Sustainability of Water Resource Management in The Wake of Climate Change: A Case Study

Syed Azmat Ali Shah*, Ubaid ullah†, Tayyab Naqash‡, Muhammad Rizwan§ and Zeeshan Khan **

Abstract

The importance of water is well known. Millions of people worldwide suffer from water scarcity. Rainwater harvesting is an ancient technique for the utilization of water. In many developed and developing countries, they use rainwater harvesting to fulfill their daily water demand in elevated areas. We know the value of water when the well is dry. Water scarcity is an alarming issue worldwide. Climate change directly affects the global temperature, weather patterns, and underground water level. The study aims to identify water scarcity, the availability of water for drinking, agricultural practices, and flood risk control. This age-old practice is still acceptable by modern feasibility criteria in hilly areas. The study has been conducted in Gandao town district Mohmand, located at an elevated place, therefore cannot use groundwater. Community wells and surface water is their primary source. The methodology used for this study is by collecting preliminary data through visiting the area and other related data such as water discharge, population, and land distribution data obtained from their concerned departments. Watershed analysis was performed for calculating catchment area and relevant parameters. It has been found that the average annual precipitation based on data from the year 1960 to 2006 is 355.2 mm. The maximum surcharge level 2045.1 foams for a peak discharge of 13623 CFS. The results show us that proper rainwater management will minimize the water scarcity problems for up to 50 years for the people of Gandao town and its surrounding settlements. Furthermore, it will supply a sufficient amount of water for drinking and agricultural practices.

Keywords: Drinking Water, Water scarcity, Climate change, Rainwater harvesting.

Introduction

Pakistan is facing a twin problem of the water crisis and climate change; if things remain as usual are destined to cross the mark of absolute

* Lecturer, Center for Disaster Preparedness and Management, University of Peshawar, Pakistan. engrazmatalishah@uop.edu.pk

† Research Scholar, Disaster Management and Resilience, Coventry university UK. Ullahu2@coventry.ac.uk

‡ Associate Professor, Department of Civil Engineering, Islamic University of Al-Madinah Al-Munawara, Saudi Arabia, tayyab@iu.edu.sa

§ Associate professor, Sarhad University of Science & Information Technology, Pakistan. rizwan.civil@suit.edu.pk

**Lecturer, City University of Science and Information Technology, Pakistan. zeeshan.khan@cusit.edu.pk

water scarcity by 2025 (Iftikhar & Shahid, 2019). The United Nations Development Program (UNDP) and Pakistan Council of Reports Research in Water Resources (PCRWR) also warn the authorities about absolute water scarcity (PCRWR, 2021). According to a recent report by the International Monetary Fund (IMF), Pakistan is third globally among countries facing acute water shortages (Nabi et al., 2019). Pakistan is on its way to becoming the most water-stressed country in the region by 2040 and has the world's fourth-highest rate of water use. Its water intensity rate, the amount of water in cubic meters used per unit of GDP, is the world's highest. This suggests that no country's economy is more water-intensive than Pakistan. According to the International Monetary Fund (IMF), Pakistan's per capita annual water availability is 1,017 cubic meters, hazardously close to the scarcity threshold of 1,000 cubic meters. Back in 2009, Pakistan's water availability was about 1,500 cubic meters. Rising temperatures have accompanied water scarcity in Pakistan.

Moreover, the global climate change risk index has ranked Pakistan in the top ten most climate-change countries (Kreft et al.,2017). The floods of 2010 were proof of the climate change risk at hand. If the problem is not considered head-on, it can have socio-economic and security repercussions (Tirado et al. 2010). Therefore, different solutions are under consideration to alleviate the water shortage in Pakistan, such as constructing dams, changing cropping intensity, replacing water-intensive crops, etc. (Sulaiman et al. 2019) (Koop et al., 2015) (Luo et al.2020) (Hermanowicz, 2008).

However, Rainwater Harvesting remains one of the most efficient solutions to the looming water crisis. It can also be used to enhance flood control capabilities (Ngigi et al., 2007). Water harvesting remained the backbone of agriculture, especially in arid and semi-arid areas worldwide. Some of the earliest agriculture in the Middle East was based on the diversion of water flow onto agricultural fields. In India, water-harvesting is an ancient technique dating back some 4000 to 5000 years. In North America, the agriculture of many indigenous peoples in the solutions states was historically dependent on the simple method (Rojas et al., 2017) (Bellard et al. 2012) (Malhi et al., 2020) (Zhong & Huang, 2019) (Mathioudakis et al., 2020) (Bilali et al. 2020).

The Federal Administrated Tribal Areas (FATA) of Pakistan are blessed with natural wealth bounties, particularly water and lands. Water is the most valuable bounty which has remained untapped due to resource constraints. A very little development has been made in the past. In the areas where small dams have been constructed in the past, flood damages have been minimized. The stored water has been used to irrigate more lands and provide drinking water to the surrounding settlements

(NESPAK, 2021). The storage of water also helps to recharge the groundwater, which can eventually be reused by installing tube wells/wells to supplement the perennial supplies. Mohmand district is blessed with natural streams, which need to be developed on sustainable grounds to fulfill different settlements' drinking water demands. Ghalanai is the Headquarter of the Mohmand district. Ghalanai and surrounding territories are facing acute storage of drinking water. The growing requirements of drinking water can be met through rainwater harvesting techniques (Wurthman, 2019).

Many studies have been devoted to water resources, water quality management, and climate change. For example, (Blount & Kroepsch, 2019) explores how collaborative watershed groups emerge and play their role in tackling long-term, multijurisdictional, and watershed-scale management challenges. A study (Nylen, 2021) provides insights on managed aquifer recharge and multi-benefit water resources. A case study (Magliocca & Jimenez, 2020) introduces students to explore multiple and overlapping waters, energy, food demands, and ecological challenges present in Guanacaste province.

This study aims to identify water scarcity, availability of potable water, agricultural practices, and flood risk control in one of the FATA regions. The methodology used for this study is by collecting primary data through visiting the study area and the secondary data like watershed, water discharge, population, and land distribution data from their concerned departments.

Materials, data, and methodology

Transect walk and Questionnaire was adopted as a methodology for this research study and is based on the following steps. The study area's water scarcity and related issues are studied through visiting the study area and watersed analysis through ArcMap (refer to Figure 1, Figure 2, Figure 3, and Figure 4). A transect walk has been done and observed the socio-economic condition, land distribution, and water sources for drinking and agricultural practices. A questionnaire was distributed among different persons of different ages, the variables of underground water level, average annual rainfall data, floods routing data, and the study area's topography. The data is assessed and concluded. There are two types of data: primary and secondary. The primary data was collected through study area visits and questionnaires. The field observations were carried out in which various aspects of the research studies were examined. The vulnerable site was examined through direct field observation. The topographic information and the information about agriculture practices were also noticed.

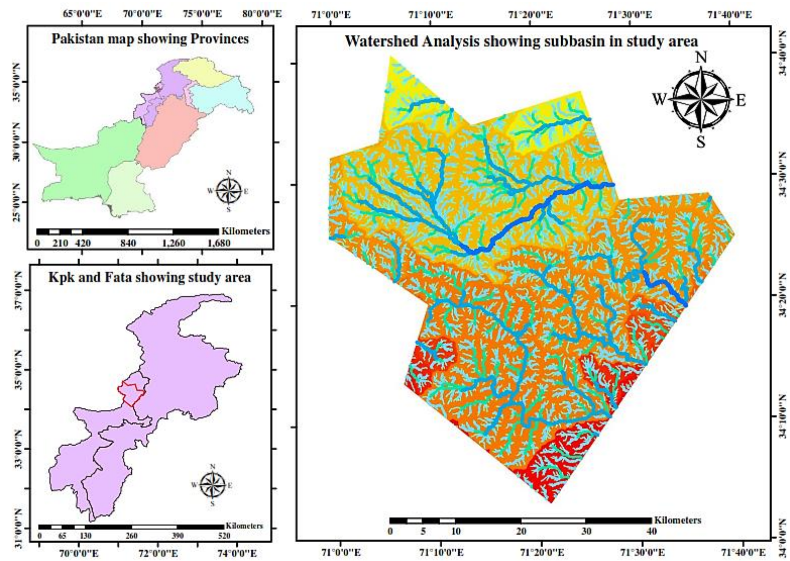

Figure 1: Watershed analysis of the study area showing it subbasin

Figure 2: Aerial view of the study area


Figure 3: Water supply line at Gandao town **Figure 4: Agricultural Land of the study area**

The secondary data was collected from various sources. The data regarding the rain precipitation were collected from Pakistan Metrological Department (PMD). The previous work and studies were done on Rain Water Harvesting in hilly areas. Earlier records of the data for 60 years and the flood data were collected from the irrigation department.

Questionnaire and results

The questionnaire data has been collected and evaluated and is shown in Figure 5.

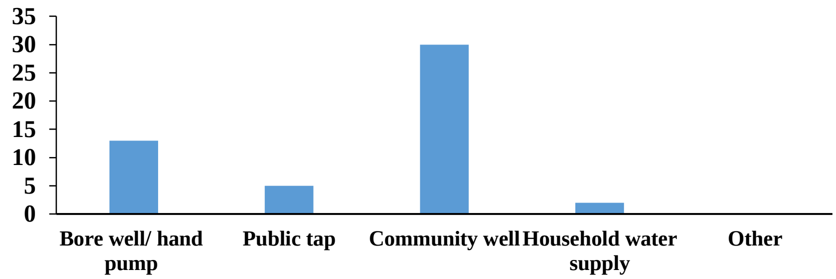

Figure 5: Drinking water available (neighborhood)

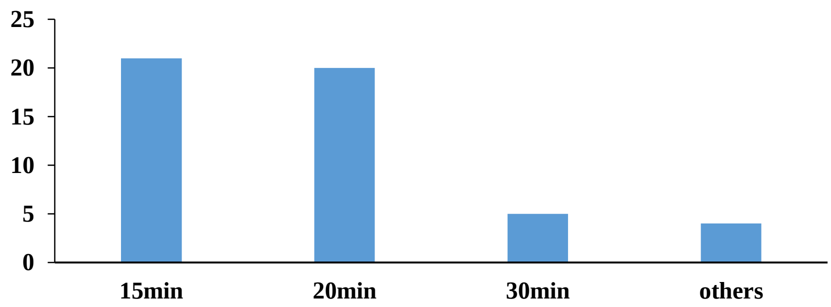

Figure 6: Time required (fetching)

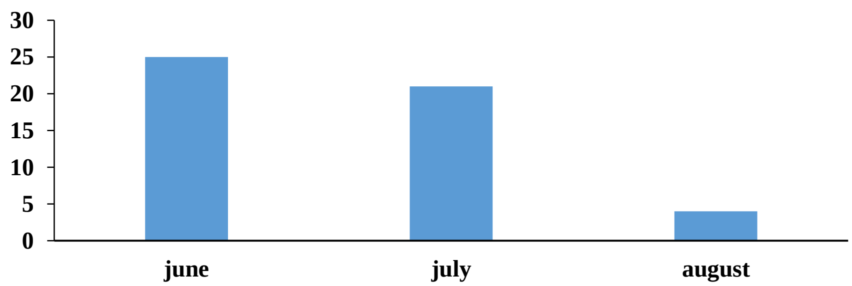

Figure 7: Water scarcity season

The data indicated that the primary source of water is available in the community wells and, in some areas, bore wells, which do not fulfill the required amount of water. Figure 8 shows the rain precipitation data of the study area. In contrast, Figure 9 shows the flood routing through the Gandao town torrent. Furthermore, it shows the rain in inches of the study area Gandao district Mohmand. The highest rainfall occurred in 1985 is 72.4 mm and lowest year 7.7 mm.

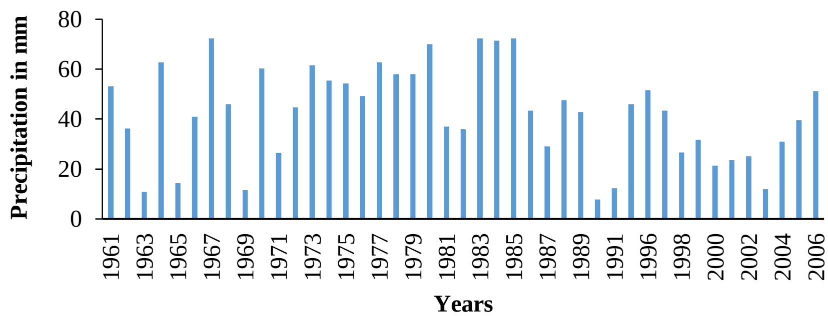

Figure 8: Rain precipitation data in mm (1961-2006)

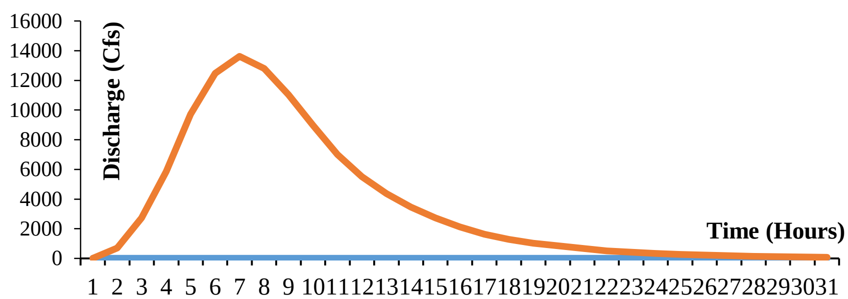

Figure 9: flood routing data

Figure 9 shows that the data indicate that the flood routing at peak season is more than 12500c. The land use pattern of the region in Mohmand district as reported in Agricultural statistics is given in Table 1. The district's land use statistic reveals that a significant portion of 93 % of the land is uncultivated. The cultivated area is only 17,182 hectares. The net shown area is 10179 hectares.

Table 1:
Agricultural Land Use

Area	hectares
Cultivated area	17182
Net shown	10179
Current fellow	7003
Uncultivated area	212438
Waste area	15 372
Forest area	3732
Not available for cultivation	193, 834
Total area	229,620

Population data

Table 2 shows the average population of district Mohmand as per the census of 1998; the population growth rate is 2.1 % and in some areas above 3 %.

Table 2:
Average Population data of Mohmand district

Name of village	Population
Ghalanai Khas	2549
Ghalanai Colony	1563
Miangano killay	2594
Durba khel	8708
Total	154414

The projected population of nearby villages is discussed in this section. To estimate the water demand for the next decade, it is imperative to project the population of local villages for the next decades at the reported growth rate. The population welfare department, the Government of Khyber Pakhtunkhwa, has published the population growth rate as 2.1%. The population growth rate of the tehsil Haleemzai was 3.7% in the year 2005. To be conservative, the population growth rate has been assumed as 3 %. Table 3 shows the population increase at the average growth rate.

The Year-wise projected population of nearby villages has been calculated. It is observed that about a 100% increase in population is expected in the nearby towns by 2050. Given this, Table 4 shows the average water demand for the average population in the study area. The supply of water to nearby villages depends on the civic facilities in the area.

Table 3:
Projected population of nearby villages

S.No	Years	Population Increased	Cumulative Population
1	1998		15414
2	2007	4648	19899
3	2012	3169	23069
4	2017	3674	26743
5	2022	4259	31002
6	2027	4938	35940
7	2033	5724	41664
8	2037	6636	48300
9	2042	7693	55993
10	2047	8918	64912
11	2052	10339	75250
12	2057	11985	87236

The local villages will be supplied 20 gallons per capita per day. Based on these criteria, the projected water supply-demand is given as below.

Table: 4:
Estimated Water Demand

Year	Population	Water demand			
		Gallon/day	Cusecs	Acre-ft/ month	Acre ft/year
2007	15251	397982	0.62	37.9	454
2012	19899	461370	0.72	43.9	527
2017	23069	534854	0.83	50.9	611
2022	26743	620043	O.96	59.0	708
2027	31002	718800	1.11	68.4	821
2032	35940	833286	1.29	79.3	951
2037	41664	966007	1.50	91.9	1103
2042	48300	1119866	1.74	106.5	1279
2047	55993	1298232	2.01	123.5	1482
2052	64912	1505007	2.33	143.2	1718
2057	75250	397982	2.70	166	1992

Discussion and Conclusions

The overall results revealed that the study area's physical characteristics of Gandao town are elevated, and 93% of land remains barren and uncultivated.

1. The maximum population is lower middle class while the bore water is available at 250 m minimum. The local people can hardly support economically. Agriculture mainly depends on rainwater. When the rainwater is not available, the remaining agricultural land remains uncultivated that year.
2. In summer, they face severe water scarcity in June and July, even sometimes in august. Since these months usually have a rainy

monsoon season, which leads to secondary hazards like flash floods. The floodwater flow at the Gandao torrent is 12800 cuses in peak season.

3. The Gandao torrent has a large catchment area. The primary water source is the tube wells that supply water to the Gandao town and surrounding settlements. However, the available water supply is insufficient and does not fulfill their needs.
4. All the data shows that by properly managing rainwater in the Gandao town district Mohmand, a check dam should be constructed to provide the water reservoir. This reservoir can be utilized for clean water supply after filtration plant supported by green energy to Gandao town and its surrounding settlements and supply water for agricultural practices. Nevertheless, on the other hand, the underground water level also recharges.
5. The area's socioeconomic condition reveals that the people are deficient in basic needs, with the main livelihood based on agriculture. Due to a shortage of highly insufficient water to meet the drinking purposes, about 90% of the cultivated area is laying waste and large fellows in both seasons. The primary source of clean water is tube wells which do not supply the required amount of water.
6. The rain precipitation and water flow data show excess rain, which can be used for household and general uses by proper management. The area is elevated, and having steep slopes and high precipitation can be systematically utilized for the study area's developmental process.

Conflict of interest

The authors declare no conflict of interest for the publication of this research work.

References

C. Bellard, C. Bertelsmeier, P. Leadley, W. Thuiller, and F. Courchamp, “Impacts of climate change on the future of biodiversity,” Ecology Letters. 2012, doi: 10.1111/j.1461-0248.2011.01736.x.

D. G. Mathioudakis, A. G. Mathioudakis, and G. A. Mathioudakis, “Climate change and human health,” Arch. Hell. Med., 2020, doi: 10.3329/jssmc.v8i1.31495.

G. Nabi, M. Ali, S. Khan, and S. Kumar, “The crisis of water shortage and pollution in Pakistan: risk to public health, biodiversity, and ecosystem,” Environmental Science and Pollution Research. 2019, doi: 10.1007/s11356-019-04483-w.

H. El Bilali, I. H. N. Bassole, L. Dambo, and S. Berjan, "Climate change and food security," Agric. For., 2020, doi: 10.17707/AgricultForest.66.3.16.

K. Blount and A. Kroepsch, "Improving the resilience of water resources after wildfire through collaborative watershed management: A case study from Colorado," Case Stud. Environ., 2019, doi: 10.1525/cse.2019.sc.960306.

K . Wurthmann, "Assessing storage requirements, water and energy savings, and costs associated with a residential rainwater harvesting system deployed across two counties in Southeast Florida", Journal of Environmental Management, Vol. 252, 2019.

M. C. Tirado, R. Clarke, L. A. Jaykus, A. McQuatters-Gollop, and J. M. Frank, "Climate change and food safety: A review," Food Res. Int., 2010, doi: 10.1016/j.foodres.2010.07.003.

M. M. Rojas-Downing, A. P. Nejadhashemi, T. Harrigan, and S. A. Woznicki, "Climate change and livestock: Impacts, adaptation, and mitigation," Climate Risk Management. 2017, doi: 10.1016/j.crm.2017.02.001.

M. N. Iftikhar and M. Shahid, "The institutional and urban design of Gwadar City," Int. Growth Cent. IGC, 2019.

N. G. Nylen, "Surface Water Quality Regulation as a Driver for Groundwater Recharge," Case Stud. Environ., 2021, doi: 10.1525/cse.2020.1124592.

N. R. Magliocca and E. Gonzalez-Jimenez, "Costa Rica's water paradox: Linking rainforests and droughts through the water-energy-food-environment nexus in Guanacaste province," Case Stud. Environ., 2020, doi: 10.1525/cse.2019.002253.

"NESPAK National Engineering Services Pakistan." http://www.nespak.com.pk/ (accessed Apr. 05, 2021).

P. Luo et al., "Historical assessment and future sustainability challenges of Egyptian water resources management," J. Clean. Prod., 2020, doi: 10.1016/j.jclepro.2020.121154.

"Pakistan Council of Research In Water Resources – PCRWR." http://pcrwr.gov.pk/ (accessed Apr. 05, 2021).

"Pakistan Meteorological Department." https://www.pmd.gov.pk/en/ (accessed Apr. 05, 2021).

S. Kreft, D. Eckstein, and I. Melchior, Global Climate Risk Index 2017. 2017.

S. H. A. Koop and C. J. van Leeuwen, "Assessment of the Sustainability of Water Resources Management: A Critical Review of the City Blueprint Approach," Water Resour. Manag., 2015, doi: 10.1007/s11269-015-1139-z.

S. O. Sulaiman, A. H. Kamel, K. N. Sayl, and M. Y. Alfadhel, "Water resources management and sustainability over the Western desert of Iraq," Environ. Earth Sci., 2019, doi: 10.1007/s12665-019-8510-y.

S. Ngigi, H. Savenije, and F. Gichuki, "Land use changes and hydrological impacts related to up-scaling of rainwater harvesting …," Land use policy, 2007.

S. W. Hermanowicz, "Sustainability in water resources management: Changes in meaning and perception," Sustain. Sci., 2008, doi: 10.1007/s11625-008-0055-z.

S. Zhong and C. Huang, "Climate change and human health: Risks and responses," Kexue Tongbao/Chinese Sci. Bull., 2019, doi: 10.1360/N972018-00898.

Y. Malhi et al., "Climate change and ecosystems: Threats, opportunities and solutions," Philosophical Transactions of the Royal Society B: Biological Sciences. 2020, doi: 10.1098/rstb.2019.0104.