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Urban Water Crisis in Kabul City: Key Challenges and Solutions

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ABSTRACT

Water is an essential human need for survival. However, billions globally wake up daily with accessible and affordable clean water. Rapid population growth, urbanization, climate change, precipitation regime changes, industrial development, and environmental degradation increase pressure on urban water resources. As a result, water demand is continuously rising, leading to prominent shortages in many cities in developing and developed countries, regardless of their developmental condition. One such city facing significant water scarcity is Kabul, the capital of Afghanistan, where rapid urbanization has outpaced local water supply infrastructure, resulting in unsustainable exploitation of groundwater resources. This directly threatens the well-being of millions of residents in this city. In anticipation of the exhaustion of local water sources, Kabul will soon need to explore alternative water supply methods, such as inter-basin water transfers, to meet the growing demand. This paper aims to offer a broad overview of urban water crises, evaluating the key drivers of water shortages, exploring the specific water crisis facing Kabul, and analyzing previous research, reports, papers, flow data, groundwater data, maps/charts, field observations, surveys, GIS data, and statistical analysis as the methods for this work. So, to combat declining groundwater levels, a sustainable groundwater management approach is crucial. The approach includes water conservation methods, the implementation of efficient irrigation techniques, and the adoption of water pricing mechanisms.

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INTRODUCTION

Water is crucial for all life on Earth; without water, there is no life. Water is fundamentally connected to several challenges civilization faces, including food security, economic growth, climate change, and poverty reduction. On the one hand, renewable water resources are becoming scarcer, while on the other hand, global water consumption is increasing, highlighting the fact that the worldwide water crisis is a real threat (Sayantani Pan Ghosh, 2021).

According to UN-Water (2007), urban development is occurring rapidly in the developing world, with cities adding an average of 5 million residents each month. Based on the (U.N. 2015), the urban population is projected to double between 2000 and 2030 in Africa and Asia. The rapid increase in urban populations has significantly contributed to the growing demand for local water resources, creating significant problems for metropolitan areas and leading to a water crisis with severe consequences (Remigios & Never, 2010). Both urbanization and climate change have combined to exacerbate water shortages in cities worldwide. Urbanization intensifies water shortages and affects food consumption (Bruinsma Jelle, 2009). Climate change directly impacts various elements of the water cycle, with cities being particularly vulnerable to risks such as flooding, inadequate water supply in quantity and quality, sanitation issues, drainage problems, and effects on ecosystem services within cities and their surrounding areas. Climate change also affects hydrological regimes, freshwater availability, and rainfed and irrigated agriculture (Turral. H. et al., 2011). Climate change has impacts on freshwater quality, quantity, and timing. Changes in water quality can often affect water quantity and timing, which is evident through observed floods and droughts (Matthews. J & Quesne, 2009). Increasing temperatures also affect water availability for urban water supply and sanitation systems. Human activities are altering runoff characteristics and the availability of surface as well as groundwater (IPCC, 2007).

Water quality degradation, intersectoral competition, and interregional and international conflicts contribute to water scarcity. Based on (Engel, 2011),70% of the world's population is expected to live in urban areas by 2050. According to a report by the Kabul municipality, rapid urbanization is both an opportunity and a challenge for Afghanistan. The most significant issues facing Afghan cities are related to solid waste management, which worsens land and water quality in the urban environment (GoIRA, 2017). The global water crisis, as highlighted by the United Nations University, reveals a 55% decline in globally available freshwater per capita since 1960. By 2030, global water demand will increase by around 50%. Water scarcity affects over 40% of the world's population, and an additional 2.3 billion people are expected to reside in areas (North and South Africa, South and Central Asia) experiencing severe water stress by 2050 (Guppy. Lisa and Anderson. Kelsey, 2017). Globally, the current water demand is estimated at around 3,800 km³ per year (Global Perspectives & Solutions, 2017). Currently, more than half of the global population resides in urban regions. It is projected that from 2018 to 2050, an additional 2.5 billion people may live in urban areas, equivalent to 68% of the global population (U.N., 2019). Cities impact all elements of the hydrological cycle (Sayantani Pan Ghosh, 2021). The rapid growth of the urban population, industrialization, and climate change have led to severe water crises in various cities around the world (Kalia, 2020)

Water supplies are degraded in many cities in developing countries(U.N., 2015). Afghanistan is a landlocked country with diverse lands and climates, experiencing significant regional and seasonal differences in water availability. Annual rainfall ranges from 1200 mm in the higher altitudes to 110 mm in the southwest. Snowfall mainly occurs in the mountainous regions at higher elevations. Recent and frequent drought has reduced the size and area of glaciers in the country, leading to projected further problems in the longer term(MIWRE, 2004; USAID & SWP, 2021; USAID & USGS, 2010). Studies show that around 50% of precipitation occurs in winter, with an additional 30% falling in spring (April to June). Runoff from snowmelt in the spring and summer months is vital for agriculture in the country (UNAMA, 2016).

On the other hand, there has been about a 12% reduction in precipitation from 2012 to 2023, and snowfall decreased by about 19% between 2014 and 2020. The distribution of these reductions is unequal across the country, with the northern basins experiencing the most significant reduction, limiting people's access to water resources for drinking and various economic uses (Faizee, 2023). While Afghanistan has multiple water resources, the country's utilization is limited(Kandemir. Fulya. Aydin & Yıldız, 2022). The more groundwater is extracted, the more aquifer depletion, groundwater pollution, and saline intrusion will occur (FAO, 2012). Typically, Afghan people obtain their drinking water from unprotected wells, rivers, and springs. Due to the increasing population rate and frequent drought events, many provinces and cities in Afghanistan face reduced water supplies for drinking(Iqbal et al., 2018). Water is crucial for living and economic development in Afghanistan (UNAMA, 2016). Estimates indicate that Afghan cities are growing at a rapid rate of around 4% per year, one of the highest rates of urbanization in the world (UN-HABITAT, 2024). The increased growth rate continues, with United Nations projections suggesting that the population of the Kabul Basin could more than double to 9 million by 2057. Models predicting the effects of increasing water use on groundwater levels show that a significant percentage of present shallow water-supply wells in urban areas may hold little or no water by 2057 (USAID & USGS, 2010)

In addition to rapid population growth, the increasing number of refugees in recent years in Kabul city has led to increased groundwater extractions and widespread drying of wells. Other concerns for water withdrawals in the Kabul basin include frequent droughts, climate change (rising temperatures and decreasing precipitation), earlier snowmelt runoff, and shrinking glaciers. According to (UNICEF, 2022), 8 out of 10 Afghans drink risky water, 93% of children in Afghanistan (15.6 million children) live in high or highly high-water vulnerability areas, approximately 4.2 million people practice open defecation, and over 6 out of every 10 Afghan people do not have access to basic hygiene facilities. The supply needed in 2010 and beyond is summarized in Figure 1 below. The figure clearly shows that the gap in 2010 is nearly 45 Mm3, equivalent to the maximum supply from existing sources. The gap is estimated to grow to about 79 Mm^3 in 2015. The incremental supply needed to keep pace with the growth of demand between 2015 and 2020 is an additional 60.4 Mm3/year (Beller and Stadtwerk, 2004).

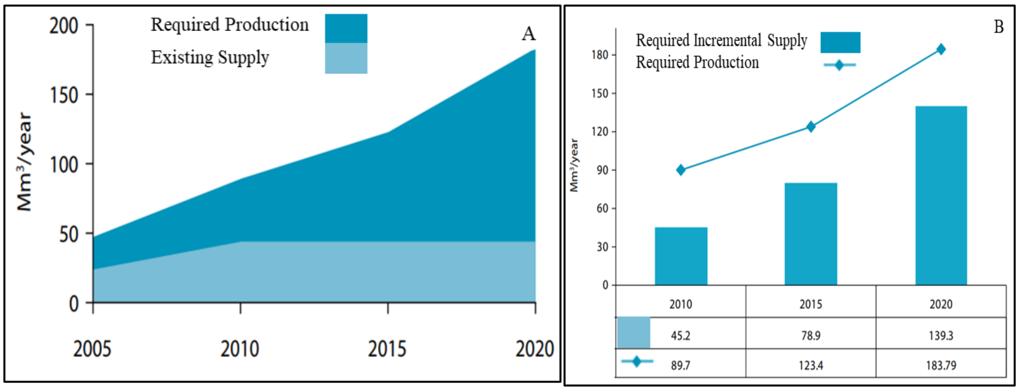

Figure 1. A-required Production and Existing Supply in Kabul City and B-Incremental bulk water production required to meet Kabul Requirements.(Beller and Stadtwerk, 2004)

With that in mind, the aims of this study are as follows:

- ✓ To offer a broad overview of urban water crises & evaluate the key drivers of water shortages,
- ✓ To explore the specific water crisis facing Kabul City and to analyze previous research, reports & data,
- ✓ To find the proper & sustainable groundwater management approach and to explore the key challenges confronted in water management in Kabul city.

METHODS & MATERIALS

When researching water crises in cities, choosing materials and methods is crucial to obtaining accurate and relevant information. Collecting secondary data from official government reports, databases, and published studies on water availability, demand, quality, and infrastructure in Kabul City is essential. In this paper, observational data of surface and groundwater has been collected from hydrological stations at several locations. This data includes river flow, groundwater, maps/charts, surveys, field observations, and government reports. Analyzing the collected data involves using statistical methods, qualitative analysis, GIS mapping, and modeling techniques to assess the current status of urban water resources and identify gaps and challenges. The methods used to investigate and analyze the data on addressing the urban water crisis with a focus on Kabul City include identifying the main challenges and issues related to the urban water crisis in Kabul City through a thorough literature review of academic papers, reports, and studies on water management, urbanization, and climate change in Afghanistan. Additionally, reviewing existing policies, regulations, and initiatives related to water supply, groundwater management, water quality, and climate change adaptation in Kabul City, as well as conducting statistical analysis and GIS map visualization, are crucial components of the research methodology.

Study area

Kabul is the biggest city in Afghanistan, with a population estimated at around 3 million in 2005, and is one of Asia's fastest-growing cities. It is located within the Kabul River basin. As the capital of Afghanistan, Kabul City covers an area of 1023 square kilometers and has an elevation of 1791 meters above sea level (CSRS, 2023; Noori & Nasimi, 2019). Kabul has remained the political, economic, and cultural center of Afghanistan. The city has 22 districts (Mutai & Ojal, 2020). Kabul has a dense population of around 7 million, with 80 percent of the population using healthy water daily. The population of Kabul has been growing in the last decade, with the current estimate exceeding 5 million. Significant risks in Kabul include flooding, landslides, earthquakes, and the influx of returnees and internally displaced persons coming to the city without adequate preparations, leading to environmental hazards such as air and water pollution (Wahid, 2010).

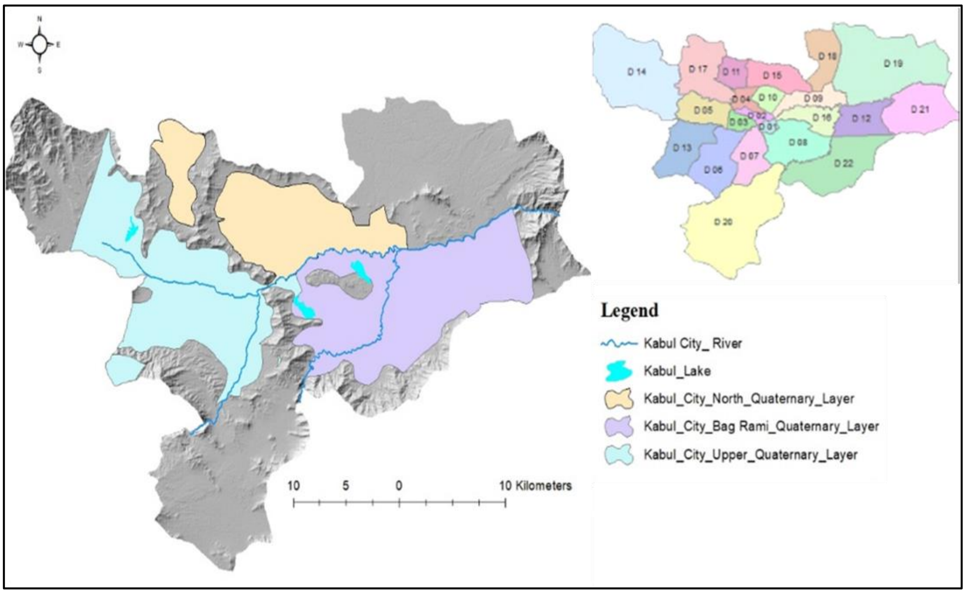

Figure 2: Study area (Kabul city) quaternary layer map. (MEW, 2023)

FINDINGS & DISCUSSION

All around the world, especially in developing countries, cities face an increasing threat of urban water shortages. Climate change poses a new challenge to cities' water supply and resources. As the country's capital, Kabul city has been grappling with significant water challenges, contributing to a water crisis. In the past, the people and rulers of Kabul city constructed streams and canals on both sides of the Kabul River for irrigation and beautification of their gardens and agricultural lands. Remnants of these water channels still exist, though some have disappeared over time, and others are currently at risk of disappearing. The following are historical channels constructed along this river: Bagh-e-Shahi Canal, Bagh-e-Bala Canal, Bagh-e-Paghman Canal, Bagh-e-Pul Canal, Bagh-e-Arghandeh Canal, Bagh-e-Bagrami Canal, Bagh-e-Kamalabad Canal, Bagh-e-Chindawol Canal, Bagh-e-Khoshal Khan Canal, and Bagh-e-Kabul Canal. These historical channels played a significant role in the expansion and prosperity of Kabul city, and their preservation is crucial for maintaining the cultural and historical heritage of the region. Unfortunately, Kabul is facing severe water scarcity and a crisis for various reasons and challenges. Addressing these issues is crucial for the sustainable development of Kabul city. Factors contributing to these problems include population growth in urban areas, lack of access to safe water, increased demand for water, sanitation, and hygiene services, strained existing infrastructure, urbanization, climate change, climate variability, frequent droughts, floods, water quality issues, aging infrastructure, water pollution, land use changes, inefficient water management, groundwater depletion, and misuse, conflict over water resources, economic development, insufficient use of surface water, lack of green spaces, disregard for the value of water, improvement of living standards, unequal distribution of freshwater, lack of investment, and more. Addressing these challenges requires a comprehensive approach involving government policies, public awareness, infrastructure development, sustainable water practices, public participation, and investment. Addressing the groundwater crisis in Kabul City necessitates long-term planning, commitment from various stakeholders, and investment. A comprehensive approach such as Integrated Water Resources Management (IWRM) is needed, combining regulatory measures, infrastructure development, water conservation practices, development of alternative water resources to reduce reliance on groundwater, promoting water conservation practices to reduce water demand, investment in water infrastructure, promoting rainwater harvesting systems, implementing groundwater recharge programs, conducting research on groundwater resources, monitoring groundwater levels, collaborating among governmental agencies, local authorities, communities, and stakeholders, implementing artificial groundwater recharge techniques, introducing water pricing mechanisms, and seeking support and collaboration from international organizations and donor agencies for additional resources, technical expertise, and funding to address the groundwater crisis in Kabul city. Therefore, implementing and adopting a comprehensive and sustainable approach is essential to mitigate the groundwater crisis in Kabul City and ensure the availability of water resources for current and future generations.

Climate

The average daily temperature in Kabul city is above 28.3 degrees Celsius, and the hottest month of the year in Kabul is June, where the average temperature is 33.8 degrees Celsius, while the average daily temperature during the cold season is less than 11.6 degrees Celsius. The coldest winter recorded in 2022 had the lowest temperature, around -15 degrees Celsius, compared to several past years. A comparison of winter seasons from 2010 to 2016 and 1960 to 1983 showed an increasing trend between 1.7 and 2.2 degrees Celsius. The snowy period of the year in Kabul city typically spans three months, from the 17th of January to the 18th of March (CSRS, 2023). According to a report by DACAAR, the average annual rainfall in Kabul from 1957-1977 was 330 mm. The Ministry of Agriculture, Irrigation, and Livestock (MAIL) reported that the average yearly rainfall in Kabul city during the years 2006-2016 was 327.6 mm. However, it is observed that the amount of rainfall in Kabul City has been decreasing, with the National Meteorological Department estimating it to be around 300mm.

Surface Water Resources

The Paghman, Maidan, and Logar rivers are the primary surface water sources that provide water to Kabul city. These rivers are fed by rainfall and snowmelt from the surrounding mountains, and Kabul city heavily relies on them for water. Three rivers pass through the

Kabul city region: the Kabul River, Paghman River, and Logar River, with Paghman River refilling the Qargha reservoir. These rivers flow only for a few months during snowmelt and rainfall. Kabul River's mean monthly runoff (Mm3) hydrograph is recorded at the Tang-E-Sayedan, Sang-i-Naweshta, and Qala-E-Malik hydrological stations. The hydrograph analysis shows that high flow volumes enter Kabul city annually through the Paghman, Maidan, and Logar rivers, the only surface water sources feeding into the city. Properly managing these flows can help reduce non-essential water consumption in Kabul City and utilize storage in small basins to transfer water to groundwater sources. This approach can contribute to a sustainable groundwater supply for Kabul city and improve its water potential. Analyzing the hydrographs and understanding the water flow patterns can enable authorities to develop strategies to reduce non-essential water usage and promote water conservation practices among residents, industries, and the agricultural sector. Capturing excess water during periods of river flow and storing it in small basins or reservoirs allows for groundwater recharge. By infiltrating the stored water into the ground, underground aquifers are replenished, serving as a future source of water supply. This method effectively utilizes surface water resources and ensures a sustainable water supply for Kabul city.

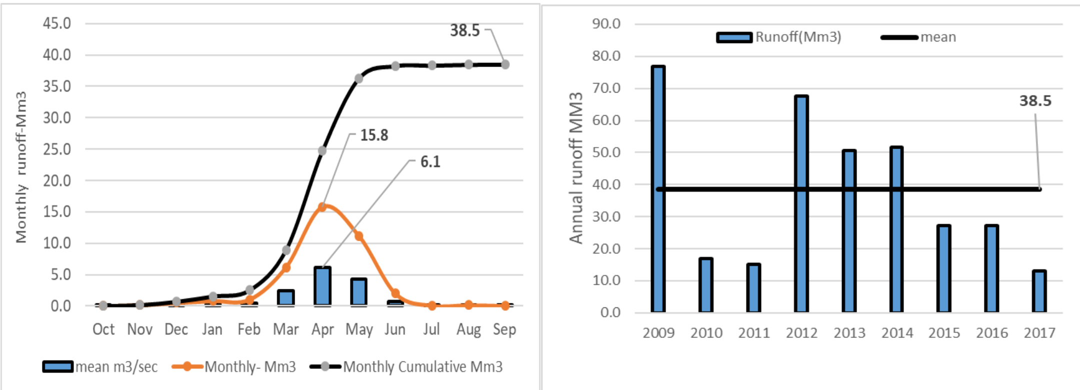

Figure 3: Monthly Runoff (Mm^3) at Qala-E-Malik hydrological station

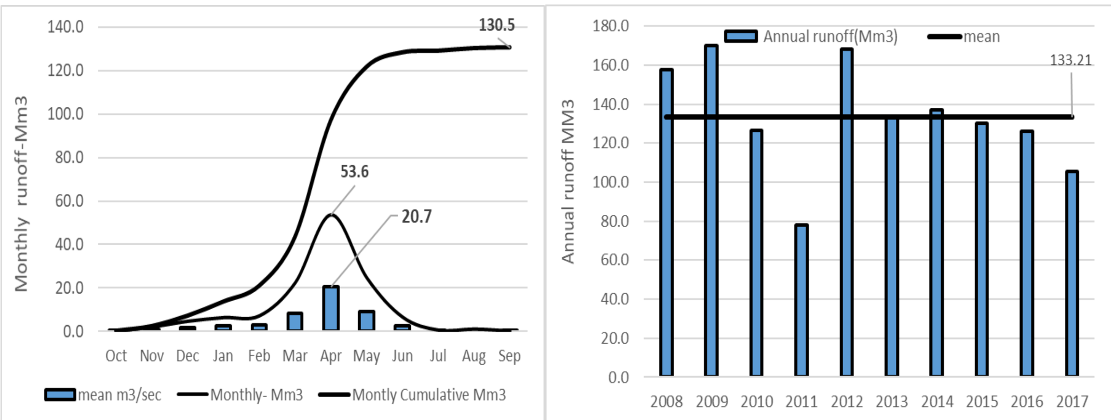

Figure 4: Monthly Runoff (Mm3) at Tangi-E-Sayedan hydrological station

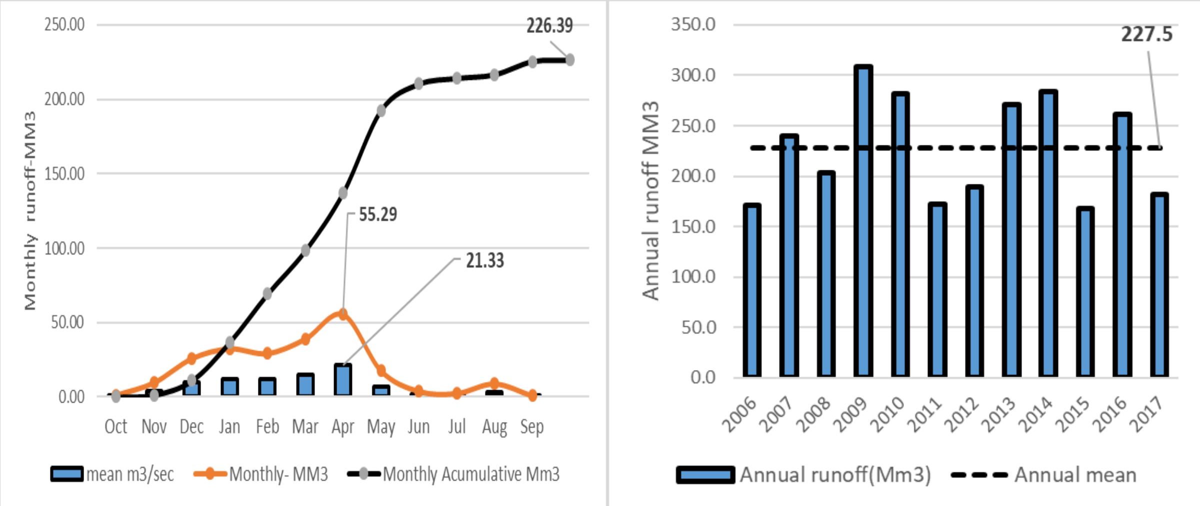

Figure 5: Monthly Runoff (Mm³) at Sang-E-Naweshta hydrological station

According to (Figures 3, 4 &5), there is a significant flow into the city of Kabul. Annually, an average of 38.5 Mm^3 of water flows from the Paghman Sub-River to Qargha Dam, 130 million cubic meters from the Maidan River, and 226 million cubic meters from the Logar River into the Kabul city area. The flow from the Paghman and Maidan Rivers comes from the upper part of the city, while the Logar River merges with the Kabul River in the lower part of the city. If these flows are properly managed, they can meet the water needs of Kabul city to a great extent and also potentially supply the underground water resources of Kabul city with the necessary measures. By managing the surface water flows and implementing practices like storage and groundwater recharge, the overall water potential of Kabul City can be enhanced. The trend analysis of river flow between 2006 and 2013 at Tangi-E-Gharu station shows a decline in annual river flow of 0.8 m^3/sec. Tangi-E-Gharu station is the conjunction point (outlet) of the Paghman, Maidan, and Logar rivers.

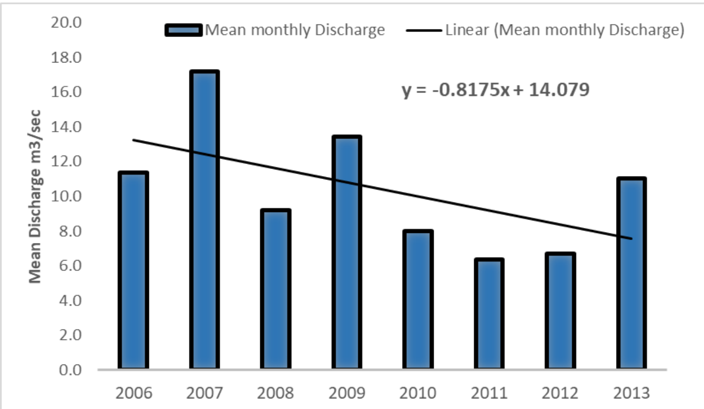

Fig 6: yearly mean discharge (m³/sec) at Tangi-E-Gharo hydrological station

Groundwater

Many people in Afghanistan, especially in big cities, primarily rely on groundwater rather than surface water for domestic, urban, industrial, agricultural, and other purposes. The groundwater discharge and recharge in Kabul City are influenced by various factors, including urbanization, population growth, climate, land use, geological conditions, and human activities. In Kabul city, groundwater discharge occurs through various natural and humaninduced processes. As water is extracted from aquifers, it reduces groundwater levels and contributes to groundwater discharge.

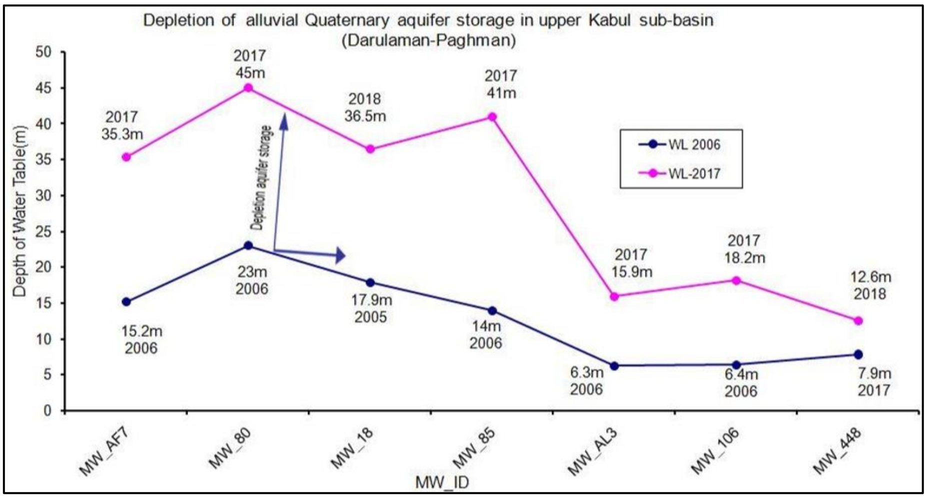

Fig 7: Depletion of alluvial Quaternary aquifer storage in upper Kabul sub-basin (Darulaman-Paghman) (MEW,2023)

The declining groundwater levels have several implications for water availability and sustainability. It can lead to reduced health yields, increased pumping energy requirements, and difficulties accessing water from existing wells. Moreover, the decline in groundwater levels can also impact ecosystems dependent on groundwater, such as wetlands and vegetation.

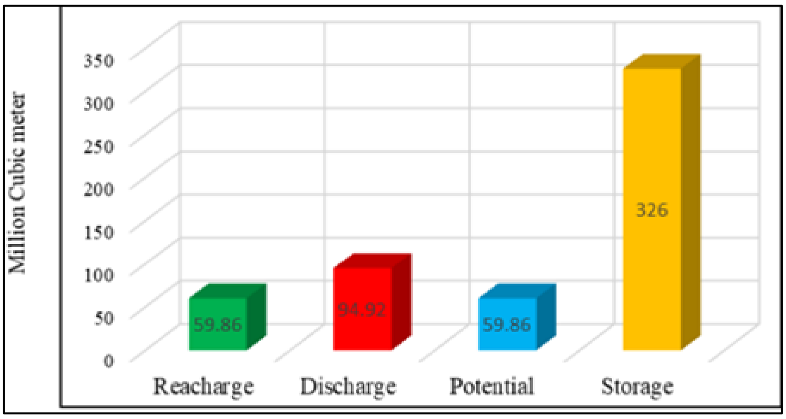

Fig 8: Kabul groundwater storage and balance in 2020 (MEW, 2023)

The extraction of groundwater exceeds its recharge rate, and over the past decade, the groundwater levels have experienced a decline of approximately 25-30 meters. Groundwater extraction in Kabul City has been higher than the natural recharge rate, which refers to the rate at which water restocks the aquifers through processes such as rainfall and infiltration. This imbalance occurs when the level of water extraction exceeds the level at which the aquifer can naturally recharge (Figure 10). Over the past decade, the overexploitation of groundwater resources in Kabul city has led to a significant decline in the groundwater table. The drop of approximately 25-30 meters indicates the extent to which the water table has dropped. This decline suggests unsustainable groundwater use and the need for better management practices.

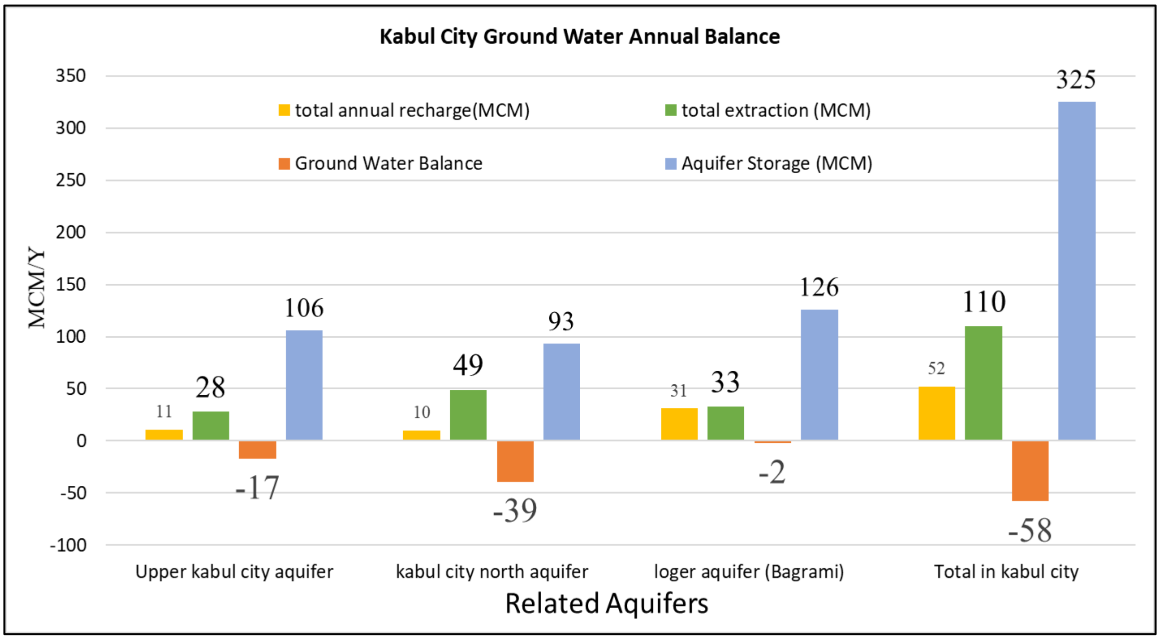

Fig 9: Imbalance between the rate of water extraction & aquifer recharge in Kabul city (MEW, 2023)

The annual recharge of groundwater is 51 Mm^3. This is the amount of water that naturally replenishes the underground aquifers annually. It is essential to maintain the groundwater resources and balance extraction and recharge. Proper management and conservation measures are needed to confirm that groundwater recharge rates aren't exceeded and that the resource remains available for future use. This paragraph discusses the groundwater balance in Kabul city and the projection of three water demand scenarios for the years 2021, 2025, and 2030. Water Demand Scenarios for 2021, 2025, and 2030 involve estimating the expected water requirements for various sectors in Kabul city. Here are three hypothetical scenarios for water demand in the specified years: In 2021, per capita drinking water requirements (for a population of 5 million) are calculated as 50 liters per day = 91 Mm^3, 80 liters per day = 136 Mm^3, and 120 liters per day = 219 Mm^3. These figures represent the estimated total volume of water required annually to meet the drinking water needs of the 5 million population, based on the specified per capita consumption rates. It's important to note that these calculations solely consider the drinking water requirements and do not account for other water needs such as sanitation, agriculture, or industrial purposes. Additionally, these estimates may vary depending on local factors, water availability, and consumption patterns.

In 2025, per capita, drinking water requirements (for a population of 6.5 million) are predicted as 50 liters per day = 118.6 Mm^3, 80 liters per day = 186.8 Mm^3, and 120 liters per day = 284.7 Mm^3. These figures represent the estimated total volume of water required annually to meet the drinking water needs of a population of 6.5 million, based on the specified per capita consumption rates and projected population size. In 2030, per capita, drinking water requirements (for a population of 8 million) are estimated as 50 liters per day = 146 million cubic meters, 80 liters per day = 233.6 Mm^3, and 120 liters per day = 350.4 Mm^3. These calculations are specific to 2030 and consider the projected population size.

CONCLUSION

Water scarcity is one of the main threats to urban water supply and resources caused by natural and human-made activities. The water crisis in Kabul is a complex issue influenced by various factors. Many districts in Kabul city face severe water shortages even when the river is full. This has led to increased groundwater extraction in the town and the need to transport water over longer distances. Although surface water is supplied to Kabul city via the Paghman, Maidan, and Logar Rivers, there is a lack of appropriate measures to manage the water flow upstream of Kabul city. As a result, many people rely on exploiting aquifers for water. Continued reliance on distant water supplies due to ongoing problems will likely result in social conflicts. A significant issue in Kabul city is wastewater discharge into the river. More than 50 percent of the city's population lives in informal settlements with poor access to quality water, forcing them to purchase water at higher prices from private sources. The reliance on groundwater as the primary source of drinking water in Kabul city has led to significant water quality challenges. Addressing the water scarcity problems in Kabul is not simple and requires action from society and the government. To combat declining groundwater levels, a sustainable groundwater management approach is crucial. This approach should include water conservation methods, the implementation of efficient irrigation techniques, the adoption of water pricing mechanisms to promote responsible water use, and the enforcement of regulations on groundwater extraction.

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