for Pakistan for the year 2023-24 to 2029-30**

| Years | 2023-24 | 2024-25 | 2025-26 | 2026-27 | 2027-28 | 2028-29 | 2029-30 |
|---|---|---|---|---|---|---|---|
| Predicted Values of SWSI ($m^3$) | 465.88 | 442.48 | 420.26 | 399.15 | 379.116 | 360.07 | 341.98 |

Forcasts for FI, WRVI, EWSI, and SWSI indices are collectively presented in Table 12. Based upon forecasted values of FI (Figure 6), WRVI (Figure 7), EWSI (Figure 8), and SWSI (Figure 9), this study finds that Pakistan is facing acute water scarcity in these days and will fall in the category of 'absolute scarce countries' of the world in near future. This finding is consistent with the anticipations of PCRWR, Khlown and Majeed (2002), Siegmann and Shezad (2006), Begum (2018), Ministry of Water Resource of Pakistan (2018), Sleet (2019) and Khetran (2023) about the arising absolute scarcity of water in Pakistan. To resolve arising absolute water scarcity problem with declining availability of freshwater in Pakistan would will be a real challenge for the region in next decades.

**Table 12**

**Water Forecasts for Year 2022-23 to 2029-30 using Univariate Time Series ARIMA Model**

| Year | 2023-24 | 2024-25 | 2025-26 | 2026-27 | 2027-28 | 2028-29 | 2029-30 |
|---|---|---|---|---|---|---|---|
| Forecasted FI ($m^3$) | 529.40 | 509.81 | 490.94 | 472.77 | 455.27 | 438.42 | 422.19 |
| Forecasted WRVI (%) | 89.34 | 91.50 | 94.60 | 97.63 | 99.95 | 101.31 | 101.83 |
| Forcasted EWSI | 1.35 | 1.37 | 1.38 | 1.39 | 1.40 | 1.42 | 1.43 |
| Forcasted SWSI ($m^3$) | 465.88 | 442.48 | 420.26 | 399.15 | 379.116 | 360.07 | 341.98 |

## Water Scarcity, Regional Security and Peace

Disputes over freshwater have become a worldwide phenomenon. Conflicts often arise among states when one state's population is deprived of basic human needs such as food, freshwater, energy, basic sanitation, clean environment and fair participation in economic and political activities. Nations, sharing major transboundary river basins often indulge in disputes in accessing freshwater, its allocation, uses, and flow diversion. These disputes lead to conflicts that, in turn, lead to violent conflicts if not adequately and properly addressed.

After presenting empirical analysis of Pakistan's freshwater availability, this section examines the implications of water scarcity to security and peace of the region, especially due to arising absolute water in case of India and Pakistan. The arising water scarcity in India and arising absolute water scarcity in Pakistan are stimulating 'dangerous tensions' between India and Pakistan with adverse repercussions to security, stability and peace of the region.

According to U.S. Senate Foreign Relations Committee Report 2011, India is going to build 190 dams in next few years. Not a single dam will affect Pakistan's access to water but the accumulative effect of multiple hydroelectric projects could give India the ability to store sufficient water to limit Pakistan's supply in the growing season. India's construction of dams on western rivers would have long term effects on Pakistan's agrarian economy. India's alleged violations of the IWT in building dams across western rivers is a type of terrorism in which "water is used as a weapon" against Pakistan. Major General Athar Abbas - a spokesman of Pakistan army expressed Baghlihar dam as a "defense security concern". Recent developments, diversion and fluctuations on upstream waters further intensify the insecurity. India's unilateral move to divert water flows, especially of Indus River can cause water war and may lead to significant insecurity of the region in the form of human as well as environmental losses.

International analysts and experts have also shown their concern that scarcity of water has emerged a new element of possible armed clashes between the two nuclear powers. India's water stress, high risk water environment and scarcity of water in Pakistan can easily lead India and Pakistan towards water conflict. According to Pervaiz Iqbal Cheema said Indus Water dispute is a burning issue between India and Pakistan and concluded "no dispute generated so much bitterness as did the one over the flow of waters" (The Post, February 26, 2006).

A few analysts already issued warning that the next war between India and Pakistan would be over water, rather than Kashmir. The mountain glaciers which are the lifeline of both countries were melting and sooner or later India and Pakistan would blame each other for climate change (McDonald, 2010). Economists in Pakistan like Akmal Huaasin warned that "water disputes with India could provoke a crisis and even, in the extreme, military conflict" (Hussain, August 15, 2011).

Extremists in India and Pakistan exploiting the water issue to gain their popularity among masses, for example Hafiz Saeed and Abdul Rahman Makki accused New Delhi for Water Terrorism. Water deprivation may provide more recruitment opportunities to the extremists groups in both India and Pakistan. Mr. Bijoya Chakroborty speaking at Guwahati, the capital of Assam State on May 23, 2002 warned " if we decide to scrap the Indus Water Treaty, then there will be drought in Pakistan and the people of that country would have to beg for every drop of water" (Malik, 2005, p. 201). Hafiz Saeed, paraded the streets of Muzaffarabad, Rawalakot, Lahore and Faisalabad with placards saying, "Water must flow or else blood will flow" (Verghese, 2011). Nationalist media on Pakistan side fears that India will use its upstream dams to control the flow of water into Pakistan (Bhatti, 2023).

Water conflicts have potential to aggravate other non-water related violent conflicts among states. For example, if India and Pakistan fail to settle their water issue promptly and timely in a peaceful and cooperative manner, it may lead to violent conflicts on other issues and disputes like Kashmir as most of the rivers are originating and flowing from Kashmir to Pakistan. Violent conflicts may result in poverty, hunger, unemployment, migration, and social instability that, in turn, impede sustainable economic growth and development. According to Sachan and Haq (2015), India could become the stage for major international water wars because so many rivers that originate in India supply water to other countries. Changing demographics and environmental conditions of thr region invites the dire need for an enhanced cooperation, rather than conflict, not only at bilateral levels but more through international agencies.

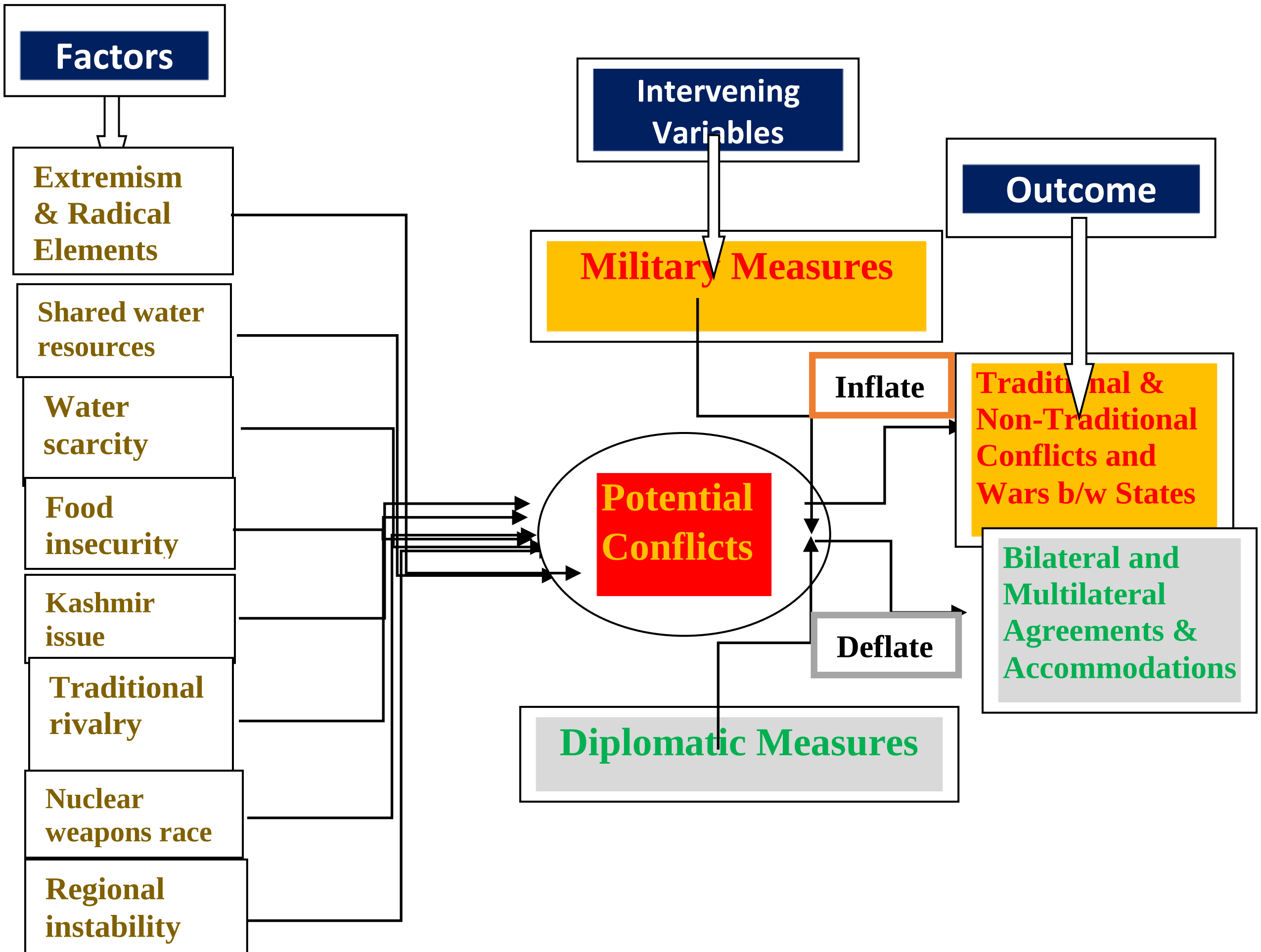
As water stress has become an apparent reality, the entire world is watching how nuclear states India and Pakistan choose to address the water stress challenge (Ali, 2012). A cold war over water between India and Pakistan has reached at its critical level and could be turned into formal war anytime. Baqai (2005) finds primacy of water as a source of conflict between South Asian states. The situation of water stress of Bangladesh, India and Pakistan is threatening the security environment of the region. Experts observe that water is the most powerful political and military tool by which India can easily screw Pakistan. According to Oregon State University research findings, India and Pakistan seem to be at brink of water conflict in near future.

South Asian regions share waters of several trans-boundary rivers such as Brahmaputra, Ganges and Indus basins which are critical to arising regional water security. South Asian nations can foster regional cooperation and reduce the potential risk of water conflicts among riparian states through strengthening existing treaties like IWT of 1960, Ganges Water Treaty of 1996 etc., making fruitful regional water sharing agreements, reforming South Asian water cooperation framework and integrated river basin management, more climate resilience and disaster management collaborations and data sharing on scientific basis.

The effect of competition over shared freshwater resources and water scarcity on regional security and peac is depicted in Figure 10. There are some patterns of independent variables (causes/factors), dependent variables (outcome), and intervening variables into two possible outcomes *i.e.*, war or peace. In Figure 10, water scarcity, shared water resources, food security, Kashmir issue, regional instability, traditional rivalry, extremism & radical elements and nuclear weapons are the independent variables, affecting the dependent variables of war or agreements and accommodations. Furthermore, military measures serve as an intervening variable for traditional & non-traditional wars between India and Pakistan, while diplomatic measures serve as an intervening variable for reaching agreements or accommodations. India and Pakistan are facing an inevitable water crisis. Military action(s) has never been sustainable solution to resolve water crises, however, diplomatic moves seem to be viable solution to prevent looming water war(s) between India and Pakistan. The South Asian region seems insecure unless some practical steps by India and Pakistan are taken to resolve their water crises alongwith other pinching issues for attaining regional security and peace.

**Figure 10**

**Peace and Water War Model in case of India and Pakistan**




**Source: Developed by the Authors**

## 5. Conclusion and Recommendations

### Conclusion

Water is the basic necessity of life. However, besides its importance, a significant number of studies have recognized that the increasing trend of global water demand and declining freshwater availability have brought a new issue of water scarcity in many regions of the world. About one-half of the world population is suffering from water scarcity issues now a days. So this study is designed to measure and forecast the status of water scarcity in Pakistan using Falkenmark Indicator (FI), Water Resource Vulnerability Index (WRVI), Environmental

Water Scarcity Index (EWSI), and Social Water Scarcity Index (SWSI). Descriptive statistics and automatic ARIMA forecasting technique was utilized to achieve the objectives of the study.

ARIMA forecasted values depicts that Pakistan will be in the category of countries that will face absolute water scarcity in near future. In terms of physical water scarcity, the forecasted value of per person freshwater availability is expected to slip below the absolute water scarcity threshold in near future. WRVI forcasted values reveals more vulnerability than the existing one. Forecasted EWSI values yields that Pakistan's water resources are under severe pressure of scarcity and the country will lack its ability to satisfy the environmental and human need for water in near future. SWSI forcasted figures depict looming danger of non-avaibility of water in Pakistan. Pakistan once a water abundant country is now a water scarce both in terms of physical and social water scarcity. This grim situation invites policy makers to resolve the problem of water scarcity on a priority basis.

Unprecedented rise in heatwaves, torrential raining, floods and droughts are expected in South Asian region. The alarming present status of freshwater availability in Pakistan and in the region poses a major challenge for the security of the region and is intensifying by climatic changes too. As a result, it may lead to violence in the region. South Asian nations are also prone to have climate related conflicts in near future.

**Recommendations**

The study recommends some measures to get rid of the problem of arising absolute water scarcity in Pakistan and to avoid water conflicts in the region.

- As the population in Pakistan and neighbouring countries is constantly growing, per capita freshwater availability is expected to decline below its threshold level. To avoid this water scarcity issues, Pakistan and other countries should form effective policies to control their population growth. Construction of more small and large water reservoirs in Pakistan can act as a strategic tool to increase per capita water availability in Pakistan.
- Water is almost free and the public pays no attention toward arising water scarcity issues, so to reduce excessive water use and withdrawals , government can introduce a national policy that contains a mechanism of water pricing to realize the public about the importance of decling availability of water in the region.
- Pakistan may invest in water-saving effiecnt technologies and practices to alleviate the scarcity of water in the country.

- To preserve ecosystem, every state should make an effective water management policy at their national level with the main objective to relieve the stress on existing water resources. Integrating climate adaptation measures into every country's National Water Policy is another solution.
- In Pakistan, various institutions for the distribution and management of water operate at federal, provincial and local levels, even after 18th Constitutional Amendment, overlapping each other responsibilities. By reforming institutional framework and strengthening these institutional coordination and capacity at all levels, Pakistan can address water scarcity challenges to some extent.
- By reforming its institutional framework, Pakistan can better mitigate water scarcity and ensure sustainable water resource management.
- It is high time for Pakistan as well as other regional states to address rising water scarcity and other related issues to avoid water conflicts in the region as water shortage is posing a big threat to the sustainability of Pakistan's agrarian economy in future.
- India and Pakistan being nuclear states should realize the looming danger and minimize blame game to attain regional security and should take some practical steps to resolve their water issues bilaterally.
- Regional players should come forward and take some solid measures in supporting cooperation among riparian states for transboundary water management and to promote security and peace to reduce poverty and hunger for the best interest of the regiony.

**Future Avenues**

Pakistan is considered among the most affected countries by extreme weather changes. So, further studies may be conducted that can include an index that incorporates the effect of climatic changes on the water resources of the countries, and may provide durable solutions in eradicating poverty, hunger and maintain peace and security in the region.

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