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ANALYSING THE THREATS OF POPULATION GROWTH, AND THE NEXUS OF CLIMATE CHANGE AND WATER SCARCITY: A CASE OF PAKISTAN

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ABSTRACT

Population growth (PG), and the nexus of climate change (CC) and water scarcity (WS) pose serious threats to various aspects of the physical and human environment in different ways. The study in point was carried out to examine the threats of PG, CC and WS linkage, focusing on Pakistan and presenting a brief and factual view of the issue. It also underlines the types, causes, and various effects of WS along with some mitigation measures against the issue. The data was mainly obtained from secondary sources including many national and international reports, internet websites, UN and other local and global surveys, research and available literature. The collected information was integrated to comprehend the risks of the PG, CC and WS nexus. The prevailing situation of WS was judged by applying Falkenmark's indicator method. A descriptive approach was used to elucidate the results. It was found that Pakistan ranks among the world's most water-scarce countries and around eighty percent of its inhabitants suffer from extreme water dearth at least for a month per annum. The investigation ascertains that due to unprecedented PG and CC, the problem of WS in Pakistan is becoming more alarming with time. Apart from impairing biodiversity and aquatic and land ecosystems, WS is also denting crop production, livestock rearing, people's health, and socio-economic progress. The study suggests that it is essential to educate people about the cautious use of water in all sectors. The key measures to deal with the issue include PG control, reduction in greenhouse gas emissions, enhancement of the capacity to store water, the wise use of water resources, handling of water pollution, and initiation of smart agriculture in water-deficient areas. As regards policy implications, this is a baseline study which can be beneficial to learn lessons for future planning and preparedness.

Keywords: Climate change, greenhouse gas emissions, Pakistan, population growth, water scarcity.

1. INTRODUCTION

Water resources (WR) are crucial for life, livelihood, and livelihood uphold (Patrick, 2021). Water is one of the most essential and limited resources which plays a vital part in every aspect of human living from existence to prosperity. About 71% of the earth's surface is covered with water. However, only about 3% of the planet's total water accounts for

freshwater that is healthy for human use. More than two-thirds of this 3% is frozen in the form of snow and glaciers, while just around one-third is readily on hand to meet global water needs. With climate change (CC) in the scene, the water security situation appears to be a big challenge for the global community that can lead to water scarcity (WS) in various parts of the earth (Hosea & Khalema, 2020). Major initiators of the issue are CC, PG and associated socio-economic development (Dehghani et al., 2022). Predictions show that by 2025, nearly 50% of the global population could be breathing in the regions facing WS. By 2030, about 0.7 billion people might be displaced due to severe WS and one in every four children globally will be living in extreme water stress conditions (Buchholz, 2023). Yet the inherent connection between PG, CC and WS is often neglected. Fast PG accelerates CC, which in turn with higher temperatures, increases evaporation, melts glaciers and interrupts rainfall patterns. The resulting disruptions in natural water systems worsen WS worldwide. While international response to CC has been little and uncoordinated, the water crisis is likely to become more threatening, especially for economically deprived countries. It is already a big challenge in semi-arid and arid tracts. Pakistan, with the world's fifth biggest population concentration, is marked by varied terrain, climate tracts, streams, rivers, and ecosystems. The country has enough natural resources like productive arable areas and mineral wealth. Its climate is predominantly sub-tropical continental type characterized by hot summers and low rainfall. About 80% of areas of the country are dominated by semi-arid and arid conditions, innately prone to WS. Because of the vast latitudinal spread from 23.5° N to 37° N and big physiographic disparities from sea level in the south to 8611 meters in the north, the spatio-temporal range of temperature in the country is high, and the distribution of rainfall and WR is highly uneven (Khan & Khan, 2023). The southern parts of the country are generally warmer while northern parts stretch to snow-covered peaks of Hindu Kush, Karakoram and Himalayan Ranges (Xu et al., 2020). However, the country is facing difficulties in harmonizing competing objectives between economic development and environmental safety (ADB, 2021). The country's WR is deteriorating mainly due to unprecedented PG and CC effects. In Pakistan, the massive water demands of various sectors are fulfilled from both the surface and groundwater sources. During the previous decades, the WS issue has cropped up primarily due to growing water demands resulting from a range of factors related to PG and CC effects such as rising temperatures, inefficient management and wastage of water, pollution of water sources, droughts and floods. Rapidly growing population demands more water on one side and causes global warming (GW) on the other side. Water availability and CC, in turn, are inextricably linked. PG along with increasing resource consumption tends to raise greenhouse gas

emissions (GHGE) into the atmosphere which cause GW and eventually disturb the hydrological system. Besides the leading greenhouse gas, Carbon Dioxide (CO_2), the levels of Methane (CH_4) and Nitrous Oxide (N_2O) in the atmosphere are also rising and playing a significant part in GW. Because of such happenings, environmentalists and other scientists are apprehensive about the capability of the earth to endure the additional burden of greenhouse gases (GHGs) incoming into the atmosphere and causing malfunctioning of ecosystems.

Though CC and WS are worldwide problems, these are specifically distressing concerns for the countries where the PG rate is high. Pakistan is world's one of the topmost countries facing the problem of water shortage due to this reason. Its current population of 240.5 million is growing at a rate of 1.9% per year (PRB, 2023). Several parts of the country, especially cities, are suffering from WS due to overpopulation and associated water pollution. The population of Karachi, Lahore, Faisalabad, Rawalpindi, Quetta, and other cities is increasing rapidly exerting extreme pressure on WR. For instance, about 0.6 million persons immigrate to Karachi every year, where water needs cannot be fulfilled for the additional population and the situation is further worsened (Ahmed & Hussain, 2022).

Furthermore, Pakistan's economy is largely agro-based and the agriculture sector is by far the biggest consumer of water. With the growing population and intensification of agricultural activity, the availability of water is declining and its quality is deteriorating. To meet the food and other demands of a growing population, agricultural developments are also taking place, causing large-scale deforestation and land-use changes. The dwindling forests are incapable of counteracting the harms of rising CO_2 emissions, which is resulting in a rise in temperatures. This, in turn, is causing the shrinking of WR, increase in salinization, WS, desertification, and loss of arable land. Shifts in agricultural practices from extensive to intensive require more water. Intensive agriculture consumes water at a rate higher than usual processes can refill it, instigating WS. Due to such reasons, Pakistan's WR is under serious stress and the risk of environmental insecurity is increasing. This state of affairs, together with institutional, operational, and governance inefficiency, is increasing local dissonance and domestic tensions, particularly between provinces. It appears that WS, droughts, floods and local mismanagement are the main factors to embitter inter-ethnic relations and foster political tensions (Mustafa et al., 2013). It is thus, imperative to properly understand the PG, CC and WS nexus and its impacts on the natural and cultural environment so that the likely sufferings from these impacts can be avoided in future. Besides, due to fast PG, CC and degradation of WR, there is an instant need to learn to manage and preserve this limited resource for coming

generations. Looking at the gravity of this multifaceted issue, concerned government departments and researchers recently have diverted their attention to highlight it. Many researchers have made efforts to develop methods and guidelines to delimit water-scarce areas, to identify causes of WS, and to manage this resource efficiently. In line with such efforts, the study in point is also an attempt to achieve this goal and can help to draw lessons for future planning and watchfulness.

2. MATERIAL AND METHODS

For this particular study, the data was obtained mainly from secondary sources that include several local and international reports, UN surveys, internet websites, research works and texts of various kinds. The collected information was integrated applying the descriptive approach to underline the risks of PG, and CC and WS nexus. The status of WS was estimated using Falkenmark's (1989) Indicator, which states;

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

Where; FI = Falkenmark water stress indicator, SW = Overall accessible surface water inside the region or country, and P = People inhabiting in the region or country under study.

3. RESULTS AND DISCUSSION

3.1 Understanding WS

In a straightforward economic model, WS begins due to an imbalance between the demand and supply of WR (Fuller & Harhay, 2010). It is a condition that arises due to a shortage of fresh WR to fulfil the standard water demands. WS begins when water demands by various sectors of a region such as domestic, agriculture, manufacturing, and others exceed than available water supply. If the availability of clean water, due to any natural or human reason, falls below 1000 m^3 per capita per year, the region is said to be water-scarce. All inhabited continents are facing WS. Many areas are facing extreme scarcity of clean water and millions of people across the world do not have access to safe drinking water. They spend almost their whole day in search of clean water. On the other hand, people with access to plenty of clean water treat it for granted and do not utilize it sagaciously. Overuse and waste of water is a big mistake that many people are submitting without realizing the impacts that it might have on the world around them. In a future scenario, where the population is growing rapidly and CC effects are becoming serious, WS can turn out to be a big challenge for several countries including Pakistan. Based on occurrence, it can be physical, economic, managerial, political,

social or of some other kind. The main reasons behind WS in Pakistan are rapid PG and CC, while other associated reasons are accelerated urbanization, mismanagement, lack of infrastructure, uneven distribution of WR, and water pollution. Several negative impacts of WS have been enlisted which can be reduced through effective mitigation measures (Figure 1).

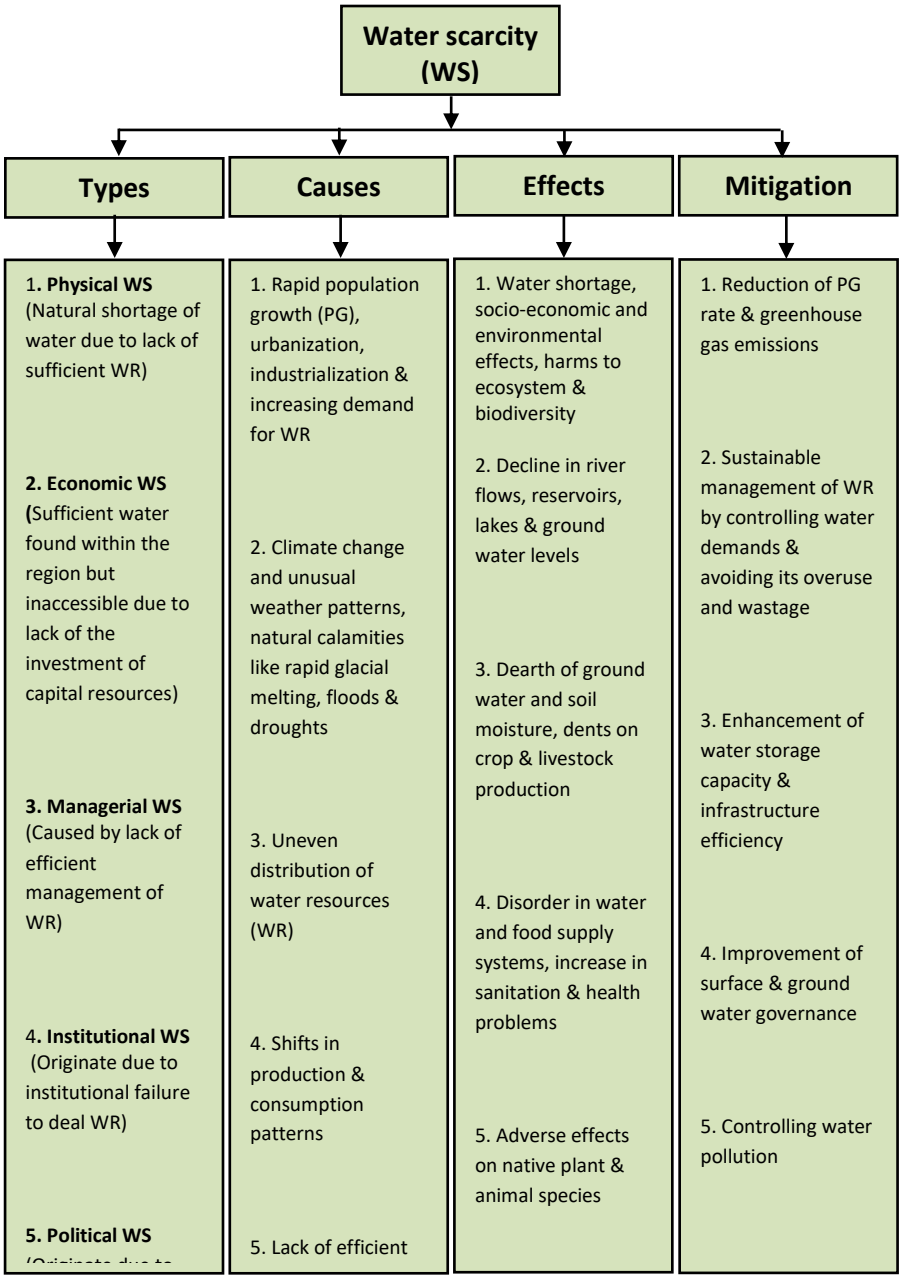

Figure 1: Kinds, reasons, effects and preventive measures against WS

3.2 Understanding the association between PG, CC and WS

The issues of rapid PG, CC and WS that the contemporary world is facing are inevitably connected (Figure 2). Understanding the linkage between PG, CC and WS is key to solving these issues. The expanding population is causing more consumption of resources, too much pollution by using fossil fuels and releasing effluents into water sources, deforestation, and much more that the earth cannot tolerate. Therefore, it is almost impossible to effectively address CC and WS without achieving the goal of a sustainable population. Water is indeed, a finite resource. Although our earth is filled with water, only a small proportion of this natural product is safe and usable for humans. Visualize, that the quantity of clean water remains unchanged, but the size of the population which depends on that water is increasing somewhat exponentially. On the other hand, CC occurs mainly due to PG, which at the same time is increasing the demand for water as well as disturbing the water supply systems. This is what initiates WS, an issue that will keep on mounting as the population grows. It means, there is a strong association between PG, CC and WS. WS is mainly the product of PG and CC, and thus can be expressed as;

$$WS = p(PG + CC)$$

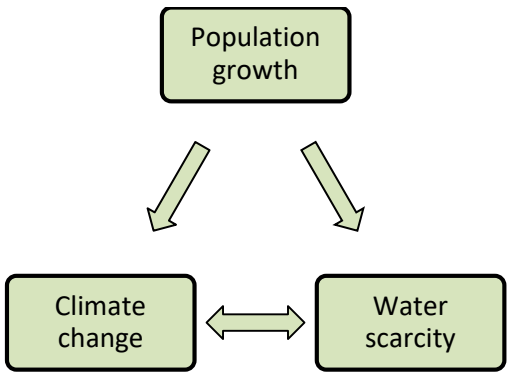

Figure 2: Population growth, CC and WS nexus

3.3 Role of PG in Causing CC and WS

Although many factors are responsible for WS, one of the major root causes that initiates the problem is rapid PG. A rapidly growing population is directly contributing to CC and WS, which in turn, are posing devastating impacts on economically weaker countries like Pakistan (Figure 3). Some studies predict that as an outcome of PG and economic growth, billions of individuals will face scarcity of safe water by 2050 (Boretti, 2023).

According to the UK-based charity organization 'Population Matters' each extra individual enhances CO_2 emissions, the wealthy much higher than the poor, and enhances the number of CC sufferers, the poor much higher than the wealthy (Population Matters, 2018). Rapid PG is certainly a main factor in GW because humans utilize fossil fuels to energize their ever-evolving mechanized ways of life. More population means more demand for fossil fuels, which when burned, emit CO_2 in the atmosphere that traps warm air inside similar to a greenhouse.

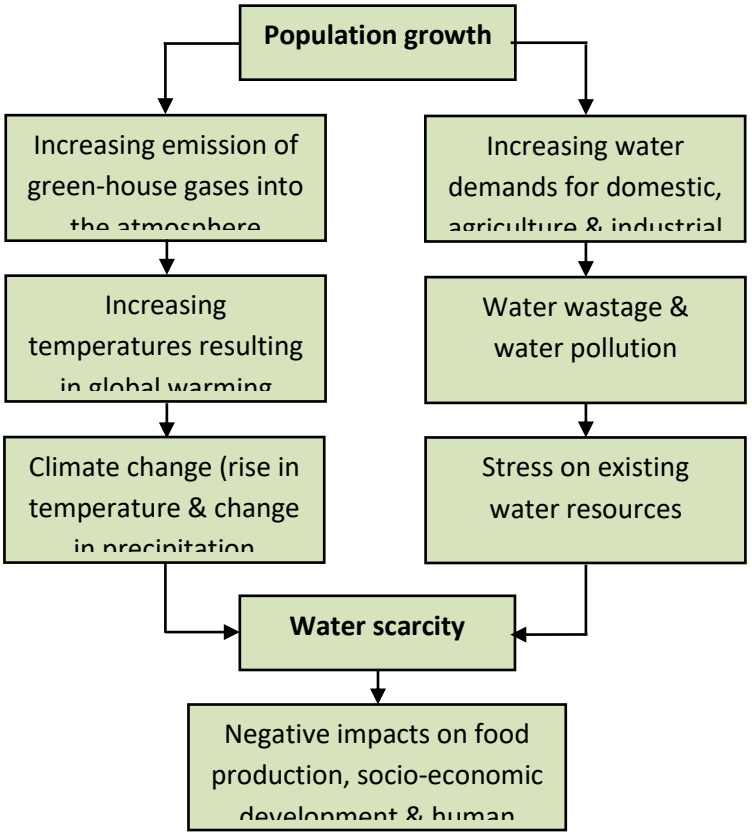

Figure 3: Linkage between population growth and water scarcity

In human history, the 20th century was the period of the fastest PG initiated by the Industrial Revolution. Since its beginning in 1900 AD, the world population took all the time to become 1.6 billion. Then in just a century, it reached 6.1 billion by 2000 AD, and now in 2023, with the addition of a further 2 billion, it shot to 8.1 billion (Worldometer, 2023a). The combination of two factors, the industrial revolution and rapid PG led to a massive increase in CO_2 emissions. Figure 4 indicates that CO_2 emissions have also increased rapidly with PG. In 1950, the amount of CO_2 in the atmosphere was 300 ppm, but just 70 years later, that level had risen to 400 ppm (Peluso, 2022). This is a big rise in a geologically minute

time. In the same period, the global population augmented by more than 5 billion. During the entire 20th century, the emissions of CO_2 increased by twelve-fold. These facts show a close relationship between PG and CO_2 emissions. Besides, the global population is projected to exceed 9 billion in 2050 and, if preventive measures are not taken, the situation may further aggravate.

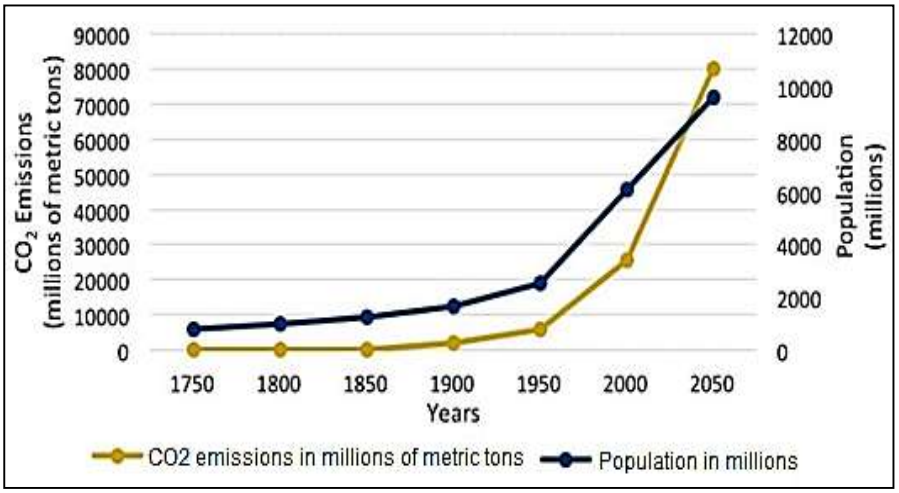

Figure 4: Population growth and rising CO_2 emissions

Source: https://populationeducation.org/resource/generating-heat/

It would be worthwhile to mention here that developed countries use massive amounts of fossil fuels and their share in CO_2 emissions is also highest. The USA for instance, contains just 5% of the global population while its share in CO_2 emissions is about one-quarter of the world's total (Figure 5).

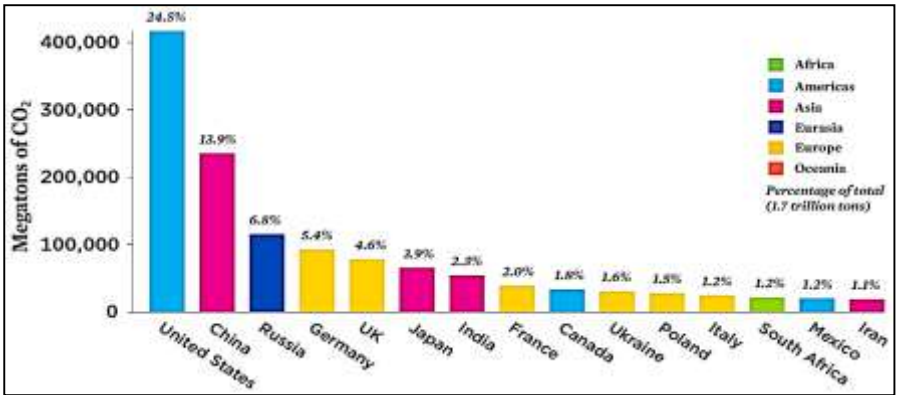

Figure 5: World's top most CO_2 emitting countries from fossil fuels consumption and cement manufacturing (1750-2020)

Source: Union of Concerned Scientists (2022). Climate change and population.

The current trends indicate that GHGE is rising quickly in fast-industrializing developing countries such as China and India. These countries will contribute over 50% of the global CO_2 emissions by 2050 (Scientific American, 2009). Conversely, the entire global community will be affected, including countries like Pakistan that have little role in such emissions.

Table 1: Pakistan's PG, share in global population, and world ranking by population size

Years	Pakistan's population in millions	Yearly % change	The world population in billions	Pakistan's % share in the world population	World ranking
1955	41.02	1.71	2.75	1.49	13
1960	45.95	2.30	3.02	1.52	12
1965	51.84	2.44	3.34	1.55	13
1970	59.29	2.72	3.69	1.60	10
1975	68.13	2.82	4.07	1.67	10
1980	80.62	3.43	4.44	1.81	09
1985	97.12	3.79	4.86	2.00	08
1990	115.41	3.51	5.32	2.17	08
1995	133.12	2.90	5.74	2.32	07
2000	154.37	3.01	6.15	2.51	06
2005	174.37	2.47	6.56	2.66	06
2010	194.45	2.20	6.98	2.78	06
2015	210.97	1.64	7.43	2.84	06
2020	227.20	1.75	7.84	2.90	05
2022	235.82	1.91	7.97	2.96	05
2023	240.48	1.98	8.04	2.99	05
2025	249.95	1.93	8.19	3.05	05
2030	274.03	1.86	8.55	3.21	05
2035	298.43	1.72	8.88	3.36	05
2040	322.59	1.57	9.19	3.51	04
2045	345.82	1.40	9.47	3.65	05
2050	367.81	1.24	9.71	3.79	05

Source: World Meter, August, 2023. Data from 2025 to 2050 is based on world meter predictions.

Several countries of the world, specifically African and Asian countries including Pakistan, where the PG rate is high, are facing serious water

stress. They are facing a decline in surface and groundwater resources. Due to rapid PG, Pakistan in particular, is experiencing a record decline in its groundwater resources. Table 1 presents a detailed picture the Pakistan's past, present and future situation of PG, share in the world population, and world's ranking by population size. PG does not simply mean more water utilization, but also more water required for food production and other activities. To produce more food, and fulfill household and other needs, groundwater is pumped at a rate faster than it is replenishing. This adds extra problems to areas in Pakistan which are already facing a decline in aquifers.

As the population of the country is growing, per capita water availability is decreasing and the proportion of individuals having no access to safe water is increasing, resulting in WS (Figure 6). The problem in urban areas appears to be more serious. Due to the absence of proper resources or infrastructure, many people perish every year as a result of using polluted water, all of which could be avoidable (Bensen, 2022). The areas already facing the worst water stress are also experiencing the highest rates of PG. Birth rates in several water-stressed areas are almost double the world average. In such areas, slowing the PG rate can lessen water demand. Whatever the reason for WS is, it often links back to higher demand from overpopulation. Several correlating factors of overpopulation such as CC, wastage of water, insufficient infrastructure, and more food production influence WS.

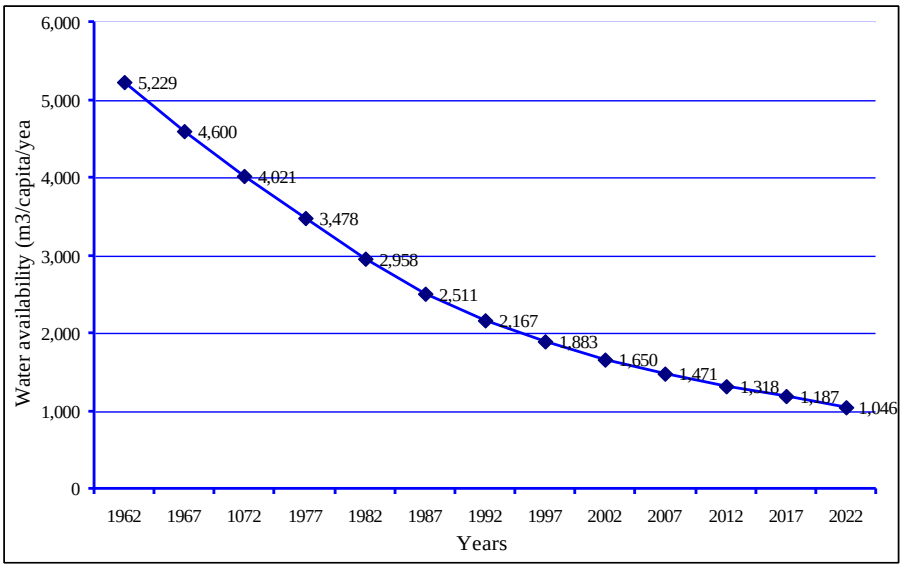

Figure 6: Declining per capita water availability in Pakistan
Data source: FAO, 2021 & PRB, 2022.

3.4 Role of CC in Causing WS

The CC denotes all types of alterations in climatic consistency, regardless of their physical cause or statistical nature, over a long duration (Patrick, 2019). It is no longer a remote menace and recently has become a major concern for the global community. It is perhaps the most influential factor that causes a big uncertainty about the existing water supplies. It is imperative to know that, while CC and WR are intricately linked, many of the environmental and social impacts resulting from CC are largely unavoidable, and a big challenge for sustainable water management (Babel et al. 2020). Intensification of human activities over time has caused the dwindling of forests and a rise in the release of GHGs abetting GW. Though variably, resulting CC is influencing almost every part of the world and its impacts on WR are much more pronounced. Shifts in the weather patterns have disrupted precipitation patterns leading to both floods and droughts. The GW has caused the melting of many vital water-storing ice packs and glaciers at a rate faster than expected, which is influencing badly the supply of fresh water. A current manuscript of the International Centre for Integrated Mountain Development (ICIMOD), released on 21 June 2023, presents a scary picture of the human future in light of rising temperatures across the globe. The most pronounced impact of global CC is on the cryosphere. The Hindu Kush-Himalaya (HKH) region extending 3,500 km through eight countries including Afghanistan, Pakistan, India, Nepal, Bhutan, China, Bangladesh, and Myanmar, is not an exception. It is rather, the world's most affected region by GW where irreversible changes are occurring. To study the impact of CC on this region, an area of 1.6 million square miles stretching from Afghanistan to Myanmar was monitored by ICIMOD. It was ascertained that glaciers of the region can melt 65% faster than in the past in the coming years, and these mountain ranges may lose 80% of their glacial mass by the closure of the current century due to the rise in temperatures (ICIMOD, 2023). Previous reports of ICIMOD also revealed the rapid melting of glaciers of the HKH region which can be devastating, especially for the mountainous communities that depend on these alpine glaciers, not only for water supply but also sustenance (ICIMOD, 2019). The consequences of this, if it were to happen at the predicted rate, include the drying up of downstream water sources and inundating of arable lands followed by severe droughts. About two billion people living along the banks of rivers originating from the glaciers of HKH ranges will be affected badly. Despite having a zilch role in GW, they will be the worst affected people by this issue. The major river systems of the HKH region are the *Indus, Ganges, and* Yarlung-*Tsangpo-Brahmaputra* (Figure 7). On their way to flowing down, these rivers supply fresh water to the residents of sixteen Asian countries including Pakistan. Experts further opine that it will be impossible to stop the melting of HKH region glaciers and the process of their melting may continue for a long. Besides, it was

also noticed that the glaciers of Mt. Everest have lost the snow accumulated in 2,000 years in just the last 30 years or so due to the impact of GW (ICIMOD, 2023).

Figure 7: River systems originating from the HKH region
Source: https://studywrap.com/himalayan-drainage-system-indus-river-system/

Furthermore, in a future where glaciers do vanish, the erosion of left-behind glacial slopes will increase the probability of floods, landslides and avalanches adding to the hardships for mountainous communities. This is an example of just one region, whilst CC is a worldwide phenomenon that may annihilate more landscapes across the globe. If we fail to formulate urgent and firm policies, there is no way that we will be able to handle the consequences of CC in the short term as well as in the long term (The Nation, 2023). The ICIMOD warned that the present level efforts are not enough to manage GW. The exigency of dealing with CC has become even more crucial as the distraction to human existence and the economy caused by this issue is likely to aggravate further in the years ahead. A precise estimation of the key factors that are accountable for and drive CC will lead to the formulation of both global and national climate policies (D'souza, 2022). A much stronger policy is required to limit the harms of CC, particularly of temperature spikes, and to control the implications of accelerated GW (The Nation, 2023). The situation demands the world's community to take action efficiently and coordinate with each other to come up with the best and most lasting solution.

In Pakistan, CC is worsening for both WS and water-associated threats like droughts and floods. CC-induced migration and health risks are increasing. At present, CC is perhaps the single largest health threat confronting

mankind. It is impairing people's health through intense weather events, diseases, stressing mental health, forced migration, and increasing starvation in areas where humans cannot produce or obtain adequate rations. The rising temperatures are disrupting not only the precipitation patterns but the whole water cycle (Mustafa et al., 2013).

Pakistan has been facing wave after wave of excessive heat for the last few years, starting with a succession of spikes over 50°C in 2010. Another extreme heat wave struck in 2015 when the temperature of Larkana went over 49°C. Again in 2018, the temperature of Nawabshah touched 50.2°C (Mulhern, 2020). Suck spikes have shown consistency over time and experienced almost every year now. Though, these temperatures are not too surprising for the people of Pakistan as they know that Jacobabad is known to be the hottest place not only in the country but in Asia as well, and maybe in the world, but, they observed a noticeable increase in maximum temperature that is attributed to CC. Temperatures over 50°C are taken as extreme and threatening for ecosystems and almost all kinds of living organisms including humans. Shockingly, a study projects that CC could make certain areas of Pakistan too hot to live in by 2070 when the average annual temperature of the country could rise as hot as that of the Sahara if we do not promptly decarbonize (Xu et al., 2020). The coastal areas are relatively more threatened by CC because of anticipated sea level increase and amplified cyclonic activity associated with rising sea surface temperature. Tension among upper riparian and lower riparian regions is increasing concerning the sharing of WR. The overall volume of river flows is decreasing. The flow of the Indus has reduced to the extent that it looks like a canal, especially in the province of Sindh where many farmers have shifted to urban areas because of WS. Even though snowmelt runoff presently feeds much of the water to the Indus River System, this may result in landslides, huge floods, lake and dam breaches, and erosion in the start while drought and famine in the long term (Bhutto, 2020). Thus, lack of water may reduce the cropland, influencing negatively the worth of agricultural production, thereby affecting the country's GDP.

In sum, rapid PG and the resulting expansion of human activities are the key drivers of recent GW and there is a visible impact of population on earth's water cycle. The CC effects on WR are intricate and influence different areas in variable manners. For the solution to the water dilemma, the focus should be on addressing rapid PG, unsustainable and void practices, and gross mismanagement. Water must be considered as a key to CC adaptation in national climate action plans and efforts to reduce GHGE should be increased. Knowledge of water demand, accessibility, and sharing systems is vital to understanding national water management challenges and security risks. In future, inter-sectoral competition, fast

urbanization, and expanding industrial infrastructure will enhance the demand both for water and for building more water infrastructure. Contradictory views of stakeholders and decision-makers about water and security are hindering feasible solutions for efficient WR management. It is suggested that the water crisis should not be taken as a tipping point but rather a way to prop up social harmony, national unity, and environmental sustainability. Effectual management can only be obtained through domestic reforms, and reliance on external help will not deliver permanent solutions. For this, the government should spend bigger political capital to normalize water rivalry and offer the best water services to all groups of people. However, conservation may prove a basic input in this process (Mustafa et al., 2013).

4. CONCLUSION

The findings of the study support to conclusion that a strong connection exists between PG, CC and WS which is threatening to the natural and cultural environment in several ways. Rapid PG and CC are the major root causes of the water crisis in Pakistan. The stress on WR of the country is likely to increase in future. It is evident that the water sector of Pakistan is facing several serious natural problems, and it has also been identified that around 83 maf of more water can be generated in the country. Therefore, a unified approach consisting of PG control, effective water governance strategy, construction of new water storages, and implementation of the researcher's and concerned department's recommendations can help us to deal with the challenges. This may also enable the planners to achieve the goals of environmentally and economically sustainable development and management of finite WR. Even though, some places are lucky enough to not suffer from WS, but can yet play their part in the water crisis by wasting this resource. In many areas of the country, potable water is recklessly used for a range of activities from washing and flushing to irrigating lawns and crop fields. Water is often overused in areas too dry to grow crops such as Cholistan. Seeking out solutions to stop unnecessary usage of clean water can help to reduce its wastage. In addition, inefficient infrastructure and poor supply systems also cause huge amounts of water wastage. Though safe water is the ultimate goal, some areas are struggling just to get any type of water for their populations due to poor maintenance of supply systems. Some of this may be in part due to the water prices not meeting the cost of services. Because of this, some areas cannot afford to spend on the maintenance of water supply systems. Our researchers and concerned departments need to seek and provide economically feasible solutions to as many people as possible. Providentially, there are many opportunities to control water wastage, provide education, and contribute to innovative and conservative water

uses. Finally, along with the lessening of the population growth rate, human activities are required to be adjusted according to the circumstances caused by CC and declining WR.

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