Climate Change Impact on Water Resources: Challenges for Sustainable Development in India with a Focus on Rajasthan

THESIS

Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

SUCHITRA PANDEY
2019PHXF0025P

Under the Supervision of

Prof. Geetilaxmi Mohapatra
and

Co-supervision of

Prof. Rahul Arora

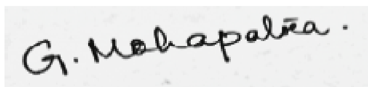
BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE PILANI
333031 (RAJASTHAN) INDIA

2024

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE
PILANI - 333031 (RAJASTHAN) INDIA

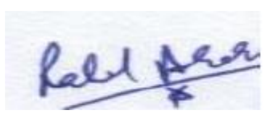
<u>CERTIFICATE</u>

This is to certify that the thesis entitled **“Climate Change Impact on Water Resources: Challenges for Sustainable Development in India with a Focus on Rajasthan”** submitted by **Suchitra Pandey,** ID. No. **2019PHXF0025P** for the award of Ph.D. of the Institute embodies original work done by her under my supervision.



Signature of the Supervisor
Name in capital letters : **PROF. GEETILAXMI MOHAPATRA**
Designation : Associate Professor
Department of Economics & Finance
Birla Institute of Technology & Science
PILANI - 333031(Rajasthan)

Date: 30/09/2024



Signature of the Co-Supervisor
Name in capital letters : **PROF. RAHUL ARORA**
Designation : Assistant Professor
Department of Economics & Finance
Birla Institute of Technology & Science
PILANI - 333031(Rajasthan)

Date: 30/09/2024

ACKNOWLEDGEMENT

I am profoundly grateful for the unwavering support and blessings bestowed upon me by God and my parents, whose guidance has been the cornerstone of my journey in research. To my mother, Mrs. Anita Pandey, my father, Mr. Ajay Kumar Pandey, and my grandmother, Smt. Rama Pandey, brother Arunabh Pandey, and sister Apporva Pandey, I am grateful for their constant encouragement and unwavering belief in my aspirations.

I want to express my deep gratitude to Prof. V. Ramgopal Rao, Vice-Chancellor of BITS Pilani, for making all the necessary facilities available for the successful completion of the study. I am highly grateful to Prof. Sudhirkumar Barai, Director, BITS Pilani, Pilani campus, for his inspiration. My pleasant duty is to thank Prof. Shamik Chakraborty, Associate Dean, and Prof. Venkata Vamsi Krishna Venuganti, Dean, Academic Graduate Studies and Research Division (AGSRD), for their constant encouragement.

I sincerely thank my Supervisor, Prof. Geetilaxmi Mohapatra, and Co-Supervisor, Prof. Rahul Arora, for their motivation, invaluable guidance, and support throughout the study. Despite their numerous academic obligations, they always make time for me. With their direction and contribution, this thesis was completed. Their constant counseling and inspiration enabled me to look forward and go in the right direction.

I thank Prof. Krishna M (Head, Department of Economics and Finance) for providing a positive academic work environment. I am solemnly indebted to the Doctoral Advisory Committee

(DAC) members Prof. N.V. Muralidhar Rao and Prof. Arun Kumar Giri for their help and guidance and for providing valuable input during the research journey.

I also express my deepest gratitude to all the respondents from the sample villages who actively participated in the field survey. With their assistance and contributions, this report was completed. Special thanks to Dr. Vikash Pawariya, a faculty member at Agriculture University, Jodhpur, and Ms. Meera George for their assistance during the survey.

I want to express heartfelt appreciation to my husband, Mr. Hitesh Kamboj, who has been my greatest strength throughout this journey. He has continuously reassured me that my efforts would eventually fructify and support me emotionally during difficult times.

Lastly, I am grateful to all the department scholars and faculty members for their support and encouragement throughout this research endeavor. Also, I thank the supporting staff, Mr. Suresh and Mr. Sushil Kumar Saini (Department of Economics & Finance), for their help.

SUCHITRA PANDEY

ABSTRACT

Water is a fundamental element crucial for sustaining life, driving economic growth, and achieving sustainable development goals. Its availability directly influences food security, human health, education, and gender equity. Owing to this enormous importance, access to safe and sufficient water has been recognized as a human right. Still, billions of people lack access to adequate water supply. Further, climate change and the intensification of anthropogenic activities are exacerbating the water demand, accelerating the depletion of water resources, and exacerbating water stress, one of the foremost challenges confronting the global community in the 21st century.

India comes under critical regions of the world where the water resources have a higher sensitivity to global changes. The renewable freshwater resources per capita continue to decline in India, and projections indicate a decline in renewable freshwater resources per capita to 1140 by 2050, indicative of an impending state of water stress. Despite significant progress achieved since the nation's liberalization in the early 1990s, India now confronts a pivotal question: Can it sustain its developmental trajectory amidst escalating water challenges?

The study aims to address this inquiry by investigating the intricate relationship between water and development. To comprehensively assess development, the Multidimensional Poverty Index (MPI) is employed, while the multifaceted nature of water scarcity is captured by utilizing the Water Poverty Index (WPI). In the study, the WPI has been modified to construct household-level WPI (MWPI) to account for the differences in the water status of households. Also, acknowledging the potential variances in poverty dynamics between urban and rural regions, the study conducts separate analyses for these regions. Additionally, considering the inevitable role of policies in combatting water woes, the study also analyses the impact of drinking water policies.

Empirical observations reveal a positive and statistically significant association between multidimensional poverty and water poverty, with the extent of the relationship being greater in rural areas. The study also found that drinking water policies significantly influence MWPI and indirectly impact MPI through MWPI.

Given the interrelationship between water poverty and multidimensional poverty, it becomes imperative for India to combat its escalating water challenges to achieve and maintain its developmental objectives. To effectively address these challenges, accurate monitoring of the water situation is indispensable for informed policymaking. To this end, in this study, WPI is utilized to comprehend the temporal trends and spatial variations in water scarcity across Indian states. The WPI is constructed for 2012 and 2018, enabling a comprehensive assessment of the evolving water dynamics. Further, descriptive statistics were used to show the required changes. The results revealed that although India's overall water status improved from 2012 to 2018, certain states experienced a decline due to deterioration in the environment and resource components. Also, it was found that Rajasthan maintained its status as one of the states with the most severe water poverty conditions in both 2012 and 2018.

Given this, the study undertakes a comprehensive investigation into the water poverty scenario in Rajasthan. For this, MWPI has been constructed using data from the National Sample Survey (NSS). To understand the spatial and temporal change, MWPI has been computed for all 33 districts for 2012 and 2018. The results indicate an overall improvement in the state's water poverty situation from 2012 to 2018, notwithstanding a decline observed in the resource component of the index.

A thorough analysis of groundwater levels and quality is conducted to further comprehend the intricacies of Rajasthan's water situation, particularly in light of climate change and the intensification of anthropogenic activities. Given the limited availability of surface water, the state heavily relies on groundwater resources, particularly in its arid and semi-arid regions. Consequently, the study examines groundwater levels and quality in arid (Barmer and Jodhpur) and semi-arid (Ajmer, Jaipur, Dausa, and Tonk) districts. To examine groundwater quality, 15 water quality parameters from 84 stations in arid and semi-arid districts were analyzed using annual data from 2000 to 2018. Statistical methods such as descriptive test statistics, Mann-Kendall (MK) test, Sen's slope estimation, and Principal component analysis (PCA) were used to analyze the hadrochemical parameters. While World Health Organization (WHO) and Bureau of Indian Standards (BIS) guidelines were used to assess the suitability of groundwater for domestic purposes, sodium adsorption ratio (SAR), electrical conductivity (EC), and United States Salinity (USSL) diagrams were used for irrigation suitability. Further Generalized Additive Model (GAM) was used to explore the effect of climatic (precipitation, temperature) and anthropogenic (net irrigated area (NIA), fertilizer usage, industrialization, and population) variables on groundwater quality.

Similarly, in the study, the analysis of groundwater level fluctuations and the impact of climatic and anthropogenic factors on it, encompassing variables such as temperature, precipitation, gross district product (DGDP), net irrigated area (NIA), and population, spanning the period from 1994 to 2020 is made. Focusing on the depth to groundwater level (DGWL), data from 113 wells/piezometers situated across arid (Barmer and Jodhpur) and semi-arid (Jaipur, Ajmer, Dausa, and Tonk) districts of Rajasthan, India, are examined. Employing statistical methodologies, annual and seasonal trends in DGWL are scrutinized, while the GAM is used to analyze the influence exerted by climatic and anthropogenic variables on DGWL dynamics. The findings reveal increasing and decreasing trends in DGWL across the examined districts, paralleled

by corresponding fluctuations in water quality parameters. Notably, the study found the predominant influence of anthropogenic variables over climatic factors on groundwater quality and quantity within the selected districts.

To further understand the water situation in selected six districts (arid and semi-arid), the study, using primary and secondary data, has analyzed households' perceptions of water-related issues, vulnerability to water scarcity, adaptation strategies, and determinants influencing these strategies. Using the Intergovernmental Panel on Climate Change (IPCC) framework, a vulnerability index to water scarcity at the household level was created. Further, logistic regression has been used to analyze the determinants influencing adaptation strategies. Results highlight widespread recognition of water challenges. Vulnerability to water scarcity varies across districts, with Tonk identified as the most vulnerable. Supply-side management, particularly water storage, is the predominant adaptation strategy. Migration, external support, land ownership, and perception of water scarcity emerge as significant determinants. Household characteristics such as age, gender, education, income, and occupation also influence adaptation strategies.

Based on the findings, the study advocates for enhanced water resource management and comprehensive policy implementation to effectively alleviate poverty. Urgent actions include enforcing regulations, promoting water-efficient practices, rejuvenating traditional water harvesting methods, and providing financial support for vulnerable groups to mitigate water stress. Also, the study suggests that anthropogenic parameters must be addressed while formulating groundwater resource management policies.

Keywords: Water scarcity; Development; Poverty; Multidimensional Poverty Index (MPI); Water Poverty Index (WPI); India; Rajasthan; Climate change; Anthropogenic activities; Groundwater levels; Groundwater quality; Arid regions; Semi-arid regions; Primary data;

Perception; Vulnerability; Adaptation; Logistic regression; Supply-side management; Migration; External support; Household characteristics; Groundwater resource management; Policy implementation; Generalized additive models (GAM); Mann-Kendall (MK) test; Drinking suitability; Irrigation suitability

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

Abbreviation	Expansion
AIC	Akaike Information Criterion
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BIC	Bayesian Information Criterion
BIS	Bureau of Indian Standards
CAG	Comptroller and Auditor General of India
CGWB	Central Ground Water Board
DAE	Department of Atomic Energy
DGDP	Gross District Product
DGWL	Depth to Groundwater Level
EC	Electrical Conductivity
GAM	Generalized Additive Model
GDP	Gross Domestic Product
GOI	Government of India
GOR	Government of Rajasthan
IBEF	India Brand Equity Foundation
IPCC	Intergovernmental Panel on Climate Change
IRF	Irrigation Returns Flow
MK	Mann-Kendall
MPI	Multidimensional Poverty Index

MWPI	Household-Level/Modified WPI
NASA Power	National Aeronautics and Space Administration Prediction of Worldwide Energy Resources
NIA	Net Irrigated Area
NRDWP	National Rural Drinking Water Programme
NSS	National Sample Survey
PCA	Principal Component Analysis
SAR	Sodium Adsorption Ratio
SCM	Smart Cities Mission
SDGs	Sustainable Development Goals
TERI	The Energy and Resources Institute
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
USSL	United States Salinity Diagram
WEF	World Economic Forum
WHO	World Health Organization
WPI	Water Poverty Index

Chapter 1

INTRODUCTION

1.1 Background of the study

Water unavailability has emerged as one of the world's greatest threats to human life. It is declared one of the threats with the highest potential impact and a greater degree of likelihood (WEF, 2021). Data shows that ever since the 1980s, global freshwater use has been continuously growing; although the world's richest countries are to be blamed for it, there has also been a continuously growing trend in developing regions as well (UNESCO, 2021). As a matter of fact, as of 2020, 2 billion people around the world did not have access to an improve source of water (UNICEF, 2021). While countries like Canada have roughly 79,000 cubic meters per capita renewable water resources available, developing countries like India and Nigeria have merely 1427 cubic meters per capita and 1499 cubic meters per capita, respectively (Tiseo, 2021). This indicates that these regions are more prone to water stress.

Anthropogenic factors such as the growing population, exponential rate of economic development, and rapid urbanization have caused drastic changes in consumption patterns, resulting in the rapid depletion of scarce water resources (Prabha et al., 2020; UN, 2021). The anthropogenic demand for groundwater is rising, resulting in the over-drafting of groundwater resources (Swain et al.,2022; Jun and Chen, 2001). Globally, in the 20th century, water use has grown at a rate more than twice the rate of population increase. To make the matter more severe, increased temperature and change in precipitation as a result of climate change are expected to increase water demand further (Parry et al., 2007; Pathak et al., 2014; Wang et al., 2017; UNESCO, 2020). Previous studies have reported that industrialization and urbanization are rapidly decreasing groundwater levels (Aggarwal et al., 2009; Roy et al., 2022; Swain et al., 2022) and drying shallow dug wells (Bera et al., 2022; Tripathi and Issac, 2016). The rapid growth of agriculture and the social economy adds to the anthropogenic stress on water supplies (Liu et al., 2018; Swain et al., 2022; Zhou et al., 2015).

Further, studies have shown that intensive anthropogenic activities are exacerbating the contamination of water resources (Ali and Ali, 2018; Rahman et al., 2021). Industrialization and increasing population, generally accompanied by a degrading environment, adds to the anthropogenic stress on groundwater quality (Silva et al., 2017; Wakejo et al., 2022; Rao et al., 2022). Reckless and improper disposal of industrial effluents enriched in various chemical, organic, inorganic, and biological pollutants leach or percolate into the groundwater, significantly impacting the hydrochemistry of groundwater (Esmeray and Gokcekli, 2020; Zacchaeus et al., 2020; Abascal et al., 2022). Untreated domestic sewage, inadequate sanitation facilities, and open defecation have also been reported to impact groundwater quality (Silva et al., 2017; Carrard et al., 2019; Rao et al., 2021; Abascal et al., 2022; Wakejo et al., 2022).

Worldwide studies have indicated that agricultural intensification resulting from the indiscriminate and intensive use of fertilizers is responsible for around 70 percent of groundwater contamination (Lwimbo et al., 2019). Excessive groundwater abstraction for irrigation and irrigation returns flow (IRF), a substantial source of groundwater recharge, particularly in agriculturally dominant regions, have also been found to significantly affect the ion concentration in groundwater (Foster et al., 2018; Merz and Lischeid, 2019; Rotiroti et al., 2019; Rao et al., 2022). In addition to anthropogenic activities, climate change significantly influences water resources through a complex process (Dhal and Swain, 2022; Masroor et al., 2021; Muenratch et al., 2022; Sharan et al., 2023).

IPCC refers to climate change as any change in climate over time, whether due to natural variability or as a result of human activity (Parry et al., 2007). Climate change affects and is affected by the terrestrial water cycle through various feedbacks and interactions that are still not fully understood or measurable (UNESCO, 2020). The melting of glaciers is a stark example of how temperatures directly affect water supplies, at least in the short term. But as glaciers continue to shrink, the amount of water they contribute could decrease, adding another layer of complexity to the situation (Akhundzadah et al., 2020). According to Labat et al. (2004) and Milly et al. (2005), as temperatures go up, so does the amount of water running off into rivers and streams in certain regions. However, the relationship is more complicated in other areas, with rising temperatures leading to less water available, as seen in parts of Africa. Shifts in precipitation regimes also impact water availability and can change river flow seasonality (Okafor and Ogbu, 2018; Duan and Cai, 2018; Abiy et al., 2019).

Global warming and reduced precipitation result in intensification of eutrophication (Tian et al., 2020). Additionally, droughts significantly affect water temperature, dissolved oxygen concentration, eutrophication, and concentration of major and heavy elements (Vliet and Zwolsman, 2008). Groundwater reserves are equally susceptible to climate variability (Chen et al., 2004; Salem et al., 2018). In particular, climate-induced precipitation variability has been found to significantly influence groundwater recharge and abstraction (Kashem et al., 2022; Kong et al., 2022; Narjary et al., 2014; Sishodia et al., 2016), as precipitation is the most significant component of the hydrologic cycle and the principal source of groundwater recharge (Dey et al., 2020). Similarly, changes in the rate of temperature caused by climate change aggravate groundwater vulnerability (Halder et al., 2020; Keerthana and Nair, 2022). In shallow aquifers, temperature significantly influences groundwater levels more than precipitation (Chen et al., 2004). Studies have indicated that global warming is causing long-term droughts in several regions of the world (Naumann et al., 2018). According to projections, the increase in global mean temperature will reduce groundwater recharge by 30 % over 4 % of land area and by 70 % over 1 % of land area globally (Portmann et al., 2013).

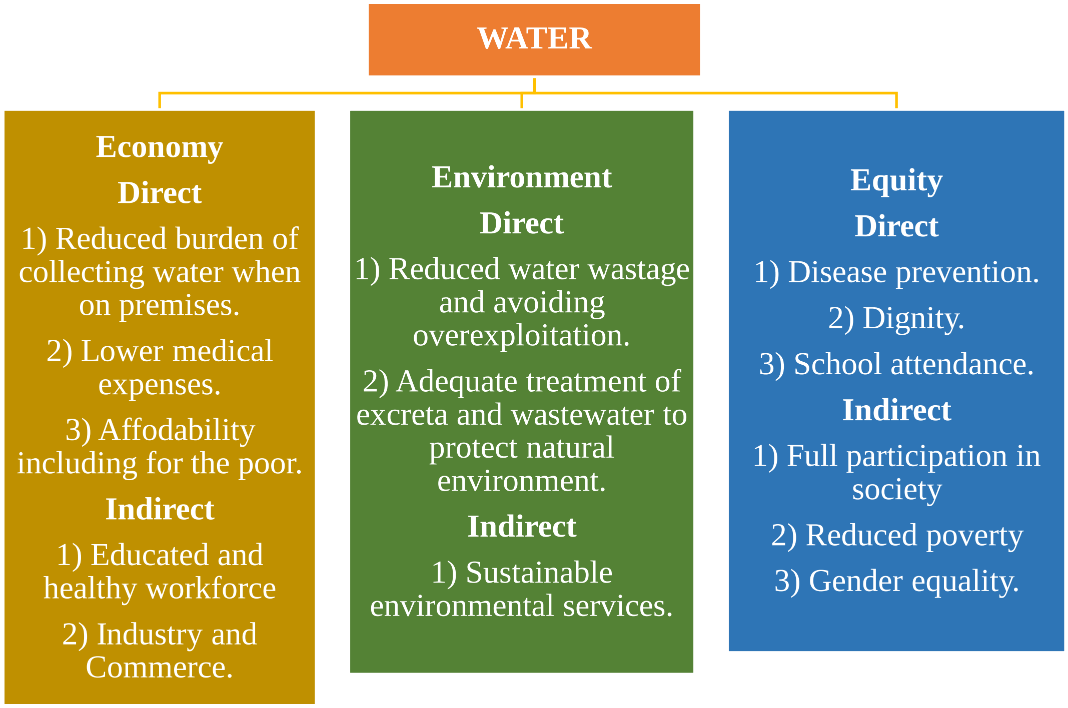
Further, rising sea levels due to climate change pose challenges, such as increased groundwater salinization (Parry et al., 2007). Seasonal flooding events, exacerbated by extreme precipitation, have been linked to elevated concentrations of ions and metals in groundwater (Aladejana et al., 2020). Hence, anthropogenic activities accompanied with changes in temperature, volume, timing, and intensity of precipitation have a significant impact on the quality as well as quantity of surface and groundwater resources. The erratic supply of water, accompanied with deteriorating quality and increasing demand, can exacerbate water stress, which is one of the main problems that the world will have to face in the 21st century if not controlled in time. (UNESCO, 2020).

Being a building block of life, water is critical and central to achieving sustainable development goals (SDGs). In the Anthropocene era, characterized by human-driven impacts on the planet's ecosystem, the concept of SDGs has expanded from the millennium development goals (MDGs), focusing on a triple-bottom-line approach to human well-being (Rey and Sachs, 2012; Janouskova et al., 2016). The innovative and distinguishing feature of the SDGs is that they were created through an inclusive and comprehensive process, and thus, the goals and targets are intertwined (UN, 2018). Among these synergies and trade-offs, the association of water with other sustainable development goals is exciting. Given the inevitability of water for human survival and development, as well as the proper functioning of the ecosystem (see Figure 1.1), it is without a doubt that it serves as the planet's central nervous system (UNDP, 2021).

Additionally, water availability has been identified as a top priority in poverty reduction, as it has a significant impact on poverty in the form of socioeconomic good or socioeconomic bad (Jemmali and Ghunmi, 2016). During the early phase of developmental studies (1950-90), poverty was considered a deprivation of income (Dehury and Mohanty, 2015). A person was considered poor if the income fell below a specified income poverty line, which was the monetary equivalent of the "minimum necessaries for the maintenance of merely physical efficiency" (i.e., food, rent, clothing, fuel, light, etc.) (Rowntree,1901).

However, beginning in the mid-1970s, with the development of basic needs, social exclusion, and Sen's capability approach, it was realized that simply increasing purchasing power cannot guarantee the achievement of basic needs (UN,2015). Because poverty can be caused as well as prolonged owing to numerous non-monetary dimensions like social exclusion, physical ill-being, lack of access to materials like water, electricity, powerlessness, etc. (Walker, 2015; Biswal et al., 2020). This realization has led to the development of several techniques for measuring multidimensional deprivation to classify poor and non-poor, such as the dashboard approach (Millennium Development Goals) and the composite index approach (Human Development Index, Gender Empowerment Index, Multidimensional Poverty Index). It is worth noting that 'water' takes center stage in all of these approaches due to its enormous importance as a driver of socio-economic development (Ladi et al., 2021).

Figure 1.1 Interlinkage between water and sustainable development



Source: UN (2015)

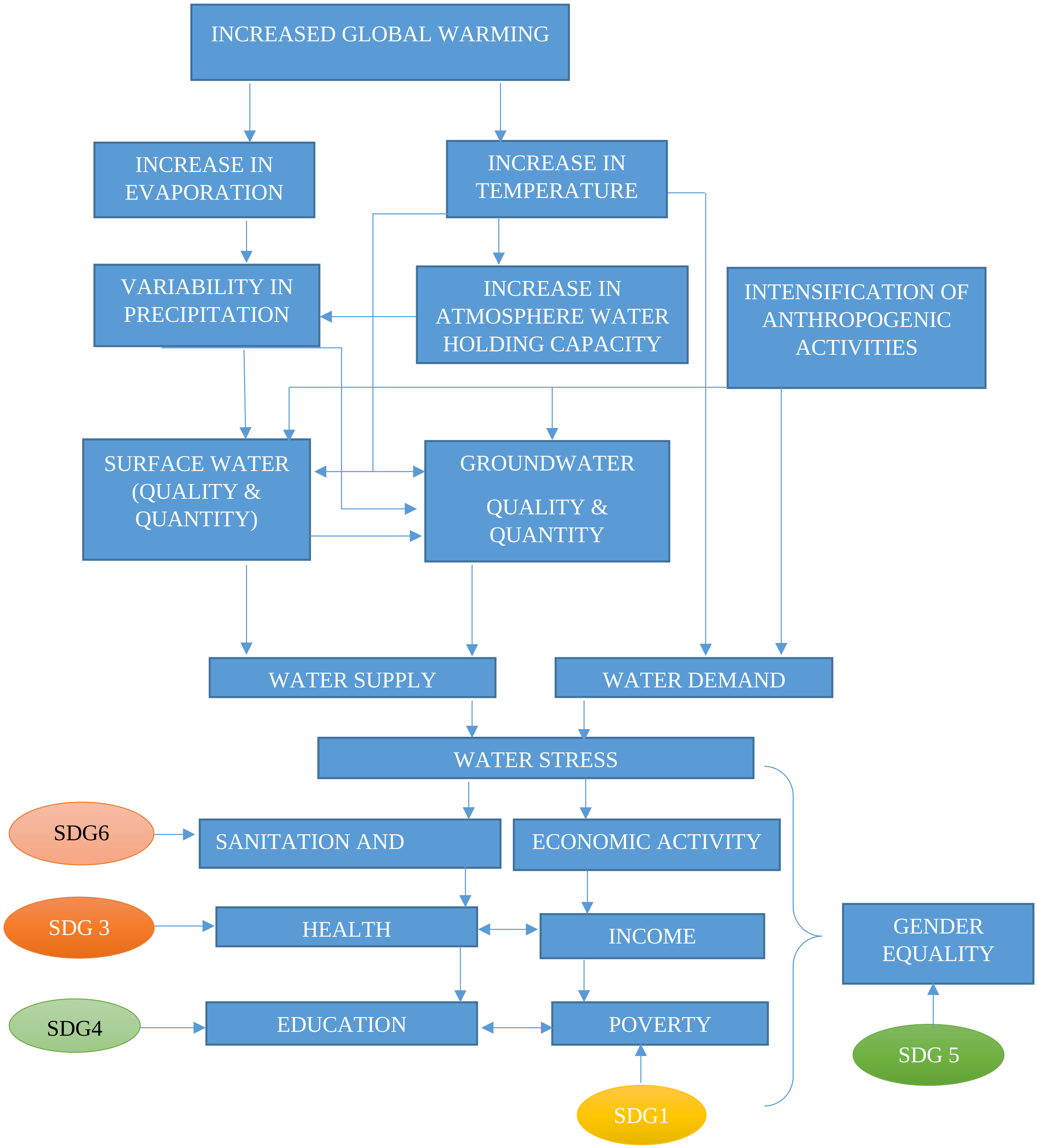
Furthermore, access to water, particularly for irrigation, is essential for achieving zero hunger and ensuring food and nutritional security. Studies have consistently shown that improved access to irrigation leads to higher crop yields, increased productivity, and enhanced total factor productivity (Huang et al., 2006; Hanjra et al., 2009). The nexus between water and food security is critical, as highlighted by the potential impact of growing water scarcity on food production and prices (Gulati et al., 2012). Studies in Ethiopia (Berg and Ruben, 2006) and India (Smith, 2004) have demonstrated that access to water for agriculture not only increases household income but also reduces reliance on public assistance programs. The spillover effects of irrigation on non-irrigated households underscore the broader socioeconomic benefits of water access (Bhattarai et al., 2007).

Water is also indispensable for livestock production, contributing to rural livelihoods and income generation, particularly in developing countries (Wilkinson, 2003; Mugagga and Nabaasa, 2016). However, increasing water stress threatens livestock health and economic stability, impacting the livelihoods of millions (World Bank, 2022). Additionally, empirical evidence highlights the critical role of water in maintaining human health and education. Studies have linked water contamination to various health risks, particularly affecting vulnerable populations such as children (Chen et al., 2021; Sarkar and Pal, 2021). Improved access to water has been associated with reduced incidence of diarrheal diseases and improved mental health outcomes (Cha et al., 2015; Slekiene and Mosler, 2019).

Access to quality water also has significant implications for education, with studies showing positive associations between water access, school attendance, and educational attainment (Hunteret al., 2014; Zhang and Xu, 2016; Correa et al., 2016). Furthermore, the gendered impacts of water scarcity underscore the importance of addressing gender equity in water management, as women often bear the burden of water collection, impacting their health and socioeconomic opportunities (Geere et al., 2018; Pouramin et al., 2020).

Being a key driver of food security, human health, industrial development, and energy production, water contributes to economic growth and human development (Ladiet al., 2021). It is owing to the centrality and criticality of water that it has been recognized as a human right (IUCN, 2004). As *'Water is the new oil.'* (Todaro & Smith, 2014) and is often an unacknowledged but essential factor in reaching the SDGs (UNESCO, 2020). Hence, there is a need to understand the response of water resources to climate change and anthropogenic activities and its impact on various dimensions of SDGs. The above complex relationship is highlighted in Figure 1.2 (given below).

Figure 1.2 Linkage between water, anthropogenic activities, climate change & sustainable development: A conceptual framework



Source: Authors' elaboration

1.2 Need of the study

Located in the northern hemisphere, a large part of India comes under critical regions of the world where the water resources have a higher sensitivity to global changes (Alcamo and Henrichs, 2002). As per estimates, out of the total landmass of the subcontinent, 12 percent is vulnerable to flood, and 68 percent is prone to drought (GoI,2015.). Additionally, over the years, the frequency of droughts and floods has increased significantly (The Hindu, 2021). As can be seen from Table 1.1, the total damage caused by flood and heavy rainfall increased from 8864.54 crore rupees in 2000 to 96806.75 crore rupees in 2018. Cumulatively, over eighteen years (2000-2018), India has lost around 469597 crore rupees to these extreme events.

Similarly, let's consider the direct impact of droughts, i.e., their impact on the agricultural sector, energy production, tourism, health, and biodiversity. Due to severe drought events, India is vulnerable to losing approximately 2-5 percent of its GDP (UNDRR, 2021). However, besides these direct impacts, droughts also have several indirect effects. Events of droughts can result in food inflation, social unrest, and conflicts, and it can trigger migration, reduce the productivity of plants, etc. Hence, the damage caused by droughts is much greater than estimated.

As evidenced by the literature, India has witnessed a declining trend in the annual streamflow of its rivers due to climate change and anthropogenic activities such as population growth and increased water withdrawal (Panda et al., 2013; Abeysingha et al., 2016; Sahu et al., 2020). Furthermore, studies have highlighted the vulnerability of groundwater resources to climate change in the subcontinent. Decreasing precipitation and rising temperatures have led to a decline in groundwater recharge, directly impacting groundwater levels (Sivarajan et al., 2019; Panda et al., 2007). The increase in temperature and reduction in streamflow have significant impacts on pollutant concentrations and dissolved oxygen levels in water bodies (Santy et al., 2020).

Additionally, irrigation accounts for the largest water usage in India, followed by the domestic and industrial sectors (Amarasinghe et al., 2008). Pathak et al. (2014) projected increased irrigation demands due to climate change, exacerbating water stress.

In India, where most states rely on agriculture, anthropogenic activities such as agriculture have emerged as significant sources of groundwater pollution (Wakejo et al., 2022; Ravindra et al., 2022). Particularly in water-scarce regions, groundwater is crucial for human life, and the growing concern for health risks associated with water contaminants has been observed (Adimalla and Wu, 2019; Aher and Deshmukh, 2019; Hoogesteger, 2022). For instance, fluoride (F-) contamination in groundwater has affected approximately 66 million people in India, with severe impacts observed in states such as Telangana, Gujarat, Andhra Pradesh, and Rajasthan (Adimalla et al., 2018). Similarly, nitrate (NO3-) pollution has emerged as a pressing issue, with over 108.2 million people exposed to concentrations exceeding permissible limits, leading to severe health risks such as methemoglobinemia in infants and increased vulnerability to various health issues in adults (Jayarajan and Kuriachan, 2021; Rahman et al., 2021; Tanwer et al., 2023).

Recognizing the importance and significance of water for growth and development, both the state governments as well as the central government of India have launched a variety of schemes like the National Water Mission, National Rural Drinking Water Programme, Atal Bhujal Yojana, Mukhya Mantri Jal Swavlambhan Abhiyan in Rajasthan, Neeru-Chettu Programme in Andhra Pradesh, Sujalam Sufalam Yojana in Gujarat to name a few. Moreover, there has also been an increase in budgetary allocations for water (see Table 1.2).

Table 1.1 Damage Due to Flood and Heavy Rainfall in India

Year	Population Affected	Damage to Crops		Damage to Houses		Cattle Lost	Human Live Lost	Damage to Public Utilities	Total Damage
	In Million	Area	Value	In Nos.	Value	In Nos.	In Nos.	Rs. in Crore	Rs. in Crore
		In M.Ha.	Rs. in Crore		Rs. in Crore				
2000	45.01	3.58	4246.62	2628855	680.94	123252	2606	3936.98	8864.54
2001	26.46	3.96	688.48	716187	816.47	32704	1444	5604.46	7109.42
2002	26.32	2.19	913.09	762492	599.37	21533	1001	1062.08	2574.54
2003	43.2	4.27	7307.23	775379	756.48	15161	2166	3262.15	11325.87
2004	43.73	2.89	778.69	1664388	879.6	134106	1813	1656.09	3314.38
2005	22.93	12.3	2370.92	715749	380.53	119674	1455	4688.22	7439.67
2006	25.22	1.82	2850.67	1497428	3636.85	266945	1431	13303.93	19791.44
2007	41.4	8.79	3121.53	3280233	2113.11	89337	3389	8049.04	13283.68
2008	29.91	3.19	3401.56	1566809	1141.89	101780	2876	5046.48	9589.94
2009	29.54	3.59	4232.61	1235628	10809.8	63383	1513	17509.35	32551.76
2010	18.3	4.99	5887.38	293830	875.95	39706	1582	12757.25	19520.59
2011	15.97	2.72	1393.85	1152518	410.48	35982	1761	6053.57	7857.89
2012	14.69	1.95	1534.11	174526	240.57	31558	933	9169.97	10944.65
2013	25.93	7.48	6378.08	699525	2032.83	163958	2180	38937.84	47348.75
2014	26.51	8.01	7255.15	311325	581.98	60196	1968	7710.95	15548.08
2015	33.2	3.37	17043.9	3959191	8046.97	45597	1420	32200.18	57291.1
2016	26.55	6.66	4052.72	278240	114.68	22367	1420	1507.93	5675.33
2017	47.01	5.09	8761.4	1221214	9271.94	23820	2060	8362.49	26395.82
2018*	79.74	2.13	3241.96	500894	2134.59	57904	1880	91430.2	96806.75
Total	2167.1	258.26	114277	81187187	55796.87	6104400	109412	299522.84	469596.71

Source: Indiastat (2018)

The ministry of Jal Shakti, which was formed by merging ministries of Water Resources, River Development, and Ganga Rejuvenation and Drinking Water and Sanitation, received an allocation of 69,053 crore rupees (60030+9023) in 2021-22 as compared to 25683 (18264+7419) in 2019-20. Similarly, for all the missions except National River Conservation, the amount allocated has significantly increased from 2019-20.

Table 1.2 Budgetary Allocation to Water Resources (in Rs crore)			
S.No.	Department /Schemes	Actuals (19-20)	Budgeted (21-22)
1	Department of Drinking Water and Sanitation	18,264	60,030
1.1	Jal Jeevan Mission (JJM)	10,030	50,011
2	Department of Water Resources, River Development, and Ganga Rejuvenation	7,419	9,023
2.1	**Water Resources Management**	626	729
2.2	**Central Water Commission**	391	389
2.3	**Central Ground Water Board**	236	238
2.4	**National River Conservation**	1,336	950
Source: PRS Legislative Research			

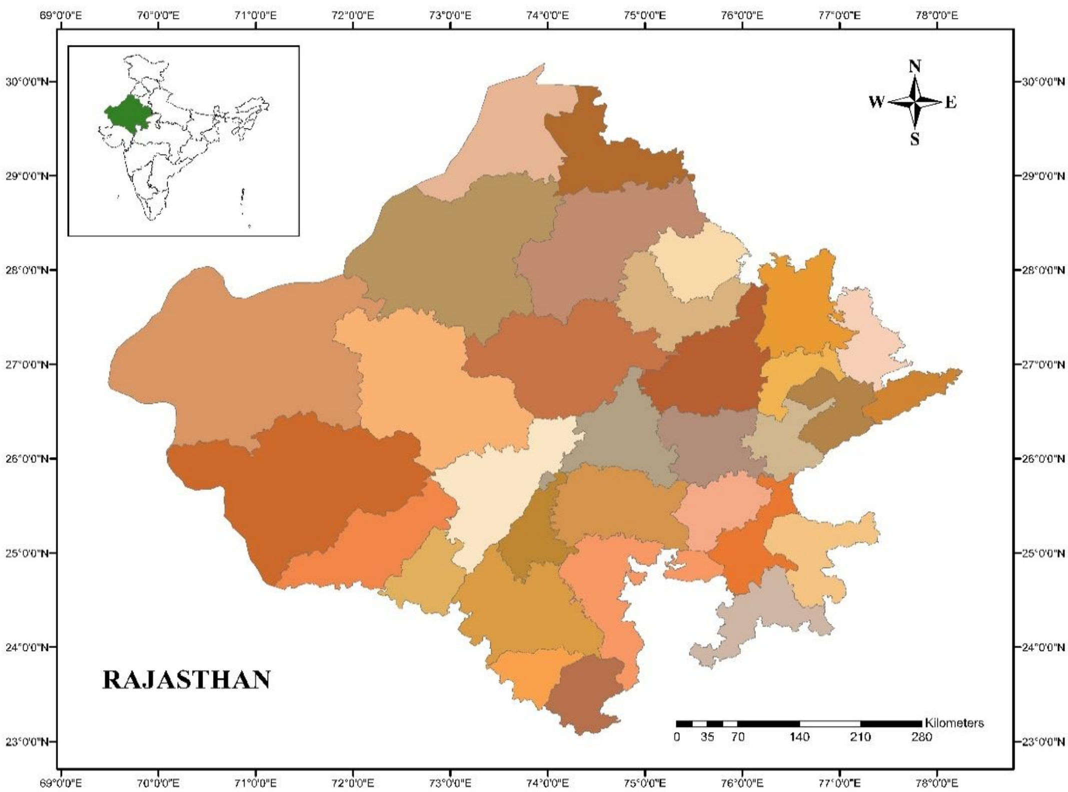
Recently, to further enhance its efforts of *"Har Ghar Nal Se Jal," the government* launched a JJM (Jal Jeevan Mission) mobile-based application. This app is said to improve awareness and transparency and increase accountability of various schemes under JJM. In addition to this, restoration of water bodies, augmentation of groundwater, creation of irrigation potential by enacting different major and minor irrigation projects, and watershed development are also being carried out in the Indian states. All these are laudable efforts made by the government. But are they sufficient? As per the CAG (2018) audit report, a huge amount of funds allocated to the National Rural Drinking Water Programme remained unutilized. The report also mentioned that the program was not properly executed, and there was no authentic monitoring mechanism, as a result of which it failed miserably in achieving its target. Similarly, the National Project Scheme was approved in 2008, under which 16 major water resource development and irrigation projects were identified for the creation of irrigation potential, drinking water facilities, and enhancement of power generation. The audit report of CAG (2018) mentions that even after almost a decade of incurring a huge expenditure of 13,288.12 crore rupees, only five out of 16 projects were implemented as of 2017. Moreover, as against the irrigation potential of 14.53 lakh Ha that was created by these five projects, only 5.36 lakh Ha was being utilized.

Furthermore, the recent report of NITI Aayog (2019) reveals significant interstate disparities in water management. When compared to other states, Rajasthan, Jharkhand, Haryana, Uttar Pradesh, the north-eastern and the Himalayan states have poor performance in the restoration of water bodies. In watershed development, Jharkhand and Haryana also have the poorest performance. When it comes to groundwater augmentation, although it has received great attention in states' policies, almost all states are facing a decline in their groundwater resources. The severity of the situation can be understood by looking at the fact that around 16 percent of groundwater wells are depleting at an alarming rate of 1 meter per year (NITI Aayog, 2019).

According to the Aqueduct Water Risk Atlas, India is among 17 extremely water-stressed countries. Even the NITI Aayog has declared that India is "suffering from the worst water crisis in its history, and millions of lives and livelihoods are under threat." Further, as noted by NITI Aayog (2019), the lack of proper implementation and monitoring of schemes, coupled with mismanagement of water resources, has significantly deepened the severity of the prevailing water crisis in India. This is particularly true in India's arid and semi-arid regions, where per capita water availability is about 1000 m^3, i.e., the water scarcity threshold limit based on Falkenmark Index (Water Aid, 2018; NITI Aayog, 2019).

In India, Rajasthan, the largest state, is predominately arid and semi-arid. Located between 23^{o} 3' to 30^{o} 12' north and 60^{0}30' to 78^{0}17' east, it lies in the north-western region of India. The state covers 342,239 square kilometers (Dutta Roy, 2015), about 10.4% of India's landmass. Bounded by an international border with Pakistan in the west and northwest, the state shares an interstate border with Punjab, Uttar Pradesh, Haryana, Gujarat, and Madhya Pradesh in India. For administrative purposes, the state is divided into 33 districts (see Figure 1.3), which can be clubbed into seven divisions- Ajmer, Bikaner, Bharatpur, Jaipur, Kota, Jodhpur, and Udaipur (Hussain, 2015).

Figure 1.3 Map of Rajasthan



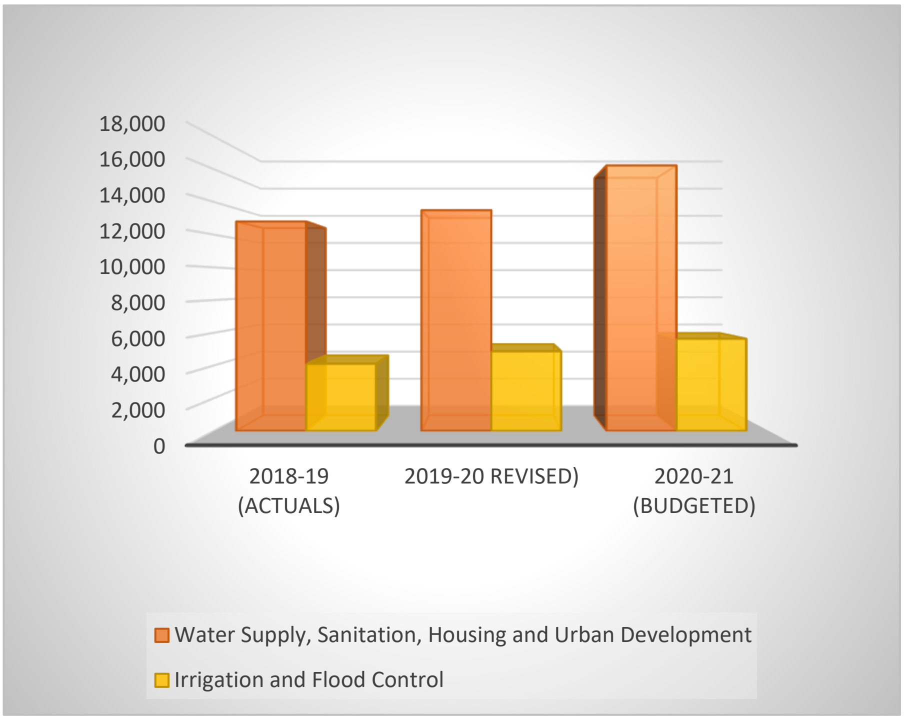
Source: Authors' construction

Rajasthan has a diverse topography and physiography. The Aravalli Range, which runs from southwest to northeast, divides the state into two sections: 60% northwest and 40% southeast. The areas in the northwest are generally sandy and unproductive, but as we move east, they become more fertile and habitable. The southeast region is 100 to 300 meters above sea level and is comparatively more fertile than the northwest region. The state can be divided into four physiographic units: the Aravalli hill range, the Eastern plains, the Western Sandy plain and dunes, and the Vindhya Scarp land and Deccan lava plateau (CGWB, 2020).

As for the climatic conditions, the temperature in the state can range from 26^0 C to 46^0 C in summer and from 8^0 C to 28^0 C in winter (Dutta Roy, 2015). The mean precipitation is nearly 574 mm in Rajasthan, significantly less than the national average of 1,100 mm (GOR, 2014). In addition to being low, the state's rainfall is also highly variable. In contrast, the average rainfall in the western desert region is only 100mm. Some districts in the southeast region may receive an average of 500mm. Further, despite being one-tenth of the landmass of India, the state accounts for merely 1 percent of the country's surface and groundwater resources. It is owing to this that it is considered to be the driest state in India.

Given a continuous water deficit and the high probability of droughts in the state (TERI, 2010), the government has enacted several policies to contain the deteriorating water situation. Some measures the state is taking include source augmentation, water conservation (rainwater harvesting), and using technologies like flash distillation and reverse osmosis to improve worsening groundwater quality (DAE, 2008). The severity of the water problem and its importance is also reflected in the state's budgetary allocation, which has been continuously increasing, as seen in Figure 1.4.

Figure 1.4 Sector-wise Expenditure for Rajasthan Budget

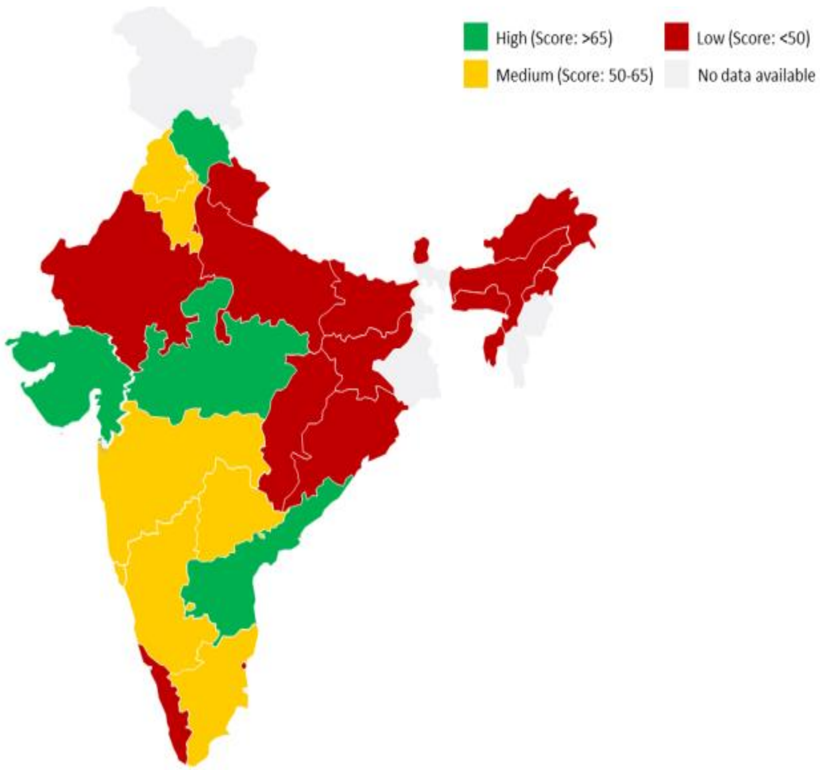


Source: PRS India

To achieve the objective of attaining water security for all, many water supply projects like Bisalpur, Jawai-Pali pipeline, Chambal-Sawai Madhopur-Baler water supply project, etc., have been initiated by the government. Undoubtedly, the government's efforts are laudable, but despite all these, the state's water situation has hardly changed. Furthermore, despite various policies, Rajasthan stands out as one of the worst-performing states in terms of water management, as indicated by the NITI Aayog's "Composite Water Management Index" (see Figure 1.5) (NITI Aayog, 2019).

There is no village in Rajasthan where piped water is available 24/7; still, approximately half of its urban population lacks access to the drinking water supply. In addition, as per the 76th round of the National Sample Survey (NSS) - ‘Drinking Water, Sanitation, Hygiene, and Housing Condition’ - around 38 percent of the population still have to travel distance to fetch water (see Table 1.3). On average, a household has to make three trips to fulfill their water requirements, which takes a total of 57 minutes (19 minutes X 3 trips) in a day and is counted as an opportunity cost by several studies (Arku, 2010; Bisung and Elliott, 2018).

Figure 1.5 Classification of states according to Composite Water Management Index (CWMI) scores



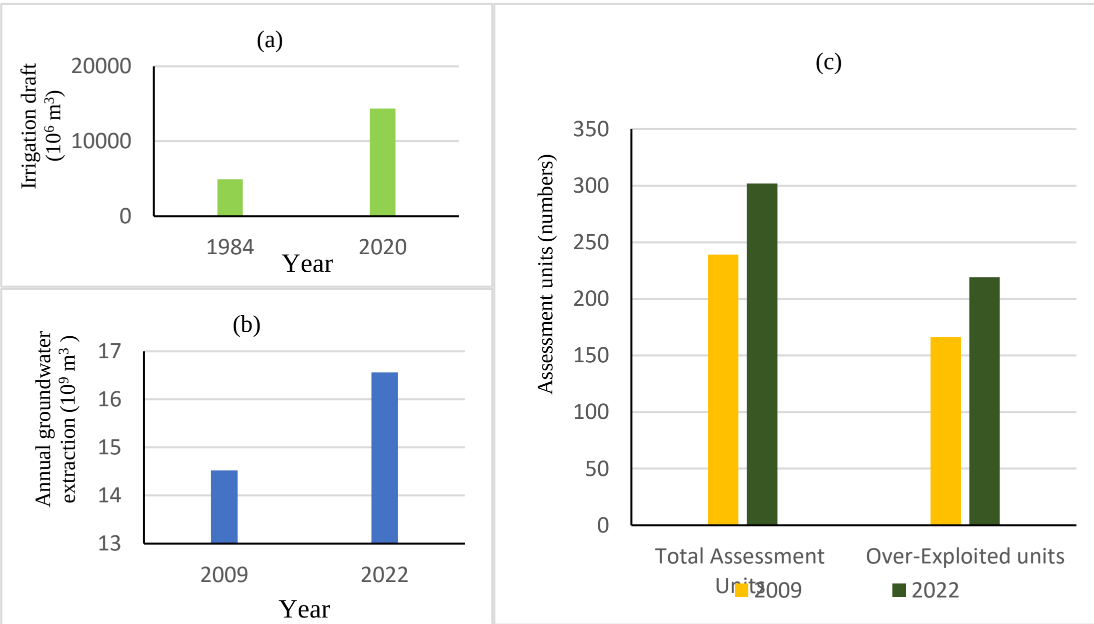
Source: NITI Aayog (2019)

Table 1.3 Summary of distance travelled and time taken for fetching water.		
Percentage of households not having water sources in the dwelling or within dwelling premises.	Time (mean)	Number of trips(mean)
38.71	18.83 minutes	2.90
Source: NSS (2018)		

To make the situation worse, the Central Ground Water Board (CGWB) of India observed that, in Rajasthan, the irrigation draft increased from $4{,}926 \times 10^6$ m^3 to $14{,}368 \times 10^6$

m^3 from 1984 to 2020 (Bansiwal et al., 2021). The annual groundwater extraction in the state has increased from 14.52 × 10^9 m^3 to 16.56 × 10^9 m^3 (CGWB, 2009, 2022). This is also evident in Figure 1.6. Further, as of 2022, 72.51% of the assessment units were found to be “overexploited,” suggesting that the abstraction of groundwater resources in these units is unregulated and uncontrolled (Carrard et al., 2019). In addition, over 80.00% of the area of Rajasthan has experienced groundwater depletion over the years (Chinnasamy et al., 2015).

Figure 1.6 Groundwater resource status of Rajasthan, India: (a) irrigation draft (106 m^3), (b) annual groundwater extraction (109 m^3), and (c) groundwater resource categorization.



Source: Bansiwal et al. (2021); CGWB (2009, 2022)

Further, the contamination of groundwater in Rajasthan has also been highlighted by the CGWB (2021), India, which observed that between 40 and 56 percent of groundwater samples in the state's districts of Barmer, Dausa, Tonk, Jaipur, and Jodhpur have electrical conductivity (EC) above the permissible limit, i.e., greater than 3000 µS/cm. In addition, roughly 40 and 31 percent of groundwater samples in Barmer and Jaipur exceeded the permissible chloride (Cl-) limit of >1000 mg/l, respectively. In approximately 67 percent of

Tonk's groundwater samples, the sulphate ($SO4_2^-$) concentration exceeded 400 mg/l (the maximum permissible limit). Further, more than 50 percent of the groundwater samples in Barmer and Jodhpur contained nitrate (NO_3^-) concentrations exceeding 45 mg/l. Also, the districts of Tonk, Barmer, Ajmer, and Jaipur were found to be afflicted by fluoride (F-) contamination.

Although the issue of groundwater depletion and contamination is not unique to Rajasthan, it is observed throughout the majority of India and worldwide (Arfanuzzaman and Atiq Rahman, 2017; Dhillon et al., 2019; Sarkar et al., 2020; Esmeray and Gökcekli, 2020; Zacchaeus et al., 2020; Abascal et al., 2022; Wakejo et al., 2022). However, accounting for 90 percent of drinking water and 60 percent of irrigation needs, groundwater is the primary water source for the state (GOR, 2004). A deterioration in its situation severely threatens the region’s sustainable development (Velis et al., 2017). The severity of the state's water situation can be gauged by the fact that the state relies heavily on external sources to meet its water needs.

Given the relationship between poverty and water, the state's poor water situation may explain why, despite a 9.86 percent compound annual growth rate (CAGR) (in Rs) in gross state domestic product from 2015-16 to 2021-22 (IBEF, 2021), the state still has approximately 29.46 percent of multidimensionally poor people (NITI Aayog, 2021). It might also explain why, despite its outstanding performance in poverty reduction since the 2000s, India continues to face widespread poverty (World Bank, 2020).

With a score of 65.7 and a ranking of 120th out of 165 countries for sustainable development, India needs more efforts, particularly in the dimensions of economic growth, poverty, gender equity, zero hunger, and quality education (Sachs et al., 2021). Given the immense importance of water for India, specifically Rajasthan, to achieve and sustain its development goals, addressing the escalating water issues is imperative. To accomplish this, accurate monitoring of the water situation is needed for policymaking. Further, with the growing warming trend (Roy, 2015; Sharma et al., 2018), increase aridity (Singh and Kumar, 2015) and projection of erratic precipitation (Pradhan et al., 2019), water resources of the state of Rajasthan will be exposed to severe stress. Therefore, it is essential to comprehensively analyze the impact of climate change and anthropogenic activities on water resources. Given the significance of groundwater, assessing the influence of climate and anthropogenic factors on groundwater resources is crucial for ensuring a sustainable water supply in the state.

1.3 Household Vulnerability to water scarcity, perception, and adaptation: a conceptual framework

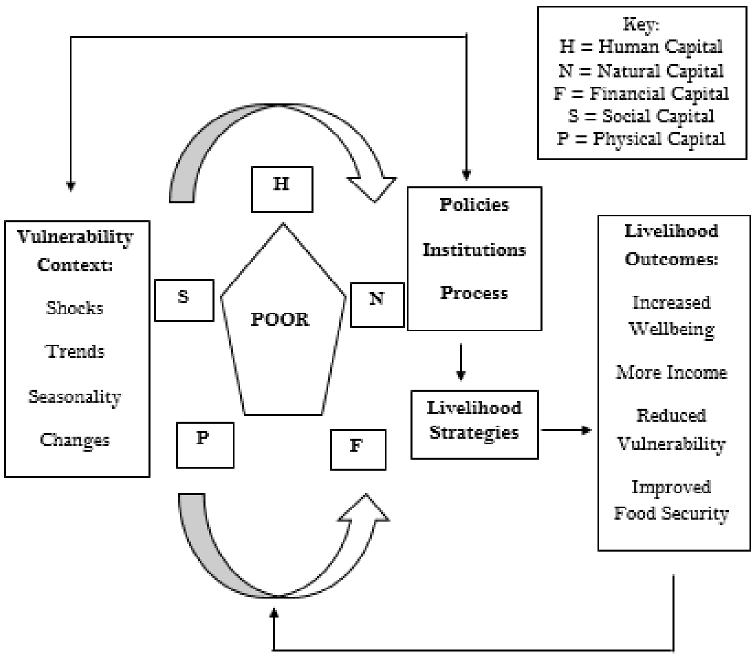
In simple terms, vulnerability refers to how likely a system is to be harmed when exposed to a hazard (Devi et al., 2017). In climate change literature, vulnerability definitions often fall into two categories: biophysical and social vulnerability. While biophysical vulnerability is a hazard function, social vulnerability exists independently of hazards. Furthermore, social vulnerability can be regarded as a determinant of biophysical vulnerability (Brooks, 2003).

Vulnerability has been conceptualized in different ways by scholars. Bohle (2001) notes that vulnerability is considered as having an external and an internal side where the internal side relates to the capacity to anticipate, cope with, resist, and recover from the impact of a hazard, and the external side involves exposure to risks and shocks. Within the hazard and risk framework, vulnerability is conceptualized as an integral component. Here, vulnerability, coping capacity, and exposure are distinct elements (Davidson, 1997; Inkani, 2015). In the sustainable livelihood approach as developed by Scoones (1998), vulnerability is assessed based on five livelihood assets/capitals (natural capital, human capital, social capital, physical capital, and financial capital), which help in coping with various shocks (see Figure 1.7). Further, as per the IPCC (2001), 'vulnerability' is defined as:

"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."

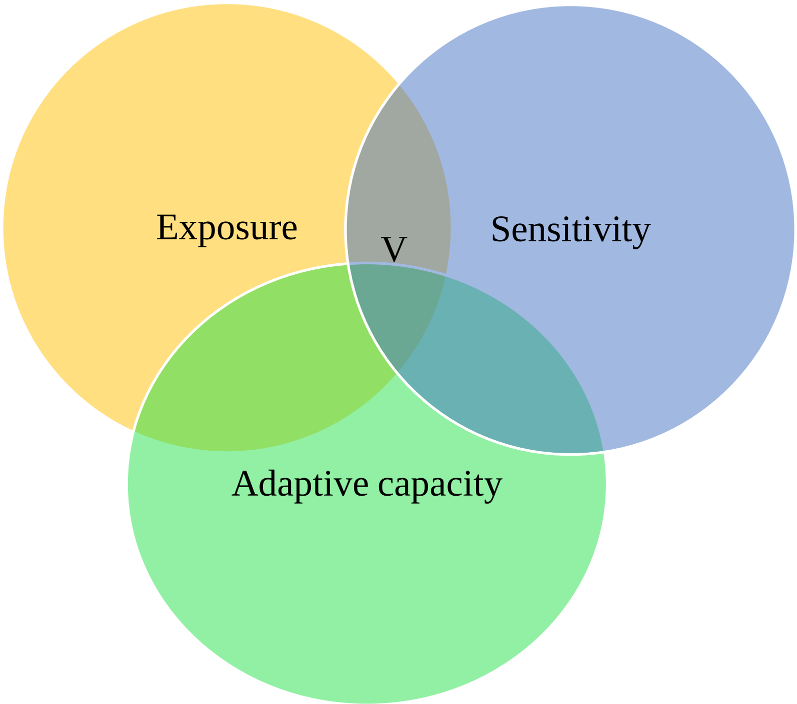
The IPCC's definition of vulnerability falls in the realm of the biophysical vulnerability approach. As per the definition, vulnerability in this framework is a function of exposure, sensitivity, and adaptive capacity (see Figure 1.8). Here, exposure, as the name suggests, is the degree and nature to which a system is exposed to a hazard. Sensitivity is the degree to which a system is adversely or beneficially affected by the hazard. Adaptive capacity is the ability of a system to adjust, moderate, and cope with the consequences of hazards.

Figure 1.7 Sustainable Rural Livelihood Framework



Source: Scoones (1998)

Figure 1.8 Vulnerability (V) assessment framework

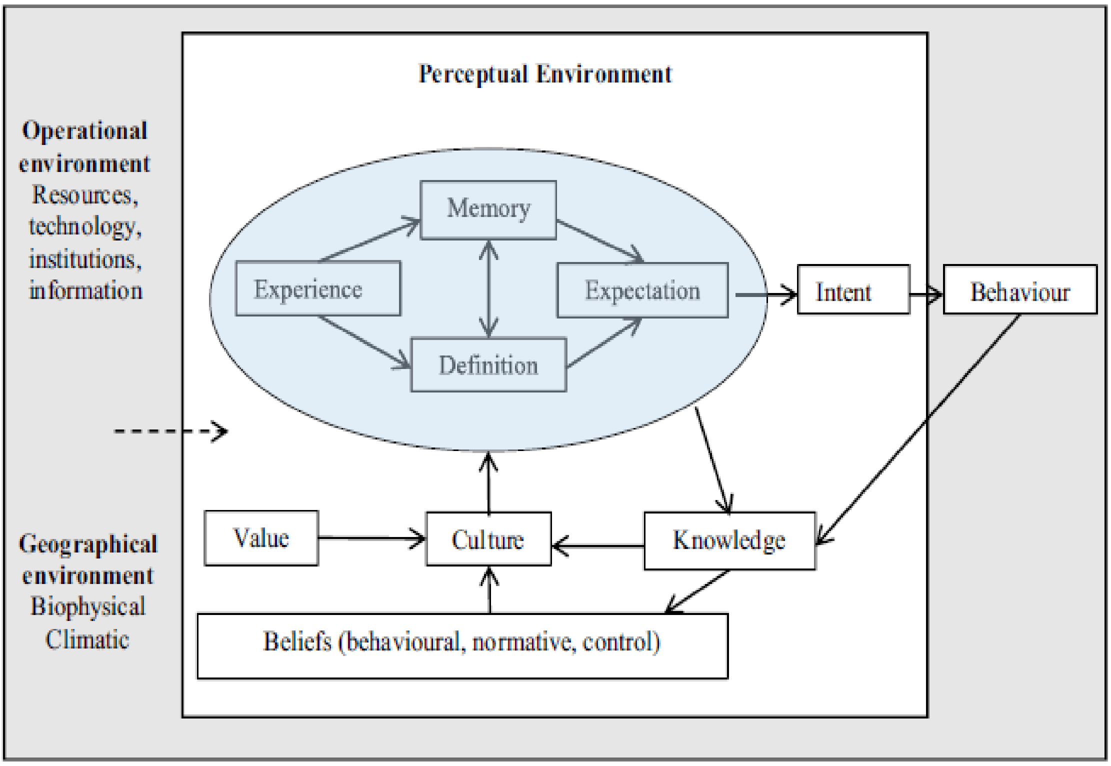


Source: IPCC (2007)

The study used the IPCC (2001) framework to quantify households' vulnerability to water scarcity. Further, according to the IPCC definition, a system with high adaptive capacity tends to exhibit lower vulnerability. Adaptive capacity represents the potential of a system to adapt, with adaptation being a process that unfolds over time. Through adaptation, a system can mitigate the risks associated with hazards.

Additionally, responses to hazards are influenced by perceptions, which can vary among individuals (Nguyen et al., 2016; Sutcliffe et al., 2016). Various frameworks have been proposed to conceptualize perception and its influence on behavior (Singh et al., 2018). One such framework, developed by Taylor et al. (1988) and later refined by Slegers (2008), outlines how perception translates into adaptive behavior (see Figure 1.9). This framework identifies four critical components—Experience, Memory, Definition, and Expectation—that collectively shape individuals' perceptions and guide their responses.

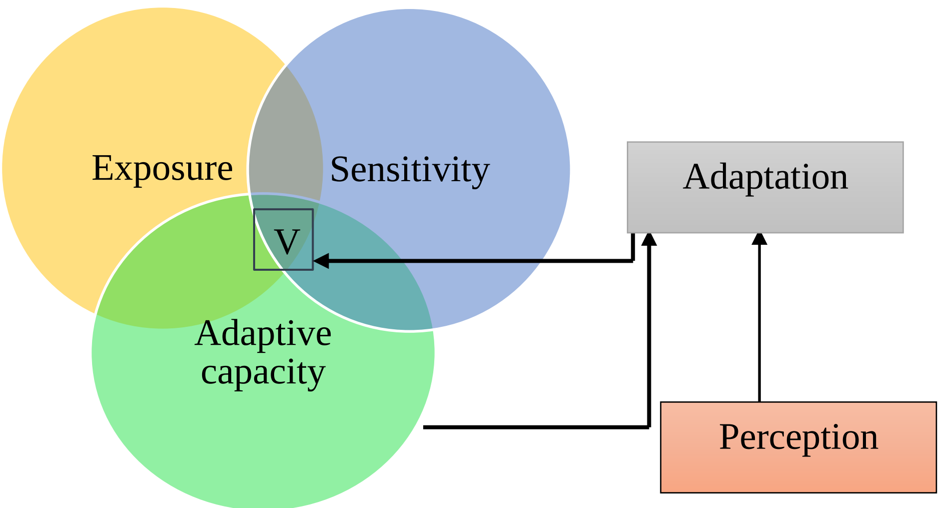
Figure 1.9 Framework for adaptation and perception



Source: (Singh et al., 2018)

In the study, the above frameworks have been combined (see Figure 1.10) to analyze households' perception, adaptation, and vulnerability to water scarcity in Rajasthan.

Figure 1.10 Vulnerability (V), perception and adaptation: conceptual framework



Source: Authors' elaboration

1.4 Research questions

Based on the above discussion, it can be asserted that water's value to humanity is practically infinite (UNESCO, 2021). Despite this, water is increasingly becoming a scarce resource for most people. Ensuring the sustainability of freshwater resources has emerged as one of the most critical challenges for sustainable development (UN, 2019). Among the available freshwater resources, groundwater has emerged as the most significant resource for human survival, agriculture, and industrial development across the globe (Coyte et al., 2019; Jeon et al., 2020), especially in Rajasthan.

With the intensification of anthropogenic activities and climate change, there is an urgent need to develop a comprehensive understanding of the water situation in India, with a specific focus on Rajasthan. This necessitates an analysis of household vulnerability to water scarcity, perceptions, adaptations, and the influence of climate and anthropogenic activities on water resources in the state. Accordingly, the present study seeks to address the following research questions:

i. What is the nexus between water availability and diverse dimensions of household development? To what extent do water-related policies influence household well-being?

ii. What spatial and temporal trends characterize water scarcity in India and Rajasthan?

iii. What are the effects of climate change and anthropogenic activities on the groundwater resources of Rajasthan?

iv. What are the prevailing perceptions among households concerning water scarcity in Rajasthan? To what degree are households vulnerable to water scarcity, and what adaptive strategies do they employ? Additionally, what factors influence their adaptation choices?

1.5 Objectives of the thesis

As observed from the above research questions, the research aims to analyze the water situation in India, focusing particularly on Rajasthan, and to assess the influence of climate change and anthropogenic activities on water resources in the region. The specific objectives are outlined as follows:

i. To investigate the impact of water scarcity on key development indicators within the Indian context.

ii. To assess the overall water situation:

a) To evaluate the water situation across India.

b) To evaluate the water situation specifically in Rajasthan.

iii. To examine the effects of climatic and anthropogenic factors on both the quality and quantity of water resources in Rajasthan.

iv. To assess perceptions, adaptation strategies, and vulnerability to water scarcity at the household level, with specific focus on gender.

1.6 Structure of the Thesis

The present study comprises six chapters, each contributing to a comprehensive understanding of the water dynamics in Rajasthan and its implications for sustainable development. Chapter 1 is an introductory section outlining the study's background, rationale, research questions, and objectives.

Chapter 2 empirically examines the interrelationship between water and major developmental parameters. It elucidates various metrics employed to measure water scarcity and assesses the efficacy of water-related policies in enhancing household well-being in India.

Chapter 3 offers a comprehensive overview of the water scenario in India and Rajasthan. It outlines the state-level, regional, and district-level variations in water scarcity, pinpointing areas necessitating intervention to address water-related challenges.

Chapter 4 delves into the groundwater dynamics in Rajasthan, analyzing trends in groundwater levels and quality parameters. It evaluates the suitability of groundwater for domestic and irrigation purposes, shedding light on the influences of climatic and anthropogenic factors on groundwater dynamics.

Chapter 5 investigates the perceptions of water scarcity, adaptation strategies, and vulnerability among households in Rajasthan. Drawing on primary data, this chapter outlines the gender disparities in vulnerability to water scarcity and identifies key determinants influencing adaptation strategies.

Finally, Chapter 6 presents the conclusion and policy implications of the present study. This chapter highlights the main issues discussed in previous chapters and suggests policy recommendations based on the empirical findings. It then concludes the study, mentioning the limitations and future scope of the research.

Chapter 2

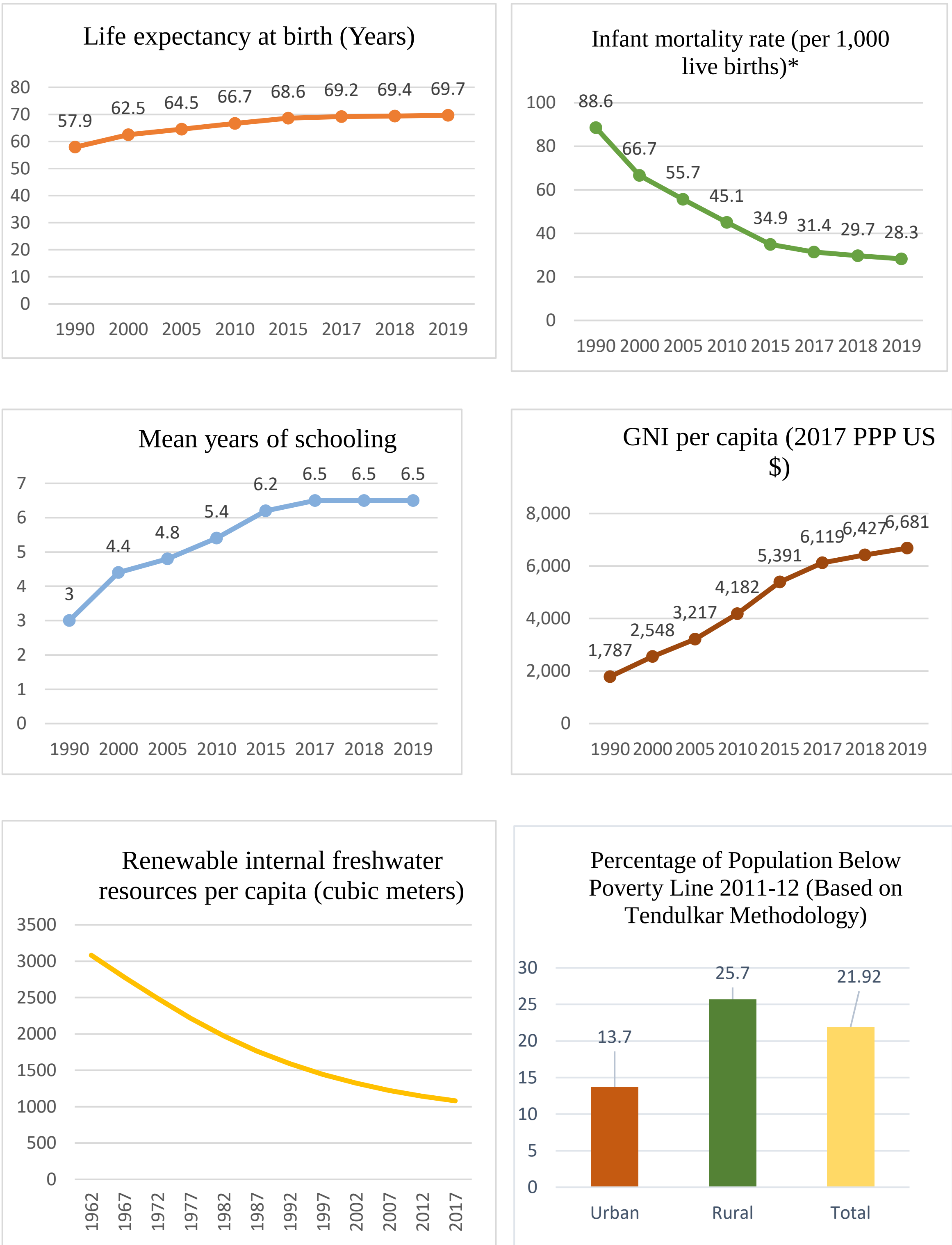
EXAMINING THE INTERLINKAGE BETWEEN WATER POVERTY AND MULTIDIMENSIONAL POVERTY IN INDIA

As mentioned in the previous chapter, water is a key driver for a country's economic growth and human development. Accordingly, this chapter presents a detailed analysis of the interrelationship between water and multidimensional poverty in the Indian context. This chapter is divided into six sub-sections. The first section provides an overview of the trends in various development and water availability indicators in the Indian context. The second section discusses the conceptual framework linking water and multi-dimensional poverty. The third section reviews the literature on various water scarcity measurements. The fourth section illustrates the data and construction of the water and multidimensional poverty indexes, along with the methodology used in the present study. The fifth section discusses the empirical findings. Finally, the sixth section provides the study's summary and concluding remarks.

2.1 Dimensions of development and water availability status: an Indian scenario

India has made significant progress since its liberalization in the early 1990s. Figure 2.1 gives a glimpse of some of the developmental indicators for India. As evident from the figure, India is making progress in all of the development indicators. The infant mortality rate in India fell from 88.6 in 1990 to 28.3 in 2019. The life expectancy rose from 57.9 years in 1990 to 69.7 years in 2019. Also, owing to the different initiatives of both the state and central government, India has witnessed a remarkable rise in its average expected years of schooling. GNI per capita also rose significantly from $1,787 in 1990 to $6,681 in 2019.

Figure 2.1 Trends in Development and Water Availability indicators



Source(s): Economic Survey 2020-21; * The World Bank Data; Ritchie and Roser (2017); Reserve Bank of India.

Despite these accomplishments, data show that approximately 22 percent of India's population was below the poverty line as of 2012. Although the proportion of the population living in poverty is higher in rural India, data show that approximately 14 percent of the population in urban India is poor as well. Also, India's water situation is not very promising. As can be seen from Figure 2.1, there is a continuous decline in India's renewable freshwater resources per capita. In the 1960s, India had 3200 cubic meters of water per person, which has reduced sharply due to the increase in population. It is predicted to fall to as low as 1140 cubic meters by 2050 (GoI, 2020). This clearly shows India is on the verge of a major water crisis. Based on the above observations, the question arises of whether India can sustain its developmental performance in the long run. Or will the country's rising water woes jeopardize its development ambitions and efforts to lift people out of poverty?

To address the rising water woes, the government of India has launched several schemes, such as the National Rural Drinking Water Programme (NRDWP), launched in 2009 to provide adequate, safe, and sustainable water to rural India. With an allocation of 10,001 crore rupees as of the financial year 2019-20, the scheme, as pointed out by the CAG report (2018), suffers from institutional ineffectiveness. The report mentions that, against the envisaged target of covering 50 percent of rural households with potable drinking water, the scheme, in reality, has covered only 18.4 percent (as of 2017). The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is another scheme to develop and provide basic amenities, especially to the disadvantaged population. The scheme seeks to provide every household access to tap and sewerage connections. The mission was proposed to be completed by 2020, but owing to the delay in meeting targets, the tenure of the mission was extended until 2022.

In addition, the Smart Cities Mission (SCM) was launched in 2015 to promote the sustainable and inclusive development of cities. Under this mission, 100 cities and towns were selected from different states to improve their infrastructure and service levels. Access to adequate water supplies and sanitation is one of the objectives of this mission. While the overall mission is laudable, the slow progress of implementing various programs under the mission is a matter of concern (Aijaz, 2021). Hence, although several schemes have been launched, the institutional infectiveness and delays cast doubt over the effectiveness of these policies in alleviating water scarcity.

2.2 Water access and Poverty: Conceptual framework from the literature

Hussain et al. (2006) and Afzal (2021) mentioned that access to water and irrigation by increasing land productivity and crop yield significantly affects rural poverty. They also mentioned that the incidence and depth of poverty in rainfed areas are significantly more than in irrigated areas. Further, an enhanced water supply saves time and increases household savings (Bisung and Elliott, 2018). This saved time is usually spent on various activities that promote the well-being of people (Arku, 2010; Abanyie et al., 2023). Time is a finite and valuable resource; the opportunity cost of the time spent collecting water is the constraint it places on the household's income-generating activities (Aiga and Umenai, 2002; Lowe et al., 2019). Sijbesma et al. (2009) found that the time lost owing to the irregular water supply resulted in a loss of INR 50 per month of earnings for women in Gujarat. Similarly, Aiga and Umenai (2002) found that after the improvement of the water supply at their study site, approximately 72 percent of households started working for more income, thereby increasing mean household income and reducing poverty.

Education is a form of human capital investment essential for development and, consequently, for poverty alleviation. The literature has identified several individual, household, and school characteristics that influence the enrolment and attendance of pupils. Gender, age, family size, educational status of fathers and mothers, caste, religion, cost of schooling, wealth, number of teachers, and quality of education are some of the variables that impact education (Kabubo-Mariara and Mwabu, 2007; Guimbert et al., 2008; Cui et al., 2019; Tiwari et al., 2020). Amongst them, water, sanitation, and hygiene (WASH) have received much attention.

Studies have shown that household and school WASH conditions significantly affect educational outcomes (Dreibelbis et al.,2013; Agol and Harvey, 2018; Ahmed et al., 2022). Hunter et al. (2014) found that providing safe drinking water in schools significantly affects school attendance because supplementary water provision ensures better hydration of students, thereby improving their general well-being and enhancing school experience and learning. Another view discusses the opportunity cost of water collection on school attendance and enrolment. Scholars supporting this view believe that water-fetching jobs for household needs are usually done by women and children; hence, with no water or water source being at a distance, they are forced to travel long distances that have an impact on their energy levels and increase the burden of household chores, often resulting in children missing out on school and leaving them with less time to study (Kookana et al., 2016; Komarulzaman et al., 2019; Choudhuri and Desai, 2021; Dhital et al., 2021). In addition to water access, water quality also influences enrolment, attendance at school, and grade advancement (Akter, 2019; Komarulzaman et al., 2019).

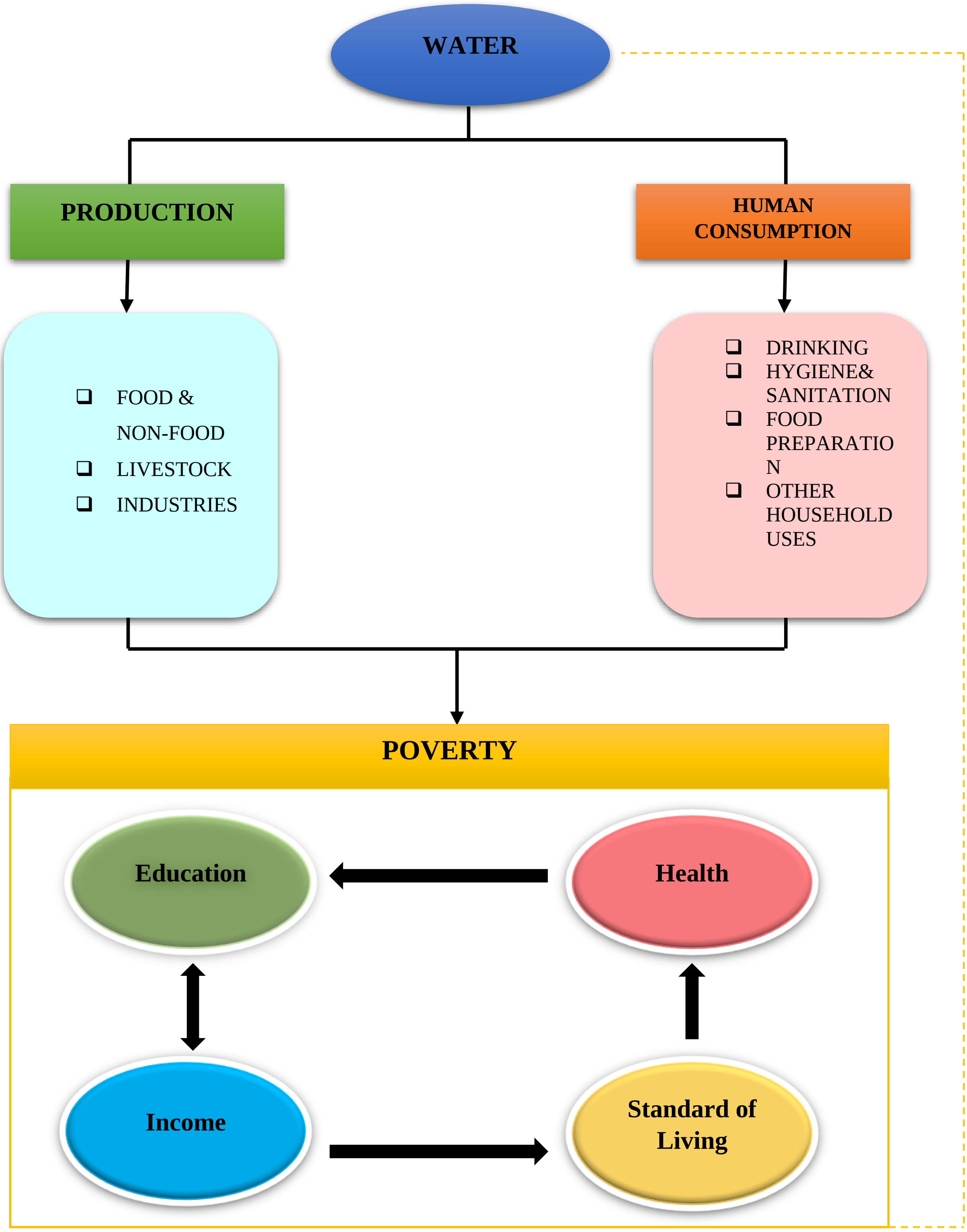
Another channel through which water has proven to be a significant driver of poverty is health. There is no denying the importance of adequate and safe water for human health (Zhang et al., 2020; Harper et al., 2020; Rosinger and Young, 2020). Access to safe water substantially reduces the prevalence of diarrhea, one of the leading causes of death in children, despite being preventable (Otsuka et al., 2019; Mallick et al., 2020; WHO, 2020). In addition to water quality, the time consumed and distance traveled to collect water also directly and indirectly affect health status (Pickering and Davis, 2012; Geere et al., 2018). An increase in the amount of time and distance traveled to collect water often results in a reduction in the volume of water collected, which, in addition to resulting in the intake of inadequate water, can also undermine the hygiene conditions of the household (Howard and Bartram, 2003; Geere and Hunter, 2020). The opportunity cost of collecting water is that mothers have less time to concentrate and care about their child's health.

Additionally, it constrains the income-generating activities of the household and takes a toll on household consumption, consequently impacting household health status (Pickering and Davis, 2012; Geere and Hunter, 2020). Hence, water access, water quality, and other parameters such as time and distance traveled to collect water significantly impact various dimensions of human life. It is this recognition that access to sufficient, safe, acceptable, and affordable water is recognized as a basic human right by the UN (2010).

Based on the above discussion, a conceptual framework has been constructed, as shown in Figure 2.2, which explains this association. It demonstrates how insufficient water availability impairs the household economy by affecting their health, education, income, and standard of living. Furthermore, as shown in Figure 2.2, the relationship between water and poverty is not one-way. Poverty also affects households' water situation, as generally, poor households are unable to manage water problems (Kaur, 2016; Nabi et al., 2019; Rosa et al., 2020; Jaren and Mondal, 2021).

Based on the above discussion, the chapter aims to unravel and comprehend the nature of the relationship that exists between various dimensions of water and poverty. Moreover, it seeks to investigate the impact of socioeconomic factors on the adoption of water policies and assess whether these policies affect the poverty levels of households. Furthermore, as previously stated, the intensity of poverty is greater in rural areas. However, poverty is also a problem in urban areas. Similarly, while rural India is prone to severe water problems due to its limited capacity for water management, access to water is also a major concern in urban India (Prabha et al., 2020). Recognizing that the characteristics of poverty and the extent of the relationship between water and poverty may differ between urban and rural areas, the inter-relationship of water and poverty has been examined separately for rural and urban areas.

Figure 2.2 Schematic Representation of the Conceptual Framework



Source: Authors' construction

2.3 Literature review: Water scarcity measurements

Many attempts have been made around the world since the late 1980s to define, measure, and assess the status of water stress (Liu et al., 2017). The Falkenmark water stress index or Hydrological Water Stress Index (HWSI) was one of the first (Kaur, 2016), is based on the neo-Malthusian view, assumes that water stress problems are directly related to population growth, measures per capita renewable water resources in m3 /cap/year (Feitelson and Chenoweth, 2002). According to the conventional use of the index, water scarcity occurs in varying degrees when a country's water supply is less than the proposed threshold of 1,700 m3 /cap/year (Liu et al., 2017), as described in Table 2.1.

Table 2.1 Classification of Falkenmark indicator

Category	Index (m^3/cap/year)
No Stress	>1,700
Stress	1,000-1,700
Scarcity	500-1,000
Absolute Scarcity	<500
Source: Jemmali and Sullivan, (2014)	

However, the index does not account for changes in water demand caused by economic growth, lifestyle changes, and technological advancements (Savenije, 2000). As Schewe et al. (2014) pointed out, the index is only a proxy for supply-side effects on water scarcity. Further, by relying solely on annual national averages, the indicator obscures critical scarcity information at smaller scales (Jemmali and Sullivan, 2014). Also, Molle and Mollinga (2003), mentioned that the definition of "renewable water" may include resources that are uncontrollable, such as floods, which will not aid in understanding a region's water situation. In this respect, Raskin et al. (1997) proposed using "water withdrawals" (or diverted/ abstracted water) instead of renewable water. Although the index as proposed by Raskin et al. (1997) modified the crude Falkenmark indicator, it has been criticized for failing to consider the water quality and economic capacity (a country's ability to develop water resources) parameters (Feitelson & Chenoweth, 2002).

Another index, named the Basic Human Needs Index, proposed by Gleick (1996), is solely based on water access and use parameters and was another major attempt to define water stress (Kaur, 2016). After identifying four basic water requirements, namely drinking, cooking, bathing, sanitation, and hygiene, the author proposed a benchmark indicator of 1,000 m3 per capita per year as a standard for distinguishing between no water stress and water stress (Jemmali and Sullivan, 2014). However, concerns were raised about data collection, as domestic-level water usage data are difficult to obtain, and the index was also criticized for failing to take into account water use by agriculture, industry, and nature. Smakhtin et al. (2004) proposed a Water Stress Indicator (WSI) in which the environment's water requirement was explicitly considered as an important parameter. According to the authors, a WSI value greater than 1 indicates that there is no water stress. Whereas a $0.6 < WSI < 1$ indicates a moderate water shortage. When the value is $0.3 < WSI < 0.6$ and $WSI < 0.3$, it indicates a situation of high chronic and absolute water scarcity, respectively (Jemmali and Sullivan, 2014).

The water use to availability ratio, also known as the criticality ratio (CR), is another classical water scarcity indicator that is widely used to assess water stress (Liu et al., 2017). This ratio has the advantage of measuring the amount of water used and relating it to the available renewable water resources. High water stress occurs when water withdrawal exceeds 40% of available water resources. However, Rijsberman (2006) highlights that the major shortcomings of the indicator are (1) it does not account for the proportion of available water resources for human use, (2) it does not account for recycling capacity, and (3) it does not account for the society's adaptive capacity.

Literature shows that water stress is not only a result of declining natural water endowments but factors like increasing population, increasing inaccessibility to water sources, declining capacity of households in the form of increasing income poverty to properly manage water, inefficient use of water as well as environmental degradation, significantly impact the water status (Thakuret al., 2017). Ohlsson and Turton (1999) first recognized the political/socioeconomic factors of water stress; they referred to this stress/scarcity as second-order scarcity or social water scarcity. Initially, Ohlsson (1998) developed the Social Water Scarcity Index (SWSI), identifying society's adaptive capacity (Jemmali and Sullivan, 2014), which is calculated by dividing the Falkenmark HWSI by the HDI (Human Development Index). The SWSI values were categorized to represent different stages of water scarcity (see Table 2.2). When we compare the SWSI to the first-generation Falkenmark index, we can see that the former has addressed some of the latter's inconsistencies. However, when discussing the SWSI, Feitelson and Chenoweth (2002) note that the index does not address water quality issues or the financial aspects of water provision. According to Molle and Mollinga (2003), the index does not adequately represent the complexities of the water situation. As a result, many economists believe that the index can be refined and improved further.

Table 2.2 Classification of SWSI

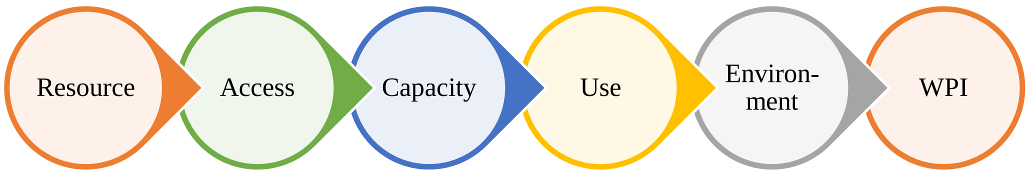
Category	Index
Relative Sufficiency	<5
Stress	5-10
Scarcity	10-20
Beyond the Barrier	>20

Source: Jemmali and Sullivan (2014)

Recently, another indicator introduced to measure water stress is "water poverty," considered to be a more complete and accurate assessment of the water situation. This measure examines water availability and access in a more holistic manner, overcoming or mitigating some of the shortcomings of other indicators (Sullivan et al., 2009). The WPI is a multidisciplinary approach based on the human development index (HDI) and consists of five components (see Figure 2.3): Resource: It measures the physical availability of water resources; 2) Access: It evaluates the ease of human access to water, encompassing aspects such as distance to the water source and the time required for collecting water, alongside other significant considerations, 3) Capacity: It quantify the people's ability to manage water, 4) Use: It assesses the actual quantity of water used in various sectors, 5) Environment: It encompasses various elements that have an impact on ecosystems related to the water supply (Sullivan et al., 2003; Goswami and Ghosal, 2022). Each component comprises various subcomponents/variables encompassing the diverse water issues (Jemmali and Sullivan, 2012).

Developed by Sullivan (2002), WPI builds upon Lawrence et al. (2003) notion of water poverty, which suggests that individuals can be water-poor due to either 1) inadequate access to sufficient water owing to its unavailability or 2) an inability to afford water even when it is accessible (Garriga and Foguet, 2010). Integrating physical water scarcity with the socioeconomic aspects of poverty, WPI is a holistic tool that has gained significant importance in policy-making as an effective water management instrument, especially in resource allocation and prioritization processes (Van Ty et al., 2010; Shalamzari and Zhang, 2018; Bidaki et al., 2022). The index enables national and international water organizations to monitor the status, availability, variability, and quality of water resources at the community, subnational, and national levels. The index has undergone significant methodological improvement over the years (Juran et al., 2017). Despite its complexities, the index provides more systematic, transparent, rational, and cogent information about the water status.

Figure 2.3 Five components of water poverty



Source: Authors' elaboration

2.4 Data, Construction of Variables, and Methodology

2.4.1 Data Source

The 76th round of Drinking Water, Sanitation, Hygiene and Housing Condition data collected by NSO (National Statistical Office), Ministry of Statistics and Programme Implementation (MOSPI), Government of India in 2018 (https://www.mospi.gov.in/web/mospi/download-tables-data/-/reports/view/templateTwo/16205?q=TBDCAT) is the source of data used in this study. The survey data gathered information on drinking water, sanitation, availability of household facilities, and microenvironment surrounding the house from all the states and union territories (Uts) of India (except for villages of Andaman and Nicobar Islands). The survey covers a total of 1,06,838 households, of which 63,736 were in rural areas and 43,102 in urban areas.

2.4.2 Construction of modified Water Poverty Index (MWPI)

Different approaches have been proposed to construct WPI (Sullivan,2002). In this study, we have used the *composite index approach* owing to its simplicity and advantage of recognizing the multidimensionality of water poverty. This method for the construction of WPI has also been widely used in the literature (Garriga and Foguet, 2010). The MWPI has been constructed following the five-components approach, using various quantifiable proxies at the household level. The indicators were chosen based on two major criteria: (1) availability of data and (2) review of relevant literature (see Table 2.3).

Further, to maintain the consistency, the indicator variables were transformed into 0 and 1 scales, where 0 represents the worst possible water situation and 1 represents the best available water situation. This was accomplished by employing the following equation:

- Positive indicator

$$X^{normalized} = \left(\frac{X^{i} - X^{minimum}}{X^{maximum} - X^{minimum}}\right) \quad ..(2.1)$$

- Negative indicator

$$X^{normalized} = \left(\frac{X^{maximum} - X^{i}}{X^{maximum} - X^{minimum}}\right) \quad ..(2.2)$$

The MWPI is represented as:

$$MWPI = \frac{W^{R}(Resource)+W^{C}(Capacity)+W^{A}(Access)+W^{U}(Use)+W^{E}(Environment)}{W^{R}+W^{C}+W^{A}+W^{U}+W^{E}} \quad ..(2.3)$$

Here, W represents weights that are applied to each of the five components. The present study used PCA to construct MWPI. The PCA was carried out separately for rural and urban areas. The sample adequacy and data reliability were assessed using the KMO (Kaiser-Mayer-Olkin) and Bartlett sphericity tests. The KMO test value was greater than 0.5 in both the rural and urban areas, indicating that the sample is adequate to proceed with the PCA (Jemmali and Sullivan, 2012). Furthermore, the values of Bartlett's test were statistically significant, indicating that the data meets the minimum requirements for PCA.

Table 2.3 Description of MWPI components and indicators used for the study			
Component	**Indicator**	**Description/Relation with MWPI**	**References**
Resource (R)	Provision and Availability of safe water	Existence of safe source of water supply within 1km (+)	Koirala et al, (2020)
	Variability and reliability of water source	Frequency of supply of water (+).	Nadeem et al. (2017)
Access (A)	Water supply coverage	Households connected with piped water supply (+)	Sullivan et al., (2009)
	Sewage or sanitation coverage	Households having access to sanitation (+).	
	Time spent collecting water, including waiting	Households spending more than one hour collecting water (-).	Sullivan et al., (2002)
Secondary source (S)	Access to alternate water source	Access to secondary sources (+).	Juran et al., (2017)
		Whether secondary source is clean, improved and safe (+).	
Use (U)	Domestic use	Households having sufficient water for domestic use (+).	Koirala et al, (2020)
Environment (E)	Qualitative assessment of water quality	Presence of stagnant water around the source of drinking water (-)	Garriga and Foguet (2010)

Table 2.4 shows the generated principal components as well as the variance explained by those components for both rural and urban areas, respectively. Using Kaiser's (1960) rule of retaining factors with eigenvalues greater than one, we get a total of three principal components in rural area and four in urban area. Furthermore, Varimax rotation was used to obtain component loadings for the preparation of index weights (see Table 2.5.a and 2.5.b). Based on the absolute value of their loadings, nine indicator variables were divided into three and four components for rural and urban area, respectively.

Table 2.4 Total Variance Explained (Rural and Urban)						
	Rural			Urban		
Component	Eigen Value	Variance (In Percentage)	Cumulative Variance	Eigen Value	Variance (In Percentage)	Cumulative Variance
1	2.20	0.24	0.24	1.89	0.21	0.21
2	1.49	0.17	0.41	1.74	0.19	0.40
3	1.10	0.12	0.53	1.12	0.12	0.52
4	0.99	0.11	0.64	1.00	0.11	0.63
5	0.92	0.10	0.74	0.95	0.11	0.74
6	0.89	0.10	0.84	0.92	0.10	0.84
7	0.79	0.09	0.93	0.77	0.09	0.93
8	0.36	0.04	0.97	0.33	0.04	0.97
9	0.24	0.03	1.00	0.28	0.03	1.00
Source: Authors' calculation						

Table 2.5.a Rotated Component Matrix for Rural area					
S.N.	Components of Water Poverty	Indicator Variable	Component Loadings		
			1	2	3
I	Resource	Existence of safe source of water supply within 1km			-0.57
II		Frequency of supply of water		0.59	
III	Access	Households connected with piped water supply		0.65	
IV		Households having access to sanitation			0.49
V		Households spending more than one hour collecting water			-0.35
VI	Secondary source	Access to secondary sources	0.65		
VII		Whether secondary source is clean, improved and safe	0.61		
VIII	Use	Households having sufficient water for domestic use	-0.37		
IX	Environment	Presence of stagnant water around the source of drinking water			0.56
Note: Cells with highest loadings are mentioned in the table.					
Source: Authors' calculation					

Table 2.5.b: Rotated Component Matrix for Urban area						
S.N.	Components of Water Poverty	Indicator Variable	Component Loadings			
			1	2	3	4
I	Resource	Existence of safe source of water supply within 1km	0.49			
II		Frequency of supply of water	0.56			

III	Access	Households connected with piped water supply	0.66			
IV		Households having access to sanitation			0.61	
V		Households spending more than one hour collecting water				0.96
VI	Secondary source	Access to secondary sources		0.67		
VII		Whether secondary source is clean, improved and safe		0.66		
VIII	Use	Households having sufficient water for domestic use		-0.28		
IX	Environment	Presence of stagnant water around the source of drinking water			0.68	
Note: Cells with highest loadings are mentioned in the table.						
Source: Authors' calculation						

The principal components, as shown in Tables 2.5.a and 2.5.b, are a mix of indicators from various MWPI sub-indices. For example, the first component in case of rural area includes indicator variable VI, VII and VIII i.e., the sub-indices of secondary source and use. Since, the secondary sources via augmenting the household supply of potable water generally help fulfill additional domestic water requirement. The access to these sources can be viewed as capturing the amount of water required by households, which is an indicator of 'use'. Hence, the first component principally reflects the MWPI's 'use' sub-index. The second component includes variables II and III. As per the literature, they are in different sets however if we go by the definition of 'resource component' in the context of MWPI, all these represents availability and variability of water. Moreover, the third factor consists of variables I, IV, V, and IX, which are sub-indices of resource, access, and environment as per surveyed literature. However, according to the definition, it primarily indicates 'access' to water resources. Hence, as per the PCA the water poverty index of rural areas consists of three indicators.

Similarly, in urban areas, the first component includes variables I, II, and III, which are resource and access sub-indices based on the literature reviewed. However, the first component, primarily representing the availability and variability of water resources, is

MWPI's 'resource' component. The second component includes variables VI, VII, and VIII, which indicate the MWPI's 'use' component. The third component, consisting of variables IV and IX, represents the MWPI's 'environment' sub-index, and factor four, consisting of variable V, represents the MWPI's 'access' component. Hence, as opposed to rural areas, the urban areas MWPI consists of four indicators as per PCA.

Based on the results given in Table 2.5.a and 2.5.b, the rural and urban MWPI is constructed using the method of arithmetic mean of all indicators variables (9 variables) (see Table 2.6). Weights have been calculate using the absolute value of factor loading of the respective variable and the proportion of variance explained by the component in which the respective variable falls. Following this, the calculation of weighted mean provides the final index value for water poverty for each household in the dataset. The value of MWPI lies in the range 0- 1 where zero represents extreme poverty and one indicates no poverty.

Table 2.6 Description of MWPI components and indicators based on PCA

Residency	Component	Indicator
Rural	PC1 (Use)	Access to secondary sources (S1)
		Whether secondary source is clean, improved and safe (S2)
		Households having sufficient water for domestic use (U1)
	PC2 (Resource)	Frequency of supply of water (R2)
		Households connected with piped water supply (A1)
	PC3 (Access)	Existence of safe source of water supply within 1km (R1)
		Households having access to sanitation (A2)
		Households spending more than one hour collecting water (A3)
		Presence of stagnant water around the source of drinking water (E1)
Urban	PC1 (Resource)	Existence of safe source of water supply within 1km (R1)
		Frequency of supply of water (R2)
		Households connected with piped water supply (A1)

	PC2 (Use)	Access to secondary sources (S1)
		Whether secondary source is clean, improved and safe (S2)
		Households having sufficient water for domestic use (U1)
	PC3 (Environment)	Households having access to sanitation (A2)
		Presence of stagnant water around the source of drinking water (E1)
	PC4 (Access)	Households spending more than one hour collecting water (A3)
Note: PC= Principal components		
Source: Authors' calculation		

Table 2.7 shows the mean value of water poverty for both the urban and rural areas. As shown in the table, the overall mean value of water poverty is 0.52 in rural areas and 0.65 in urban areas.

Table 2.7 Modified Water Poverty and Multidimensionally Poverty values (in average)

	Modified Water Poverty Index (Average value)		Multidimensionally poor households (Percentage)	
	Rural MWPI	Urban MWPI	Rural MPI	Urban MPI
India	0.52	0.65	14.93	2.98
Source: Authors' calculation				

2.4.3 Construction of Multidimensional Poverty Index (MPI)

In the study to account for the multi-dimensional aspect of measuring poverty, the multi-dimensional poverty index (MPI) has been constructed using the Oxford Poverty and Human Development Initiative (OPHI) methodology. The advantage of using this index is that it is very flexible and can be adjusted to add alternate indicators, cutoffs, and weights (Alkire et al., 2015).

For measuring MPI, Alkire and Foster (2015) methodology have been used. Four dimensions: health and hygiene, education, income, and standard of living have been selected for the analysis based on the available data given the 76th round of the NSSO data. This study does not consider the water dimension when constructing the MPI, as it is calculated separately in the MWPI.

Within these four dimensions, a total of thirteen indicators were identified. The value ‘1’ has been assigned to households who are deprived in particular indicators and ‘0’ have been assigned otherwise. All the dimensions and indicators used in the analysis are as follow:

1) Income:

- Monthly per-capita consumption expenditure (MPCE) has been used as a proxy since NSSO data does not contain any income information. To derive the income poverty lines, state-wise Tendulkar Committee poverty cutoffs were computed following the approach of Mothkoor and Badgaiyan, (2021). A household considered income deprived if its MPCE is less than state-level poverty cutoff.

2) Education: It contains two indicators:

- i) Literacy: A household considered deprived if it does not have a single literate adult (15+ years) (Mohanty,2011).
- ii) Education: A household is deprived if at least one school-going aged child (6-14 years) is not enrolled in school (Dehury and Mohanty, 2015).

3) Standard of Living: This dimension is composed of four indicators:

- i) Dwelling: deprived if household has no dwelling (Dehury and Mohanty,2015);
- ii) Cooking: deprived if household use other than LPG, other natural gas and electricity as cooking fuel (Mothkoor and Badgaiyan, 2021);

- iii) Electricity: deprived if household has no access to electricity (Mothkoor and Badgaiyan, 2021);

4) Health and Hygiene: Following the paper of Hooda and Tanwar (2018) this dimension contains variables such as:

- whether household faced the problem of flies/mosquitoes during last 365 days; if any member of household suffered from a stomach problem, jaundice, malaria/dengue/chikungunya, skin diseases or any other disease.

For weighing these dimensions and indicators, equal weight approach has been used as suggested by Lalnunmawia and Lalhriatpuii, (2019). Then a weighted deprivation score was calculated for each household as follows:

$$C_i = \sum_{j=1}^{13} W_j X_{ij} \qquad \dots (2.4)$$

$$Such\ that \qquad \sum_{j=1}^{13} W_j = 1 \qquad \dots (2.4.a)$$

Where, X_{ij} is the deprivation status of i^{th} household in the j^{th} indicator; W_j are the weights that have been assigned to the indicators; and C_i is the deprivation score.

Further, Das *et al.* (2021) mentioned that a household is multidimensionally poor if deprived of at least one-third of the indicators. Following Dehury and Mohanty (2015) and Das et al. (2021), the households were divided as follows: 1- if the weighted deprivation score of households is >0.33, then the household is considered multidimensionally poor, and 0- otherwise. Following this approach the status of multi-dimensional poor households is presented in Table 2.7. The table shows that rural areas have a significantly higher proportion of multidimensionally poor households than urban areas.

2.4.4 Methodology: Kendall tau-b and Tobit Regression

The present study has utilized correlation and regression analysis to show the relationship between MWPI and MPI[1] . Under the correlation analysis, the value of Kendall-tau b statistics has been reported to show the level of correlation between two index variables. For regression analysis, the Tobit model, also known as a censored regression model, was estimated. This model estimates linear relationships between variables when the dependent variable is censored to the left or right. In our case, all index variables are censored between 0 to 1. The study has estimated the following regression equations each for rural and urban areas separately to establish the link between MWPI and MPI.

For both rural and urban areas

$$MWPI_i = \alpha_1 + \alpha_2 MPI_i + U_i \quad \dots (2.5)$$

$$MWPI_i = \alpha_3 + \alpha_4 Edu_i + \alpha_5 Lit_i + \alpha_6 Inc_i + \alpha_7 Hyg_i + \alpha_8 Elec_i + \alpha_9 Fuel_i + U_i \quad \dots (2.6)$$

$$MPI_i = \beta_1 + \beta_2 MWPI_i + U_i \quad \dots (2.7)$$

For rural areas

$$MPI_i = \beta_3 + \beta_4 Use_i + \beta_5 Resource_i + \beta_6 Access_i + U_i \quad \dots (2.8)$$

For urban areas

$$MPI_i = \beta_3 + \beta_4 Use_i + \beta_5 Resource_i + \beta_6 Access_i + \beta_7 Environment_i + U_i \quad \dots (2.9)$$

Where MWPI and MPI are the index variables of water and multidimensional poverty, respectively; use, resource, access, and environment are the principal components of MWPI constructed using PCA; Edu, Lit, Inc, Hyg, Elec, and Fuel are the components of MPI

[1] For the empirical analysis, the weighted deprivation scores of Indian households have been used.

representing deprivation in education, literacy, hygiene, electricity, and cooking fuel, respectively; U is the error term; Beta's and alphas are the regression equation parameters, and i represents cross-sectional unit. The model has been estimated using the method of maximum likelihood in STATA 17.

Furthermore, because water availability and access can vary over very short distances, the water environment is heterogeneous and very much a local subject (Sullivan, 2002). To account for this geographical variation, the current study computed the Tobit regression with clustered standard error at the district level. As districts are the unit that groups people within the same geographical distance, they can account for heterogeneity as well as omitted variable biases caused by geographical complexities.

2.4.5 Methodology: Generalized structural equation model (GSEM)

GSEM was fitted to understand the impact of policy interventions on the MWPI and MPI. In addition, district variables were considered to understand the influence of the place of residence of households. The policy variable was constructed using the NSS data. In the NSS questionnaire, households were asked if they had ever received any drinking water policy benefit; the answers were yes, no, or not known. In the study, households that answered not known were excluded from the analysis for the policy variable construction. Following this, the policy variable was constructed as a categorical binary variable, where 0 represents that household has not received any drinking water policy, and 1 represents otherwise. The NSS questionnaire considered various drinking water policies like NRDWP, AMRUT, and SCM.

Similarly, MWPI and MPI were considered at the all-India level and as categorical binary variables. With respect to MWPI to classify households into poor and non-poor categories, the MWPI average (for both rural and urban areas) was used as follows: households with average scores greater than the average are considered non-poor (assigned a value of 1), while those with scores equal to or below the average are considered water-poor (assigned a value of 0). The advantage of using GSEM is that it allows us to operate with generalized linear response variables. Policy, MWPI, and MPI are categorical binary variables. Equation 10 shows the structural model of the GSEM.

$$\left.\begin{array}{c} Policy_i = \beta_1 + \beta_2 District_i + \mu_i \\ Rural\_MWPI_i = \beta_3 + \beta_4 Policy_i + \beta_5 District_i + \mu_i \\ Rural\_MPI_i = \beta_6 + \beta_7 Rural\_MWPI_i + \beta_9 District_i + \mu_i \\ Urban\_MWPI_i = \beta_{10} + \beta_{11} Policy_i + \beta_{12} District_i + \mu_i \\ Urban\_MPI_i = \beta_{13} + \beta_{14} Urban\_MWPI_i + \beta_{15} District_i + \mu_i \end{array}\right\} \quad \ldots(2.10)$$

A path diagram of the GSEM structure is shown in Figure 2.4. The hypotheses were as follows:

H1: The place of residence of the household influence if the household receives the benefit of a drinking water policy.

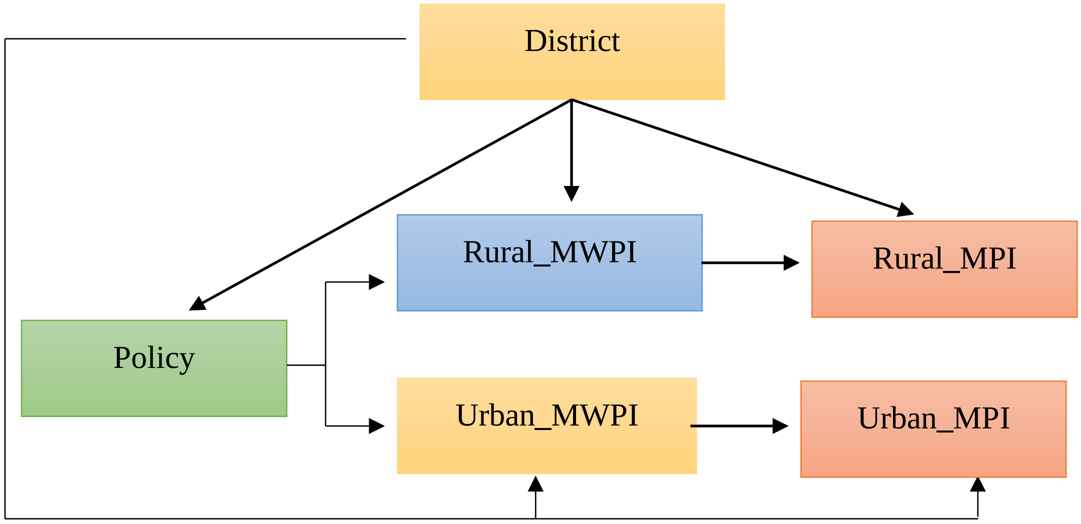
H2: Drinking water policy negatively influences water poverty of households in both rural and urban areas.

This implies that if a household has received a drinking water policy, the water poverty of the household decreases.

H3: Water poverty has a positive influence on multidimensional poverty in both rural and urban areas.

In the study, two GSEM models are estimated using a logit model and the other using a probit model to check the consistency of the results. The AIC and BIC test statistics for both were compared and found to be similar.

Figure 2.4 Specification of relationship between water policy, MWPI and MPI



Source: Authors' construction

2.5 Empirical Findings and Discussion

2.5.1 Descriptive analysis: Linking MWPI with MPI

The Kendall tau-b correlation results are shown in Tables 2.8.a and 2.8.b, and as can be seen, all of the correlation coefficients are statistically significant. Regarding the extent of their relationship, the resource component has the strongest correlation with MPI for rural areas, followed by the access component. In terms of urban areas, the environment component has the strongest correlation with the MPI, followed by the resource component. Overall, the correlation between MWPI and MPI is negative and significant in both rural and urban areas, with the extent of correlation being greater in rural areas.

Table 2.8.a Kendall's Tau-b statistic for rural area

	Use	Resource	Access	MWPI	MPI
Use	1.000				
Resource	0.237*	1.000			

Access	0.034*	0.198*	1.000		
MWPI	0.528*	0.664*	0.409*	1.000	
MPI	-0.043*	-0.192*	-0.123*	-0.171*	1.000
Note: * represents the value is statistically significant at 0.05 level					
Source: Authors' calculation					

Table 2.8.b: Kendall's Tau-b statistic for urban area						
	Resource	Use	Environment	Access	MWPI	MPI
Resource	1.000					
Use	0.051*	1.000				
Environment	0.045*	0.008*	1.000			
Access	0.029*	-0.011*	0.025*	1.000		
MWPI	-0.509*	0.535*	0.360*	0.052*	1.000	
MPI	-0.092*	0.021*	-0.174*	-0.024*	-0.097*	1.000
Note: * represents the value is statistically significant at 0.05 level						
Source: Authors' calculation						

2.5.2 Tobit Regression Estimation: Impact of MWPI on MPI

This section shows the Tobit regression results for both rural and urban areas, with MPI as the dependent variable and water poverty and its dimensions as the regressors. Four separate regressions have been estimated, and the marginal effects are shown in Table 2.9.a and 2.9.b. As evident from these tables, there is a negative and significant relationship between MPI and MWPI in both rural and urban areas. One percent point decrease in MWPI will lead to a 0.157 percent point increase in MPI from its mean value in rural areas and a 0.093 percent point increase in MPI from its mean value in urban areas. Although the effect of MWPI on MPI is higher in the case of rural areas, the regression results imply that if water poverty increases, it will push the household towards multi-dimensional poverty both in rural and urban areas.

Further, the estimation results of Model 2 and 4 looks into the impact of each of the components of MWPI on MPI. In both rural and urban areas, the access component of water poverty was found to be negatively related to MPI. This means that if the variables in this component deteriorate the likelihood of a household falling into multidimensional poverty increases. Furthermore, for the urban areas, a one percentage point decrease in environment component value was found to lead to a 0.083 percent point increase in MPI from its mean value.

These findings are justified both theoretically and empirically, as it has been discovered that the time and distance traveled to fetch water results in households having less time for other economically productive activities (Arku, 2010). The resulting loss of energy and fatigue, in addition to having a negative impact on household productivity, will also have an impact on children's educational status. This will have an impact on the household's current financial situation and will result in a bleak future as a result of the missed educational opportunity. The presence of stagnant water near a source of drinking water (considered a source of pollution) as well as the lack of sanitation facilities have negative health consequences that can decrease the household's ability to generate income.

The results also show that the frequency of water supply and the presence of piped water connections i.e., the resource component have a significant impact on MPI in rural areas. In urban areas as well, MPI was found to be influenced by the variables of the resource component i.e., frequency, piped water supply, and the presence of water within 1km. Time is a scarce and valuable resource, and the opportunity cost of the amount of time given for the activity of collecting water is the constraint it imposes on household income-generating activities. A water source within 1km of the house or a household piped water connection saves time and promotes the well-being of the household. Furthermore, because adequate water intake is an important determinant of health, a decrease in the frequency of water supply resulting in inadequate water intake, which can have negative health effects, can translate to low income-generating capacity.

In contrast to urban areas, in rural areas, households' water sufficiency, as well as access to safe secondary sources of water, was also found to have an impact on MPI. To maintain good health, adequate water resource availability is required throughout the year. Also, if the required amount of water cannot be obtained from the primary source, it may be obtained from other supplementary sources. As a result, the presence of a supplemental source could be interpreted as a positive indicator of meeting minimum water requirements.

Table 2.9.a Tobit Regression Estimation for rural area			
Marginal Effects			
Independent Variables (X)		**Dependent Variable: MPI (Y)**	
		Model 1	**Model 2**
Intercept		0.253** (0.000)	0.297** (0.000)
Rural_ MWPI	dy/dx	-0.157** (0.000)	--
Use		--	-0.014** (0.004)
Resource		--	-0.061** (0.000)
Access		---	-0.121** (0.000)
Linear Prediction of Dependent Variable			
Expected Value of Dependent Variable		0.172	0.172
Panel C: Regression Diagnostics			
LR Chi-Square (P-value)		0.000	0.000
Sample Size		63,732	63,732
Left-censored observations			959
Right-censored observations			0

Notes: Resource, Use, Environment and Access are the principal components of WPI constructed using PCA; Value in parenthesis of type () is the probability value of respective coefficient; ** represents the value is statistically significant at 1% and * represents the value is statistically significant at 5%.
Source: Authors' calculation

Table 2.9.b: Tobit Regression Estimation for urban area			
Marginal Effects			
Independent Variables (X)		**Dependent Variable: MPI (Y)**	
		Model 3	**Model 4**
Intercept		0.153** (0.000)	0.210** (0.000)
Urban_ MWPI	dy/dx	-0.093** (0.000)	--
Resource		--	-0.019** (0.000)
Use		--	0.004 (0.369)
Environment		---	-0.083** (0.000)
Access		---	-0.042** (0.009)
Linear Prediction of Dependent Variable			
Expected Value of Dependent Variable		0.084	0.084
Panel C: Regression Diagnostics			
LR Chi-Square (P-value)		0.000	0.000
Sample Size		43,072	43,072
Left-censored observations			1,412
Right-censored observations			0
Notes: Resource, Use, Environment and Access are the principal components of WPI constructed using PCA; Value in parenthesis of type () is the probability value of			

respective coefficient; ** represents the value is statistically significant at 1% and * represents the value is statistically significant at 5%.
Source: Authors' calculation

2.5.3 Tobit Regression Estimation: Impact of MPI on MWPI

An attempt is also made to examine the impact of MPI on MWPI in both rural and urban areas, using MWPI as the dependent variable and MPI and its various dimensions as the independent variables (see Table 2.10).

The estimated results of model 1 and 3 reveal that overall poverty translates into water poverty. It demonstrates that an increase in the level of multidimensional poverty leads to a decrease in the value of water poverty, causing the value of MWPI to decrease towards zero, i.e., towards more poverty. The findings also show that the impact of MPI on MWPI is marginally higher in rural areas than in urban areas. Furthermore, the estimated values of models 2 and 4 show that MPI dimensions have a significant impact on water poverty in rural areas. On the contrary, in urban areas, only a lack of literacy, income, electricity, and cooking fuel has an impact on the level of water poverty.

Aside from the usual links between education and income with water, the empirical analysis reveals a link between energy poverty (lack of electricity and cooking fuel) and water poverty. Being deprived of electricity and cooking fuel was found to increase the likelihood of being water-poor. Previous studies have supported the argument suggesting the benefit of energy on the economic and social aspects of households. Energy poverty has been associated with ill health and income poverty (Sadath and Acharya, 2017). Hence, it is no surprise that being energy-poor is positively related to being water-poor.

Table 2.10 Tobit Regression Estimation for rural and urban area
Marginal Effects

Independent Variables (X)		**Dependent Variable: Rural_ MWPI (Y)**		**Dependent Variable: Urban_ MWPI (Y)**	
		Model 1	**Model 2**	**Model 3**	**Model 4**
Intercept		0.584** (0.000)	0.677** (0.000)	0.764** (0.000)	0.761** (0.000)
MPI	dy/dx	-0.385** (0.000)	--	-0.280** (0.000)	--
Education		--	-0.044** (0.000)	--	-0.019 (0.070)
Literacy		--	-0.020** (0.000)	--	-0.036** (0.000)
Income		--	-0.026** (0.000)	--	-0.021* (0.013)
Hygiene		--	-0.095** (0.000)	--	0.008 (0.544)
Deprived Electricity		--	-0.106** (0.000)	--	-0.057** (0.003)
Deprived Cooking Fuel		--	-0.094** (0.000)	--	-0.092** (0.000)
Linear Prediction of Dependent Variable					
Expected Value of Dependent Variable		0.518	0.518	0.740	0.740
Panel C: Regression Diagnostics					
LR Chi-Square (P-value)		0.000	0.000	0.000	0.000
Sample Size		63,732	63,736	43,072	43,102
Left-censored observations		0	0	0	0
Right-censored observations		2,636	2,636	2,798	2,799
Notes: Resource, Use, Environment and Access are the principal components of WPI constructed using PCA; Value in parenthesis of type () is the probability value of respective coefficient; ** represents the value is statistically significant at 1% and * represents the value is statistically significant at 5%.					
Source: Authors' calculation					

2.5.4 GSEM Estimation: Determinants and Impact of Drinking Water Policies

Table 2.11 shows that only 3.28 percent of households in India have ever received any benefit from drinking water. Further, the estimated results of the GSEM model (see Figure 2.5) showing the impact of policy intervention on various aspects of poverty are given in Table 2.12. As per the results, policy is significantly and positively related to MWPI. Hence availing of water policies decreases the probability of being water-poor. Moreover, as seen from Table 2.12, MWPI is negatively and significantly related to MPI, hence a decrease in the probability of being water-poor also decreases the probability of being multidimensionally poor. Therefore, drinking water policies significantly impact households' multidimensional poverty status via the channel of water poverty.

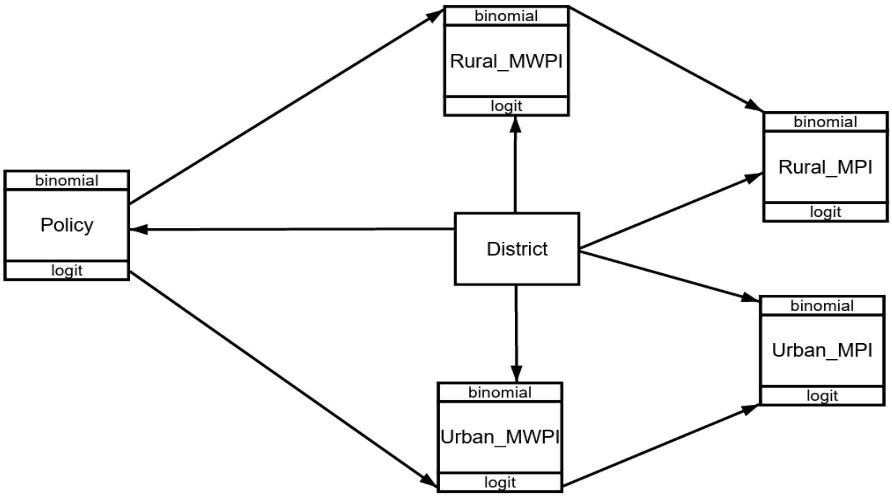
Table 2.11 Percent of households ever received any drinking water benefit

	Percent
Received	3.28
Not Received	96.72
Source: Authors' calculation	

Table 2.12 GSEM Results

Panel A: Impact of district on opting water policy	
District→ Policy	-0.00
Panel B: Impact of district and water Policy on water poverty	
Policy → Rural_MWPI	0.42***
District → Rural_MWPI	0.15***
Policy → Urban_MWPI	0.01***
District → Urban_MWPI	0.03***
Panel C: Impact of district and water poverty on multidimensional poverty	
Rural_MWPI → Rural_MPI	-1.69***
District → Rural_MPI	0.01***
Urban_MWPI → Urban_MPI	-3.55***
District → Urban_MPI	0.01***
Note: *, ** and *** represent significance at 10%,5% and 1% level respectively.	
Source: Authors' calculation	

Figure 2.5 Estimated GSEM model.



Source: Authors' construction

2.6 Conclusion

This study attempts to unravel the interrelationship between the multi-dimensional aspects of water poverty and multi-dimensional aspects of poverty. The empirical findings suggest that there is a positive and significant relationship between multidimensional poverty and water poverty, with the extent of the relationship being greater in rural areas. The results show that in rural areas all the components of water poverty have significant impact on multidimensional poverty, whereas in urban areas except use component all others have significant impact on multidimensional poverty. Further, components of multidimensional poverty were also found to be significantly impacting water poverty. The analysis also reveals that by significantly affecting the water poverty level, drinking water policies significantly influence multidimensional poverty.

Chapter 3

ASSESSING WATER POVERTY IN INDIA: A COMPREHENSIVE ANALYSIS WITH A FOCUS ON RAJASTHAN

Given the immense importance of water, and the fact that water poverty and multidimensional poverty are intrinsically intertwined and mutually reinforcing; we cannot treat either form of poverty in isolation. Hence, if India is to achieve and sustain its development goals, it must address the country's growing water problems. To accomplish this, accurate monitoring of the water situation is needed for policymaking. As discussed in the previous chapter, the Water Poverty Index (WPI) is a multidimensional indicator that expresses the multifaceted water issues in comprehensive form. It connects physical estimates of water availability to socioeconomic variables. The distinct advantage of the WPI lies in its comprehensive nature and its inherent adaptability across various scales and criteria, due to which it is been extensively employed worldwide to assess water resources on different scales, from national to regional to local.

Based on the above facts, this chapter employs the Water Poverty Index (WPI) as a tool to conduct a detailed analysis of the water situation across the Indian states. Furthermore, as previously discussed, the situation of water scarcity is alarming in Rajasthan, which is the largest state of India. Rajasthan also ranks among the poorest-performing states concerning water management. Therefore, in this chapter a comprehensives analysis of water situation in Rajasthan using WPI was undertaken, to highlight the lacking areas responsible for the deterioration in the water status of the state.

This chapter is divided into five sub-sections. The first section is devoted to provide an overview of the existing empirical studies on WPI in India. The second section illustrates the data and the methods used for the construction of WPI and modified WPI (MWPI). The third section discusses the empirical findings of the spatiotemporal pattern of WPI in the states of India. The fourth section presents the results of water poverty in Rajasthan. Finally, the fifth section provides the summary and the concluding remarks of the study.

3.1 Empirical Studies on Water Poverty Index in India

The WPI has been widely used to study the global water situation due to its flexibility. Within India also, Juran et al. (2016) used the modified WPI to study the micro-level water situation in 14 post-tsunami settlements in Nagapattinam District (ND) in the state of Tamil Nadu and Karaikal District (KD) in the Union Territory of Puducherry. Although the new index is conceptually similar to the WPI, new indicators and parameters have been added to broaden the scope of the index. As a result, rather than the subcomponents proposed by Sullivan et al., (2003), indicators such as quality, quantity, access, secondary sources, and capacity were employed. The authors of this novel study used data collected from 300 households in 14 villages (seven in each district). The modified WPI was calculated using a weighted mean after using min-max equations to standardize the dataset. As for the weights. three different weighting schemes were used: (a) traditional equal weights; (b) survey weights; and (c) weights based on key informant interviews, literature, and independent observations. The results indicated that except for the capacity component KD outperformed ND in quality, quantity, access, and secondary sources components. The study also discovered that WPI scores change as the weighing system changes.

Kaur (2016) used the WPI tool to examine the interstate water poverty situation in 2011-12. Secondary data sources were used to gather information about the states' resources, access, use, capacity, and environmental components. The index in this study was created using principal component analysis, and its value ranged from 0 to 100, with 0 representing the most water-poor and 100 representing the least. The study discovered that at the national level, the

WPI value is around 53.2, with Jharkhand having the lowest score of 37.2 and Sikkim having the highest score of 67.9. As for union territories, Delhi came in last with a score of 53.4, while Dadra and Nagar Haveli came in first with a score of 68.9.

Likewise, Goel et al. (2020) used WPI to investigate the water status in 20 major Indian states. The data for the access, resource, use, capacity, and environment component was gathered using secondary data sources. The index was built using principal component analysis and equal weight assignment. According to the study, the majority of Indian states are experiencing severe water stress as of 2014. Jharkhand and Rajasthan had the most water scarcity, while Punjab, Haryana, and Maharashtra had the least. The study also discovered that in addition to water availability, which is captured by the WPI's resource component, other socioeconomic parameters captured in the WPI's access, capacity, use, and environment components are important in defining a state's water status.

Prabha et al. (2020) used WPI to investigate water scarcity in India's 54 million-plus urban agglomerations. The WPI for the year 2011 was created by the authors using data from the Indian Household Development Survey, the Indian Meteorological Department, and the Central Ground Water Commission, and it included five critical components: access, resource, use, environment, and capacity. Using three different approaches: (a) additive no weights; (b) additive with weights; and (c) multiplicative, the study discovered that the top five urban agglomerations in terms of water are all in Kerala, regardless of aggregation method. Overall, the WPI for urban agglomerates using the three different approaches was found to be in the 0.47-0.59 range.

Copra and Ramachandran (2021) used the WPI index approach to measure the performance of the water sector in India. The authors used the weighted average method to create the index for 11 major Indian states. A total of 20 variables were used in the analysis, which were divided into five components: resource, access, capacity, use, and environment. Recognizing the subjectivity and criticism surrounding the index's weighing system, the authors developed the index objectively using the data envelopment analysis (DEA) method in addition to traditional WPI. According to the study's findings, Kerala, Punjab, and Tamil Nadu were among the top-performing states in the water sector, while Uttar Pradesh, Madhya Pradesh, and Bihar were among the least efficient.

Yadav and Ibrar (2022) studied the relationship between flood damage and water stress in twenty-one districts of North Bihar from 2008 to 2017. To quantify water stress, the authors developed WPI, which consists of five components: resource, access, capacity, use, and environment. The index was created using weighted arithmetic mean, with a value ranging from 0 to 1. The authors then divided the value into three ranges to represent the various degree of water stress: 0-0.35 high stress, 0.36-0.75 moderate stress, and 0.76-1.0 low stress. A flood damage index (FDI) was created to quantify flood damage. The authors discovered that 14 of the 21 districts were highly stressed, with WPI values ranging from 0-0.35. The overall WPI score for north Bihar was 0.35, indicating a highly stressed situation. As for flood damage, Darbhanga and Muzaffarpur districts were found to be the most affected.

In light of the above discussion, it can be concluded that there is a paucity of studies that use WPI to access water situations in India. The studies that have used WPI have been done for a limited number of states. Kaur (2016) and Goel et al. (2020) were the only studies that examined the water situation in India as a whole. However, the dataset that they use is relatively old, and they, too, have not provided a trend of WPI over time. The current study proposes to add to the existing literature by calculating the WPI score for all Indian states for two time period (2012 and 2018). Further, a component-wise analysis is performed to obtain a picture of state-wise water poverty progress as well as to examine the major areas of deficiency. Also, within our current scope of understanding, there appears to be a lack of research employing WPI to evaluate water conditions, particularly in Rajasthan, India.

3.2 Materials and Methods

3.2.1 Data Source

For the construction of WPI for the states of India, secondary data from sources such as NSS rounds of Drinking Water, Sanitation, Hygiene and Housing Condition survey (2012 and 2018), Indiastat, Central Ground Water Commission, Reserve Bank of India, Ministry of Education, Central Pollution Control Board were extracted. The NSS Drinking water, Sanitation, Hygiene, and Housing Condition data set is a survey collecting information on various aspects of household dwelling units and basic housing amenities such as drinking water, bathrooms, latrine, etc. The dataset in 2012 covered a total of 95,548 households comprising about 4,44,224 persons and in 2018 information was collected from 1,06,838 households covering a total of 4,66,527 people at the all-India level.

For Rajasthan, the present study has used household-level (micro-scale) data to calculate the WPI, referred to as the MWPI. Although WPI can be applied at various scales, Nadeem et al. (2017) and Juran et al. (2017) note that macro data have been widely used in studies to compute WPI. The disadvantage of using macro data is that it obscures spatial variability, resulting in issues of representativeness.

In the present study the household level data for Rajasthan was extracted from the National Sample Survey (NSS) dataset on 'Drinking Water, Sanitation, Hygiene, and Housing Conditions' conducted in 2012 and 2018 was extracted. For this study, data for exclusively Rajasthan were segregated. A total of 4,223 and 5,240 households for 2012 and 2018 were analyzed. Of these households, 2,521 and 3,384 were in rural areas, and 1,702 and 1,856 were in urban areas in 2012 and 2018, respectively.

The novelty of the present study is that for the first time within India and Rajasthan, WPI is applied to evaluate the temporal changes in the water poverty situation of the state. According to Huang et al. (2017), the WPI computed at a reasonable time interval can be used to track regional development progress.

3.2.2 WPI construction for the states of India

The WPI is constructed following the methodology of Sullivan et al. (2003). Following an indicator-based approach to measuring the components, we have identified and selected fourteen sub-components after reviewing the literature and checking the availability of the dataset. The following section briefly explains each of the components and their indicators and highlights the dataset used for accessing each of the sub-components.

3.2.2.1 Resource

It measures the water endowment of a particular country or region. To capture the resource following the work of Kaur (2016) and Ladi et al. (2021), groundwater resources per capita (R^1) and annual rainfall (R^2) are used as indicators. State/UT-wise data of annual extractable groundwater resource (Total annual groundwater recharge - Total natural discharge) were taken from the groundwater yearbook of India 2016-17 and 2018-19 for representing scenario of water in 2012 and 2018 respectively. This dataset is published by the Central Ground Water Board. For arriving at the per capita figure of the groundwater resources population figures were taken from the Reserve bank of India and extrapolated for the years 2012 and 2018 using the compound annual growth rate from 2001-2011. The data for the annual rainfall was extracted from Indiastat for 2012 and 2018. The 38 subdivisions were compiled as per the India Meteorological Department (IMD) to get the state-wise annual rainfall figures.

$$Resource = \frac{R^1 + R^2}{2} \quad ..(3.1)$$

3.2.2.2 Access

It refers to the ability of people of a particular country or region to obtain water in order to satisfy their needs. The component takes into account the time, distance, as well as cost, incurred in collecting water. In the present study "access" have been computed using four indicators, namely access to safe drinking water (Garriga and Foguet, 2010), access to improved sanitation (Prabha et al., 2020), time devoted (Panthi et al., 2018) and distance traveled (Garriga and Foguet, 2010) to collect water. The NSS rounds of Drinking Water, Sanitation, Hygiene and Housing Condition survey 2012 and 2018 were the data source for the given indicators. The definition of improved sanitation has been taken from the NSS schedule of Drinking Water, Sanitation, Hygiene and Housing Condition survey, and for defining access to safe water WHO guideline has been used.

$$Access = \frac{A^1 + A^2 + A^3 + A^4}{4} \quad ..(3.2)$$

Where A^1 is access to safe drinking water; A^2 is access to improved sanitation; A^3 is time devoted to collect; and A^4 is the distance traveled to collect water.

3.2.2.3 Environment

As given by Sullivan et al. (2003) this component captures the environmental integrity related to water. Following the study of Kaur (2016) , municipal wastewater generation (E^1), municipal solid waste generation (E^2), and forest cover (E^3) were taken as an indicator of the component. The data for municipal wastewater generation was taken from Central Pollution Control Board 2009-10 report titled "Status of Water Supply, Wastewater Generation and Treatment in Class-I cities and Class- II towns of India" and Government of India Ministry of Environment, Forest and Climate change Lok Sabha's Unstarred question no. 2541 for the year 2012 and 2018 respectively. Report on municipal solid waste management published by Central Pollution Control Board has been used as a data source for solid waste generation in 2012 and 2018. For evaluation the forest cover of states percentage of forest cover to the total geographical area of states were considered, the data for which was obtained from Ministry of Statistics and Programme Implementation (MOSPI) compendium of environment statistics 2013 and Indiastat for 2012 and 2018 respectively.

$$Environment = \frac{E^1 + E^2 + E^3}{3} \quad ..(3.3)$$

3.2.2.4 Use

The use dimension captures the different usage of water. In the present study domestic (U^1) and agricultural (U^2) use have been computed. For computing the amount of water used for domestic purposes, following the study of Prabha et al. (2020) type of toilet was used as an indicator. The data for which have been extracted from the NSS survey on Drinking Water, Sanitation, Hygiene, and Housing Condition survey 2012 and 2018. For the agricultural water usage, the percentage of the net irrigated area (NIA) to the net sown area (NSA) was taken following the work of Shalamzari and Zhang (2018). All India Report on Agricultural Census 2010-11 and 2015-16 published by Ministry of Agriculture and Farmers Welfare, Government of India was the data source of the mentioned variable.

$$Use = \frac{U^1 + U^2}{2} \quad ..(3.4)$$

3.2.2.5 Capacity

Even if a region or country is sufficiently endowed with water resources it may happen that people are still "water-poor" owing to a lack of income to buy water (Kaur, 2016). Capacity can be understood as the ability of people to manage water. Access to income as well as education and health that translates income-generating capacity of individuals enhance the lobbying power of people in managing water supply (Sullivan et al., 2003). Following this infant mortality rate (Garriga and Foguet, 2010), the higher education enrolment rate (Liu et al., 2019), and the per capita net state domestic product (NSDP) (Chopra and Ramachandran, 2021) were taken as indicators for this component. The data for infant mortality rates for 2012 and 2018 were taken from Indiastat. All India Survey on Higher Education 2012-13 and 2019-20 published by Ministry of Education, Government of India was the data source for higher education enrolment rate. For the per capita net state domestic product data was taken from National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India.

$$Capacity = \frac{C^1 + C^2 + C^3}{3} \quad ..(3.5)$$

Where C^1 is the infant mortality rate; C^2 is the higher education enrolment rate; and C^3 is the per capita net state domestic product (NSDP).

3.2.3 Normalization

Since a number of indicator variables are used to measure each of the components, it becomes mandatory to rescale all of them on one scale before calculating WPI. In this study, we choose to assign each indicator a score between 0 to 100. Therefore, the indicators that were already in percentage form were not changed, the rest of the variables were normalized using the following formula:

Positive indicator

$$X^{normalized} = \left(\frac{X^{i} - X^{minimum}}{X^{maximum} - X^{minimum}}\right)100 \quad ..(3.6)$$

Negative indicator

$$X^{normalized} = \left(\frac{X^{maximum} - X^{i}}{X^{maximum} - X^{minimum}}\right)100 \quad ..(3.7)$$

3.2.4 Aggregation of components

The weighted arithmetic mean is the aggregation method for combining all the sub-component to create the WPI. This aggregation method has been employed in a number of studies (Garriga and Foguet, 2010; Jemmali and Sullivan, 2014; Prabha et al., 2020) owing to its simplicity. For easy interpretation and to avoid any subjectivity equal weights were assigned to all the components.

$$WPI = \frac{Resource + Access + Environment + Use + Capacity}{5} \quad ..(3.8)$$

3.2.5 Construction of MWPI for Rajasthan

The MWPI was computed for 2012 and 2018, integrating multidimensional aspects of water into a series of indicators to provide a complete picture of the water status of the state. Conceptually similar to WPI, the MWPI was created using the composite index approach. While the conceptual framework is similar, the MWPI modified the WPI by incorporating new components and indicators, capitalizing on the WPI's built-in flexibility in selecting components and indicators (Garriga and Foguet, 2010). Therefore, while resembling the WPI, which consists of five components (Resources, Access, Capacity, Use, Environment), the MWPI also encompasses five components (Resource, Access, Secondary sources, Capacity, and Environment). Based on available data rather than the 'use' component, 'secondary sources' was considered one of the components. The indicators were chosen using three criteria: 1) availability of data, 2) review of relevant literature, and 3) reflect the most pressing water-related issues (see Table 3.1).

The MWPI encompasses a total of 10 indicators (see Table 3.1). Further, to maintain consistency, the indicators were normalized using the standard min-max formula to get a uniform scale of 0 to 1 (see Equations 3.9 and 3.10).

- Positive indicator

$$X^{normalized} = \left(\frac{X^{i} - X^{minimum}}{X^{maximum} - X^{minimum}}\right) \ldots (3.9)$$

- Negative indicator

$$X^{normalized} = \left(\frac{X^{maximum} - X^{i}}{X^{maximum} - X^{minimum}}\right) \ldots (3.10)$$

After normalizing the indicators, the next step is assigning them weights. In the present study, following the paper of Zahra et al. (2018), equal weights have been assigned to each component to avoid subjectivity and bias. Further, the weighted additive function was employed to construct the index. Equation 3.11 shows the mathematical formulation of the MWPI.

$$MWPI = \frac{Wr*Resource + Wa*Access + Ws*Supplementary\ source + Wc*Capacity + We*Environment}{Wr + Wa + Ws + Wc + We} \ldots (3.11)$$

Wr, Wa, Ws, Wc, and We are weights assigned to resource, access, secondary source, capacity, and environment components. In the present study, an equal weight of 1 has been assigned to each component. This results in the following formula for the construction of the index (see Equation 3.12):

$$MWPI = \frac{Resource + Access + Supplementary\ source + Capacity + Environment}{5} \ldots (3.12)$$

The final index value ranged from 0 to 1, with 0 indicating extreme water poverty and 1 indicating no water poverty. Further, unlike the macro-level approach, the current study creates household-level MWPI that accounts for micro-level differences in water status. Following Juran et al. (2017), the household-level MWPI scores were pooled and averaged to calculate the MWPI scores at the district, region, and state levels.

Table 3.1 Indicators for construction of MWPI				
Component (Weight)	Indicators	Indicators Weight	Values	Reference
Resource (1)	Water quantity sufficiency	0.5	1-Yes 0-No	Nadeem et al. (2017)
	Reliability of water source	0.5	Frequency of supply of water	
Access (1)	Access to safe water	0.25	1-Households have access to improve water source 0- Otherwise	Juran et al. (2017)
	Access to sanitation	0.25	1-Households have access to improve sanitation 0- Otherwise	Garriga and Foguet (2010)
	Distance	0.25	Distance travelled to reach the water source	
	Time spent collecting water (to and fro)	0.25	In minutes (Excluding time taken for waiting at the source)	
Secondary sources (1)	Access to secondary source	1	1-Yes 0-No	Juran et al. (2017)
Capacity (1)	Income	0.5	Higher the income, lower the water poverty	Azqueta and Montoya (2017)
	Illness due to water	0.5	1-No 0-Yes	
Environment (1)	The presence of stagnant water around the source of drinking water	1	1-No 0-Yes	Garriga and Foguet (2010)

3.2.6 Sensitivity analysis of MWPI

In the study, equal importance was given to all the components while constructing MWPI. However, it is imperative to do a sensitivity analysis to test the robustness of the index to improve the credibility and accuracy of the results. Consequently, following Garriga and Foguet (2010), the weights of the components were altered. Principal component analysis (PCA) was employed for the alternative weighting scheme. Using PCA, the MWPI was calculated for the years 2012 and 2018. Before that, both periods' datasets were evaluated for sample adequacy and data reliability using the KMO (Kaiser-Mayer-Olkin) and Bartlett sphericity tests. In both periods, the KMO test value was greater than 0.5, and the results of Bartlett's test were statistically significant, indicating that the data satisfied the minimum requirements for PCA.

3.3 Results: The spatiotemporal patterns of WPI for the states of India

This section analyses the spatio-temporal patterns of WPI, its five components, along with their sub-components at the state level.

3.3.1 Spatio-temporal patterns of Components of WPI

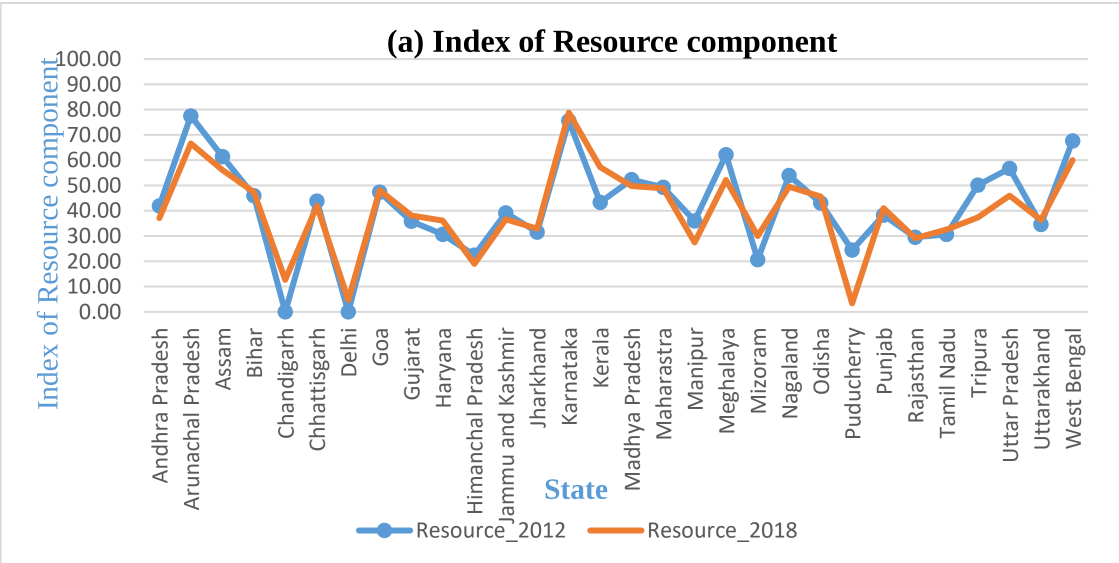
a) Resource

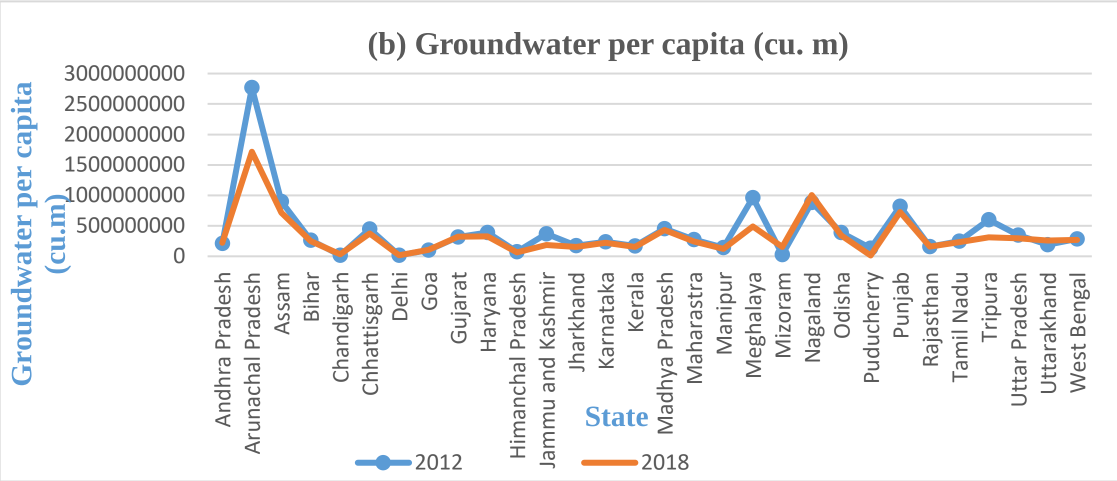
The results obtained for the resources components at each state are provided in Fig. 3.1. As seen, the highest water resources are endowed in the states of Arunachal Pradesh in 2012 and Karnataka in 2018 and the lowest endowment is in the states of Delhi in 2012 and Puducherry in 2018. Further, from the figure, it is clear that the resource component has witnessed a decline in the states of Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Puducherry, Rajasthan, Tripura, Uttar Pradesh, and West Bengal.

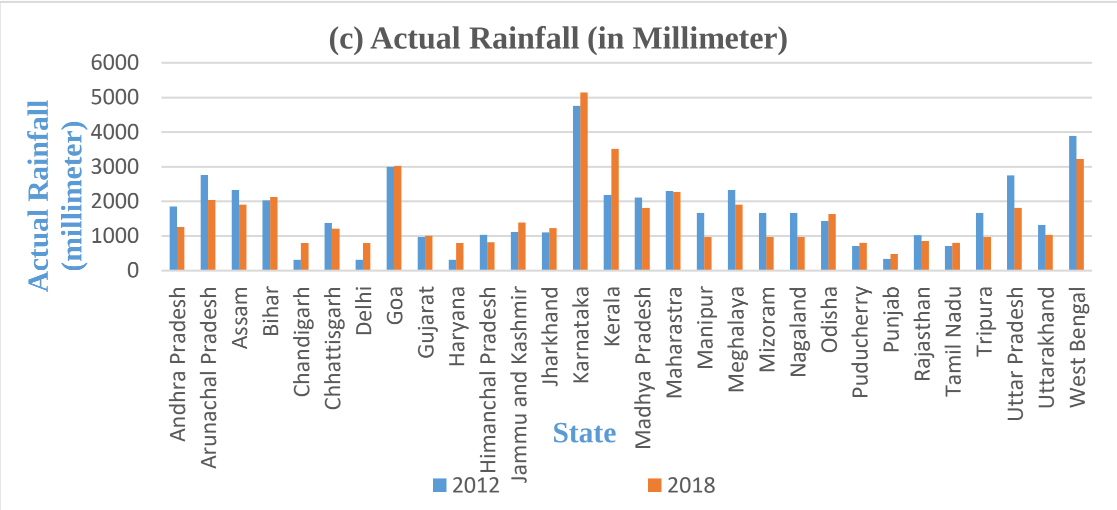
While looking at the sub-components of resource in figure 3.1.b, the groundwater resources per capita over this time period has declined. Leaving the states of Andhra Pradesh, Chandigarh, Goa, Gujarat, Nagaland, Puducherry, and Uttarakhand rest all have witnessed a downfall in their per capita groundwater resource availability. The average groundwater per capita for the entire landmass of India was approximately 413124020 cubic meters in 2012 which declined to 330876276 cubic meters in the year 2018.

Rainfall plays a major role as a source in replenishing the groundwater and surface water resources but the annual rainfall over the entire landmass of India is very variable both in space as well as time. As an important sub-component of resource, data for the time period of 2012 and 2018 shows that the mean annual rainfall declined from 1699.02 mm in 2012 to 1583.87 mm in 2018. As evident from Fig.3.1.c the decline was not witnessed in all the states but for states of Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Rajasthan, Tripura, Uttar Pradesh, Uttarakhand, and West Bengal it shows a decrease in annual rainfall. Hence, we can say that declining rainfall accompanied by a decrease in groundwater availability per capita has resulted in the decline of resources for India's states.

Figure 3.1 Spatio-temporal patterns of resource component of WPI







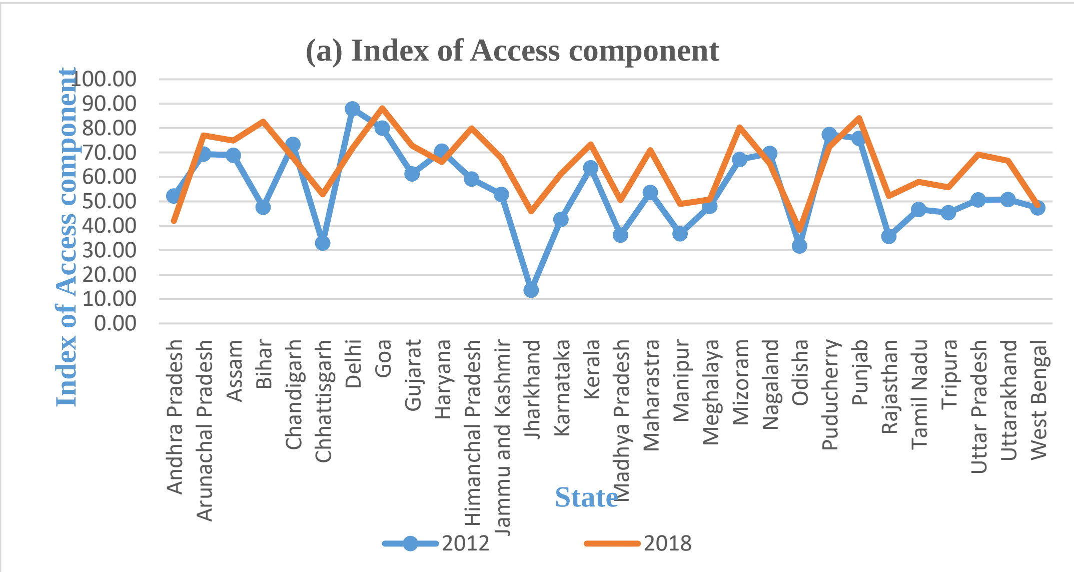
Source: Authors' construction

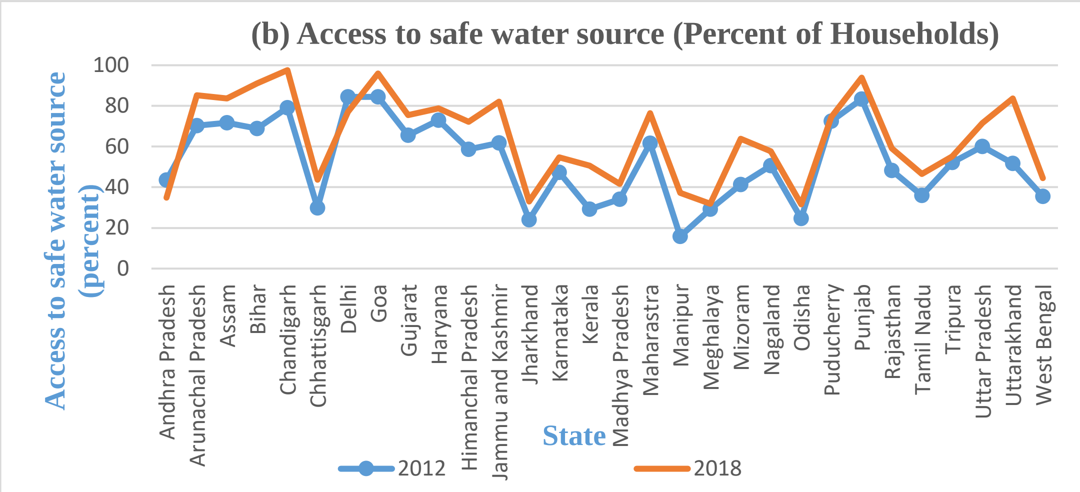
b) Access

The access component stands in contrast with the resource component as is seen in Fig 3.2.a. Compared to the year 2012 almost all the states leaving Haryana, Andhra Pradesh, Chandigarh, Delhi, Nagaland, and Puducherry have witnessed an improvement in access in 2018. Further, of all states Delhi represents the best access condition in 2012 and Goa in 2018, the worst access condition is witnessed in the state of Jharkhand in 2012 and Odisha in 2018.

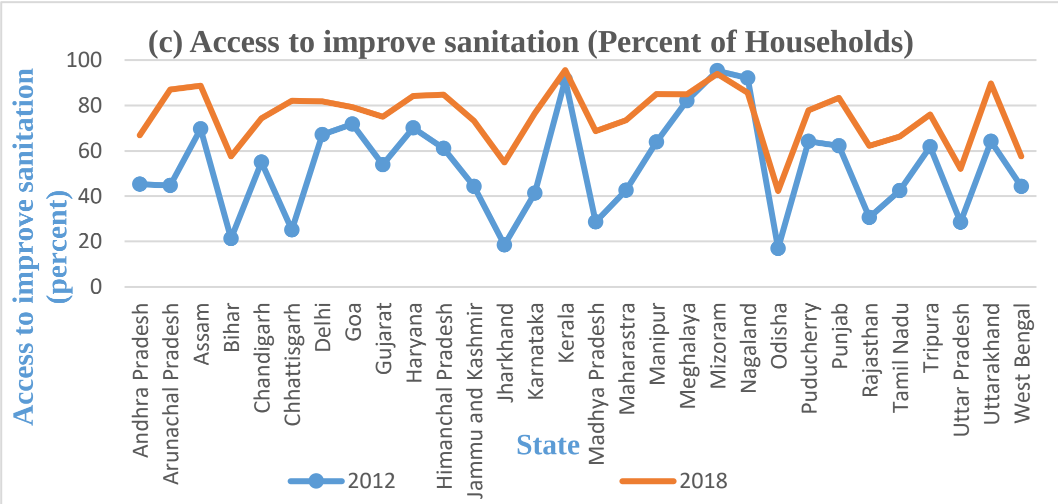
As for the sub-components constituting access all showed an improvement in the considered time period. As can be seen from it, leaving Andhra Pradesh and Delhi, all other states witnessed an increase in the percentage of people having access to improved sources of drinking water (see Figure 3.2.b). For the access to improve sanitation as well, except for Mizoram and Nagaland all other states witnessed an improvement in their situation when compared to 2012 (see Fig. 3..2.c). The amount of time devoted to the collection of water also improved in all the states leaving Andhra Pradesh, Arunachal Pradesh, Chandigarh, Delhi, Haryana, Nagaland, and West Bengal which saw an increase in time required for fetching water as evident from Fig.3.2.d. From Fig. 3.2.e we can also see the distance travelled for the task of water collection also decreased in all states except for Andhra Pradesh.

Figure 3.2 Spatio-temporal patterns of access component of WPI

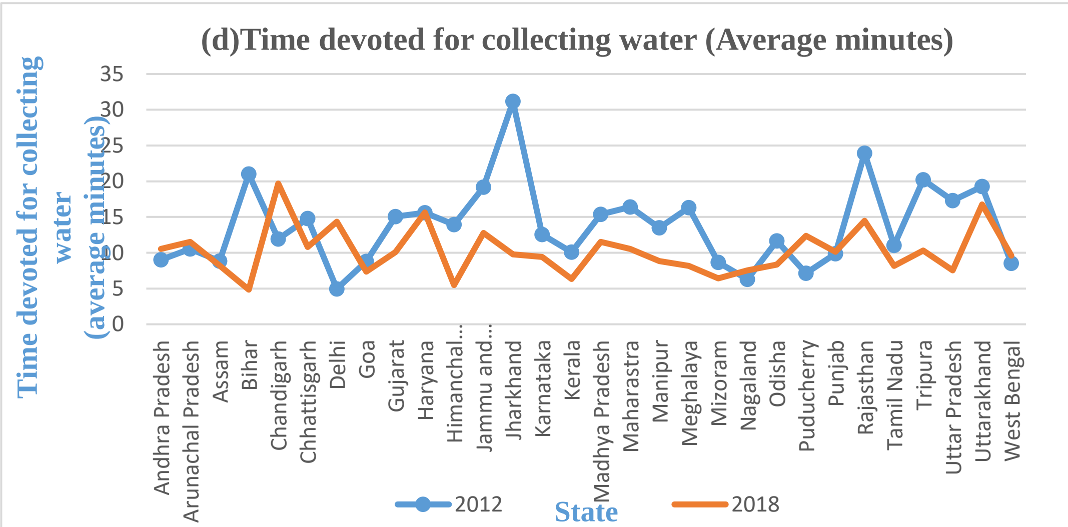




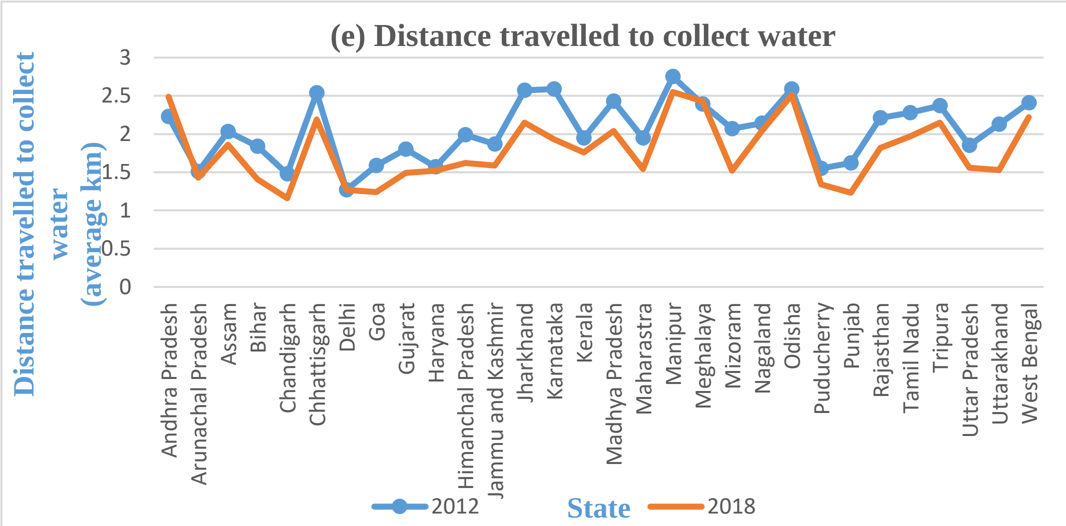
(b) Access to safe water source (Percent of Households)
Access to safe water source (percent)
100
80
60
40
20
0
Andhra Pradesh
Arunachal Pradesh
Assam
Bihar
Chandigarh
Chhattisgarh
Delhi
Goa
Gujarat
Haryana
Himanchal Pradesh
Jammu and Kashmir
Jharkhand
Karnataka
Kerala
Madhya Pradesh
Maharastra
Manipur
Meghalaya
Mizoram
Nagaland
Odisha
Puducherry
Punjab
Rajasthan
Tamil Nadu
Tripura
Uttar Pradesh
Uttarakhand
West Bengal
State
2012
2018



(c) Access to improve sanitation (Percent of Households)
Access to improve sanitation (percent)
100
80
60
40
20
0
Andhra Pradesh
Arunachal Pradesh
Assam
Bihar
Chandigarh
Chhattisgarh
Delhi
Goa
Gujarat
Haryana
Himanchal Pradesh
Jammu and Kashmir
Jharkhand
Karnataka
Kerala
Madhya Pradesh
Maharastra
Manipur
Meghalaya
Mizoram
Nagaland
Odisha
Puducherry
Punjab
Rajasthan
Tamil Nadu
Tripura
Uttar Pradesh
Uttarakhand
West Bengal
State
2012
2018



(d)Time devoted for collecting water (Average minutes)
Time devoted for collecting water (average minutes)
35
30
25
20
15
10
5
0
Andhra Pradesh
Arunachal Pradesh
Assam
Bihar
Chandigarh
Chhattisgarh
Delhi
Goa
Gujarat
Haryana
Himanchal...
Jammu and...
Jharkhand
Karnataka
Kerala
Madhya Pradesh
Maharastra
Manipur
Meghalaya
Mizoram
Nagaland
Odisha
Puducherry
Punjab
Rajasthan
Tamil Nadu
Tripura
Uttar Pradesh
Uttarakhand
West Bengal
2012
State
2018



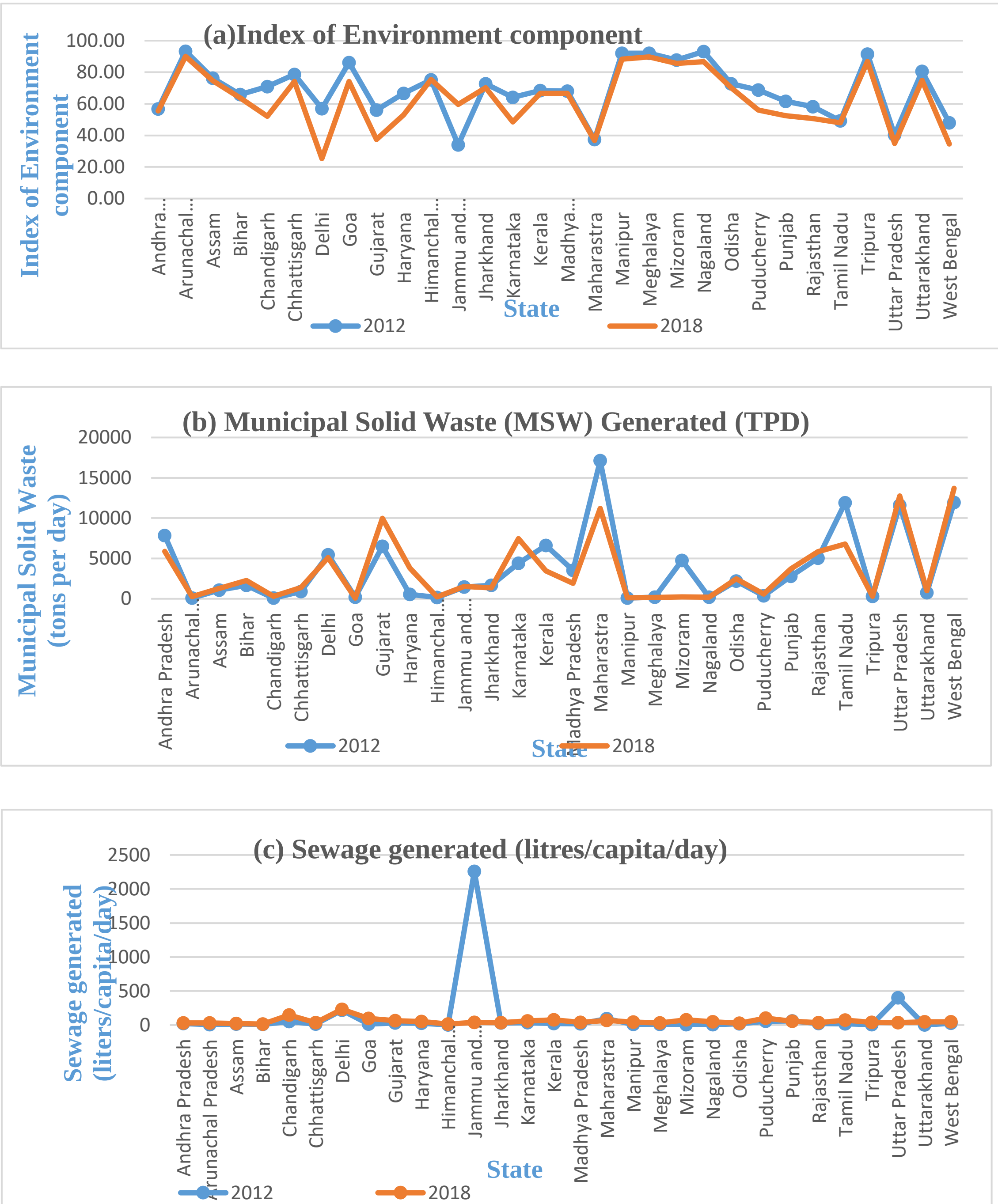
Source: Authors' construction

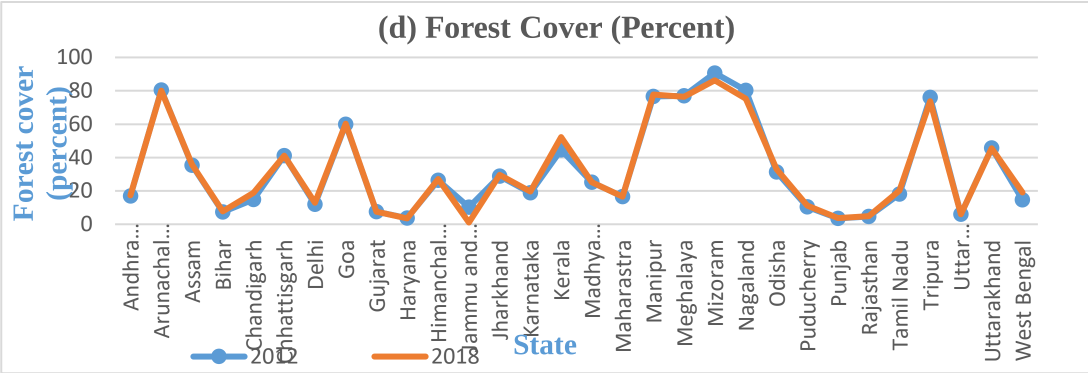
c) Environment

This component clearly indicates that from 2012 to 2018 the environmental integrity of India has been compromised. The mean value of the environment component was 68.78 in 2012 which decreased to 62.75 in 2018. The worst performers amongst all the states were Jammu and Kashmir in 2012 and Delhi in 2018. The severity of the deterioration can be understood by seeing Fig. 3.3.a which indicates that except for Himachal Pradesh the rest of the states have deteriorated their environmental conditions.

To further investigate if we look at its sub-components represented in Fig., 3.3.b we observe that the solid municipal waste generated has increased in all the states leaving Andhra Pradesh, Delhi, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Tamil Nadu, and Tripura. The maximum amount of municipal solid waste was generated by Maharashtra in 2012 and West Bengal in 2018. Similarly, for sewage generation leaving the states of Jammu and Kashmir, Maharashtra, Punjab and Uttar Pradesh rest all have witnessed an increase in sewage generation (see Fig 3.3.c). Further, although the forest cover has marginally increased in India from 2012 to 2018, the observed data as evident from Fig., 3.3.d shows a decline in forest cover in states of Arunachal Pradesh, Chhattisgarh, Haryana, Jammu and Kashmir, Madhya Pradesh, Meghalaya, Mizoram, Nagaland, Tripura and Uttarakhand.

Figure 3.3 Spatio-temporal patterns of environment component of WPI





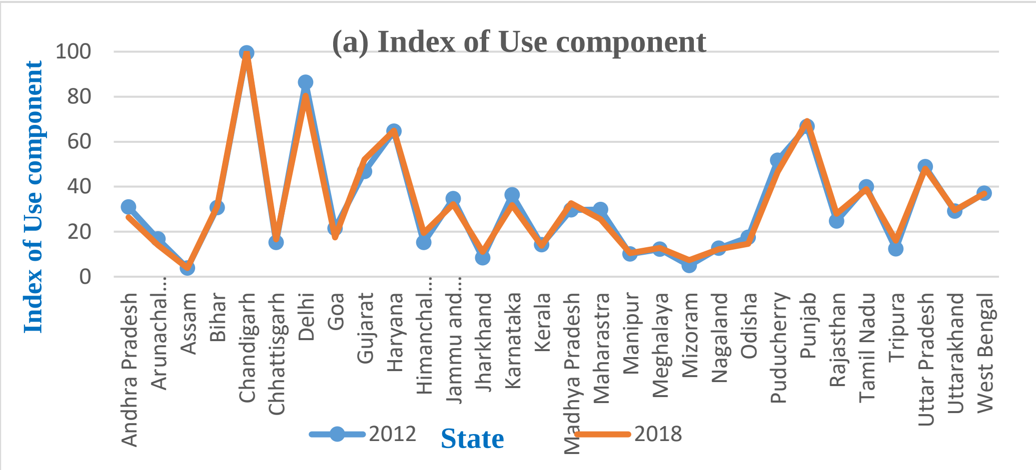
Source: Authors' construction

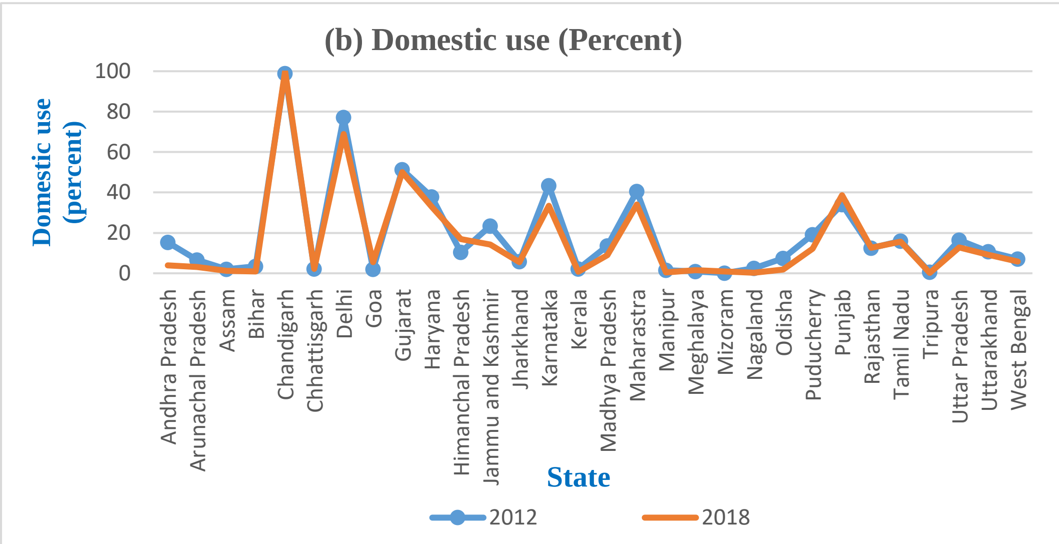
d) Use

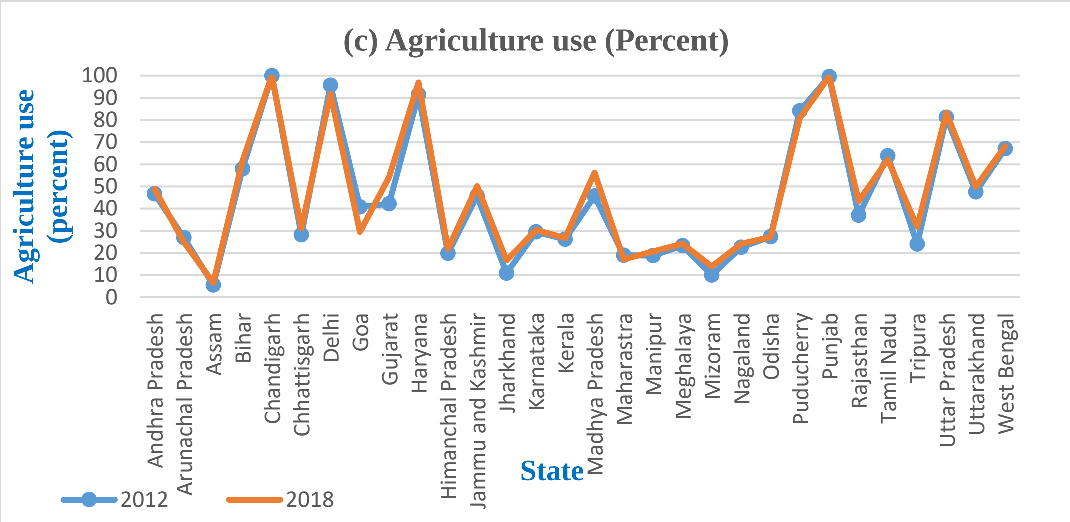
As for the use component that is being evaluated by the sub-components; the amount of water usage in the domestic and agriculture sector. Over the given period we notice a marginal decline in the value of the aggregate index of use. The mean value of the index dropped from 31.73 in 2012 to 31.47 in 2018. Chandigarh recorded the highest level of water use in both years while Assam continues to be the state with the least water use. Further, from Fig. 3.4.a it is observed that over the given time period the use of water has declined in the states of Andhra Pradesh, Arunachal Pradesh, Delhi, Goa, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Nagaland, Odisha, Puducherry, Tamil Nadu, Uttar Pradesh, and West Bengal.

As for the sub-components, domestic water use witnessed a decline from 18.84 in 2012 to 16.48 in 2018. Leaving Chandigarh, Goa, Himachal Pradesh, Meghalaya, Mizoram, Punjab, and Rajasthan rests in all states the domestic water use declined (See Fig.3.4.b). With respect to agricultural water usage evaluated as the percentage of the net irrigated area (NIA) to net area sown (NAS), the mean value of this sub-component shows an increase from 44.63 to 46.45. The agricultural water use was highest in Chandigarh and lowest in Assam in both the years. Although over the given period majority of the states witnessed an improvement in the percentage of NIA to NAS some states like Arunachal Pradesh, Delhi, Goa, Odisha, and Puducherry witnessed a decline in their agriculture water usage as evident from Fig. 3.4.c.

Figure 3.4 Spatio-temporal patterns of use component of WPI







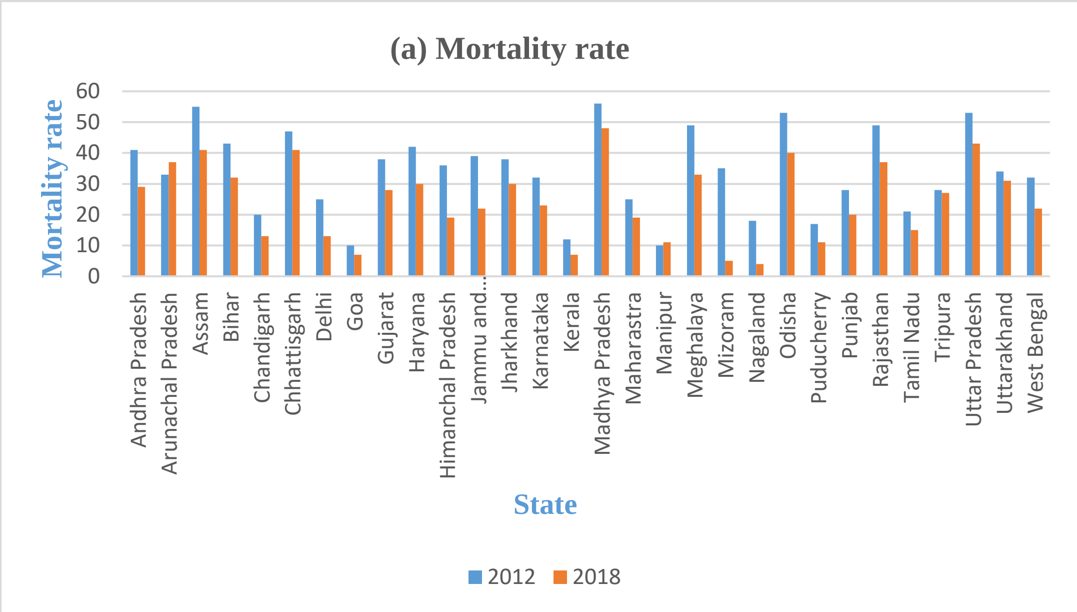
Source: Authors' construction

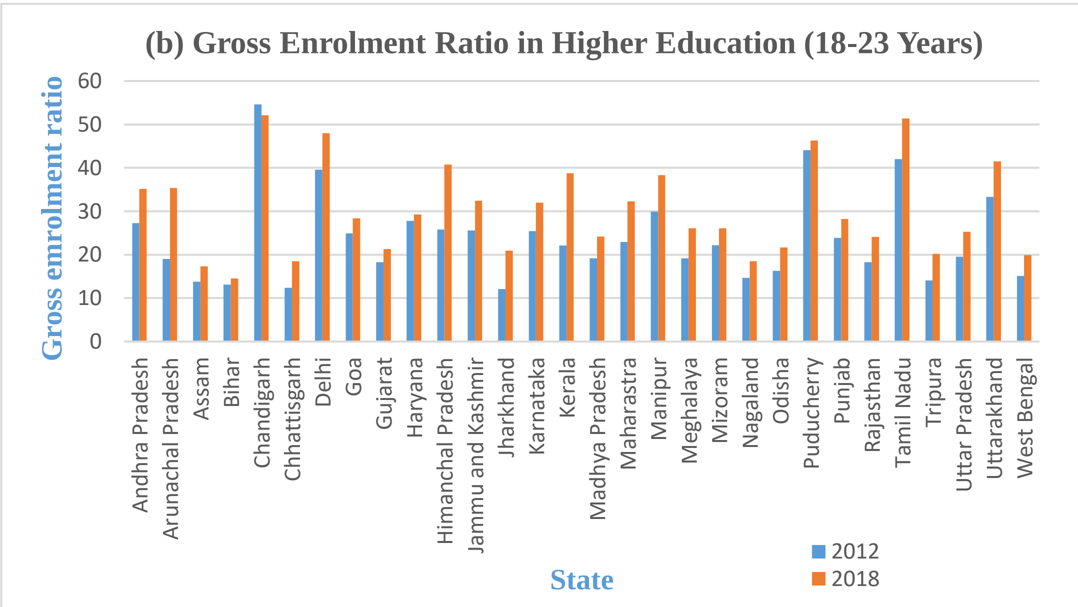
e) Capacity

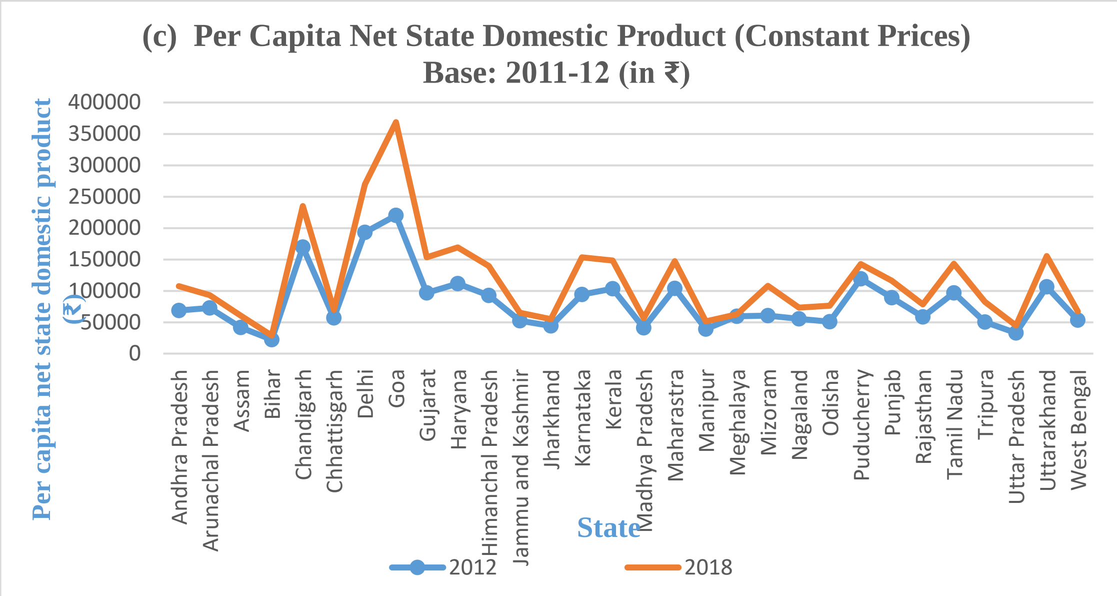
The mortality rate over the given time period has declined significantly from approximately 34 in 2012 to 25 in 2018. This decline in observed across all the states in the said time period. Madhya Pradesh has the highest mortality rate in both time periods while Goa and Manipur had the lowest mortality rate in 2012 and Nagaland in 2018 (see Fig. 3.5.a). With respect to enrolment in higher education leaving Chandigarh which continues to have the highest enrolment ratio in both the years but saw a decline from 54.6 in 2012 to 52.1 in 2018, rest all states witnessed an increase in the higher education gross enrolment ratio (see Fig. 3.5.b). As for the state that has the lowest ratio Jharkhand occupies the last position in 2012 and Bihar in 2018. The per capita net state domestic product also saw an increase from 81900.23 rupees in 2012 to 117366.1 rupees in 2018. As evident from Fig 3.5c across all states significant improvement can be observed in the per capita net state domestic product in the given time period.

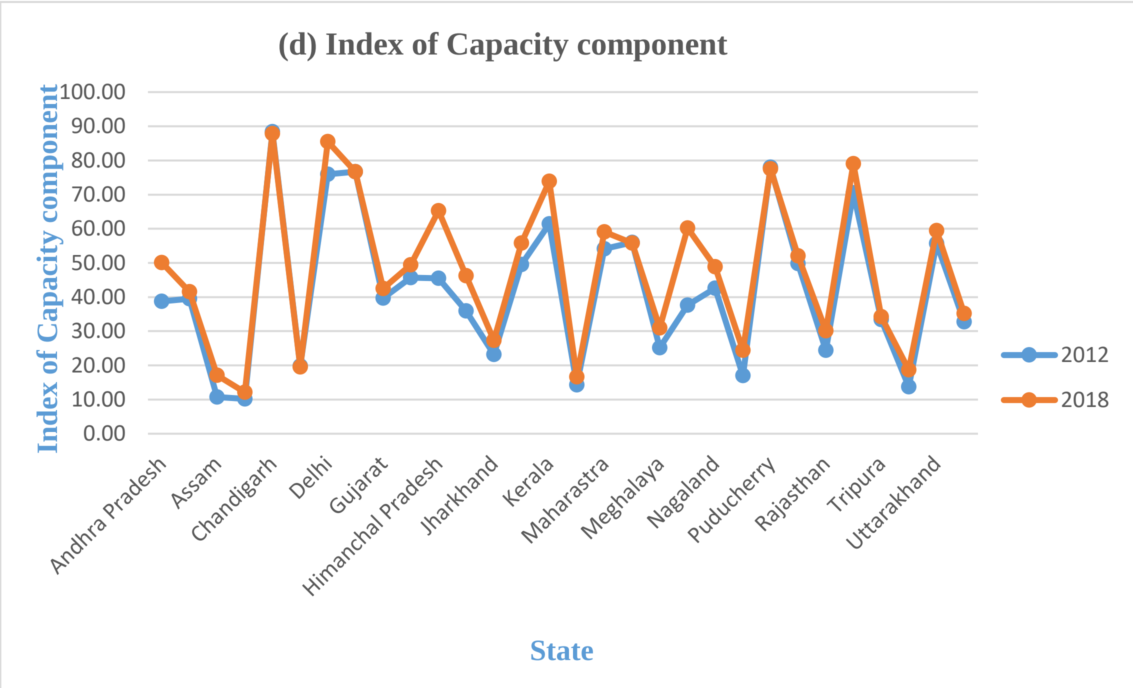
Overall if we look at the aggregate index of capacity a significant improvement is visible from 2012 to 2018. Leaving Puducherry which witnessed a marginal decline from 2012 to 2018 rest all states have seen a positive change. The overall value of the index improved from 42.21 in 2012 to 47.78 in 2018. The highest value of the capacity index was in Chandigarh and the lowest value is in Bihar in both the time periods (see Fig.3.5d).

Figure 3.5 Spatio-temporal patterns of capacity component of WPI









Source: Authors' construction

3.3.2 Spatio-temporal patterns of Water Poverty Situation

The scores of WPI are shown in Table 3.2 and Fig. 3.6. As can be seen from Fig. 3.6 despite the efforts of governments as well as the enactment of numerous policies the water situation of the country has marginally changed in the last 6 years that we have considered.

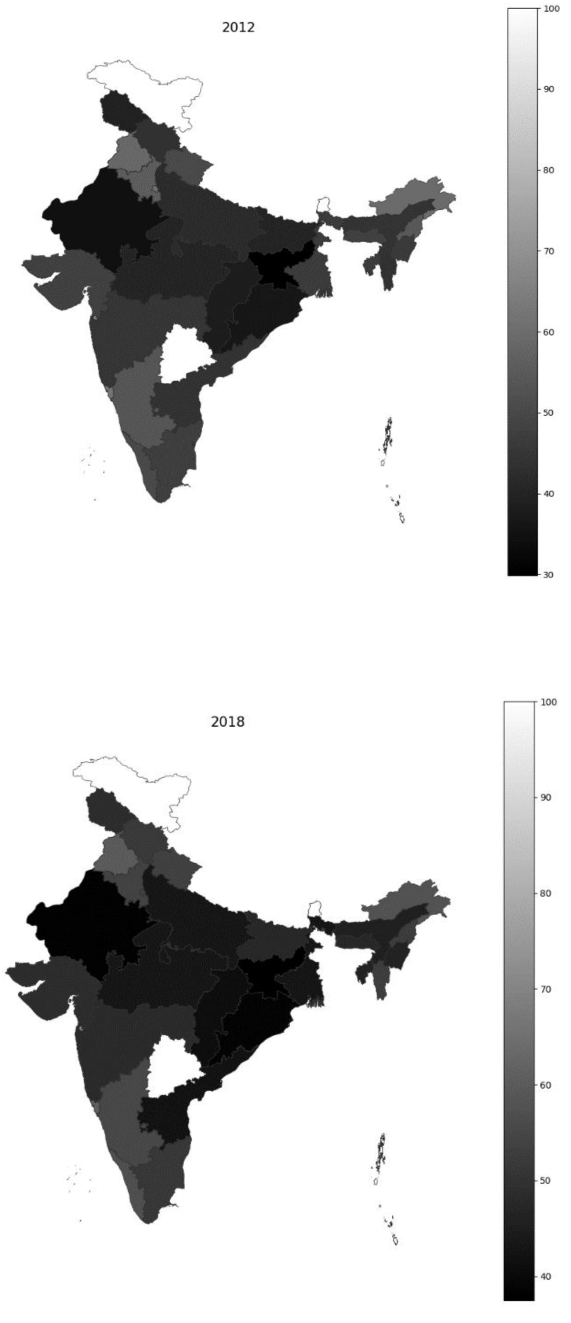
The state with the best water situation is Chandigarh in both years, with the value of 66.42 in 2012 and 64.15 in 2018 (see Table 3.2). Although the situation of the state is better than the rest however the value of WPI is declined during the given time period showing a worsening of water situation. Interestingly, the highest score is approximately twice the value of the lowest score that was observed in the state of Jharkhand in both years.

For a better representation of the water situation in India, following the work of Guppy (2014) the generated values of WPI were divided into five degrees as follows:

- WPD1- Extremely unsafe degree (WPI<47.9)
- WPD2- Unsafe degree (48<WPI<55.9)
- WPD3- Generally safe degree (56< WPI< 61.9)
- WPD4- Safe degree (62<WPI<67.9)
- WPD5- Very safe degree (68<WPI)

Table 3.2 shows the division of all the states/UT in the above-mentioned categories. As evident from the table as per the mentioned classification, no state is there in the very safe category in both the years. Also, from the table we can see that the states of Jharkhand, Rajasthan, Odisha, and Chhattisgarh continue to occupy the bottom positions in 2012 as well as in 2018, implying continuous prevalence of extremely unsafe water situations in these states. Further, in the given time period the water situation in the states of Andhra Pradesh, Arunachal Pradesh, Chandigarh, Delhi, Goa, Haryana, Meghalaya, Nagaland, Puducherry, West Bengal, and Tripura have deteriorated as evident from their decreased WPI (see Table 3.2). The severity of the water problem in India can be understood by the fact that as of 2018 thirteen states were facing extremely unsafe water situations and twelve were under unsafe degree.

Figure 3.6 Water poverty status

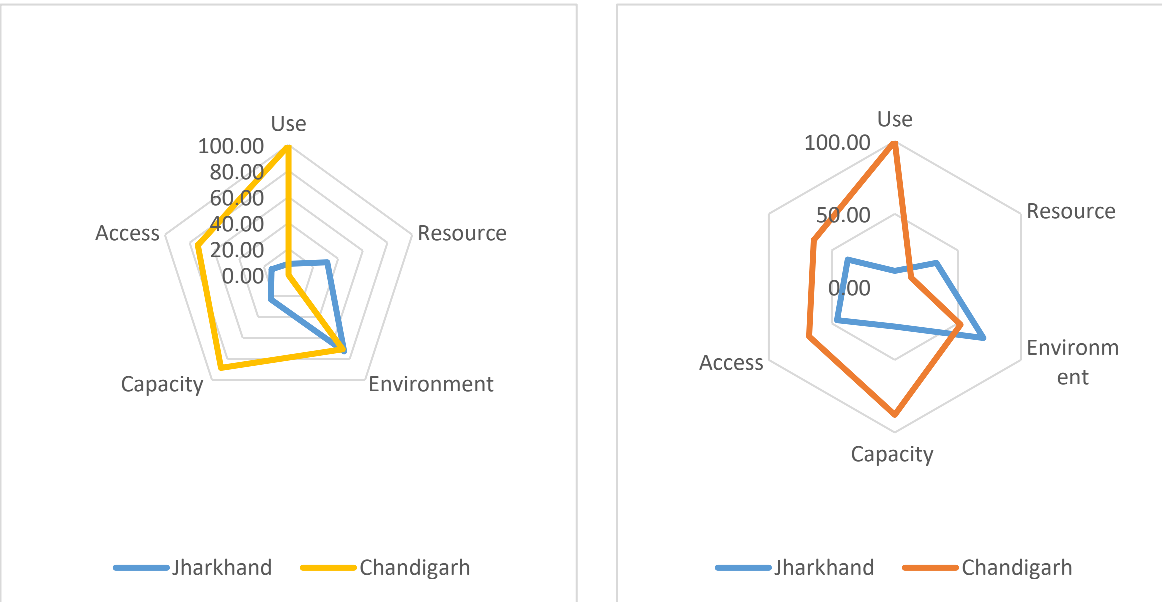


Source: Authors' construction

Table 3.2 State-wise WPI Status				
State	WPI (2012)	Water Poverty class	WPI (2018)	Water Poverty class
Andhra Pradesh	44.09	WPD1	42.26	WPD1
Arunachal Pradesh	59.3	WPD3	57.83	WPD3
Assam	44.26	WPD1	45.35	WPD1
Bihar	40.02	WPD1	47.43	WPD1
Chandigarh	66.42	WPD4	64.15	WPD4
Chhattisgarh	38.05	WPD1	40.98	WPD1
Delhi	61.42	WPD3	53.58	WPD2
Goa	62.29	WPD4	60.96	WPD3
Gujarat	47.92	WPD1	48.59	WPD2
Haryana	55.59	WPD2	53.86	WPD2
Himanchal Pradesh	43.55	WPD1	51.79	WPD2
Jammu and Kashmir	39.29	WPD1	48.49	WPD2
Jharkhand	29.87	WPD1	37.47	WPD1
Karnataka	53.63	WPD2	55.27	WPD2
Kerala	50.18	WPD2	56.93	WPD3
Madhya Pradesh	40.07	WPD1	43.2	WPD1
Maharashtra	44.86	WPD1	48.2	WPD2
Manipur	46.12	WPD1	46.2	WPD1
Meghalaya	47.88	WPD1	47.32	WPD1
Mizoram	43.65	WPD1	52.74	WPD2
Nagaland	54.37	WPD2	52.56	WPD2
Odisha	36.4	WPD1	38.66	WPD1
Puducherry	60.03	WPD3	51.16	WPD2
Punjab	58.47	WPD3	59.76	WPD3
Rajasthan	34.5	WPD1	38.04	WPD1
Tamil Nadu	47.39	WPD1	51.29	WPD2
Tripura	46.56	WPD1	46.12	WPD1
Uttar Pradesh	42.07	WPD1	43.28	WPD1
Uttarakhand	50.21	WPD2	53.36	WPD2
West Bengal	46.58	WPD1	43.07	WPD1
Source: Authors' calculation				

For a better understanding, we have also looked at the component-wise difference of the best and the worst state with respect to the water situation. Fig. 3.7 represents the pentagrams for both 2012 and 2018, as evident from it in 2012 the largest difference lies in the use component between the two states. As per the index value households in Chandigarh use more water than households in Jharkhand. As a matter of fact, Chandigarh is considerably more developed than Jharkhand, and as expected this fact is clearly visible by the presence of a stark difference between their capacity component. Access to water is also relatively higher in Chandigarh which scored a value of 73.35 as opposed to Jharkhand which has a score of only 13.65. Interestingly, if we look at the other two components i.e., Resource and Environment Jharkhand is comparatively better than Chandigarh in both these aspects. In 2018 also the largest difference was between the use component followed by capacity and access. The resource and environment component continues to be considerably more in Jharkhand in 2018 as well. Hence, Jharkhand can be said to be a water-rich but adaptively poor state while Chandigarh represents the case of a water-poor but the adaptively rich state.

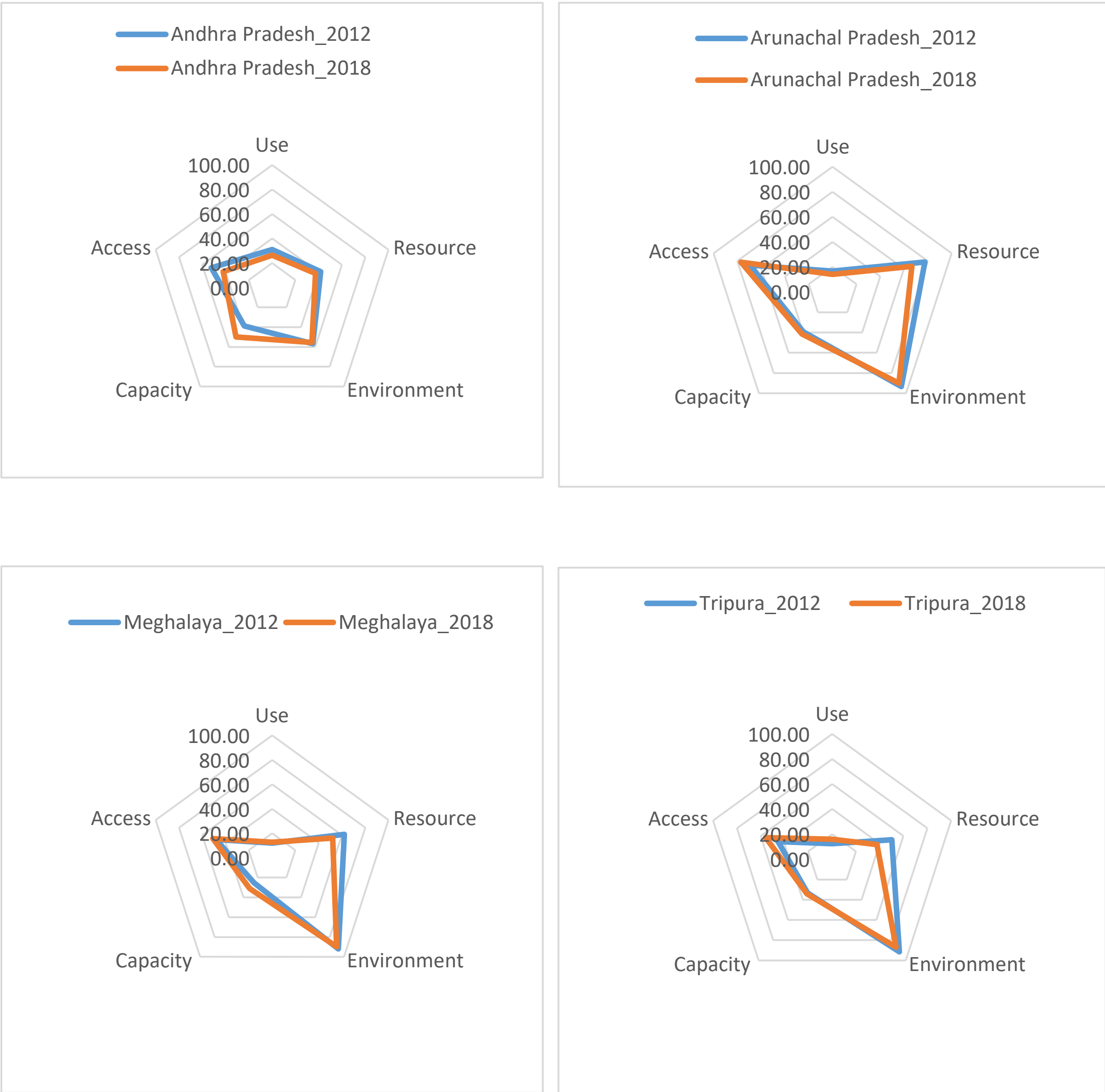
Figure 3.7 Pentagram of Best and Worst water poor states

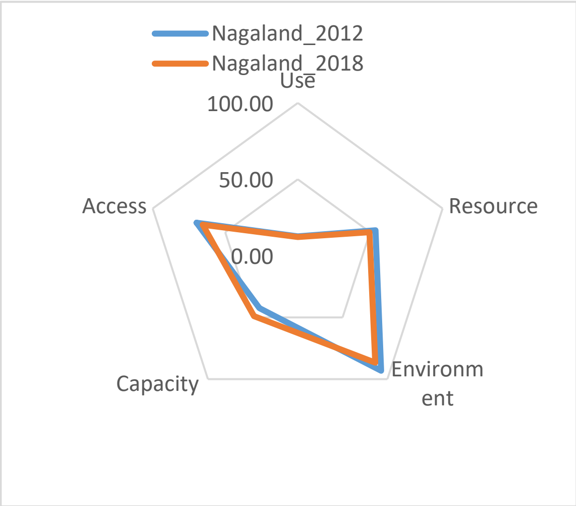


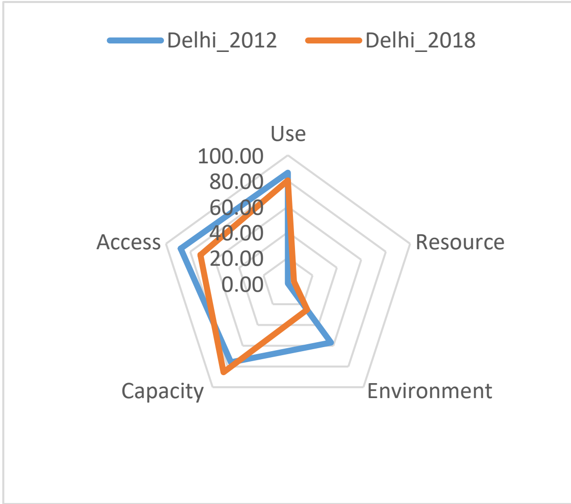
Source: Authors' construction

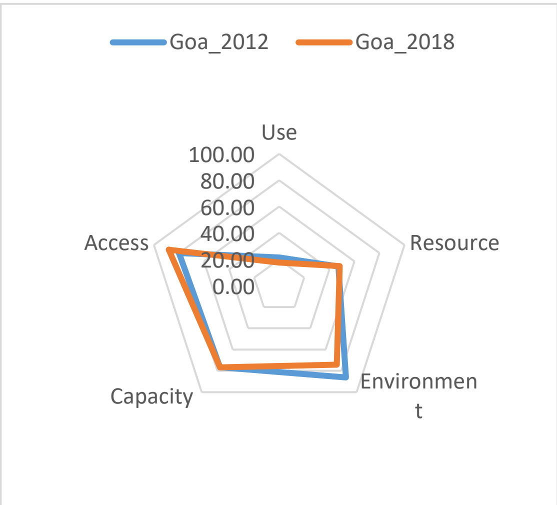
As previously shown over the given time period in both the states the environment component has witnessed a decline. Further, in Chandigarh, a decline in access and capacity components was also visible. Talking about the deteriorating water situation as previously seen Andhra Pradesh, Arunachal Pradesh, Chandigarh, Delhi, Goa, Haryana, Meghalaya, Nagaland, and Tripura have witnessed a decline in their WPI scores. Looking at their aggregate picture for both the years we find that for Andhra Pradesh as seen in Fig 3.8 leaving capacity component a decline is evident in the use, resource, environment, and access from 2012 to 2018. The largest decline can be seen in the access component followed by use, resource, and environment. Contrary to this in Arunachal Pradesh, the access component witnessed the highest increase followed by the capacity component. The resource component of Arunachal Pradesh as evident from Fig.3.8 has gone through the maximum deterioration this was followed by the environment and use component. Similarly, Meghalaya saw an increase in capacity and access component, also the use component witnessed a marginal increase from 2012 to 2018. The largest increase was there in the capacity component followed by access and use. For the state of Meghalaya, the largest decline was witnessed in the resource component followed by the environment component. For Tripura as well the largest fall can be seen in the resource component followed by the environment component. Access saw the maximum increase followed by use and capacity in the state.

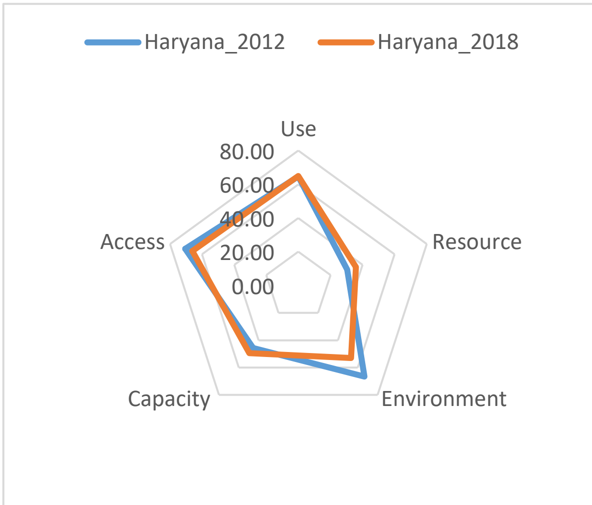
Figure 3.8 Pentagram of various components of WPI

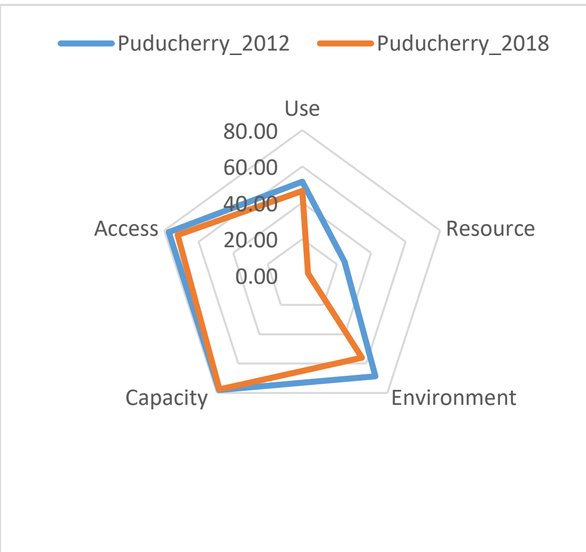


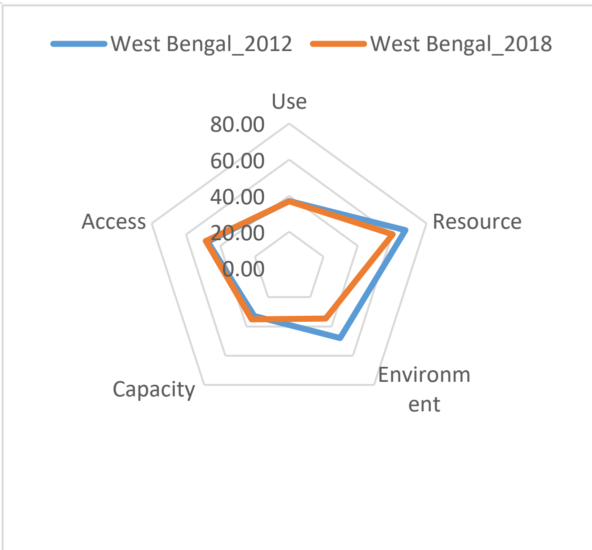












Source : Authors' construction

In Nagaland also a deterioration in resource and environment components can be seen, the use and access component also witnessed a decline from 2012 to 2018. The largest decline is seen in the environment followed by access, resource, and use. The capacity component saw an increase during this period. As opposed to this Delhi, Haryana, and Goa saw an increase in their resource and capacity components. In Delhi, the environment component saw the largest deterioration followed by the access and use component. Goa too witnessed the largest deterioration in the environment component followed by the use component. A significant decline in environmental integrity can be also seen in Haryana, the state in the given time period has also witnessed a decline in its access component.

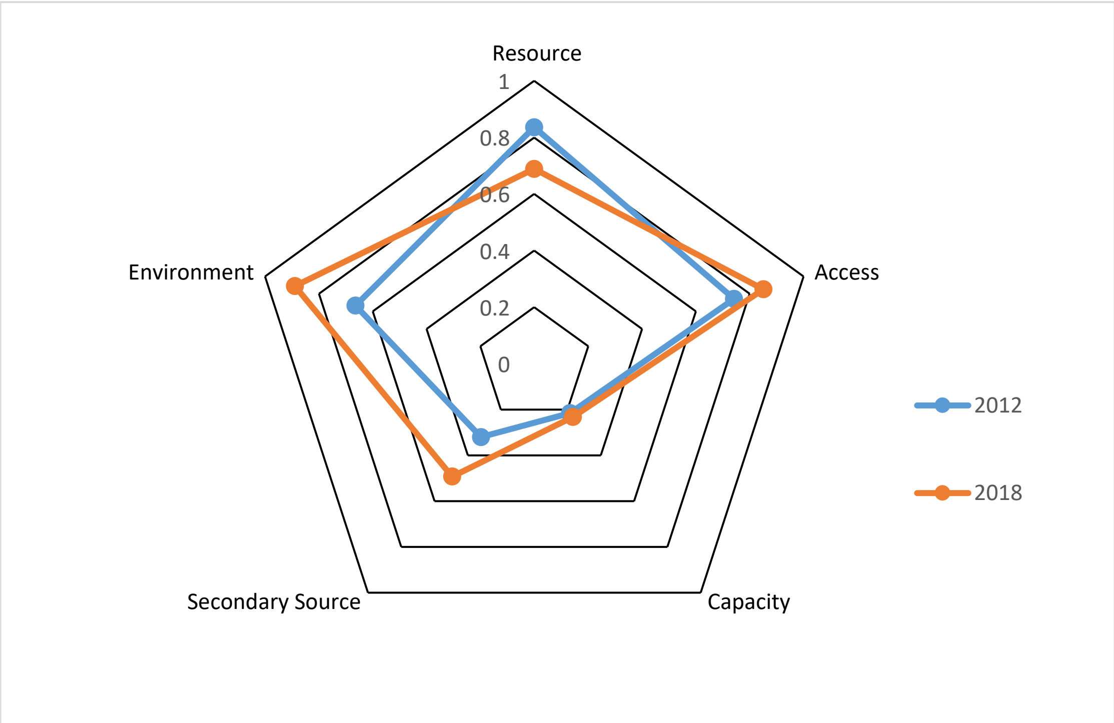
Similarly, for the states of Puducherry and West Bengal resource, the environment and use components deteriorated from 2012 to 2018. In Puducherry capacity also saw a marginal decline in 2018 (Fig 3.8). To sum up we can say deterioration in the environment and resource component are dominant factors responsible for the worsening of the water situation in the majority of mentioned states. Overall, also if we see the average value of the index for India the largest decline in the given time period was there in the environment followed by the resource component. This implies that although as a nation we are becoming adaptively rich as evident from the increased capacity of households over the years our water situation continues to worsen.

3.4 Results of water poverty in Rajasthan

3.4.1 The spatiotemporal patterns of MWPI

The final MWPI score for all 33 districts of Rajasthan, India, was 0.61 in 2012 and 0.67 in 2018, indicating an improvement in the state's water status. The radar diagram in Figure 3.9 illustrates the final scores for all components of the MWPI. The central point of the diagram symbolizes the origin, denoted as '0', for each axis. As we progress further from the origin, the magnitude of the represented quantity increases. Therefore, in this scenario, the outer layer symbolizes the optimal score of 1 that each component can achieve. The figure shows that out of the five components of MWPI, capacity was the lowest (0.22 in 2012 and 0.23 in 2018) in both periods, followed by secondary sources (0.32 in 2012 and 0.49 in 2018). The third lowest value in 2012 was environment (0.67); in 2018, it was resource (0.69). Furthermore, leaving the resource component, improvement is visible in all components from 2012 to 2018. The most significant improvement is seen in the environment component, followed by the secondary sources' component.

Figure 3.9 Component-wise scores of MWPI



Source: Authors' construction

Table 3.3 shows the MWPI scores by region. As evident from the table, the western region has the lowest score during both periods. Also, from 2012 to 2018, an improvement in the MWPI score across all the regions is evident. During the period, the 'southern' region witnessed the most improvement, followed by the north-eastern, south-eastern, western and northern regions.

Table 3.3 Region-wise[2] MWPI score (average)		
Region	2012	2018
Western	0.57	0.64
North-Eastern	0.59	0.68
Southern	0.59	0.69
South-Eastern	0.58	0.67
Northern	0.64	0.67
Source: Authors' calculation		

Despite an observable improvement in the MWPI score within the specified period, it is imperative to note that the improvement was not uniform across all the index components. Table 3.4 shows the indicators of the resource component. As evident, from 2012 to 2018, the percentage of households experiencing water insufficiency has increased in the western and southern regions. The water frequency has also deteriorated across all regions during the given time frame.

Table 3.4 Resource Component		
3.4 a: Water insufficiency (in percentage)		
Region	2012	2018
Western	16	23
North-Eastern	22	18
Southern	20	27
South-Eastern	38	25
Northern	27	18
3.4 b: Water Frequency (Index Value)		
Western	0.87	0.54
North-Eastern	0.94	0.62
Southern	0.93	0.41
South-Eastern	0.97	0.55
Northern	0.94	0.68
Source: Authors' calculation		

[2] Region-wise specification of districts in Rajasthan is mentioned in Appendix 3.1.

Regarding access, the percentage of households having access to safe water sources increased across all the regions except the northern region (see Table 3.5.a). In the northern region in 2012, 84 per cent of households reported having access to safe water, which declined slightly to 83 per cent in 2018. In addition, as evident from Tables 3.5. b and 3.5. c, the distance travelled and time taken to fetch water improved across all the regions. Contrary to this, the percentage of households with access to improved sanitation declined across all regions in the given period (see Table 3.5.d).

Table 3.5 Access Component

3.5. a: Access to safe water sources (in percentage)		
Region	2012	2018
Western	74	87
North-Eastern	87	92
Southern	86	90
South-Eastern	91	92
Northern	84	83
3.5. b: Time taken to fetch water (index value)		
Region	2012	2018
Western	0.83	0.93
North-Eastern	0.84	0.94
Southern	0.84	0.94
South-Eastern	0.80	0.93
Northern	0.83	0.97
3.5. c: Distance travelled to fetch water (Index value)		
Western	0.70	0.87
North-Eastern	0.75	0.90
Southern	0.72	0.84
South-Eastern	0.73	0.85
Northern	0.79	0.95
3.5.d: Access to improve sanitation (in percentage)		
Western	69	35
North-Eastern	80	69
Southern	99	86
South-Eastern	85	76
Northern	67	52

Source: Authors' calculation

For the capacity component, during the period, an improvement in the income level of households is visible in all regions (see Table 3.6. a). Also, due to an increase in water insufficiency in the southern region, a decline in water frequency, and a decline in the proportion of households with access to improved sanitation in the southern, south-eastern, and northern regions, the proportion of households reporting water-related illness has increased in these regions (see Table 3.6. b). A decrease in water frequency may translate into a reduction of water household access. Studies have shown insufficient water intake can affect an individual's physical and gastrointestinal function (Popkin et al., 2010). In addition, in the northern region, a decrease in households' access to safe water may also have increased the incidence of water-related illness.

Table 3.6 Capacity Component

3.6. a: Income (Index value)		
Region	2012	2018
Western	0.01	0.02
North-Eastern	0.01	0.02
Southern	0.01	0.02
South-Eastern	0.01	0.02
Northern	0.01	0.03
3.6. b: Water-related illness (in percentage)		
Region	2012	2018
Western	51	30
North-Eastern	64	62
Southern	63	80
South-Eastern	58	65
Northern	48	49

Source: Authors' calculation

In all regions, access to secondary water sources has improved (see Table 3.7). Improvement is also visible in the regions' environment component (see Table 3.8).

Table 3.7 Secondary source: Access to secondary sources of water (in percentage)		
Region	2012	2018
Western	25	32
North-Eastern	27	58
Southern	36	63
South-Eastern	41	50
Northern	38	41
Source: Authors' calculation		

Table 3.8 Environment: Presence of stagnant water around the source of drinking water (in percentage)		
Region	2012	2018
Western	40	7
North-Eastern	33	16
Southern	20	7
South-Eastern	52	21
Northern	15	4
Source: Authors' calculation		

The largest increase is visible in the environment component in the western region; in this region, leaving the resource component, which saw a decline, the rest of the components, although marginal, have witnessed improvement (see Figure 3.10). The access component has seen the most growth in the southern region, followed by the western and north-eastern regions. The resource component has declined in all regions in 2018 compared to 2012. In the northern region, the environment component had the highest increase, followed by the secondary source and access component. However, owing to the increase in the incidence of water-related illness, the capacity component declined in the given period. From 2012 to 2018, the capacity component declined in the southern and south-eastern regions.

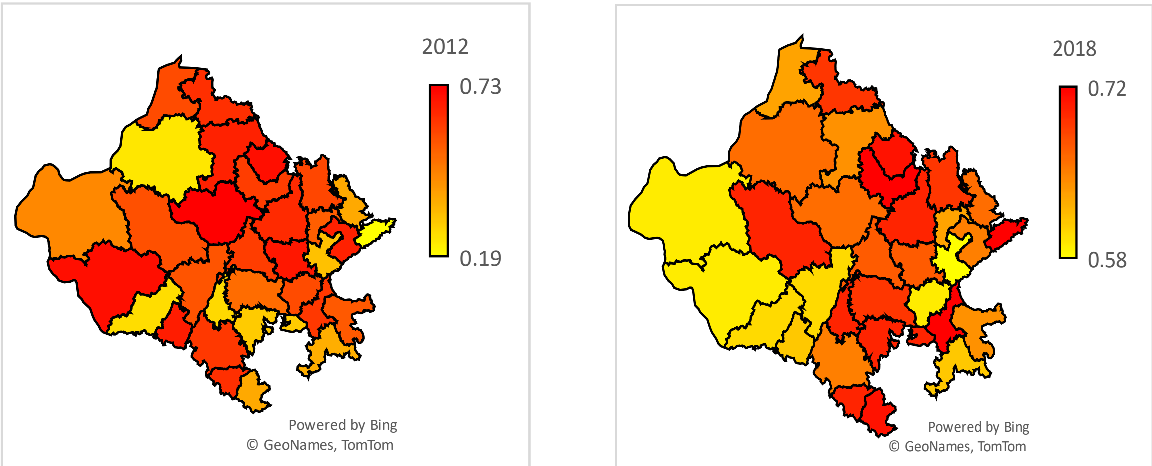
Figure 3.10 Region-wise pentagram of components of MWPI

Source: Authors' construction

3.4.2 District Level MWPI score

The district-level MWPI scores varied from 0.19 to 0.73 in 2012 and 0.58 to 0.72 in 2018. In 2012, Dhaulpur, Bikaner and Jalor were the most water-poor districts, while Nagaur, Jhunjhunu and Barmer were the least. In 2018, the most water-poor districts were Sawai Madhopur, Jaisalmer and Barmer, while the least were Sikar, Kota and Dhaulpur (see Table 3.9 and Figure 3.11). It is worth noting that the most water-poor districts are situated in the western and north-eastern regions. Also, from the table, it is evident that leaving Churu (Northern region), Karauli (North-eastern region), Nagaur (Northern region), Barmer (Western region), Sirohi (Western region), Tonk (North-eastern region), and Pratapgarh (South-eastern region) rest in all districts over the given period the MWPI scores have improved indicating an improvement in the water poverty situation.

Figure 3.11 District-wise MWPI score (average)



Source: Authors' construction

Table 3.9 District-wise MWPI score (average)

District	MWPI_2012	MWPI_2018
Ajmer	0.60	0.67
Alwar	0.58	0.69
Banswara	0.37	0.71
Baran	0.54	0.64
Barmer	0.70	0.59
Bharatpur	0.37	0.66
Bhilwara	0.50	0.69

Bikaner	0.24	0.66
Bundi	0.57	0.59
Chittaurgarh	0.30	0.70
Churu	0.66	0.64
Dausa	0.53	0.63
Dhaulpur	0.19	0.72
Dungarpur	0.63	0.70
Hanumangarh	0.63	0.69
Jaipur	0.64	0.70
Jaisalmer	0.44	0.59
Jalor	0.26	0.60
Jhalawar	0.36	0.61
Jhunjhunun	0.70	0.71
Jodhpur	0.56	0.70
Karauli	0.66	0.65
Kota	0.61	0.72
Nagaur	0.73	0.66
Pali	0.55	0.60
Pratapgarh	0.64	0.63
Rajsamand	0.27	0.70
Sawai Madhopur	0.32	0.58
Sikar	0.60	0.72
Sirohi	0.67	0.61
Sri Ganganagar	0.57	0.63
Tonk	0.68	0.67
Udaipur	0.61	0.65
Source: Authors' calculation		

To investigate the factors contributing to variations in the MWPI scores among districts, a component-wise analysis of MWPI has been conducted (see Appendix chapter 3). The analysis reveals that from 2012 to 2018, in all the districts except for Sri Ganganagar (Northern region), Churu (Northern region), Jaisalmer (Western region), Bhilwara (North-Eastern region) and Jhalawar (South-eastern region), the resource component witnessed a decline. This decline was mainly due to the deterioration in water supply reliability (measured as frequency of water supply) across all the districts. For the districts that witnessed an improvement in the resource component, it was due to a significant decline in the percentage of households experiencing water insufficiency (see Appendix table 3.2).

In Sri Ganganagar, the improvement in the resource component can be attributed to the canal-based water supply scheme, wherein water from the Gang Canal and Bhakra Canal has led to a notable enhancement in water availability. Similarly, Bhilwara has improved water availability due to the Bhilwara Water Supply Project operating under the National Rural Drinking Water Programme (NRDWP). This initiative involves sourcing water from the Chambal River to augment the water supply. In Jaisalmer, the Drinking Water Supply Project, which derives water from the Indira Gandhi Nahar Project, has been instrumental in addressing the water availability challenge. Similarly, Churu has seen advancements in water availability through the Apna Yojna scheme, focusing on community engagement (WSP, 2011). Further, by utilizing support from the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and other governmental financial resources to build up water infrastructure, the community-based water conservation initiative in Jhalawar has effectively enhanced the availability of water resources (TOI, 2020).

The component analysis also reveals that during the given period, except for the districts of Bundi (South-eastern region) and Sawai Madhopur (North-eastern region), the access component was improved in all other districts. From 2012 to 2018, a decrease in the distance travelled and time taken to fetch water (as evident from the increase in the index value) across all the districts is one of the prime reasons for an improvement in the access score (see Table Appendix table 3.4). This can be attributed to policies like Mukhya Mantri Jal Swavlambhan Abhiyan (MJSA), the Bisalpur project, the Jal Chetana Abhiyaan, and the Bharat Nirman Program. Further, in Bundi and Sawai Madhopur, a decline in the percentage of households having access to safe water and improved sanitation has led to the deterioration in the access component.

As for the capacity component, a deterioration in the score is witnessed in Alwar (North-eastern region), Banswara (Southern region), Bundi (South-eastern region), Chittaurgarh (South-eastern region), Churu (Northern region), Dausa (North-eastern region), Dhaulpur (North-eastern region), Dungarpur (Southern region), Jaipur (North-eastern region), Jhalawar (South-eastern region), Kota (South-eastern region), Nagaur (Northern region), Pratapgarh (South-eastern region), Rajsamand (Southern region), Sikar (Northern region), Sirohi (Western region), Sri Ganganagar (Northern region), Tonk (North-eastern region) and Udaipur (Southern region) (see Appendix table 3.5). This deterioration is due to the increase in the percentage of households reporting water-related illness.

Also, for the secondary source component, a deterioration is witnessed in Barmer (Western region), Churu (Northern-region), Jaisalmer (Western region), Jalor (Western region), Jhalawar (South-eastern region), Pali (Western region) and Sri-Ganganagar (Northern region). This implies that, during the given period in these districts, the percentage of households with access to secondary water sources has declined. Similarly, a deterioration in the environment component was witnessed in Alwar (North-eastern region), Bikaner (Western region), Jhunjhunu (Northern region) and Sri-Ganganagar (Northern region), indicating an increase in the percentage of households fetching water from an unfit source.

The component-wise analysis also reveals that in 2018, Barmer and Jaisalmer districts experienced a decline in access to secondary water sources and water supply frequency compared to 2012. As a result, both districts transitioned into being the most water-poor. Similarly, Sawai Madhopur saw a decline in access, water supply frequency and an increase in households facing water insufficiency, making it one of the most water-poor districts in 2018. In addition, the decline in MWPI scores for Churu, Karauli, Nagaur, Barmer, Sirohi, Tonk, and Pratapgarh can be attributed to the deterioration in the frequency of water supply. The increase in the incidence of water-related diseases in Barmer, Nagaur, Sirohi, Tonk, and Pratapgarh, coupled with an increased percentage of households lacking access to improved sanitation in Churu, Nagaur, Karauli, Tonk, and Pratapgarh, as well as an increase in percentage of households experiencing water insufficiency in Nagaur, Karauli, and Sirohi, and an increase in the percentage of households without access to safe water in Churu and Sirohi, collectively emerge as the principal factors contributing to the observed decline in their respective MWPI scores.

Moreover, the relatively remote locations of Churu, Barmer, and Pratapgarh from major urban centres may pose challenges in resource and service accessibility and hinder access to urban amenities and developmental prospects, potentially contributing to their declining water status. In contrast, despite their proximity to urban centres, Tonk, Nagaur, Karauli, and Sirohi, a degradation in water status is witnessed due to deficient groundwater regulation policies, the absence of mandates for rainwater harvesting, and a lack of infrastructure for water storage (NITI Aayog, 2019).

3.4.3 Sensitivity Analysis

Table 3.10 presents the MWPI scores generated using an alternative weighting scheme of PCA. The results indicate that under both periods, water poverty levels appear to decrease (as evidenced by an increased value of MWPI) when PCA is applied. Notably, the utilization of PCA led to an increase in the average MWPI score in 2012: a rise from 0.57 to 0.6 in the Western region (reflecting an increase of 5.2 percent), an increase from 0.59 to 0.6 in the North-eastern region (a rise of 1.7 percent), an augmentation from 0.59 to 0.62 in the Southern region (reflecting a growth of 5.08 percent), and an increase from 0.58 to 0.6 in the South-eastern region (a rise of 3.44 percent). However, for the Northern region in 2012, the application of PCA decreased the average MWPI from 0.64 to 0.63 (a decrease of 1.6 percent).

Furthermore, in the year 2018, the PCA led to an increase in the average MWPI scores from 0.64 to 0.66 (an increase of 3.12 percent) in the Western region, from 0.68 to 0.7 (a rise of 2.94 percent) in the North-eastern region, from 0.69 to 0.71 (a growth of 2.89 percent) in the Southern region, and from 0.67 to 0.69 (an increase of 2.98 percent) in both the South-eastern and Northern regions, respectively. Moreover, for the districts, PCA results in an increase in the MWPI scores during both periods (see Appendix table 3.6), with a significant increase observed in Banswara, Bharatpur, Bhilwara, Bikaner, Dhaulpur, Jalor, Jhalawar, Rajsamand, and Sawai Madhopur in 2012.

Table 3.10 Region-wise MWPI score (average) using PCA

Region	2012	2018
Western	0.6	0.66
North-Eastern	0.6	0.7
Southern	0.62	0.71
South-Eastern	0.6	0.69
Northern	0.63	0.69
Overall	0.62	0.69

Source: Authors' calculation

3.5 Conclusion

This study aims to provide a picture of the water situation of the states of India and to identify key areas in which intervention is necessary for sustainable development and poverty elevation. The results indicate that Jharkhand and Rajasthan continue to be the worst performers in both time periods. Water poverty was the least in the states of Goa and Chandigarh for both time periods. Although owing to improvement in access and capacity components, the water status of India as a whole improved from 2012 to 2018 few states have witnessed a decline in their water situation mainly due to deterioration in the environment and resource components.

Furthermore, the study also examines the evolution of Rajasthan's water poverty status and identifies key areas where intervention is needed to address the state's water woes. The results indicate that the state's overall water poverty status has improved over the given period.

Descriptive data analysis reveals a decline in the resource component of the index. A deterioration in the index value of some of the districts' access, capacity, and secondary sources is also a concern.

Chapter 4

IMPACT OF CLIMATIC AND ANTHROPOGENIC FACTORS ON GROUNDWATER RESOURCES IN ARID AND SEMI-ARID REGIONS OF RAJASTHAN, INDIA: SPATIOTEMPORAL TREND AND DETERMINANTS

As elucidated in the previous chapter, Rajasthan continues to rank among the states exhibiting the most acute water poverty situation within India. Furthermore, it was also seen that the state's overall water poverty status improved from 2012 to 2018, but the descriptive data analysis revealed a decline in the resource component of the index. The analysis conducted at the state level unveiled a decline in per capita groundwater resource availability within Rajasthan between 2012 and 2018. Furthermore, the micro-level analysis, conducted at the regional and district levels within Rajasthan, reveals deterioration in water supply reliability (measured as the frequency of water supply) across all the districts over the given time period. Due to the fact that Rajasthan, particularly the arid and semi-arid regions, has always had a low water resource base, the declining groundwater level, which is the lifeline of the state's arid and semi-arid ecosystem, poses a severe threat to the sustainable development of the region.

With climate change and anthropogenic activities widening the gap between groundwater "haves" and "have nots", a comprehensive analysis of how the groundwater resources are changing and the effects of climatic and anthropogenic factors on groundwater becomes imperative to ensure sustainable groundwater supply. Accordingly, this chapter aims to conduct a thorough investigation into the trends and variability of groundwater resources (both quality and quantity) in the arid and semi-arid districts of Rajasthan. Moreover, the chapter seeks to determine the relative influence of climatic and anthropogenic variables on the groundwater resources within these districts.

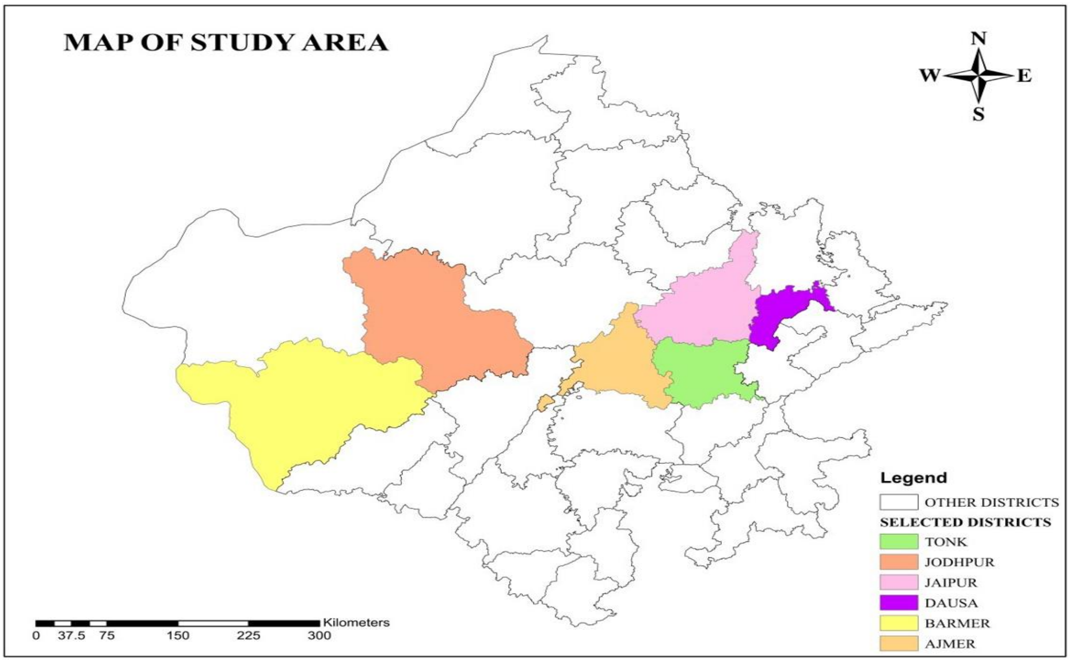
This chapter is divided into seven sections. The first section provides an overview of the selected arid and semi-arid districts for the analysis. The second section talks about the rationale for the study. The third section illustrates the data and methodology used in the study. The fourth section describes the spatiotemporal trend of groundwater level. The fifth section highlights the spatiotemporal trend of groundwater quality and its suitability for drinking and irrigation. The sixth section underscores the effect of climate change and anthropogenic factors on groundwater level and quality. Finally, the seventh section provides the summary and the concluding remarks of the study.

4.1 Study Area

Rajasthan consists of 33 districts, each with distinctive socio-economic characteristics. Additionally, the state is divided into ten agro-climatic zones: arid western plains, irrigated northwestern plains, hyper-arid partial irrigated zone, internal drainage dry zone, transitional plain of the Luni basin, semi-arid eastern plains, flood-prone eastern plains, sub-humid southern plains, humid southern plains, and humid southeastern plains (Chinnasamy et al., 2015). In the present study, the arid western plains, consisting of two districts (Barmer and Jodhpur), and the semi-arid eastern plains, comprised of four districts (Jaipur, Dausa, Tonk, and Ajmer), are considered for investigation (see Figure 4.1). Located in the western (Barmer and Jodhpur), eastern (Jaipur, Dausa, and Tonk), and northern (Ajmer) parts of Rajasthan, the selected districts not only provide a geographically diverse representation but also offer insights into varying levels of development and economic activities across the state (GOR, 2022).

Geologically, Jodhpur comprises various igneous, metamorphic, and sedimentary rocks, spanning from the pre-Cambrian to recent geological ages (Singh et al., 2011). Regarding the aquifer system, the major part is underlain by sandstone belonging to the Marwar super group (CGWB, 2017). Groundwater within the sandstone formations is typically found under unconfined to semi-confined conditions (CGWB, 2017). In Barmer, the predominant portion of the district is comprised of desert sand and dunes with sporadic rock formations (GOR, 2017). Quaternary alluvium consisting of slit, sand, clay, kankar, gravel, and cobbles mainly forms the aquifers in the district (CGWB, 2020). Groundwater is typically found under semi-confined to unconfined conditions within the quaternary alluvium formation (CGWB, 2020)

Figure 4.1 Map of the study area.



Source: Authors' construction

The geological succession in the Jaipur district exhibits a broad spectrum of rock formations; groundwater within the district is distributed across various lithologic units, with aquifers in the more significant part of the area primarily formed in younger alluvium, older alluvium, and gneiss (GOR, 2013). Groundwater at shallower depths is typically found under water table conditions, while at greater depths it occurs under semi-confined conditions (GOR, 2013). The aquifer system in Tonk predominantly comprises weathered, fractured, and jointed schistose rocks, covering approximately 65.00% of the district's area (GOR, 2013). Groundwater is mainly encountered as water tables (CGWB, 2022).

Similarly, in Dausa, the principal and potential aquifer is constituted by quaternary alluvium, encompassing approximately 80.00% of the district's total area (GOR, 2013). Groundwater in the district is typically found under conditions that range from unconfined to confined (Tiwari et al., 2020). In Ajmer, aquifers are mainly formed within gneiss, schist, and the younger alluvium. Groundwater in these geological units is primarily found as water tables (Gantait et al., 2022).

In the climatic context of the mentioned regions, Barmer exhibits a substantial temperature range, ranging from an average high of 46.40°C to an average low of 5.30°C. Similarly, in Jodhpur, January emerges as the coldest month, characterized by an average low temperature of 9.60°C, while May registers as the warmest month, marked by an average high temperature of 41.40°C. Jaipur experiences an average high temperature of 32°C and an average low temperature of 19°C. In Dausa, the climate records depict a minimum temperature of 4°C and a maximum temperature of 45°C, reflecting significant temperature variations within the district. Ajmer witnesses an average low temperature of 10.6°C and an average high temperature of 40.8°C. In Tonk, the temperature averages 26.5°C, with recorded minimum and maximum temperatures of 5.5°C and 45°C, respectively.

The average annual precipitation during the period 2010–2018 in the districts of Barmer, Jodhpur, Jaipur, Ajmer, Dausa, and Tonk was 355.50 mm, 397.60 mm, 583.60 mm, 560.00 mm, 691.60 mm, and 836.80 mm, respectively; the national average was 1,190 mm (CGWB, 2020). Approximately 80.00%–90.00% of the total annual precipitation in these districts occurs during the southwest monsoon season, typically from June to September. Furthermore, the distribution of this scant precipitation is highly variable within the districts. For instance, in Barmer, the southern and southeastern regions receive more precipitation, which gradually diminishes as one moves toward the northwest.

A similar pattern is observed in Jodhpur, where precipitation intensity declines from east to west and southeast to northwest. In Jaipur, the eastern area receives a greater share of precipitation compared to the western region, and this distribution gradually decreases from east to west. In Dausa, precipitation exhibits an increasing trend from northeast to south. In Tonk, the highest precipitation is concentrated in and around Tonk itself, with reductions observed in both the northeast and southwest directions. In Ajmer, the south-central sector receives more precipitation than the southwest, gradually decreasing as one moves northward.

Precipitation accounts for approximately 93.00%, 91.00%, 88.00%, 88.00%, 70.00%, and 62.00% of the total annual groundwater recharge in Barmer, Jodhpur, Jaipur, Dausa, Tonk and Ajmer, respectively (CGWB, 2020). The low and erratic nature of precipitation within the districts accompanied by the stage of groundwater extraction of 231.22%, 125.39%, 216.32%, 101.57%, 254.07%, and 176.19% in Jaipur, Barmer, Dausa, Tonk, Jodhpur, and Ajmer, respectively, has led to 100.00%, 71.00%, 100.00%, 50.00%, 88.00% and 100.00% of assessed administrative units (or blocks) being classified as overexploited (CGWB, 2020).

4.2 Rationale for the Study

In recent decades, in hydro-climatic data analysis, time series trend analysis techniques have gained popularity (Gupta et al., 2021; Sahoo et al., 2021; Swain et al., 2023). In the scientific literature, parametric and non-parametric techniques have been employed to evaluate current trends in hydroclimatic series (Bera et al., 2022; Kashem et al., 2022; Swain et al., 2021). The Mann-Kendall (M-K) test and other modified versions of the M–K test and Sen's slope estimator are the most often used non-parametric methods (Kashem et al., 2022; Swain et al., 2019; Swain et al., 2022), and they alleviate the limitations of parametric techniques, such as their dependence on data distribution and sensitivity to missing values (Bera et al., 2022), and can also offer unbiased trend for an autocorrelated data series (Kashem et al., 2022;

Swain et al.,2022). Previous research has utilized these non-parametric trend analysis techniques to comprehend groundwater data trends at the international level (Gibrilla et al., 2018; Tabari et al., 2012; Tirogo et al., 2016), as well as in the Indian context (Halder et al., 2020; Sahoo et al., 2021; Sishodia et al., 2016; Swain et al., 2022; Swain et al., 2022).

Furthermore, previous studies investigating anthropogenic and climate factors' effects on groundwater levels have addressed the issue, considering the impact of climate change or anthropogenic activities separately (Li et al., 2020; Panda et al., 2012; Tabari et al., 2012). Only recently, the emphasis shifted to evaluating groundwater resources' response to climate change coupled with anthropogenic activities(Li et al., 2020). In this context, correlation analysis (Muhammad et al., 2022), multivariate statistical analysis (Wang et al., 2018), local regression (LOESS) (Sishodia et al., 2016), as well as integrated hydrological modeling (Feng et al., 2018), have been used to assess the influence of climate change and anthropogenic activities on the groundwater system. But in recent years, multivariate techniques, such as generalized additive models (GAM), have seen increased application (Hwang et al., 2016; Wang et al., 2022). Though GAM is similar to LOESS, it has an efficient method for analyzing non-linear relationships (Simpson, 2018). Except for Liu et al. (2021), GAM has not been widely used to assess the quantity of groundwater resources. Furthermore, multivariate statistical techniques such as principal component analysis (PCA), cluster analysis (CA), and discriminant analysis have been widely used to assess the spatial variations in groundwater quality (Kim et al., 2020; Liu et al., 2020; Zavareh et al., 2021; Taşan et al., 2022; Gugulothu et al., 2022).

Although there are some studies analyzing the trends of groundwater level in Rajasthan (Saikia and Chetry, 2020; Singh and Bhakar, 2022), few studies, such as Chinnasamy et al. (2015) and Tembhurne et al. (2022), have comprehensively looked at the factors that influence groundwater fluctuations in Rajasthan as a whole. However, studies exclusively related to the arid and semi-arid regions are limited.

Moreover, although numerous studies have previously been conducted to assess groundwater quality across different districts of Rajasthan, particularly regarding F^- and NO_3^- (Chaudhary and Satheeshkumar, 2018; Tiwari et al., 2020; Aggarwal et al., 2021; Singh and Bhakar, 2021; Choubisa et al., 2022; Tanwer et al., 2023). However, particularly for the districts of Jaipur and Dausa, studies on water quality and availability are scarce (Tiwari et al., 2020; Pandit and Kateja, 2023). In addition, the literature on the effects of climate change on water quality is limited (Barbieri et al., 2021). Also, to the best of our knowledge, a comprehensive assessment of climatic and anthropogenic activities influencing the groundwater quality in the selected districts is sparse, although notable exceptions include Coyte et al. (2019).

4.3 Materials and Methods

4.3.1 Data source

The CGWB in India has been monitoring groundwater levels and quality using a network of observation wells known as National Hydrograph Network Stations (NHS). These NHSs are typically monitored four times a year: in May (pre-monsoon), August (monsoon), November (post-monsoon), and January (winter). There are 554 NHSs in the study area. Among these, 113 observations of wells or piezometers have credible data, and no significant gaps exist between 1994 and 2020. Furthermore, of the 113, 12 wells or piezometers are in Tonk, 17 are in Jaipur, 24 are in Jodhpur, 17 are in Ajmer, 9 are in Dausa, and 34 are in Barmer (see Figure 4. 2 and Appendix table 4.1). The India- Water Resource Information System (WRIS) portal was used to collect the annual and seasonal (pre-monsoon, monsoon, post-monsoon, and winter) depth to groundwater level (DGWL) data of these 113 wells or piezometers.

Groundwater quality parameters data from 2000-2018 were also collected from the CGWB (from the India-WRIS website). To study the hydrochemistry in the arid and semi-arid districts, fifteen water quality (Total Alkalinity (TA (mg/L)), Calcium (Ca^{2+} (mg/L)), Chloride (Cl- (mg/L)), Electrical Conductivity (EC (mumhos/cm) at 25 C)), Fluoride (F- (mg/L)), Iron (Fe (mg/L)), Total Hardness (TH (mg/L)), Bicarbonate (HCO_3- (mg/L)), Carbonate (CO_3^{2-} (mg/L)), Potassium (K+(mg/L)), Magnesium (Mg_2+ (mg/L)), Sodium (Na+(mg/L)), Nitrate (NO_3- (mg/L)), pH and Sulphate (SO_4^{2-} (mg/L)) parameters from 84 wells/piezometers were selected. These 84 wells/piezometers are distributed as follows: 21 in Ajmer, 13 in Jaipur, 20 in Barmer, 14 in Jodhpur, 12 in Tonk, and 4 in Dausa (see Figure 4.3 and Appendix table 4.2).

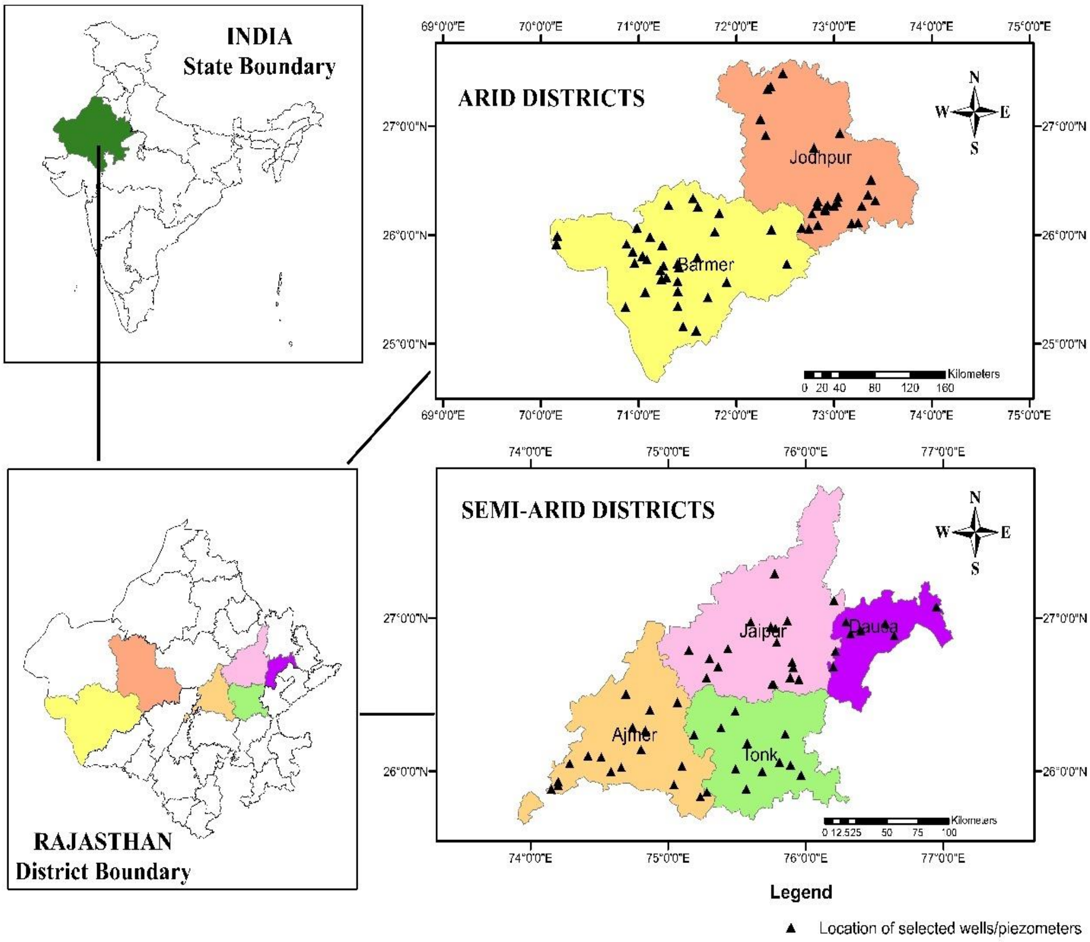
In addition, the NASA POWER database (https://power.larc.nasa.gov/data-access -viewer/) was used to collect location-specific statistics for monthly and annual values of climatic parameters (precipitation and temperature) from 1994 to 2020. The monthly numbers were averaged to determine seasonal values. According to the India Meteorological Department (IMD) definition, the following seasons were considered: (a) winter (January–February), (b) pre-monsoon (March–May), (c) monsoon (June–September), and (d) post-monsoon (October–December).

For groundwater level, Net Irrigated Area (NIA), Gross District Product (DGDP) and Population were considered as anthropogenic variables, the data source and time period of these variables is mentioned in Table 4.1. NIA, Population, Fertilizer (kg/hectares), and Industrialization were considered anthropogenic variables for groundwater quality assessment. Following Ghosh et al. (2016), industrialization was defined as the share of manufacturing in the gross district product. The statistics on anthropogenic variables from 2000 to 2018 were obtained from the Directorate of Economics and Statistics, Rajasthan.

Table 4.1 Data source for Anthropogenic variables for groundwater level impact assessment

Variables	Data Source	Time-Period
Net Irrigated Area (NIA)	ICRISAT[3], Directorate of Economics and Statistics, Rajasthan	1994-2019
Gross District Product (DGDP)		1999-2020
Population	Authors' computation based on data from ICRISAT, Directorate of Economics and Statistics, Rajasthan	

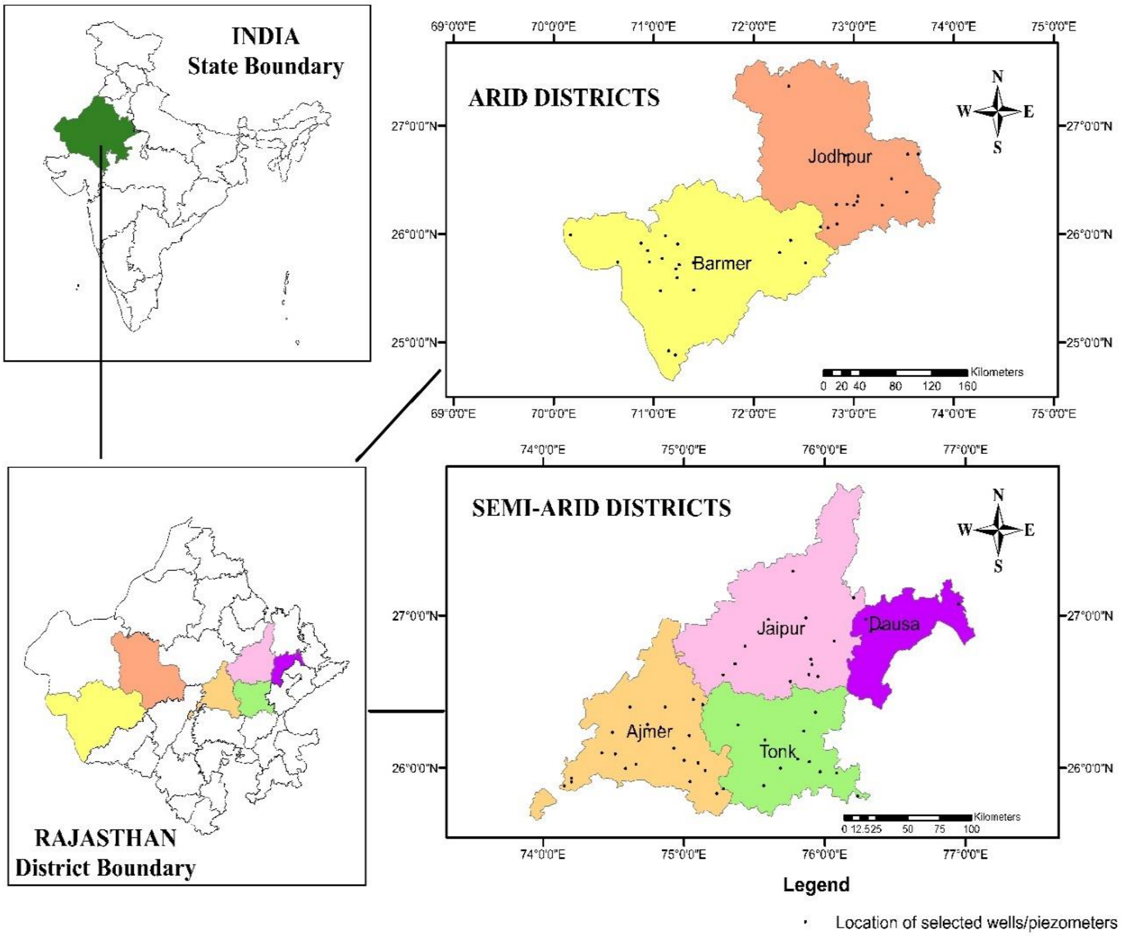
Figure 4.2 Geographical location of selected wells or piezometers for groundwater level assessment.



Source: Authors' construction

[3] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Figure 4.3 Geographical location of selected wells or piezometers for groundwater quality assessment.



Source: Authors' construction

4.3.2 Methods

4.3.2.1 Statistical Analysis

For the data on groundwater level, descriptive statistics including mean, standard deviation (SD), coefficients of variation (CV), skewness, and kurtosis were calculated. Similarly, for groundwater quality data, descriptive statistics, including median, SD, maximum, and minimum, were calculated.

In addition, for the groundwater quality the Mann-Kendall (Mann, 1945; Kendall, 1975) and Sen's slope estimator (Sen, 1968) were employed to determine the spatiotemporal trend within the data set. MK is a non-parametric trend analysis test resilient to nonlinearity, nonnormality, and seasonality (Kashem et al., 2022).

For groundwater level and climatic factors, modified Mann–Kendall (MMK) (Hamed and Rao,1998) and Sen's slope estimator (Sen, 1968) were employed to determine the spatio-temporal trend within the data set. The MMK test, similar to the MK test, is a non-parametric method employed for trend analysis. However, MMK is an enhanced version of the MK test, as it considers autocorrelations existing within the dataset, thus enhancing the effectiveness in providing more robust and accurate results in trend analysis (Pathak and Dodamani, 2019; Swain et al., 2021). Computed as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}(x_j - x_k) \quad \ldots (4.1)$$

Where n is the total number of data points, x_j and x_k are the data values, and sgn is the signum function such that:

$$\mathrm{sgn}\left(x_j - x_k\right) = \begin{cases} +1 & if \left(x_j - x_k\right) > 0 \\ 0 & if \left(x_j - x_k\right) = 0 \\ -1 & if \left(x_j - x_k\right) < 0 \end{cases} \quad \ldots . (4.2)$$

As n > 10 in this investigation, the variance of S was determined as follows:

$$\mathrm{Var}(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p-1}^{g} t_p(t_p - 1)(2t_p + 5) \quad \ldots . (4.3)$$

Where n is the number of data points, g is the number of samples having the same value, and t_p is the number of samples with ties p. This computation assumes that autocorrelation among the data points is negligible. The MMK test adjusts the variance by multiplying a correction factor that accounts for the autocorrelation structures across all lags within a dataset (Swain et al., 2022), which is given as:

$$V^{*}(S) = Var(S) * \ C_f \ \dots (4.4)$$

Here C_f is the correction factor given as:

$$C_f = 1 + \frac{2}{n(n-1)(n-2)} * \sum_{k=1}^{n-1}(n-k)(n-k-1)(n-k-2)\rho_s(k) \ \dots (4.5)$$

Where $\rho_s(k)$ is the serial autocorrelation. Based on $V^{*}(S)$ and S, the test statistic Z, which follows the standard normal distribution, is calculated as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{V^{*}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{V^{*}(S)}} & \text{if } S < 0 \end{cases} \quad \dots .(4.6)$$

A positive value of Z signifies an increasing trend with time, while a negative value indicates a decreasing trend. The significance test of MK and MMK is based on the following hypothesis:

Null hypothesis (Ho): There is no monotonic trend

Alternative hypothesis (H_1): There exists an increasing/decreasing trend

Ho is rejected if the series exhibits an increasing/decreasing trend at a predetermined significance level (α). Following Gibrilla et al. (2018), α was assumed to be 5% in this study. Furthermore, to obtain the magnitude of the trend (change per unit of time), Sen's slope estimator can be calculated as:

$$\text{Sen's Slope} = \text{Median}\{\frac{x_j - x_k}{j-k}\} \qquad \dots (4.7)$$

Where j is between 1 and n, k is between 1 and (n-1).

4.3.2.2 Evaluation of Groundwater Suitability for Drinking and Irrigation

The suitability of groundwater for drinking was evaluated by comparing the parameters such as pH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl-, F-, SO_4^{2-}, and NO_3^{-} with the guidelines specified by the WHO (2011) and BIS (2012). In the study, these guidelines limit have been used to highlight the human health risks. In addition, SAR, EC, and USSL diagrams were used to evaluate groundwater quality suitability for irrigation.

4.3.2.3 Principal Component Analysis (PCA)

PCA was utilized to reduce the dimensionality of the groundwater quality data. Before the analysis, the data were normalized, and the Bartlett sphericity and KMO (Kaiser-Mayer-Olkin) tests were applied to check the data reliability and adequacy of the sample. Furthermore, varimax rotation was used to obtain the component loadings. Based on the absolute value of the loadings, the data were divided into principal components (PCs).

4.3.2.4 Generalized Additive Model (GAM)

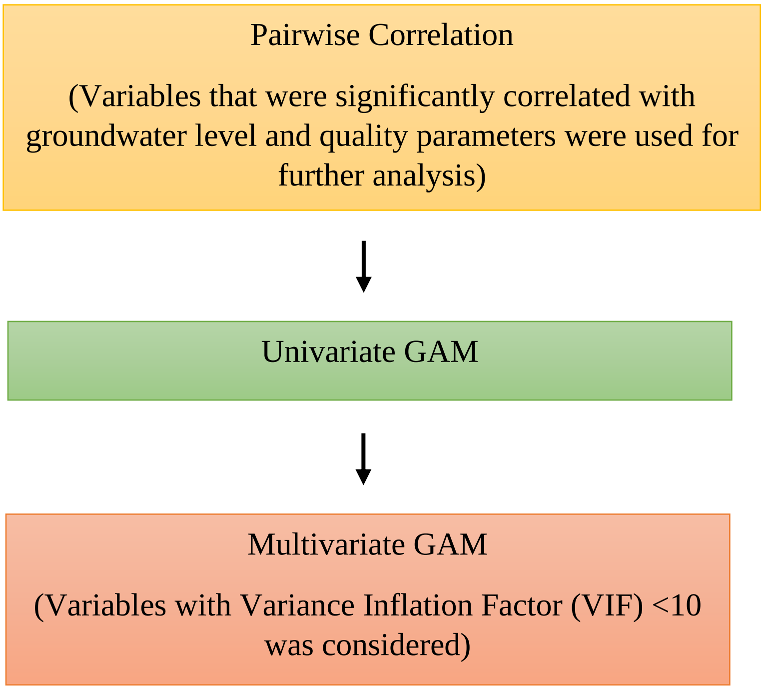
GAM was used to analyze the influence of climatic and anthropogenic factors on groundwater level and quality. Conceptualized by Hastie and Tibshirani (1986) and Stone (1986), GAM is a non-parametric regression model. It is an extended version of the General Linear Model (GLM). Especially for modelling non-linear relationships, GAM is a more reliable and flexible technique than a liner-based model (Lin et al., 2018). One of the advantages of using GAM is that the nature of the relationship between the dependent and independent variable does not need to be modelled a priori; instead, the data determine the nature of the relationship (Wang et al., 2021).

The general formula of GAM is given in Equation 4.8.

$$g(\mu_i) = \alpha + f_1(x_{1i}) + f_2(x_{2i}) + f_3(x_{3i}) \dots \dots + f_n(x_{ni}) \dots (4.8)$$

Where α is the intercept of the model, μ_i is the expected value of the dependent variable Y_i, $g()$ is a continuous function, x_n is the independent/explanatory variable and f_n is the smooth function of the independent variables. The smooth function of the independent variable can either be thin plate regression splines (TPRS), tensor product, TPRS with shrinkage, etc. In this study, TPRS has been used as the smooth function. Further, generalized cross-validation (GCV) was used for selecting the smoothing parameters. In addition, following Wang et al. (2021), to evaluate the model's goodness-of-fit, deviance explained (DE), residual analysis, AIC, and adjusted R-square (R-sq. (adj)) were employed. Further, AIC and adjusted R-square (R-sq. (adj)) were used to determine the optimal model. Figure 4.4 shows the steps taken to analyze the impact of climatic and anthropogenic factors on groundwater level and quality using GAM.

Figure 4.4 Flow chart for GAM



Source: Authors' construction

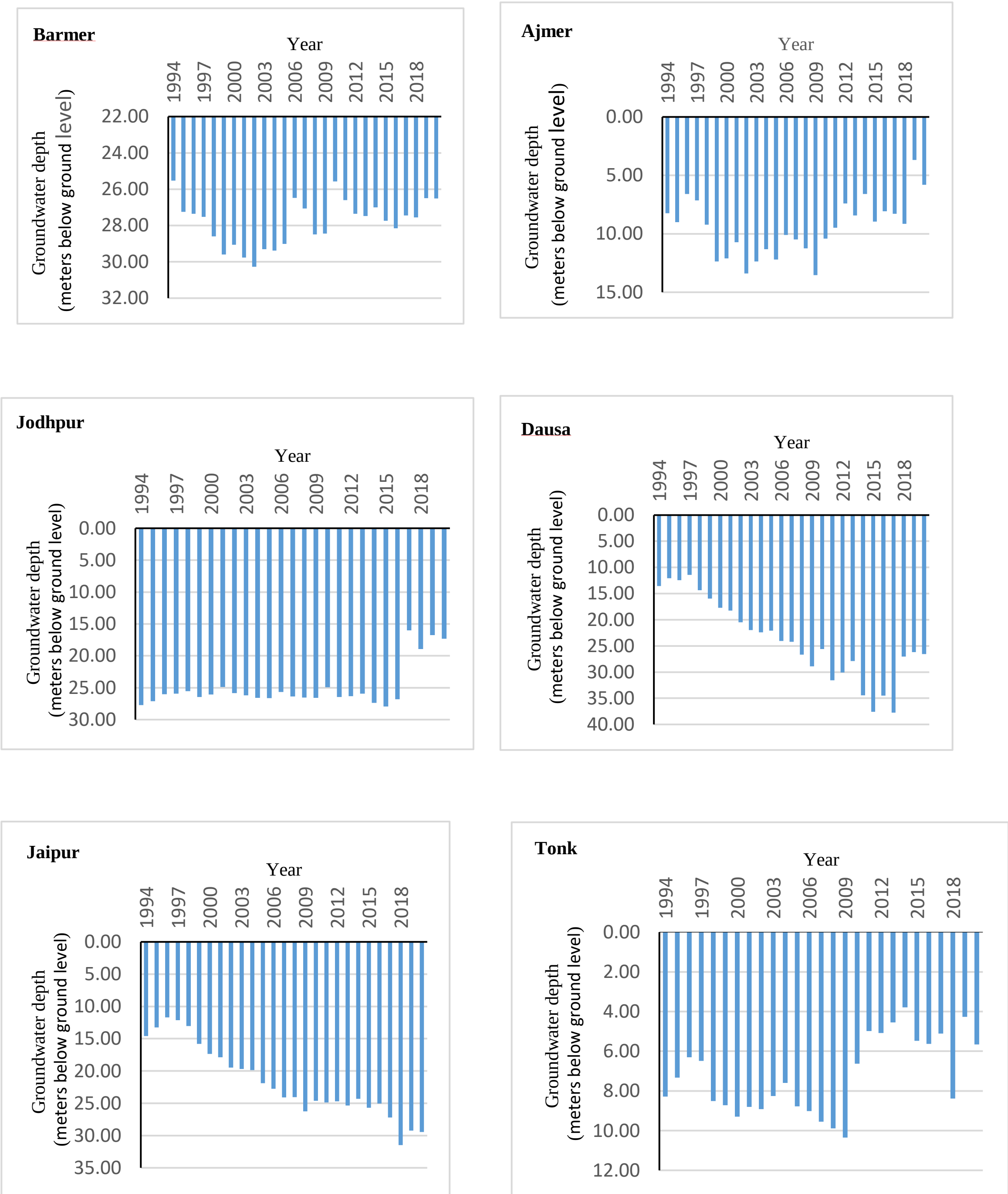
4.4 Results: Groundwater level

4.4.1 Spatio-temporal distribution of DGWL since 1994

The district-wise average annual DGWL of the representative observatory wells is shown in Figure 4.5 from 1994 to 2020. In the districts of Dausa, Jaipur, and Barmer, the average annual DGWL increased from 13.54 to 26.53 m below ground level, from 14.60 to 29.46 m below ground level, and from 25.53 to 26.51 m below ground level, respectively. Contrary to this, for the districts of Ajmer, Tonk, and Jodhpur, the average annual DGWL declined from 8.23 to 5.82 m below ground level, from 8.28 to 5.65 m below ground level, and from 27.72 to 17.31 m below ground level, respectively. During 2019–2020, except for Barmer, where the average annual DGWL was almost constant (i.e., around 26.50 m below ground level), in all other districts, it has increased, with Ajmer experiencing the most growth.

Similarly, the district-wise average monthly DGWL is shown in Fig. 4.6. Signifying the importance of monsoons for the groundwater, the figure reveals that, in most years, generally, the average DGWL is lowest during the monsoon and post-monsoon seasons and highest during the pre-monsoon season. One exception to this general pattern is Dausa, where DGWL increased from winter to post-monsoon from 2018–2020. Especially from 2014 onward, the average DGWL in Dausa consistently increased during all four seasons. Further, for all seasons, the wells with the highest average depth are located in the arid districts of Barmer or Jodhpur. Those with the lowest average are located in the districts of Ajmer or Tonk, except in the pre-monsoon season, during which the wells with the lowest average depth are in Jodhpur.

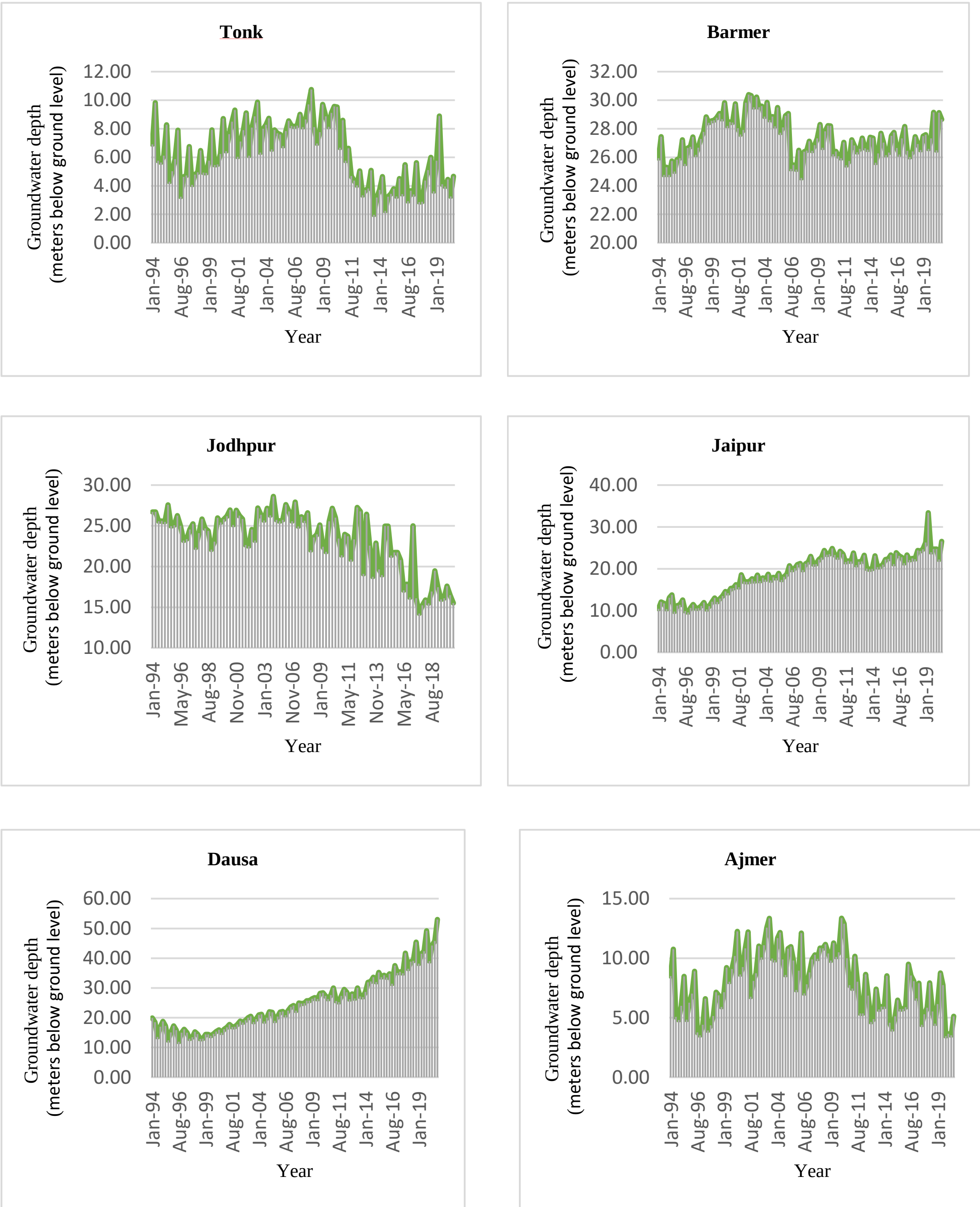
Figure 4.5 District-wise average annual DGWL, in meters below ground level.



Source: Authors' construction

To further understand the groundwater level and its variability, Appendix table 4.3 shows a detailed descriptive analysis of each of the observation wells. From the computed Kurtosis and Skewness values it is found that most of the values during the winter, pre-monsoon, monsoon and post-monsoon are highly skewed and are asymmetrically distributed.

Figure 4.6 District-wise average monthly DGWL.



Source: Authors' construction

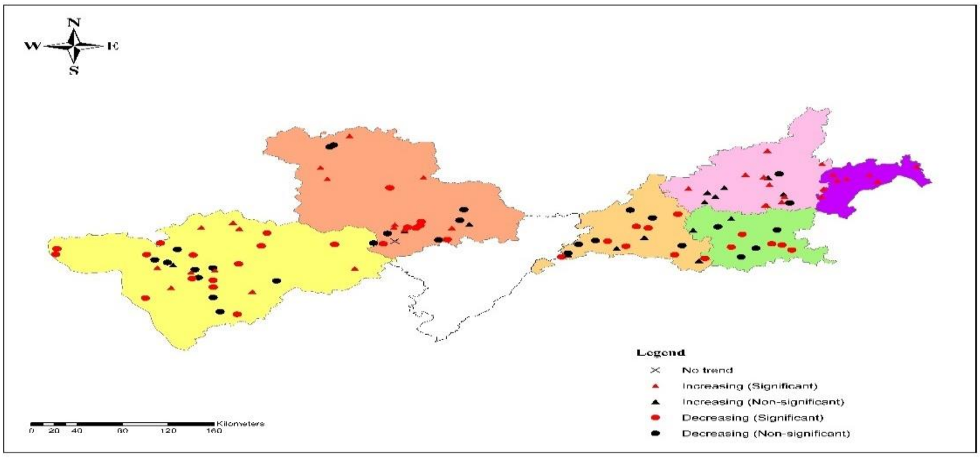
4.4.2 Spatial patterns in DGWL

The results of the annual and seasonal trend analysis of the 113 selected wells of CGWB are shown in Figure 4.7 and Appendix table 4.4. The test results indicate that approximately 42.00 percent of the total wells in the post-monsoon season have a positive trend, implying that these wells have witnessed an increasing DGWL. Furthermore, the results show that, of these 42.00 percent, approximately 29.00 percent of wells (*n* = 33) have a statistically significant (α = .05) positive trend, with Sen's slope ranging from 0.03 to 2.16 m•a–1. The test results also indicate that approximately 33.00percent of the wells (*n* = 37) have a statistically significant negative trend, with the Sen coefficient ranging from –0.05 to –0.98 m•a–1.

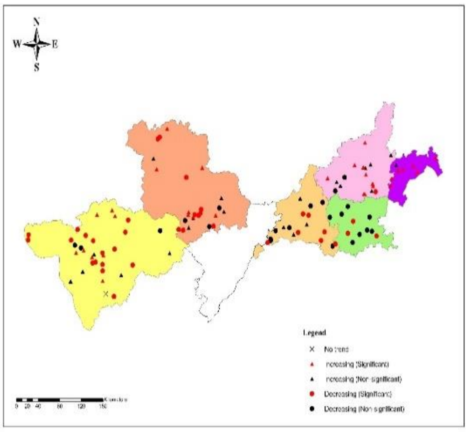
About 51.00 percent of the 113 wells show a positive trend during the monsoon season. Of these, 37 wells (32.00 percent) exhibit a statistically significant rise in DGWL. The magnitude of the trend in these wells ranged from 0.06 to 2.17 m•a–1. Furthermore, of the 53 wells experiencing a downward trend, 30 wells (26.00 percent) exhibit a statistically significant decline in DGWL. During the pre-monsoon season, a positive trend was found in 51 wells (45.00 percent). Furthermore, 35 of these 51 wells showed a statistically significant positive trend, with Sen slope values ranging from 0.03 to 2.26 m•a–1. Comparing the pre- and post-monsoon seasons, there is not much difference between the trends, with most of the wells displaying positive changes in both pre-monsoon and post-monsoon seasons. This demonstrates that the amount of rain during the monsoon season is insufficient to replenish the water drained during the previous season.

Figure 4.7 Annual and seasonal trends of DGWL in the arid and semi-arid districts of Rajasthan from 1994 to 2020.

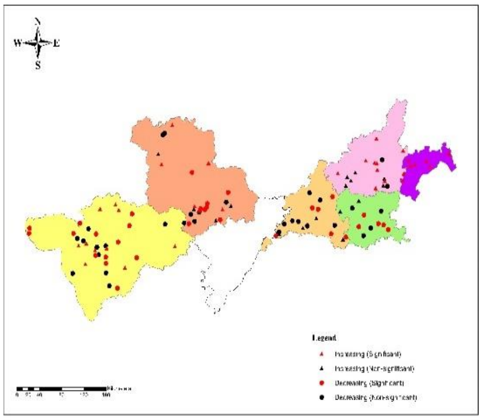
Annual



Winter

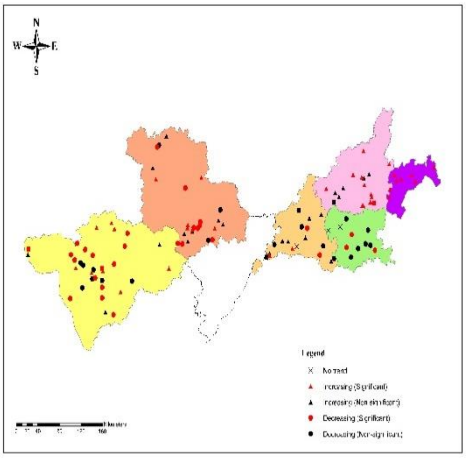


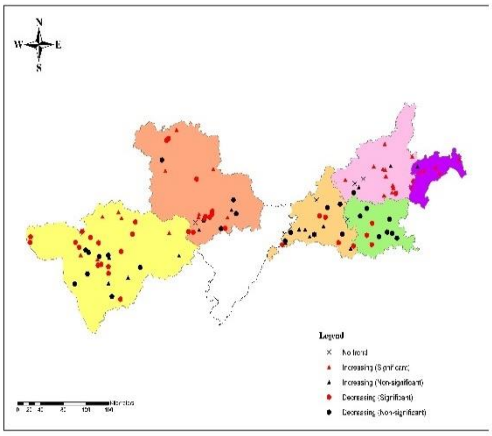
Pre-Monsoon



Monsoon

Post- Monsoon





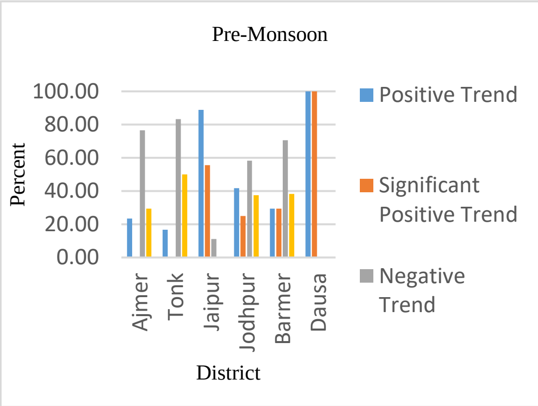
Source: Authors' construction

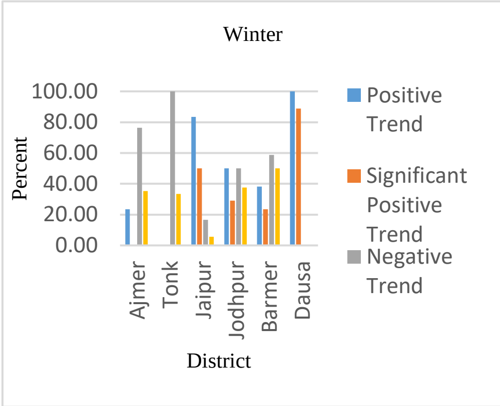
Furthermore, based on the trend analysis results for the winter season, 32 of the 113 wells have a statistically significant positive trend, with Sen slope values ranging from 0.04 to 2.22 m•a–1. At the same time, 37 (32.50 percent) of the wells showed a statistically significant negative trend. The trend analysis also demonstrates that, out of the 113 wells, five during the post-monsoon season, three during the monsoon season, and one during the winter season have no trend. The rate/magnitude of the positive trend is almost identical during all seasons. Consistent with the seasonal trends, the annual groundwater level shows a significant positive trend in 36 (32.00 percent) of the wells, with Sen slope values ranging from 0.03 to 2.34 m•a–1. Sixty-two of the 113 wells exhibit an annual negative trend, with 35 having significant changes and 27 wells showing insignificant trends.

Similarly, the spatial pattern of the annual groundwater level reveals that most of the wells in the districts of Dausa and Jaipur indicate a positive trend. For Dausa, all of the wells considered, and for Jaipur, 10 of the 18 wells (56.00 percent), show a significant positive trend with the Sen slope coefficients ranging from 0.12 to 1.72 m•a–1 and 0.08 to 2.34 m•a–1, respectively. The season-wise analysis also reveals the same picture. As evident from Figure 4.8, during the post-monsoon, monsoon, pre-monsoon, and winter seasons, in Jaipur, roughly

67.00 percent, 61.00 percent, 56.00 percent, and 50.00 percent of wells, and in Dausa, approximately 89.00 percent, 100.00 percent, 100.00 percent, and 89.00 percent of wells, respectively, have significant increasing or positive trends. The Sen slope coefficient for Dausa and Jaipur ranges from 0.11 to 1.96 m•a–1 and 0.09 to 2.26 m•a–1, respectively, from winter to post-monsoon season. Contrary to this, Tonk and Barmer have the highest percentages of wells with a significant decreasing/negative trend.

Figure 4.8 Percentage of wells or piezometers having increasing or decreasing trends.





Source: Authors' construction

4.5 Results: Groundwater quality

4.5.1 District-wise Groundwater Hydrochemistry

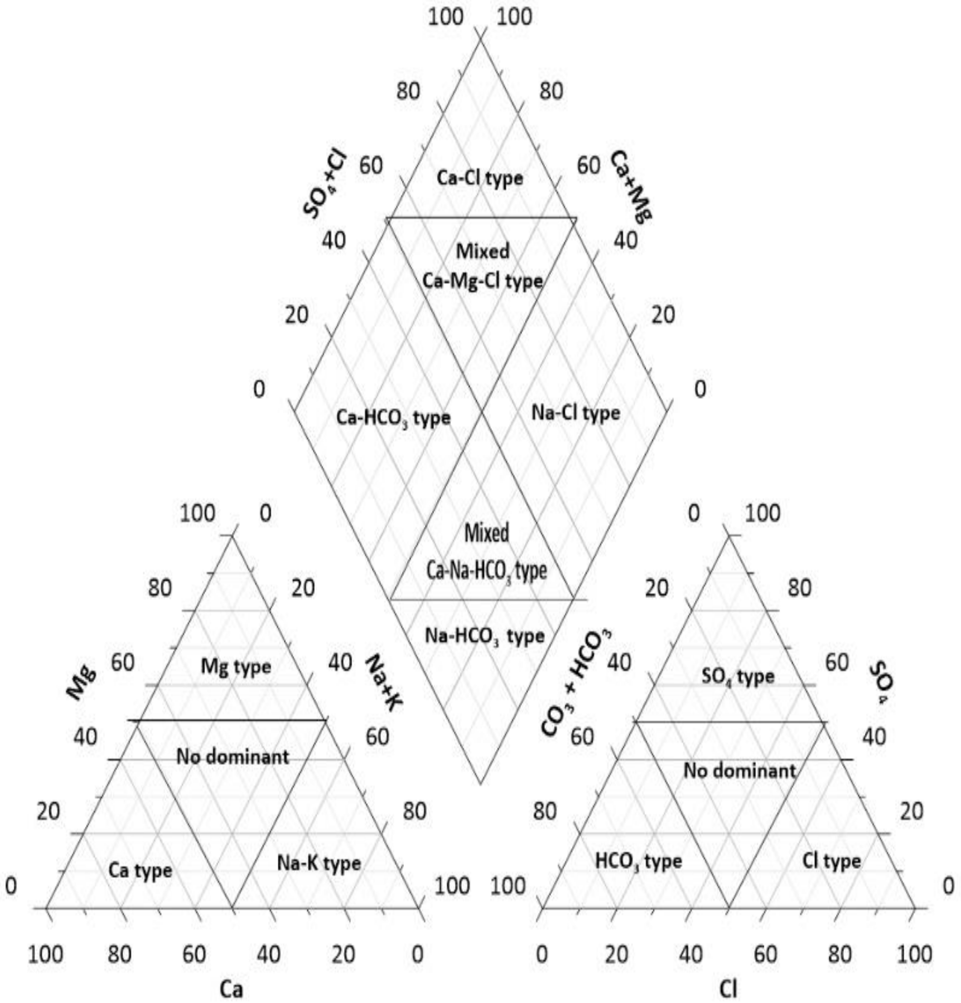
The analysis reveals that the pH of groundwater in the examined region remained neutral to slightly alkaline throughout the entire period (2000 to 2018) (see Appendix table 4.5). Further, from 2000 to 2018, the median value of EC declined in Ajmer, Barmer, and Jodhpur, which indicates a decrease in groundwater contamination (Jeon et al., 2020). While an increase in median values in Jaipur, Dausa, and Tonk was evident, indicating an accumulation of salts and ion particles in the groundwater in these districts. Also, the median value of NO_3^- in Ajmer, HCO_3^- in Barmer, Cl^-, F^-, HCO_3^- and NO_3^- in Dausa and Tonk, SO_4^{2-} and NO_3^- in Jaipur and Jodhpur and SO_4^{2-} in Tonk have shown an increase from 2000 to 2018. As a result of an increase in HCO_3^- in Barmer, Dausa, and Tonk, the median value of TA in these districts has also increased. Additionally, in Dausa, the concentration of Ca^{2+}, K^+, Mg^{2+}, and Na^+ increased from 2000 to 2018. From 2000 to 2018, the median concentration of Ca^{2+} in Jaipur declined, whereas the median concentrations of K^+, Mg^{2+}, and Na^+ increased. Similarly, while the median concentrations of Ca^{2+} and K^+ decreased in Tonk from 2000 to 2018, the median concentrations of Mg^{2+} and Na^+ increased. In Dausa and Tonk, the TH value, which measures dissolved Ca^{2+} and Mg^{2+} (Wu et al., 2017), increased from 2000 to 2018. In addition, from 2000 to 2018, the median concentration of trace element Fe increased in Barmer, Jodhpur, and Tonk.

4.5.2 Dominant Water Types

Piper's (1944) trilinear diagram was used to classify the groundwater in Ajmer, Barmer, Tonk, Dausa, Jodhpur, and Jaipur. As evident from Figure 4.9 the diagram consists of three parts: a diamond-shaped figure in the center, a trilinear diagram depicting the concentration of cations (Ca^{2+}, Mg^{2+}, K^+ + Na^+) on the left, and a trilinear diagram depicting the concentration of anions (Cl^- , SO_4^{2-} , HCO_3^- + CO_3^-) on the right. The concentration of anions and cations is expressed in milliequivalent percentages (mEq) (Oinam et al., 2012) . The composition of groundwater in the examined districts has not changed significantly (see Appendix figure 4.1). In Dausa the dominating cation in groundwater was Na^+ + K^+ and dominating anion was Cl^-. During the later period HCO_3^- was also evident in the groundwater. In Dausa the water type was Na-Cl and mixed Ca-Na-HCO_3.

Similarly, in Tonk the dominating cation was Na^+ + K^+ and Ca^{2+} and dominating anion was Cl^- and HCO_3^-. The groundwater type in Tonk was Na-Cl, Ca-Na-HCO_3, Ca-Mg-Cl, Na-HCO_3 and Ca-HCO_3. During the study period, in Ajmer, Barmer and Jodhpur Na^+ + K^+ was the dominating cation and Cl^- and HCO_3^- was the dominating anion. The water type in these districts was primarily Na-Cl type. Nonetheless, Ca-HCO_3, Ca-Na-HCO_3, Ca-Mg-Cl, and Na-HCO_3 water types were also observed during some years. Likewise, Na^+ + K^+ was the most prevalent cation in Jaipur, whilst Cl^- and HCO_3^- was the most prevalent anion. In the district, the prevalence of the following water types was observed: Na-Cl > Ca-Na-HCO_3> Na-HCO_3> Ca-Mg-Cl> Ca-HCO_3. Overall, in the examined region, alkali metal predominates over alkaline earth metal.

Figure 4.9 Piper Plot



Source: Reddy et al (2019)

4.5.3 Trend Analysis of Groundwater Quality Parameters

Trend analysis of different quality parameters for 84 observation stations in the examined region from 2000-2018 is shown in Figure 4.10 and the Appendix table 4.6. As evident from the figure, MK and Sen's tests for the data detected both positive/increasing and negative/decreasing trends. Out of 84 stations significant increasing trend was evident for TA (42percent), EC (35percent), TH (40percent), pH (19percent), Ca^{2+} (31percent), K^{+}(14percent), Mg^{2+} (35percent), Na^{+}(34percent), Cl^{-} (32percent), HCO_3^{-} (40percent), SO_4^{2-} (27percent), F^{-} (12percent), NO_3^{-} (25percent) and Fe (30percent). While significant decreasing trend was evident for TA (18percent), EC (20percent), TH (13percent), pH (30percent), Ca^{2+} (8percent), K^{+}(36percent), Mg^{2+} (22percent), Na^{+}(27percent), Cl^{-} (23percent), HCO_3^{-} (25percent), SO_4^{2-} (19percent), F^{-} (61percent), NO_3^{-} (37percent) and Fe (24percent). The district-wise number of stations exhibiting a significant increasing trend is shown in Table 4.2.

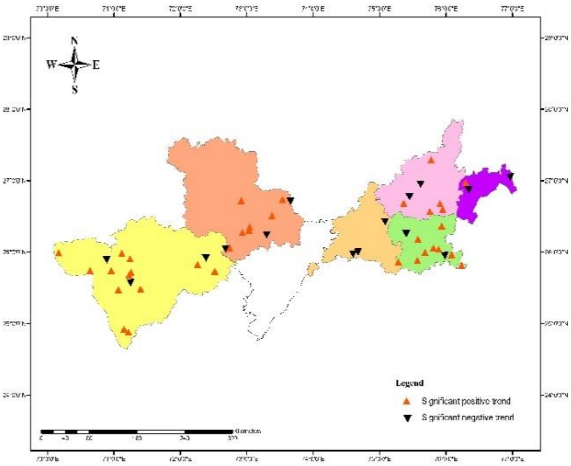
Table 4.2 District-wise number of stations with a significant increasing trend

	Barmer	Jodhpur	Jaipur	Dausa	Ajmer	Tonk
Total number of stations	20	14	13	4	21	12
TA (mg/L)	13	7	5	1	-	9
EC (mumhos/cm) at 25 C)	7	6	8	-	4	5
pH	10	1	1	-	4	-
TH (mg/L)	8	3	6	-	8	8
Ca^{2+} (mg/L)	7	5	6	-	4	5
K^{+}(mg/L)	3	2	4	-	3	-
Mg^{2+} (mg/L)	8	4	5	1	6	5
Na^{+}(mg/L)	5	8	7	-	3	5
Cl^{-} (mg/L)	7	5	6	-	4	5
F^{-} (mg/L)	-	1	3	4	1	1
HCO_3^{-} (mg/L)	9	7	6	-	4	7
NO_3^{-} (mg/L)	3	5	4	1	5	3
SO_4^{2-} (mg/L)	5	7	7	-	2	2
Fe (mg/L)	8	5	1	-	7	4

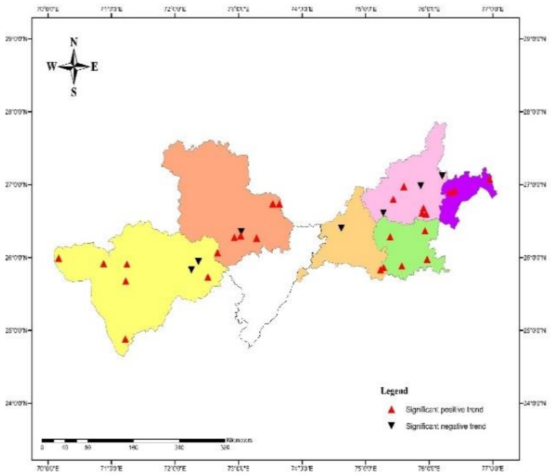
Source: Authors' calculation

Figure 4.10 Trends in groundwater quality (significance level < 0.05)

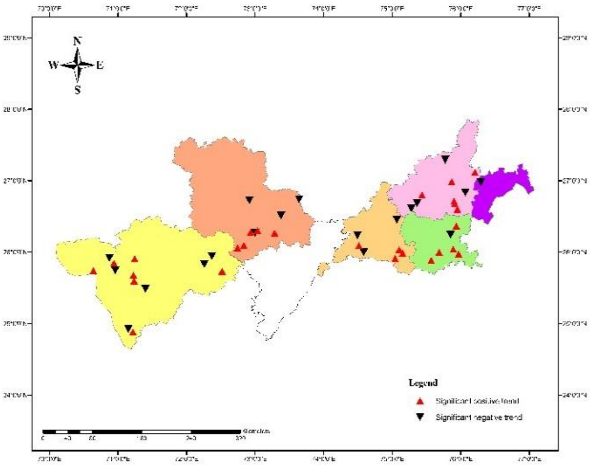
Total Alkalinity (mg/L)



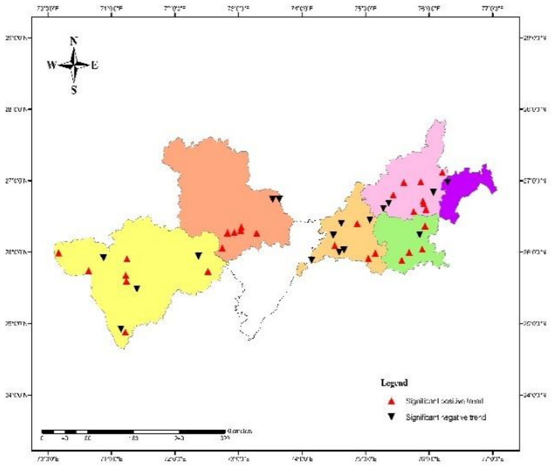
Calcium (mg/L)



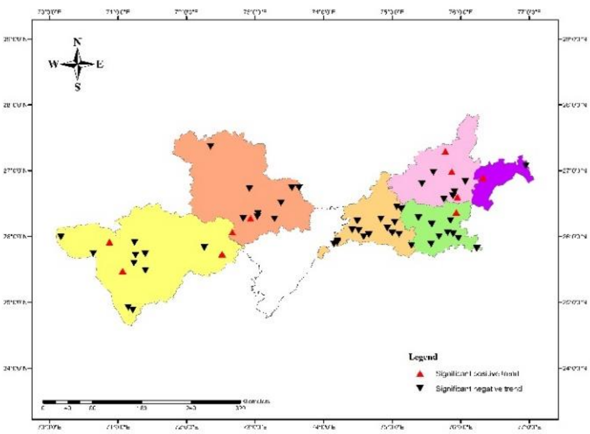
Chloride (mg/L)



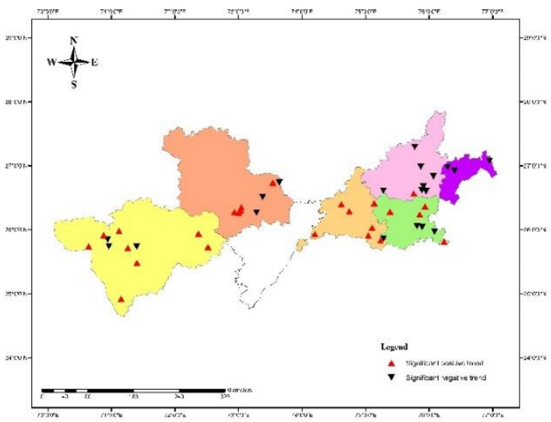
Electrical Conductivity (mumhos/cm) at 25 C)



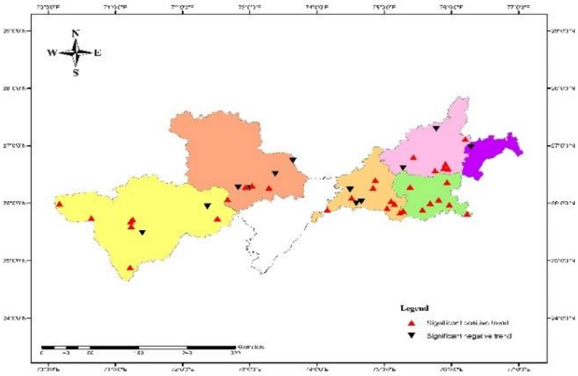
Fluoride (mg/L)



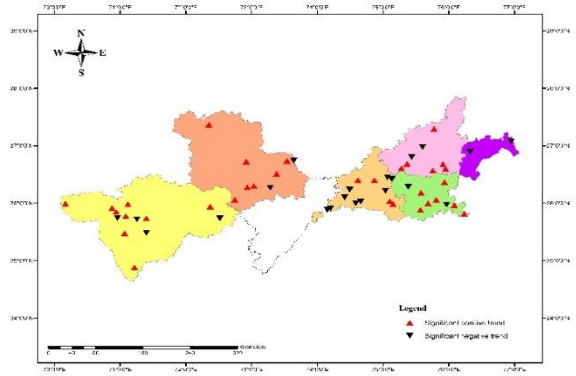
Iron (mg/L)



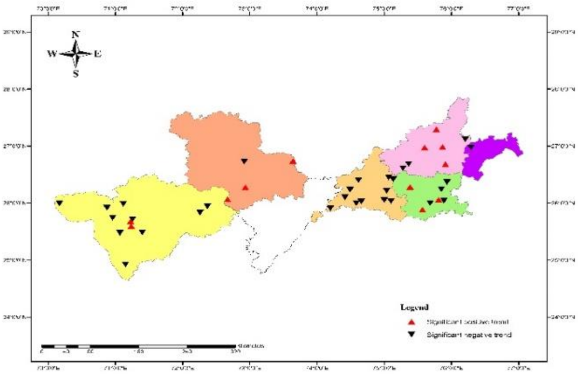
Total Hardness (mg/L)



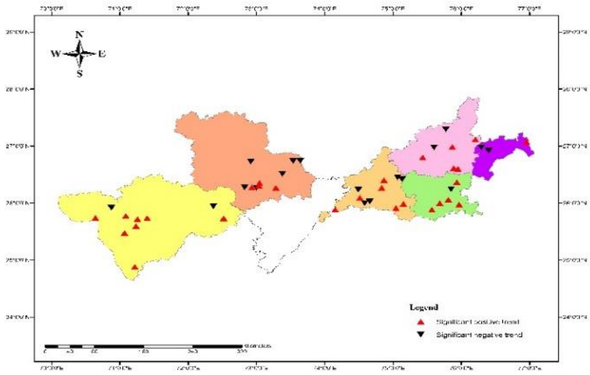
Bicarbonate (mg/L)



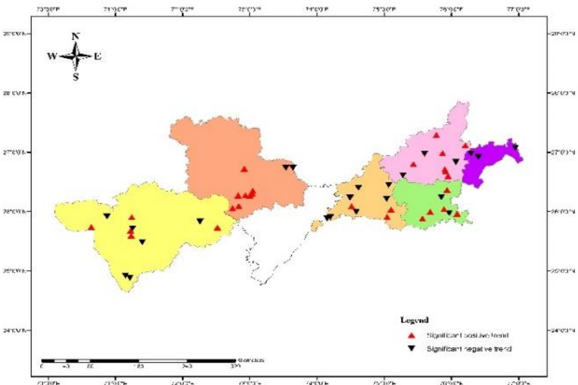
Potassium (mg/L)



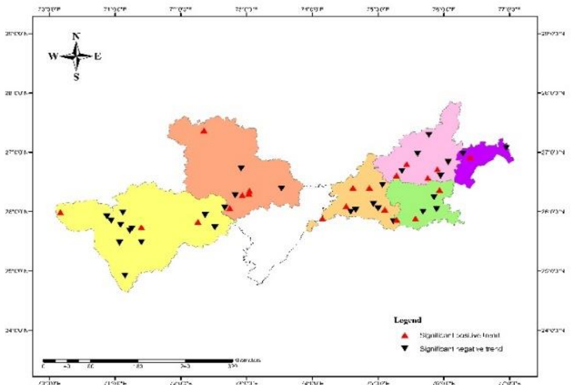
Magnesium (mg/L)



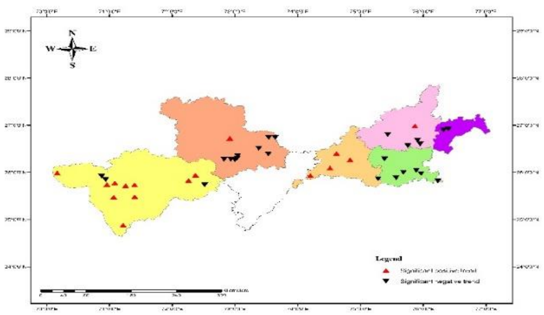
Sodium (mg/L)



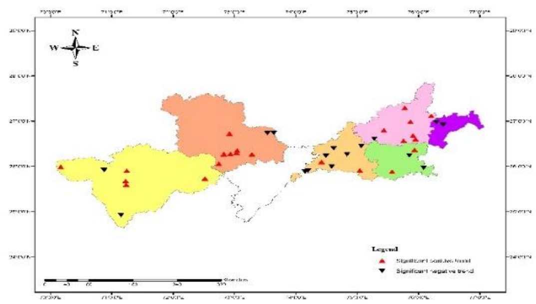
Nitrate (mg/L)



pH



Sulphate (mg/L)



Source: Authors' construction

4.5.4 Groundwater Suitability

(A) Suitability for Drinking

Table 4.3 shows the BIS (2012) and WHO (2011) guidelines for groundwater quality parameters. The year-wise percentage of observation stations that exceed the BIS and WHO acceptable and permissible thresholds are given in the Appendix table 4.7. The analysis shows that from 2000 to 2018, a comparatively higher percentage of stations exceeded the guideline limit for Cl- (mg/L), F- (mg/L), and Na+ (mg/L). In 2018, 44, 35, and 53 percent of stations exceeded the desirable limit of 250 mg/L for Cl-, 1 mg/L for F-, and 200 mg/L for Na+, respectively. District-wise, from 2009 to 2018 in Dausa, 100 percent of stations exceeded the BIS acceptable limit for F-. Also, during the study period, more than 50 percent of stations in Jaipur (excluding the year 2018) and Barmer were found to exceed the acceptable limit for F-. Similarly, except for 2018, the Cl- levels exceeded the acceptable limit in over 50 percent of the stations in Barmer and Jodhpur. In Dausa, the presence of Cl- also posed a concern, as it exceeded the limit in more than 50 percent of the stations between 2013 and 2018. Likewise, during 2000- 2018, Na+ exceeded the acceptable limit in more than 50 percent of stations in Jodhpur and Barmer (except the year 2018). The high sodium level is also a matter of concern for Jaipur and Dausa, where during 2001-2018, Na+ exceeded the acceptable limit for over 50 percent of stations. Also, in Ajmer for 2017 and 2018, Na+ concentration was greater than 200 mg/L in 57 percent and 53 percent of stations. In addition, approximately 50 and 53 percent of stations in Jodhpur and Jaipur exceeded the desirable SO42- limit. Also, in Dausa, from 2014 to 2017, SO42- concentration exceeded the desirable limit for 50 percent of the stations. Moreover, in Barmer and Jodhpur, most stations exceeded the acceptable NO3- limit, which is cause for concern.

Based on this, the suitability of groundwater, particularly in Dausa, raises considerable apprehension. Continuous consumption of water with high concentrations of these ions increases the vulnerability to health problems like fluorosis and bone fluorosis, neurological impairments, hypertension, cancer, infertility, heart disease, stroke, and high blood pressure (Tanwer et al., 2022; Kom et al., 2022). Consumption of higher NO3- increases the risk of cancer and can cause hypertension and methemoglobinemia (Kom et al., 2022; Tanwer et al., 2023). The non-carcinogenic health effect of high-concentration NO3- (mg/L) consumption has become a significant concern (Marghade et al., 2021).

Table 4.3 Water Quality Guideline

Parameter	WHO Guideline (2011)	Bureau of Indian Standards (BIS) (2012)		Effects
		Acceptable Limit	Permissible limit	
pH		6.5-8.5		Taste
Calcium (mg/L)		75	200	Kidney and bladder
Magnesium (mg/L)			100	Laxative effects
Sodium (mg/L)	200			Taste, Heart Disease
Potassium (mg/L)	12			Laxative effects
Chloride (mg/L)		250	1000	High Blood Pressure, Taste
Sulphate (mg/L)		200	400	Taste, Gastrointestinal
Fluoride (mg/L)		1	1.5	Bone and Skeletal damage, Discoloration of Teeth
Nitrate (mg/L)		45		Methemoglobinemia
Source: BIS (2012); WHO (2011)				

(B) Suitability for Irrigation

The high salinity concentration in irrigation water augments the soil's osmotic pressure and leads to physiological drought that adversely impacts plant health (Zaman et al., 2018). Likewise, high Na+ concentration reduces soil permeability and can adversely affect crop productivity (Islam et al., 2017). EC is one of the most significant and reliable measurements to assess water salinity (Gullu and Kavurmaci, 2023). Following Sharma et al. (2017), the EC values were grouped into five categories according to Richard (1954) classification to determine groundwater suitability. Further, as evident from Table 4.4, based on BIS, the SAR values were classified into four groups to assess the irrigation water quality.

Table 4.4 Irrigation Water Quality Guideline

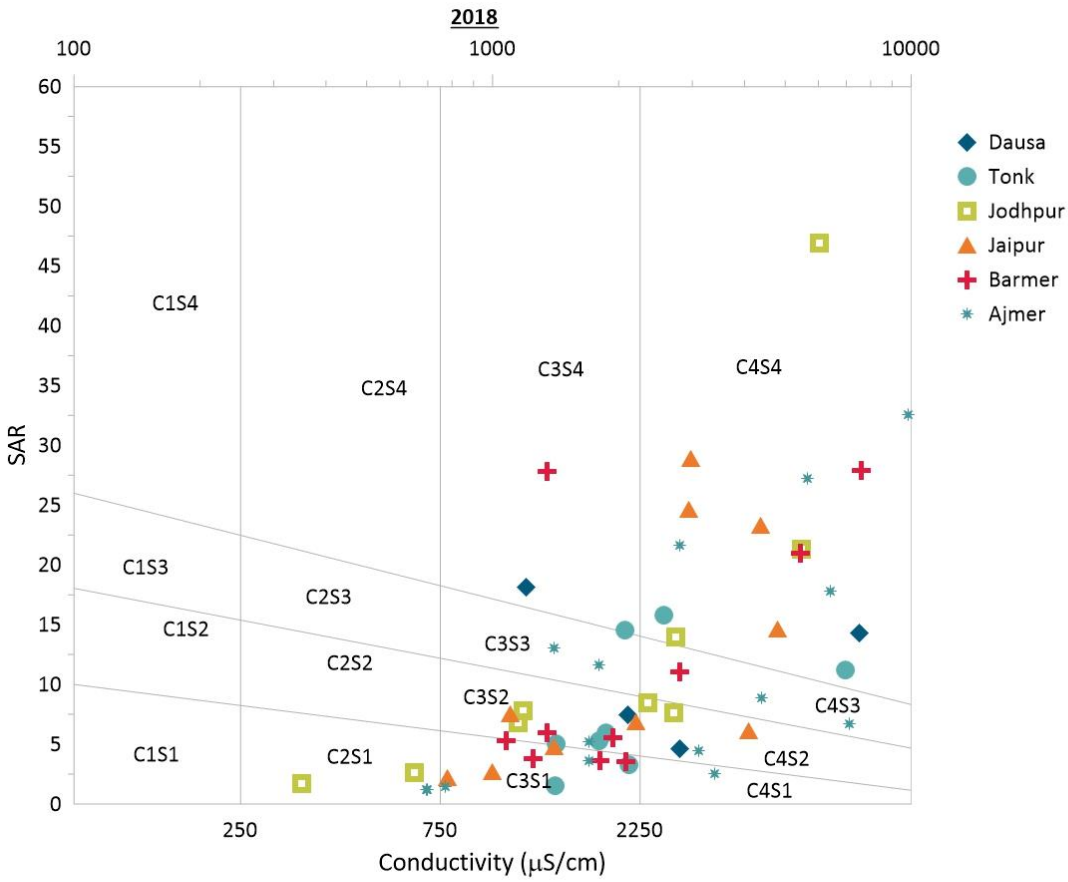
Parameter	Water Class
EC (µS/cm)	<250 -Excellent 250-750 - Good 750-2000 -Permissible 2000-3000 -Doubtful >3000 - Unsuitable
SAR	<10 - Excellent 10-18 – Good 18-26 – Doubtful >26 - Unsuitable
Source: Sharma et al. (2017); Goswami et al. (2022)	

Results reveal that from 2000-2018 in most stations, the SAR value was less than ten, showing the water is excellent for irrigation (see Appendix table 4.8). Also, during the study period in all the districts, the sequence of SAR-based groundwater classification was: excellent > good > questionable > unsuitable. Based on EC classification, in 2018, approximately 5, 29, 18, and 23 percent of stations were under the good, permissible, doubtful, and unsuitable category. During the entire study period, the sequence of EC-based classification was: unsuitable/permissible > doubtful > good > excellent. District-wise, during 2000-2018, most stations in Tonk had EC values between 750 and 2000 µS/cm (Permissible), whereas most stations in Jodhpur had EC values greater than 3000 µS/cm (Unsuitable).

The USSL diagram was used to analyze groundwater suitability for irrigation. The plot divides water into sixteen classes: four according to EC (C1=low salinity, C2=medium salinity, C3=high salinity, C4=very high salinity) and four according to SAR (S1=low-sodium water, S2=medium-sodium water, S3=high-sodium water, and S4=very high sodium water)

(Saghebian et al., 2013). Figure 4.11 shows the USSL diagram. As evident from the figure, most observation station belongs to the C3S2 category, i.e., high salinity and medium sodium hazard. Notably, this C3S2 category remained predominant throughout the study period (see Appendix figure 4.2). The water in this category can be used to irrigate soil with good permeability if salinity control measures can be implemented (Aravinthasamy et al., 2020).

Figure 4.11 USSL Plot for the year 2018



Source: Authors' construction

4.6 Effect of climatic and anthropogenic variables on DGWL and groundwater quality

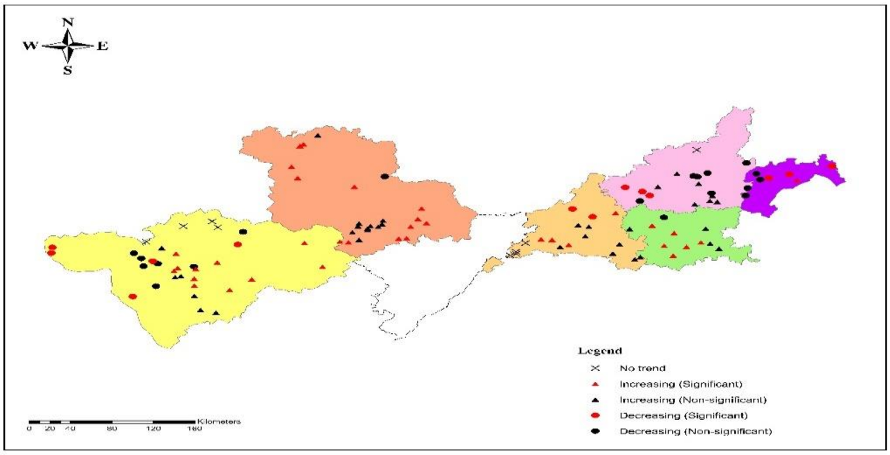
4.6.1 Trends in climate and anthropogenic variables

Figure 4.12 illustrates the trends of climatic and anthropogenic variables considered for the impact assessment of DGWL. The trend analysis results of the climatic variables are also shown in Appendix table 4.9 All monitoring stations recorded an increasing pattern in minimum and maximum temperature between 1994 and 2020. However, a statistically significant ($p < .05$) increasing trend was recorded at approximately 6.00 percent of the stations in cases of maximum temperature and in approximately 97.00 percent of stations in cases of minimum temperature. In the precipitation data, approximately 29.00 percent (33 of 113) of the observation stations witnessed a decreasing trend. Of these 33 stations, 14 witnessed a significant decreasing trend in precipitation. District-wise, two stations in Ajmer, five in Barmer, four in Dausa, and three in Jaipur experienced a significant negative trend. No trend was witnessed in nine of the observation stations, while an increasing trend was evident in 63.00 percent (71 of 113). Of these 71 stations, 35 witnessed a significant increasing trend.

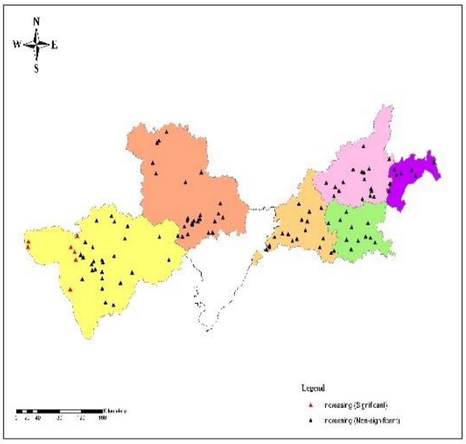
Further, as evident from Figure 4.12, from 1999 to 2020, all the districts witnessed an increase in DGDP, with the average annual growth rate ranging from 3.50percent in Barmer to 6.11 percent in Jaipur. Although the overall DGDP improved, all districts experienced a decline during 2001–2002 due to the widespread drought in Rajasthan, and in 2019–2020 due to the COVID-19 pandemic. From 1999 to 2020, consistent population growth is also evident in every district except for Tonk, which saw a population decline during 2009–2010. Furthermore, from 1994 to 2019, the NIA trend has fluctuated in all of the semi-arid districts. In contrast, the NIA rose steadily in the arid districts of Jodhpur and Barmer.

Figure 4.11 Trends in a) precipitation, b) temperature (maximum), c) temperature (minimum), (d) DGDP at constant price (Billion USD ($ bn) ; base year = 2011–2012), (e) population, and (f) NIA (000 hectares).

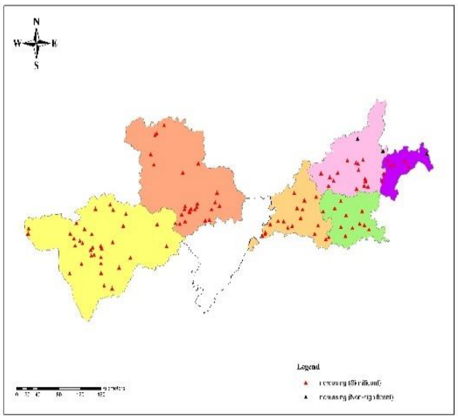
(a)

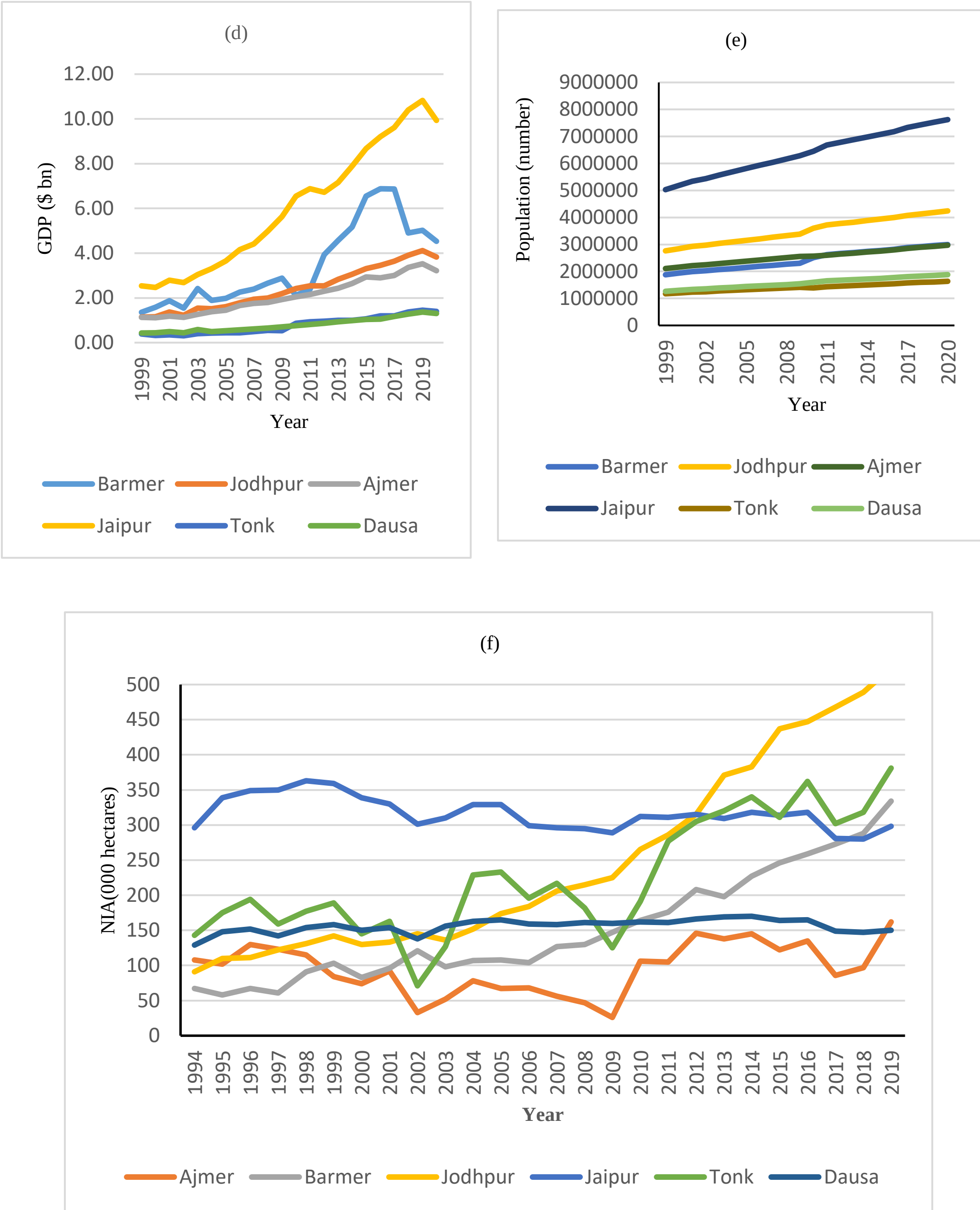


(b)



(c)





Source: Authors' construction

Figure 4.13 illustrates the trend of variables considered for impact assessment of water quality. As shown in Figure 4.13, most monitoring stations recorded an increasing trend in temperature between 2000 and 2018[4]. Although, a statistically significant ($p< 0.05$) increasing

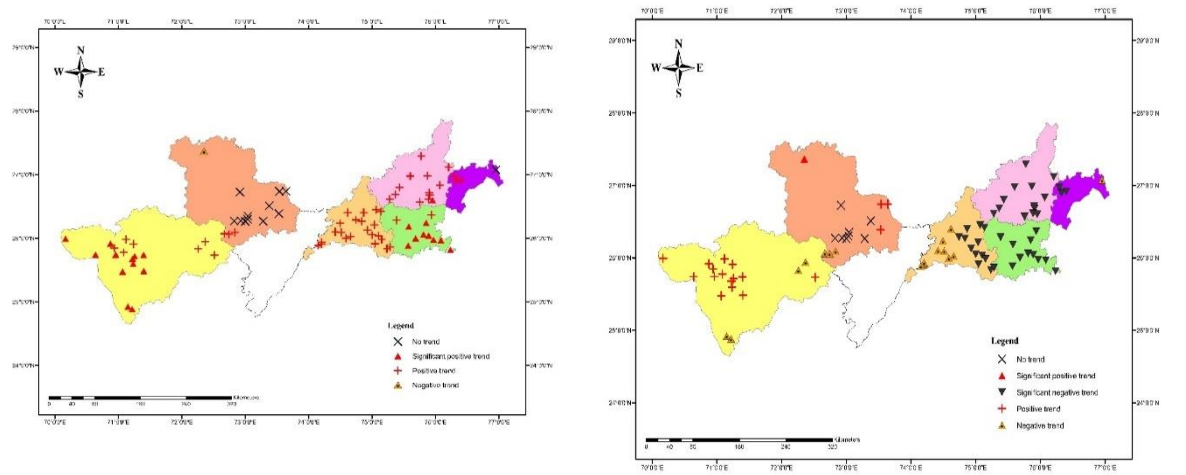
[4] Trend analysis results are given in Appendix table 4.10.

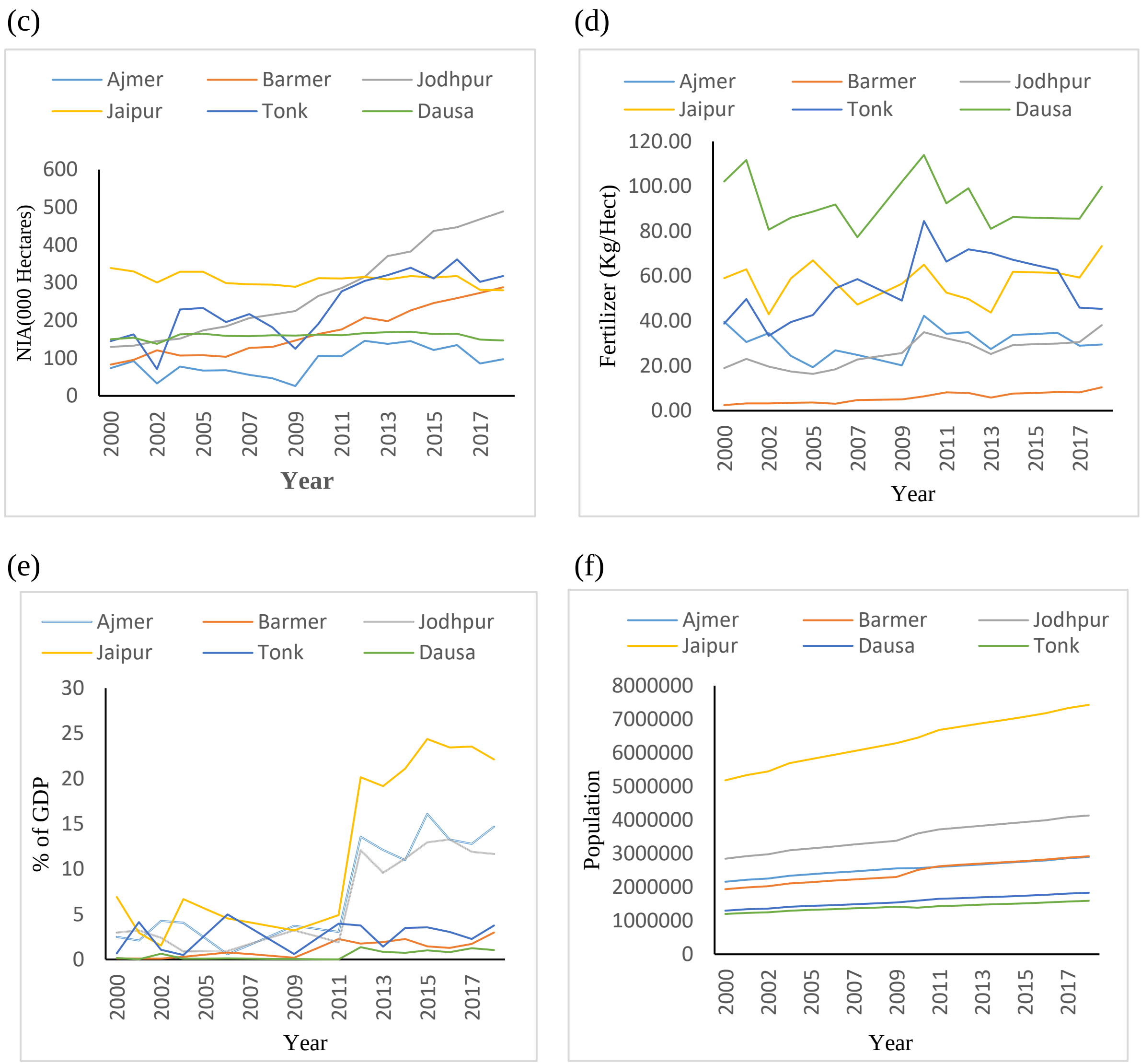
trend was recorded at approximately 27 percent of the stations. In the precipitation data, approximately 68 percent (57 out of 84) of the observation station witnessed a decreasing trend. Of these 57 stations, 40 witnessed a significant decreasing trend in precipitation. In eight of the observation station, no trend was witnessed, while an increasing trend was evident in 19 of the stations.

The anthropogenic parameter, population over the given period, has increased in all the districts. Further, as evident from Figure 4.13, the NIA shows a fluctuating upward trend for Ajmer, Barmer, Jodhpur, and Tonk during the given period, whereas in Jaipur and Dausa, NIA declined. Like the NIA, the districts' fertilizer usage exhibits a fluctuating trend. Also, the share of manufacturing in the DGDP increased in all districts from 2000 to 2018

Figure 4.12 Trend in a) Temperature, b) Precipitation, (c) NIA, (d) Fertilizer usage, (c) Gross value added by manufacturing in DGDP, and (d) Population in the study area

(a) (b)





Source: Authors' construction

4.6.2 Correlation between DGWL and climatic and anthropogenic variables

Correlation analysis of each variable was performed to eliminate the indicators that were not significantly correlated with the DGWL. Before the analysis, all variables were standardized to remove the effect of their magnitude. Table 4.5 shows the results of the pairwise correlation analysis. The mean DGWL in Ajmer is significantly correlated with climatic variables, such as mean precipitation and mean temperature (maximum), and anthropogenic-induced factors, such as NIA and DGDP. Similarly, in Tonk, mean precipitation and anthropogenic variables

NIA and DGDP were significantly correlated with the mean DGWL. For Barmer, the mean precipitation was significantly correlated with the mean DGWL. However, for Dausa and Jaipur, the mean DGWL was significantly correlated with all the non-climatic factors: NIA, DGDP, and population. Even in the arid district of Jodhpur, the mean DGWL was significantly correlated with anthropogenic-induced variables, such as NIA and DGDP

Table 4.5 District-wise correlation analysis of variables

District	Variables	Precipitation	Temperature (Maximum)	Temperature (Minimum)	DGWL	NIA	DGDP	Population
Ajmer	Precipitation	1.00						
	Temperature (Maximum)	–0.47*	1.00					
	Temperature (Minimum)	–0.15	0.62*	1.00				
	DGWL	–0.74*	0.55*	0.16	1.00			
	NIA	–0.75*	0.50*	0.18	0.90*	1.00		
	DGDP	–0.51*	0.25	–0.23	0.84*	0.70*	1.00	
	Population	–0.53*	0.29	–0.26	0.11	0.64*	0.98*	1.00
Barmer	Precipitation	1.00						
	Temperature (Maximum)	–0.36	1.00					
	Temperature (Minimum)	–0.01	0.44*	1.00				
	DGWL	–0.60*	0.33	–0.11	1.00			
	NIA	0.04	–0.21	–0.64*	–0.26	1.00		
	DGDP	–0.14	0.02	–0.52*	–0.40	0.86*	1.00	
	Population	–0.21	0.14	–0.60*	–0.01	0.95*	0.86*	1.00
Dausa	Precipitation	1.00						

	Temperature (Maximum)	–0.42*	1.00					
	Temperature (Minimum)	–0.31	0.69*	1.00				
	DGWL	–0.17	0.13	0.22	1.00			
	NIA	–0.04	–0.05	–0.27	0.42*	1.00		
	DGDP	–0.18	0.25	0.14	0.97*	0.13	1.00	
	Population	–0.23	0.22	0.06	0.76*	0.27	0.97*	1.00
Jaipur	Precipitation	1.00						
	Temperature (Maximum)	–0.56*	1.00					
	Temperature (Minimum)	–0.40*	0.71*	1.00				
	DGWL	–0.23	0.29	0.30	1.00			
	NIA	–0.25	0.41*	0.44*	–0.76*	1.00		
	DGDP	–0.43*	0.20	0.01	0.91*	–0.47*	1.00	
	Population	–0.47*	0.22	0.01	0.89*	–0.54*	0.98*	1.00
Jodhpur	Precipitation	1.00						
	Temperature (Maximum)	–0.50*	1.00					
	Temperature (Minimum)	–0.01	0.47*	1.00				
	DGWL	–0.31	–0.02	–0.33	1.00			
	NIA	–0.35	–0.09	–0.59*	–0.51*	1.00		
	DGDP	–0.44*	–0.08	–0.59*	–0.64*	0.99*	1.00	
	Population	–0.61*	0.24	–0.53*	–0.36	0.96*	0.98*	1.00
Tonk	Precipitation	1.00						
	Temperature	–0.36	1.00					

	(Maximum)							
	Temperature (Minimum)	–0.17	0.72*	1.00				
	DGWL	–0.66*	0.32	0.10	1.00			
	NIA	–0.70*	0.12	0.02	–0.73*	1.00		
	DGDP	–0.56*	0.27	0.10	–0.74*	0.87*	1.00	
	Population	–0.47*	0.19	0.02	–0.16	0.82*	0.95*	1.00
Note. ***** p = .05.								
Source: Authors' calculation								

4.6.3 Correlation between groundwater quality and climatic and anthropogenic variables

Table 4.6 shows district-wise results of PCA analysis of water quality indicators (TA, Ca^{2+}, Cl^- , EC, F^-, Fe, TH, HCO_3^-, K^+, Mg^{2+},Na^+, NO_3^-,SO_4^{2-} and pH). The KMO and Bartlett test scores for each district indicated that the sample is adequate and suitable for PCA. Based on Kaiser's rule, four principal components with eigenvalue> 1 were selected for Barmer, Ajmer and Jodhpur, explaining the cumulative variance of 81 percent, 90 percent, and 82 percent, respectively. Whereas five principal components were selected for the districts of Jaipur, Tonk, and Dausa, explaining the total variance of 83.7 percent, 88.2 percent, and 90.5 percent, respectively (see Appendix figure 4.3). Further, from the varimax rotated component matrix (see Table 4.6) it is evident that parameters have both positive and negative loadings. If the parameter loadings have the same sign, they are positively correlated, while if they have opposing signs, they are negatively correlated (Zavareh et al., 2021). The principal components extracted by PCA concisely depict the hydrochemistry of groundwater in the examined region. For GAM analysis, the district-wise extracted principal components were used to examine the effect of climate change and anthropogenic activities on water quality.

The PCs of the water quality were used for the correlation analysis (see Appendix table 4.11). Component-wise, only the explanatory variables which were significantly correlated were considered for GAM construction. Further, the second and fourth extracted component in Ajmer, forth component in Jodhpur and the fourth and fifth components in Tonk was not having a significant correlation with any of the considered variables; hence it was not included in the further analysis.

Table 4.6 Rotated component Matrix

District	Barmer				Ajmer				Jaipur					Jodhpur				Tonk					Dausa				
Paramete	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4	PC	PC2	PC3	PC4	PC5	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4	PC5	PC1	PC2	PC3	PC4	PC5
TA	0.0	0.0	0.0	0.6	0.3	0.2	0.2	0.0	-0.1	0.6	-0.2	0.0	-0.1	0.2	-0.1	-0.5	-0.1	0.5	-0.2	-0.1	0.0	0.0	0.1	0.0	-0.3	0.4	0.2
Ca^{2+}	0.2	-0.1	0.6	-0.1	0.1	0.5	-0.2	-0.1	0.0	-0.2	0.6	0.1	-0.1	0.5	0.2	0.0	-0.1	0.3	0.3	-0.2	-0.1	0.3	-0.1	0.2	0.4	0.0	0.2
Cl^-	0.4	0.2	0.2	-0.1	0.4	0.0	-0.1	0.1	0.4	0.0	0.0	0.0	0.2	0.4	-0.1	0.1	0.1	0.2	0.4	0.1	-0.1	0.1	0.1	0.5	0.0	0.0	-0.1
EC	0.2	0.4	0.2	-0.1	0.4	0.0	-0.1	0.2	0.5	0.0	0.0	0.2	-0.1	0.3	0.0	-0.2	0.2	0.4	0.1	0.1	0.0	0.1	0.4	0.3	0.2	0.0	0.2
F-	0.1	0.1	-0.4	-0.1	0.0	0.1	0.8	0.0	0.0	0.0	-0.2	0.5	0.4	-0.1	-0.3	0.5	0.1	-0.1	-0.3	0.0	0.3	-0.2	0.1	-0.1	0.7	0.1	0.0
Fe	-0.3	-0.1	0.2	-0.1	-0.1	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.8	0.0	0.6	0.0	-0.1	0.0	0.0	0.1	0.7	0.3	0.3	-0.1	-0.3	-0.1	0.2
TH	-0.2	0.1	0.5	0.0	0.3	0.2	-0.3	-0.2	0.1	0.1	0.5	0.0	0.2	0.0	-0.3	-0.1	0.5	0.3	0.1	0.2	-0.1	0.2	0.0	0.5	0.1	0.1	0.1
HCO_3-	0.1	-0.1	-0.1	0.6	0.2	0.3	0.2	0.0	0.0	0.6	0.1	0.0	0.0	0.2	-0.1	-0.4	-0.3	0.5	-0.2	-0.2	0.1	-0.1	0.1	0.0	-0.3	0.4	0.1
K^+	0.0	0.4	-0.3	0.0	0.3	-0.2	0.2	-0.4	0.4	-0.1	-0.1	-0.4	0.1	0.4	-0.1	0.0	-0.3	0.0	-0.1	0.0	0.2	0.8	0.0	0.0	0.0	0.0	0.9
Mg^{2+}	-0.2	0.4	0.2	0.3	0.4	0.0	-0.1	0.0	0.3	0.4	0.2	-0.1	0.1	0.3	-0.3	0.0	0.2	0.2	0.0	0.3	-0.1	0.0	0.0	0.5	-0.3	0.1	-0.1
Na^+	0.3	0.3	0.1	-0.2	0.4	0.0	0.2	0.0	0.4	0.2	-0.1	0.2	-0.3	0.4	0.1	0.2	0.2	0.2	0.0	0.4	0.2	-0.3	0.5	0.1	0.0	0.0	0.1
NO_3^-	0.6	-0.2	-0.1	0.0	0.0	0.5	0.2	0.0	0.1	0.0	0.1	0.7	-0.1	0.0	0.5	0.0	0.1	-0.1	0.7	-0.1	0.1	-0.1	0.5	-0.3	0.1	0.2	-0.2
pH	-0.5	0.0	0.0	-0.2	0.0	0.0	0.0	0.8	0.1	-0.1	-0.5	0.0	0.1	0.2	0.1	0.6	-0.3	-0.3	-0.3	0.1	-0.5	0.3	0.1	0.0	-0.2	-0.7	0.1
SO_4^{2-}	-0.1	0.6	-0.1	0.0	0.4	-0.1	0.1	0.0	0.5	-0.2	0.0	-0.1	-0.1	0.1	0.2	0.0	0.5	-0.1	0.0	0.8	0.0	0.0	0.6	0.0	0.1	-0.2	-0.1

Source: Authors' calculation

4.6.4 Univariate and multivariate GAM construction for DGWL

Table 4.7 shows the results of the univariate GAM technique. For Ajmer, all variables have a statistically significant impact on the DGWL. The degrees of freedom of the univariate GAM with DGDP and precipitation as an explanatory variable equal 1; the rest of the univariate GAM models had degrees of freedom greater than 1, indicating that, in Ajmer, the DGWL is nonlinearly correlated with all parameters except DGDP and precipitation. For Ajmer, the GAM model with NIA as an explanatory variable was the best univariate model, with –41.20 and 88.70percent as Akaike's information criterion (AIC) and deviance explained (DE) values, respectively.

For Barmer, the univariate GAM reveals that the DGWL in the district is significantly and linearly (degrees of freedom = 1) correlated with mean precipitation. The univariate GAM model for the district has AIC and DE values of –1.87 and 36.20percent, respectively. For Dausa, leaving the univariate model with NIA as an explanatory variable, which was found to be significant at $p < .05$ and has degrees of freedom equal to 1, the rest of the GAM models had degrees of freedom greater than 1 and were found to be highly significant ($p < .001$). The GAM model with the population as an explanatory variable has the best fit, with AIC and DE values of –62.66 and 97.00percent, respectively. Similarly, for Jaipur, all explanatory variables—NIA, DGDP, and population—were significantly correlated with the DGWL. All the univariate GAM models had degrees of freedom greater than 1, indicating the non-linear relationship between DGWL and the explanatory variables. With the lowest AIC (–62.55), the GAM model with population as an explanatory variable was the best fit for the district.

For Tonk and Jodhpur, all the explanatory variables were highly significant. For Tonk, the GAM model with NIA as the explanatory variable has degrees of freedom = 1, rest for precipitation, and DGDP degrees of freedom greater than 1. DGDP with an AIC value of −29.04 and a DE of 93.20percent was the best-fit univariate model for the district. For Jodhpur, both NIA and DGDP have degrees of freedom greater than 1. With the lowest AIC (–71.74), the univariate model using NIA as the explanatory variable was the best fit for the district. The results of the univariate GAM analysis indicate that, either linearly or nonlinearly, all explanatory variables significantly influence the DGWL. Therefore, multivariate GAM can be used to assess the relationships between multiple explanatory variables and DGWL.

Table 4.8 shows the multivariate GAM results. In this study, the maximum number of explanatory variables was limited to two based on sample size and to ensure convergence of all models. In addition, a collinearity test was conducted for each variable combination, and combinations with a VIF greater than 10 were omitted from the analysis. Following Wang et al. (2022), the best-fit model was determined based on the value of the AIC. The table shows that, in Ajmer, six multivariate GAMs of DGWL were screened out (i.e., Models 1–6). Similarly, in Dausa two (i.e., Models 1 and 2), in Tonk three (i.e., Models 1–3), and in Jaipur two (i.e., Models 1 and 2) multivariate GAMs of DGWL were screened out. For Jodhpur, multivariate GAM was not computed, as the VIF between NIA and DGDP was greater than 10. Further, based on the AIC values, Model 6 in Ajmer, Model 3 in Tonk, and Model 2 in Jaipur and Dausa were selected as the best-fit/optimal models.

Table 4.9 and Appendix figure 4.4 presents the model fit results of the optimal multivariate GAM models. The value of the k-index is approximately 1 or greater than 1 in all models, and the *p*-value is sufficiently large, indicating no significant patterns in the models' residuals. Further, the Shapiro–Wilk normality test verifies that the residuals of each model are normally distributed. This implies that the models are fitted well.

Table 4.7 District wise parameters of the univariate GAM							
District	Response variable	Explaining variables	Degrees of freedom	*p*-value	Adjusted coefficient of determination	Akaike's information criterion	Deviance explained (percent)
Ajmer	DGWL	Precipitation	1.00	0.00***	0.53	–15.47	54.70
		Temperature (Maximum)	3.48	0.02*	0.32	–3.52	41.30
		NIA	5.05	0.00***	0.85	–41.20	88.70
		DGDP	1.00	0.00***	0.68	–19.08	70.30
Barmer	DGWL	Precipitation	1.00	0.00***	0.33	–1.87	36.20
Dausa	DGWL	NIA	1.00	0.03*	0.14	7.60	17.70
		DGDP	1.42	0.00***	0.94	–53.13	94.90
		Population	2.76	0.00***	0.96	–62.66	97.00
Tonk	DGWL	Precipitation	1.44	0.00***	0.44	–0.78	47.00
		NIA	1.00	0.00***	0.51	–4.74	53.70
		DGDP	7.35	0.00***	0.89	–29.04	93.20
Jaipur	DGWL	NIA	4.40	0.00***	0.69	–15.70	74.70
		DGDP	4.38	0.00***	0.93	–61.70	95.10
		Population	4.98	0.00***	0.94	–62.55	95.50
Jodhpur	DGWL	NIA	8.70	0.00***	0.94	–71.74	96.60
		DGDP	7.01	0.00***	0.82	–19.50	88.30

Note: *** $p < .001$; ** $p < .01$; * $p < .05$; degrees of freedom = 1, implies linear relationship; Degrees of freedom > 1 implies non-linear relationship.

Source: Authors' calculation

Table 4.8 District wise parameters of multivariate GAM.

No.	Model formula	Adjusted coefficient of determination	Akaike's information criterion	Deviance explained (percent)	Degrees of freedom	F-statistics	p-value	Variance inflation factor
				Ajmer				
Model 1	Precipitation	0.56	-16.69	59.80	1.00	17.47	0.00***	1.30
	Temperature				1.00	3.03	0.09	1.30
Model 2	Precipitation	0.86	-43.00	87.40	1.00	5.93	0.02*	2.32
	NIA				1.88	15.28	0.00***	2.32
Model 3	Precipitation	0.81	-28.85	83.80	1.00	14.00	0.00***	1.36
	DGDP				1.75	16.31	0.00***	1.36
Model 4	Temperature	0.83	-39.98	85.90	1.00	2.62	0.12	1.34
	NIA				1.96	32.20	0.00***	1.34
Model 5	Temperature	0.78	-26.76	80.90	1.00	10.51	0.00***	1.07
	DGDP				1.00	52.58	0.00***	1.07
Model 6	DGDP	0.94	-48.61	96.00	4.21	17.70	0.00***	2.01
	NIA				1.46	8.75	0.00**	2.01
				Dausa				
Model 1	NIA	0.94	-48.31	95.40	3.88	1.45	0.30	1.02
	DGDP				1.00	232.26	0.00***	1.02

Model 2	NIA	0.95	-55.2	96.00	1.00	3.63	0.07	1.08
	Population				1.00	392.67	0.00^{***}	1.08
Tonk								
Model 1	Precipitation	0.73	-16.89	77.20	2.80	5.60	0.00^{***}	1.98
	NIA				1.00	6.06	0.02^{*}	1.98
Model 2	Precipitation	0.88	-26.99	93.20	1.00	0.14	0.72	1.46
	DGDP				7.37	9.63	0.00^{***}	1.46
Model 3	DGDP	0.96	-47.90	98.30	7.05	19.92	0.00^{***}	4.34
	NIA				2.68	4.19	0.03^{*}	4.34
Jaipur								
Model 1	NIA	0.98	-80.77	99.00	3.24	12.87	0.00^{***}	1.3
	DGDP				4.38	65.95	0.00^{***}	1.3
Model 2	NIA	0.98	-88.11	99.40	4.75	12.58	0.00^{***}	1.41
	Population				4.08	81.82	0.00^{***}	1.41

Note: *** p < .001; ** p < .01; * p < .05; degrees of freedom = 1, implies linear relationship; degrees of freedom > 1 implies non-linear relationship.

Source: Authors' calculation

Table 4.9 Model test of best-fit multivariate GAM.						
Model no.	Variables	Basis checking results				Shapiro–Wilk normality test of GAM residuals
		Number of basis functions (k)	degrees of freedom	k-index	*p*-value	*p*-value
Ajmer						
Model 6	DGDP	9.00	1.46	1.75	1.00	0.47
	NIA	9.00	4.21	1.13	0.61	
Dausa						
Model 2	NIA	9.00	1.00	1.04	0.45	0.32
	Population	9.00	1.00	1.24	0.79	
Tonk						
Model 3	DGDP	9.00	7.05	1.13	0.61	0.28
	NIA	9.00	2.68	1.66	1.00	
Jaipur						
Model 2	NIA	9.00	4.75	1.09	0.56	0.20
	Population	9.00	4.08	1.58	0.99	
Note: *** p < .001; ** p < .01; * p < .05.						
Source: Authors' calculation						

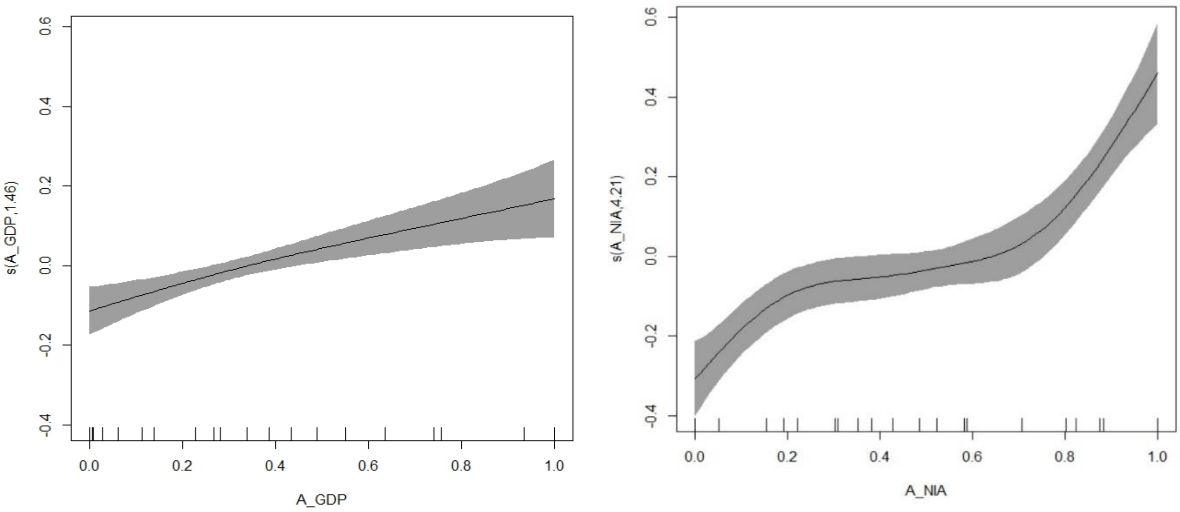
Comparing the district-wise fitting effects of univariate and multivariate GAM techniques, it is evident that, for Ajmer, Tonk, and Jaipur, multivariate GAM provides the best fit. In contrast, for Dausa, univariate GAM offers the best fit. In addition, because the VIF of the variables in Jodhpur was larger than 10, and only one explanatory variable was significantly correlated with DGWL in Barmer, univariate GAM was selected for modelling the relationship between DGWL and climatic and anthropogenic variables.

Figure 4.14 shows the district-wise response curve of the optimal GAM. In the optimal multivariate GAM of Ajmer, the influence of NIA on the DGWL showed a fluctuating upward trend, and the DGWL kept increasing with an increase in DGDP. In Barmer, precipitation's effect on DGWL showed a negative linear trend. In Jaipur, DGWL showed a trend of decreasing and then gradually increasing with an increase in NIA, and it fluctuated up with an increase in population. In the optimal multivariate GAM of Tonk, the influence of DGDP on DGWL also fluctuated. In the district, with an increase in NIA, the DGWL showed a slightly increasing and then gradually decreasing trend. For Dausa, with an increase in population, the DGWL showed a positive upward trend. The DGWL in Jodhpur initially fluctuated with an increase in NIA, and then a gradually decreasing trend emerged (Figure 4.14).

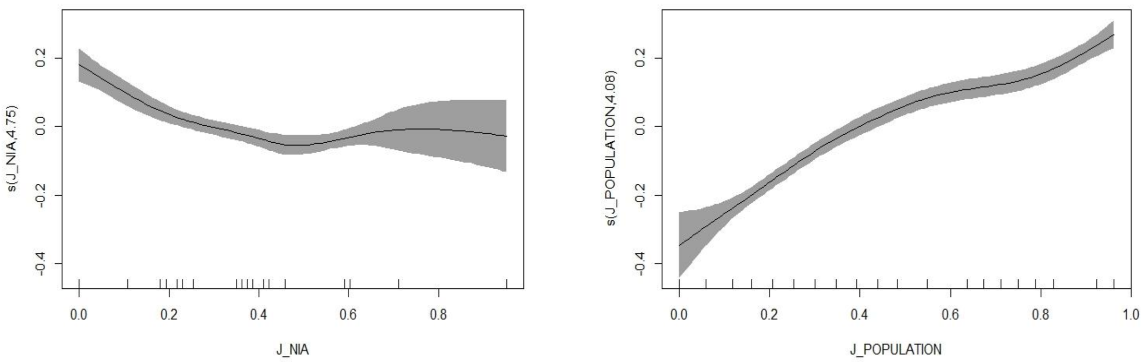
Previous studies have shown that, with population growth, the demand for food, energy, water, space, and so on also increases, putting pressure on the groundwater system (Jia et al., 2019; Odeh et al., 2019). This study identified that the increasing population size is one of the primary drivers of the increasing DGWL in Jaipur and Dausa. Notably, most wells analyzed in these districts exhibited a significant increasing trend in DGWL. Also, NIA was a crucial factor affecting the DGWL in Tonk, Jodhpur, Ajmer, and Jaipur. Interestingly, as shown in Figure 4.14, the response curve for the explanatory variable NIA, particularly for Tonk, is non-linear but exhibits a declining trend, indicating that an increase in NIA in the district leads to an improvement in DGWL. Also, for Jodhpur, an initial fluctuating but increasing trend suggests that an increase in NIA leads to a deterioration in DGWL. In contrast, a subsequent non-linear decreasing trend indicates that an increase in NIA leads to improved DGWL. This is not what was anticipated in Rajasthan, as the state relies heavily on groundwater for irrigation.

Figure 4.13 Optimal GAM response curves: (a) multivariate GAM and (b) univariate GAM.

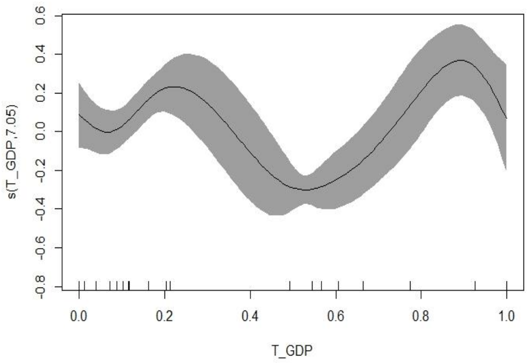
(a) Multivariate GAM
Ajmer: Model6

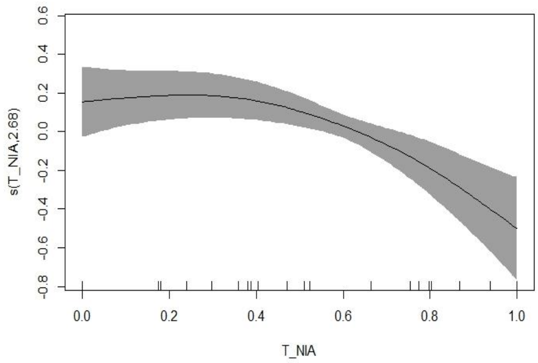


Jaipur: Model2



Tonk: Model3

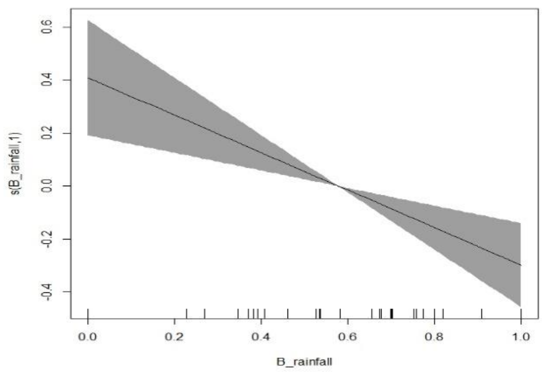


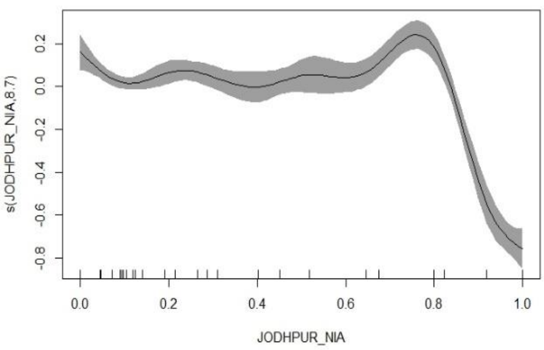


(b) Univariate GAM

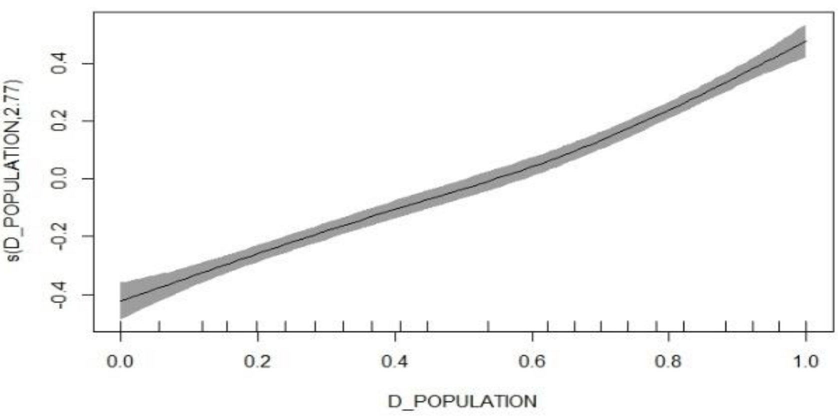
Barmer

Jodhpur





Dausa

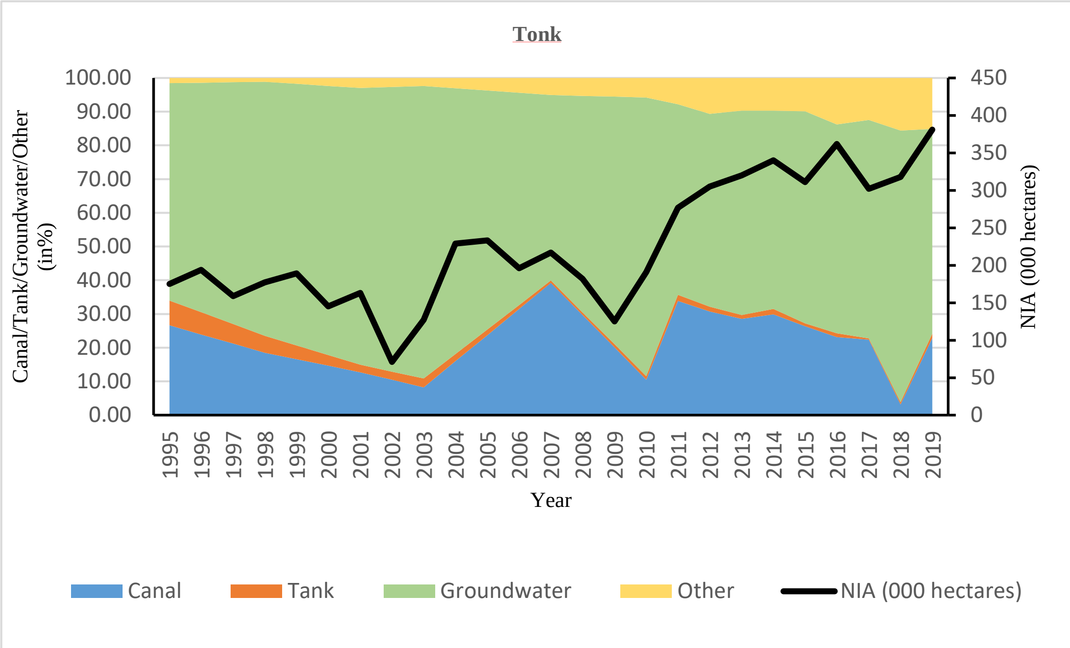


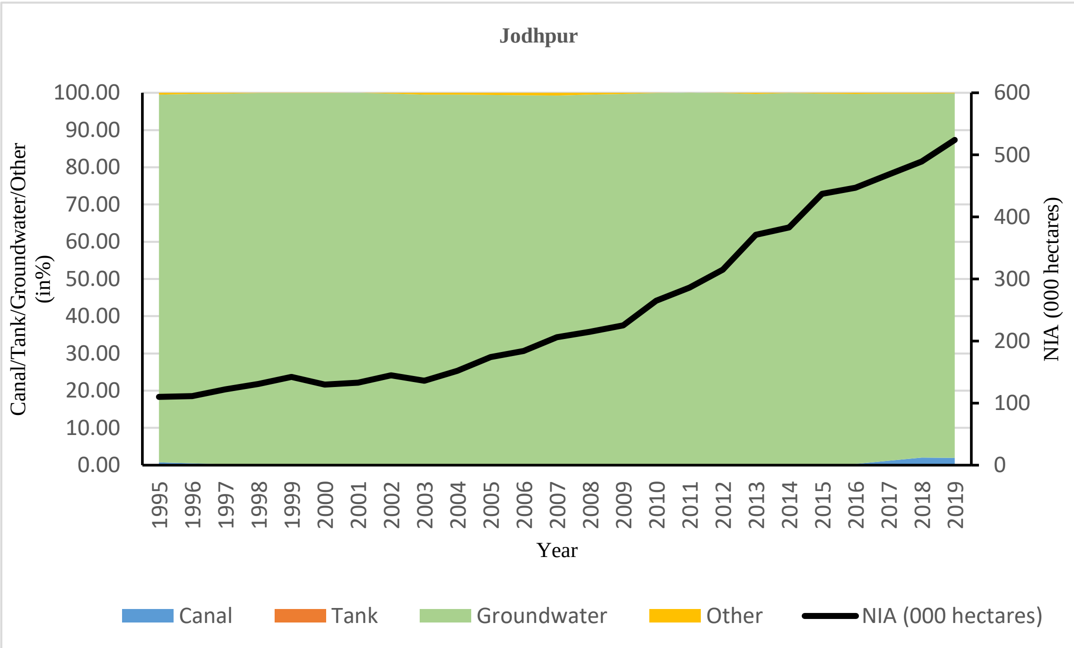
Source: Authors' construction

An examination of the source of NIA in these districts reveals that, in Tonk, if there is a significant increase in NIA, it is primarily due to a rise in surface irrigation and not groundwater irrigation (Figure 4.15). Similarly, in Jodhpur, when groundwater was the primary source of the increase in NIA from 1995 to 2012, NIA and DGWL were positively correlated, albeit not significantly, suggesting that the rise in NIA deteriorated the groundwater level. During 2013–2019, as the percentage of land irrigated by canals increased, a negative correlation between NIA and DGWL was discovered, indicating that an increase in NIA improved groundwater levels. Previous studies have found that, if irrigation is sourced from surface water, it facilitates recharge (Jiménez-Martínez et al., 2009), whereas if it is sourced from groundwater, it results in the depletion of groundwater resources (Leng et al., 2014).

The DGDP of a region quantifies the extent of its socio-economic activity, which is a significant factor affecting groundwater consumption (Gao et al., 2018; Qiu et al., 2018). Our study's findings reveal that, in Tonk and Ajmer, DGDP emerges as a pivotal determinant influencing the DGWL. Specifically, in Tonk, an increase in DGDP corresponds to an improvement in the groundwater level, whereas in Ajmer, a rise in DGDP is associated with its deterioration. Studies have shown that increased DGDP significantly increases domestic and industrial water use (Ouyang et al., 2011). Jia et al. (2019) have demonstrated that groundwater sustainability is negatively related to DGDP, implying that economic development hampers groundwater resources. On the contrary, studies have also shown that the cost to natural resources is lower if development is centred on innovation and technology rather than production (Oki and Kanae, 2006; Jia et al., 2019).

Figure 4.14 Net irrigated area, by source in Tonk and Jodhpur





Source: Authors' construction

Further, precipitation as a climatic variable was found to be the primary factor affecting the DGWL in Barmer. Previous studies have demonstrated that precipitation variability is one of the primary determinants of groundwater level fluctuations (Liu et al., 2021; Gautam et al., 2022). That is, a decline in precipitation reduces water availability, accelerating groundwater extraction (Narjary et al., 2014). Also, being dependent on surface and sub-surface water infiltration, groundwater recharge is highly reliant on precipitation (Kambale et al., 2017; Ouhamdouch et al., 2019; Andaryani et al., 2021; Panahi et al., 2022), especially in Rajasthan where precipitation is the major source of recharge (CGWB, 2020b). In addition to precipitation, previous studies also identified temperature as a crucial meteorological component influencing groundwater level (Yadav et al., 2020). However, in the present work, in the final selected optimal GAM models of districts, temperature was not found to be a significant variable.

The present study's findings are consistent with that of similar research conducted in Rajasthan. For instance, Singh and Kumar (2015) observed that the escalating demand for irrigation, predominantly reliant on groundwater, is a primary driver of inefficient and wasteful groundwater utilization. Similarly, Saikia and Chetry (2020) found that population growth significantly contributes to groundwater level deterioration. Phulpagar and Kale (2021) noted that most of the blocks in Jaipur are witnessing a decrease in the groundwater level, which is mainly attributed to the overexploitation of groundwater (i.e., it is anthropogenically induced).

4.6.5 Univariate and Multivariate GAM Construction for water quality

Univariate GAM was constructed to explore the contribution and correlation between water quality parameters and climatic and anthropogenic variables (see Appendix table 4.12). The results reveal that in Barmer, for PC1, PC2, PC3, and PC4, the GAM model with the population as an explanatory variable was the best univariate model. For Jodhpur, for PC1, PC2, and PC3 as response variable NIA, fertilizer usage and NIA was the best univariate model, respectively. Similarly, in Tonk for PC1, PC2, and PC3 GAM model with NIA, population and fertilizer usage has the lowest AIC (and hence was the best fit), respectively. For Dausa, PC1, PC2, PC3, and PC5 as response variables, GAM with population, industrialization, population, and rainfall as explanatory variables was the best fit.

For Ajmer, the constructed univariate GAM with PC1 and PC3 as the response variable was non-linearly correlated with industrialization (edf>1). For Jaipur, the univariate GAM with industrialization as an explanatory variable had an edf > 1 when PC2 and PC3 are the response variable and efd=1 when PC4 is the response variable. For PC1 in Jaipur, the GAM model with the population as an explanatory variable was linearly correlated. GAM model with PC5 as response variable had edf=1 with NIA and population. For PC5, GAM with the population as an explanatory variable was the best fit.

The multivariate GAM results are shown in the Appendix table 4.13. For response variables with more than one multivariate GAM, the best fit was determined based on AIC and R-sq. (adj) values. Accordingly, in Barmer for PC3 and PC4, Model1 was the best fit. In Jodhpur, for PC2 Model5, and in Tonk for PC1 and PC3, Model2 and Model1, respectively, were the best fit. Likewise, in Dausa, Model2 for PC3 and Model3 for PC5 were the best fit (see figure 4.16). Model fit results of the best fit/ optimal multivariate GAM models, as shown in the Appendix table 4.14 and figure 4.5. The results show that the fitting of each optimal GAM model is satisfactory.

4.6.5.1 Correlation of groundwater quality with anthropogenic and climatic variables

Population and Industrialization

Rajasthan generates the most waste, producing between 3,842 and 7,662 tonnes of municipal solid waste daily (Kumar et al., 2017). As per the statistics during 2018-2019, Rajasthan generated 24.18 lakh tonnes of municipal solid waste and 5.62 lakh metric tonnes of hazardous waste (MOSPI, 2019). Further, according to Jain (2014), during 2001-2010, the amount of solid waste generated in Jaipur (state capital) increased by approximately 16 percent. Despite Jaipur being the state's capital, there is a lack of proper waste storage and collection facilities, and often open dumping is followed (Jain, 2014). Studies have shown that deterioration in the water quality, particularly an increase in the concentration of NO_3^- is significantly and positively linked to wastewater and solid waste disposal (Silva et al., 2017; Gao et al., 2020; Wakejo et al., 2022), which is substantially associated with population and industrialization (Zhang et al., 2019; Qian et al., 2020). As evident from Table 4.10 and Figure 4.16, in the best fit GAM, population increase was found to be an important factor for the rise in pollution of Ca^{2+} and TH in Barmer, Ca^{2+}, Cl^-, NO_3^-, Mg^{2+}, Na^+, and SO_4^{2-} in Tonk, Ca^{2+} and F^- in Dausa and EC, SO_4^{2-}, Cl^- and Na^+ in Jaipur. Similarly, in the best-fit GAMs of Ajmer, Jaipur, and Dausa, industrialization was identified as a significant causal factor. An increase in industrialization was found to increase the concentration of Cl^-, EC, Mg^{2+}, Na^+, SO_4^{2-}, F^- in Ajmer, TA, HCO_3^-, TH, Ca^{2+}, NO_3^- and F^- in Jaipur, and Cl^-, TH, Mg^{2+}, TA, and HCO_3^{2-} in Dausa. Hence, the result of the present study is consistent with the previous literature, except in the case of Barmer and Dausa, whereby a contradictory result is found. NO_3^- concentration reduction is only achievable if preventive measures are taken (Wakejo et al., 2022). In the district of Dausa and Barmer, the decrease in NO_3^- with population growth may be attributable, in part, to the improvement of sanitary parameters (see Appendix figure 4.6).

Fertilizer and NIA

Given that Rajasthan is predominantly an agrarian state, the intensive cultivation of crops, particularly within the irrigated regions of western Rajasthan, presents an ecological concern owing to the excessive application of chemical fertilizers (Bhati et al., 2017). As evident from Figure 4.13, the usage of fertilizer in Tonk and Jodhpur has witnessed an increase from 2000 to 2018, and it was found to be strongly correlated with Mg^{2+}, Na^+, and SO_4^{2-} in Tonk and NO_3^- and Fe in Jodhpur. Studies have shown that due to the extensive use of chemical fertilizers in agriculture, nitrate, and sulphate concentrations have increased significantly (Ju and Zhang, 2017; Wang et al., 2019; Singh and Craswell, 2021). Chemical fertilizer has also been recognized as a source of Na^+ and Fe concentrations in groundwater (Zhai et al., 2021).

Ammonium (NH_4^+) produced by nitrogen fertilizers potentially leads to the release of iron (Fe) in water (Zhai et al., 2021). The results also reveal that an increase in NIA increases the concentration of TA and HCO_3^- in Tonk and Barmer and decreases the concentration of Ca^{2+}, Cl^-, Na^+, K^+, EC, F^-, and pH values in Jodhpur. Irrigation via influencing fertilizers' leaching affects groundwater's ion concentration (Lwimbo et al., 2019). In the case of highly mineralized irrigation water, the IRF will lead to a rise in the ion concentration of groundwater (Foster et al., 2018), resulting in a deterioration of groundwater quality. However, if irrigation water contains a low concentration of solutes, an increase in irrigation will dilute the ion concentration (Rotiroti et al., 2019; Bouimouass et al., 2022).

Climatic Parameters

CGWB (2020) states that approximately 74 percent of the total annual groundwater recharge is sourced from precipitation, making it the major source of groundwater recharge in Rajasthan. Consequently, the precipitation patterns substantially influence the hydrogeochemical and hydrodynamic processes of the state. Although all the quality parameters of the groundwater are influenced by precipitation, in the current study, precipitation was found to significantly and negatively affect the concentration of TA and HCO_3^- in Tonk and K^+ in Dausa. One possible explanation for this is the subsurface infiltration of rainwater, which results in the dissolving and dilution of ions in groundwater (Aher and Deshmukh, 2019; Nemčić-Jurec et al., 2022; He et al., 2022). In Dausa, the concentration of K^+ was also significantly influenced by temperature.

Table 4.10 Effect of climatic and anthropogenic variables on water quality parameters (based on optimal GAM) and mapping the direct and indirect effect on Sustainable Development Goals (SDGs)

District	Principal Components	Parameters	GAM Result			Problematic quality parameters	Health Impact And Impact on Agriculture	Mapping SDGs (UNESCO (2022))
			Best Fit GAM	Significant Explanatory variable	Relation to quality parameter			
Arid Districts								
Barmer	PC1	NO_3^- , Cl^- and Na^+	UV	Population	Negative	Cl-, Na+, NO3-, EC	Methemoglobinemia, Bone and Skeletal damage and Discoloration of Teeth Physiological drought that adversely impact the plant health	**SDG 1**= No Poverty; **SDG 3=** Good health and Wellbeing, **SDG 6**= Clean Water and Sanitation, **SDG 13** = Climate Action
	PC2	SO_4^{2-} , Mg^{2+}, EC, and K^+			Negative			
	PC3	Ca^{2+} and TH			Positive			
	PC4	TA and HCO_3^-	MV	NIA	Positive			
Jodhpur	PC1	Ca^{2+}, Cl^-, Na^+, K^+, and EC	UV	NIA	Negative	Na+, NO3-, Cl-, F- and EC	Heart Disease, Methemoglobinemia, High Blood Pressure, Bone and Skeletal damage, and	
	PC2	NO_3^- and Fe	UV	Fertilizer usage	Positive			

	PC3	F^- and pH	UV	NIA	Negative		Discoloration of Teeth Physiological drought that adversely impact the plant health	
Semi-Arid Districts								
Dausa	PC1	NO_3^- , SO_4^{2-} and Na^+	UV	Population	Negative	F-, Cl-, Na+, SO42-, NO3-	High Blood Pressure, Bone and Skeletal damage, Discoloration of Teeth, Heart Disease, and, Methemoglobinemia	
	PC2	Cl-, TH, and Mg^{2+}	UV	Industrialization	Positive			
	PC3	Ca^{2+} and F^-	MV	Population	Positive			
	PC4	TA and HCO_3^{2-}	UV	Industrialization	Positive			
	PC5	K+	MV	Temperature	Negative			
				Precipitation	Negative			
Tonk	PC1	TA, TH and HCO_3^-	MV	NIA	Positive	TA, TH. Mg2+, HCO3-, Cl-, F-, Na+ and SO42-	Laxative effects, High Blood Pressure, Taste, Bone and Skeletal damage, Discoloration of Teeth and Heart Disease	
				Rainfall	Negative			
	PC2	Ca^{2+}, Cl^-, and NO_3^-,	UV	Population	Positive			
	PC3	Mg^{2+} , Na^+, and SO_4^{2-}	MV	Population	Positive			
				Fertilizer usage	Positive			

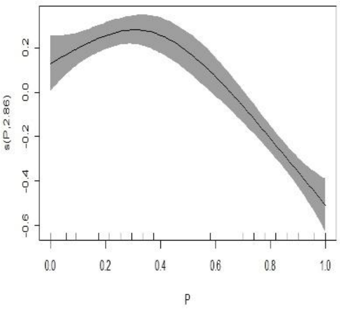
Jaipur	PC1	EC, SO_4^{2-}, Cl^-, K+ and Na^+	UV	Population	Positive	EC, Ca2+, K+, Cl-, SO42-, F- and Na+	Kidney and bladder problems, Laxative effects, Heart Disease, High Blood Pressure, Bone and Skeletal damage, Discoloration of Teeth Physiological drought that adversely impact the plant health	
	PC2	TA and HCO_3^-	UV	Industrialization	Positive			
	PC3	TH and Ca2+	UV	Industrialization	Positive			
	PC4	NO32- and F-	UV	Industrialization	Positive			
	PC5	Fe	MV	Population	Negative			
Ajmer	PC1	Cl^-, EC, Mg^{2+}, Na^+, and SO_4^{2-}	UV	Industrialization	Positive	Cl-, F- and Na+	Heart Disease, High Blood Pressure, Bone and Skeletal damage, and Discoloration of Teeth	
	PC3	F^-	UV	Industrialization	Positive			
Note: UV= Univariate; MV= Multivariate								
Source: Authors' construction								

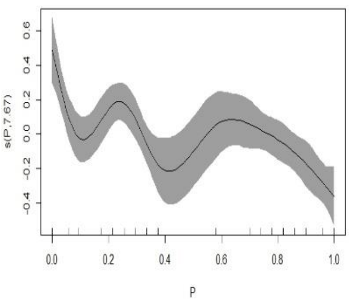
Figure 4.15 Optimal GAM response curves

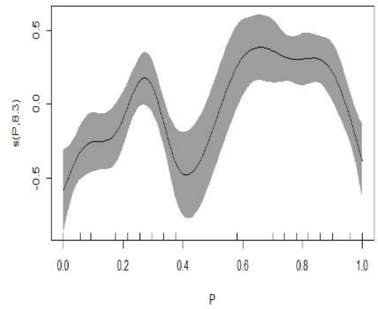
Barmer: PC1-Population

Barmer: PC2-Population

Barmer: PC3-Population

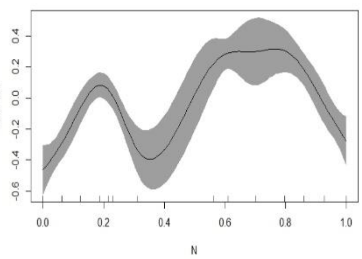


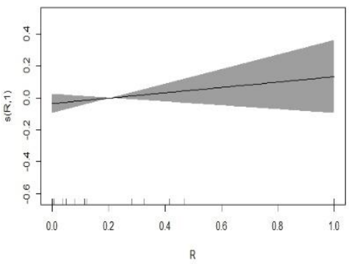


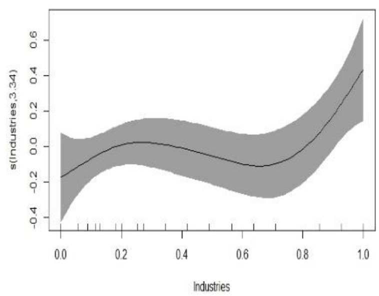


Barmer: PC4-Model1

Ajmer: PC1-Industrialization



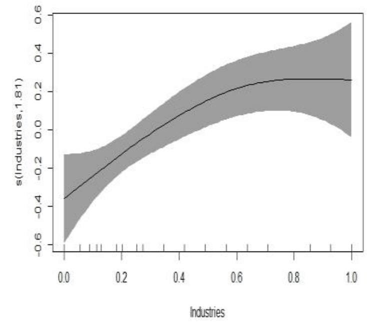


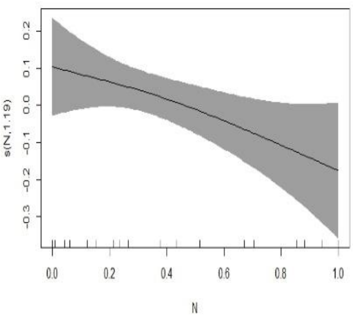


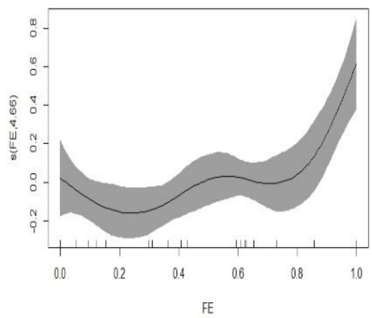
Ajmer: PC3-Industrialization

Jodhpur: PC1-NIA

Jodhpur: PC2-Fertilizer usage

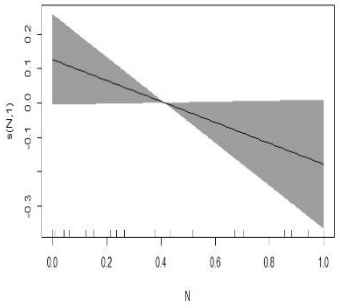


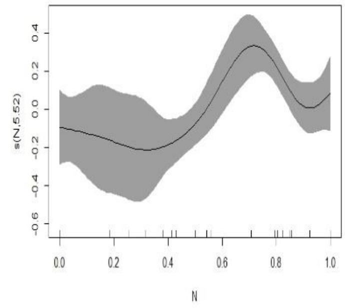


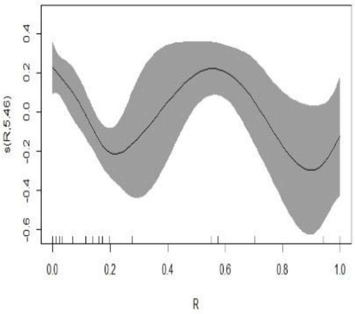


Jodhpur: PC3-NIA

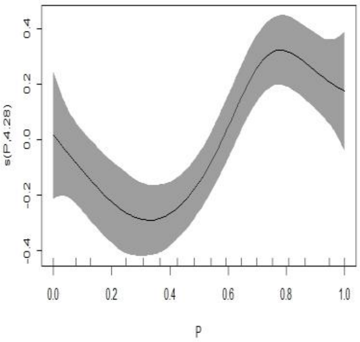
Tonk-PC1-Model2

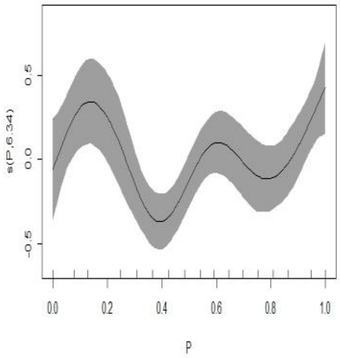


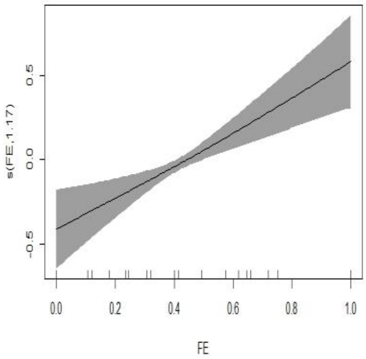




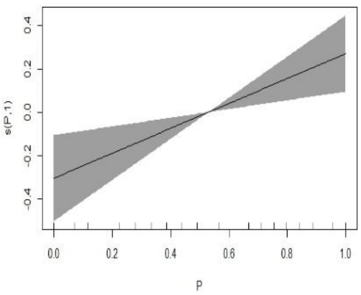
Tonk-PC2-Population Tonk-PC3-Model1

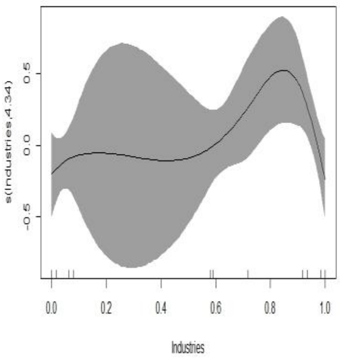


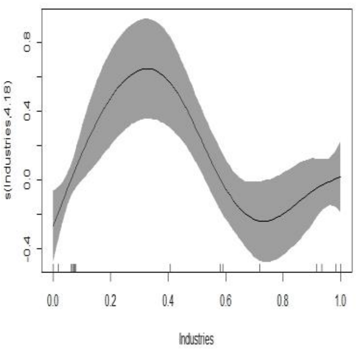




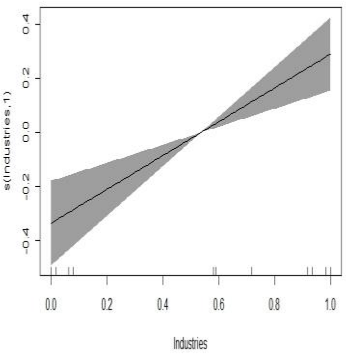
Jaipur-PC1-Population Jaipur-PC2-Industrilization Jaipur-PC3-Industrilization

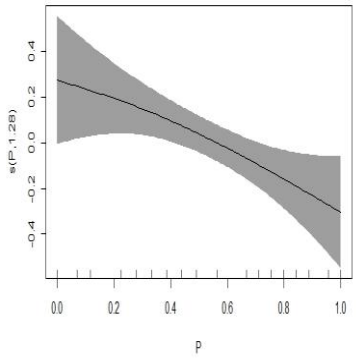


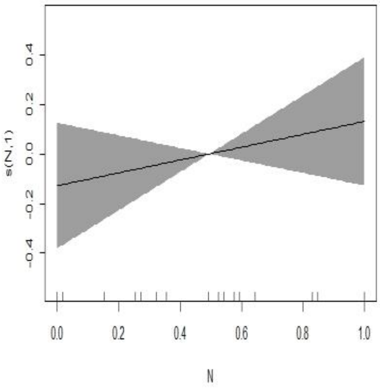




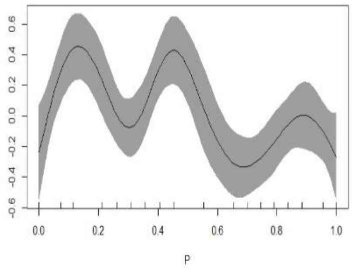
Jaipur-PC4-Industrilization Jaipur-PC5-Model1

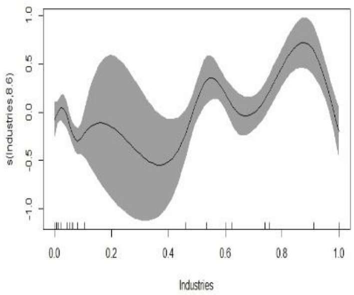


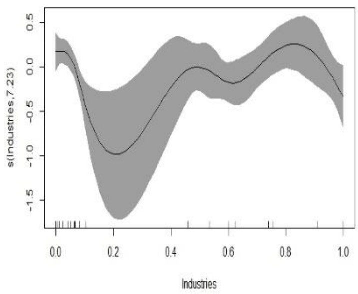




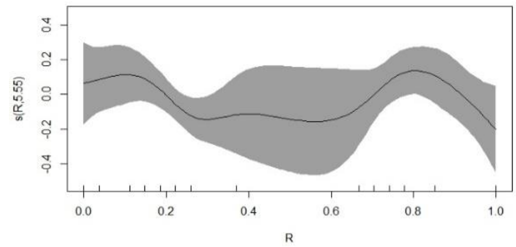
Dausa-PC1-Population Dausa-PC2-Industrilization Dausa-PC4-Industrilization

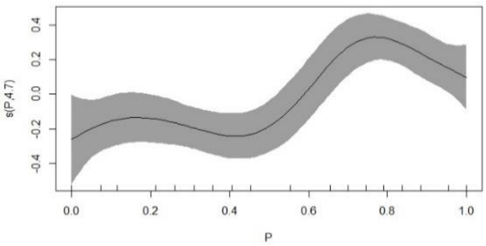




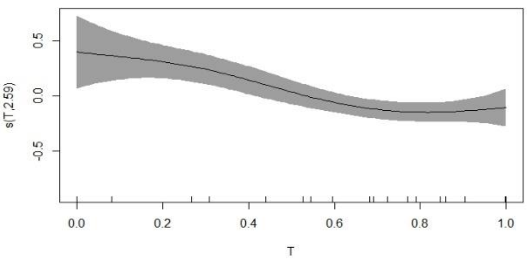


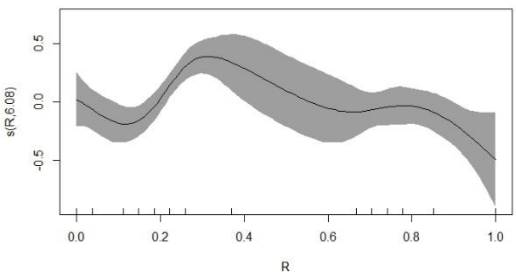
Dausa-PC3-Model2





Dausa-PC5-Model3





Source: Authors' construction

4.7 Conclusion

The study evaluates the groundwater level trend and investigates the effect of climatic and anthropogenic variables on groundwater levels in arid and semi-arid districts of Rajasthan using annual data from 1994 to 2020. Furthermore, the groundwater quality for 15 water quality parameters from 84 stations in arid and semi-arid districts of Rajasthan was also examined using annual data from 2000 to 2018.

The empirical results reveal an increasing (deterioration) trend in groundwater level in all the seasons (pre-monsoon, monsoon, and post-monsoon) in most wells/piezometers in the districts of Dausa and Jaipur. Additionally, most stations witnessed an increasing trend in calcium, magnesium, sodium, chloride, bicarbonate and sulphate and a decreasing trend in potassium, fluoride and nitrate. The SAR, EC, and USSL indicate that the groundwater in the region is suitable for irrigation if salinity control measures are implemented. Chloride, fluoride, and sodium concentrations exceeded the prescribed guideline limits in most stations, jeopardizing the suitability of water for drinking and posing significant health hazards. GAM analysis revealed that compared to the climatic variables, the groundwater level and quality are significantly influenced by anthropogenic variables.

Chapter 5

GENDERED PERCEPTIONS, ADAPTATION, AND VULNERABILITY TO WATER SCARCITY IN RURAL HOUSEHOLDS: A STUDY OF ARID AND SEMI-ARID DISTRICTS IN RAJASTHAN

In the previous chapter, the comprehensive investigation of groundwater resources within the selected arid and semi-arid districts in Rajasthan unveiled that the groundwater level in these districts exhibits both increasing and decreasing trends. Notably, most of the wells/piezometers in Dausa and Jaipur exhibited a significant increasing trend, signifying a deterioration in the groundwater situation. Also, an examination of groundwater quality parameters revealed that concentrations of Cl^-, F^-, and Na^+ exceed the acceptable limit in most of the wells/piezometers, raising serious concern about the suitability of groundwater for consumption. Moreover, it was found that in the selected districts, compared to the climatic variables, various anthropogenic variables significantly influence the groundwater quantity and quality parameters.

Recognizing access to safe and sufficient water as a key for both the economic and physical well-being of households, this chapter undertakes a comprehensive analysis of the perceptions of households surrounding water issues within the selected arid and semi-arid districts. Given the significance of perception in shaping vulnerability and adaptive responses of households, an in-depth analysis of household vulnerability to water stress, as well as an exploration of the adaptive measures employed to manage and alleviate such stress, is also made. Additionally, the chapter also talks about the main determinants influencing the adoption of these adaptive strategies, as well as the barriers impeding their implementation. Understanding how people cope with water-related challenges is important. By knowing the different ways individuals and households adapt in areas with limited water, we can create better strategies to help them. This means designing interventions that fit the specific needs of each community.

This chapter is divided into seven sections. The first section talks about the rationale for the study. The second section provides an overview of the study area. The third section talks about the data sources. The fourth section illuminates the sampling strategy. The fifth section discusses the methodology employed in the study. The sixth section presents the results. Finally, the seventh section provides the conclusion of the study.

5.1 Rationale for the Study

As outlined by Inkani et al. (2020), to achieve sustainable development, it is important to understand and incorporate the perspectives of households into developmental initiatives. Also, as water scarcity profoundly impacts people's lives, it's crucial to understand how vulnerable households are to this issue and how they adapt. This understanding helps pinpoint the challenges that need addressing to ensure that coping and adaptation strategies support sustainable development goals effectively.

Additionally, being at the bottom of social and economic hierarchies' women are often the poorest of the poor. The disadvantage of women is highlighted by the fact that female-headed households account for one in every six multidimensionally poor people (207 million) across 108 countries (Alkire et al., 2021). Hence, this disproportionate representation of women amongst the extremely poor is a worldwide phenomenon (UN Women,2000). Diana Pearce, an American sociologist, coined the term "feminization of poverty" in the late 1970s to describe this persistent pattern of economic inequality.

Being an intricate part of the social, economic, and cultural systems, water-related domains often mirror and even reinforce these existing inequalities (Ngarava et al., 2019). The most common of these inequalities is the gender-based work division, which has resulted in women being the primary water providers. These roles of women are frequently "naturalized" and unpaid, but they mean that women face water scarcity and contamination on a daily basis (Cole, 2017). The frequent exposure to contaminated water, as well as the great distances traveled to fetch water and heavy lifting, increase women's health vulnerabilities and make them more prone to water scarcity (Sorenson et al., 2011; Ngarava et al., 2019). However, only a few studies have analyzed the association between gender and water scarcity (Crow and Sultana, 2010; Tsai et al., 2016).

With the onset of the COVID-19 crisis, it is expected that the poverty rate for women will rise significantly, widening the already existing poverty gap between men and women. Projections show that 47 million of the 96 million people pushed into extreme poverty as a result of the pandemic will be women and girls (UNDP,2020). Women's poverty is expected to increase by 9.1 percent as a result of the pandemic and its aftermath (UN Women,2020). In fact, according to recent data from India, 53 million females are poor as of 2021, compared to 45 million males (Statista, 2021). Given the extreme importance of water for poverty alleviation and its gendered impact, it is critical to examine the gender disparities in perception, vulnerability, and adaptation to water scarcity.

5.2 Study area

This study was undertaken within the six districts of Rajasthan, encompassing both arid (Barmer, Jodhpur) and semi-arid (Jaipur, Dausa, Tonk, and Ajmer) regions.

Situated in the western region of Rajasthan, Barmer ranks as the third largest district in the state. As per the 2011 census, the district is divided into eight sub-districts/tehsil and has 2,460 villages. Among these villages, 2,452 are inhabited, and eight are uninhabited. The population of the district, as recorded in the 2011 census, amounted to 2,603,751 individuals, with 1,369,022 being male and 1,234,729 females. Within the district, the rural population was

2,421,914, with 1,273,249 males and 1,148,665 females. The urban population was 181,837, with 95,773 males and 86,064 females. Notably, the literacy rate within Barmer was 56.53 percent, with a marked discrepancy between genders—70.86 percent for males and 40.63 percent for females. The primary economic activity of the district is agriculture.

Renowned for its tourist attractions, Jodhpur ranks second in terms of population within Rajasthan. For administrative purposes, the district has been divided into seven sub-districts/tehsil. As per the 2011 census, the district is comprised of 1,838 villages, with 1,836 villages inhabited and two villages uninhabited. The 2011 census reported the district's population at 3,687,165, comprising 1,923,928 males and 1,763,237 females. The rural population numbered 2,422,551, with 1,260,328 males and 1,162,223 females, while the urban population totaled 1,264,614, consisting of 663,600 males and 601,014 females. The literacy rate in Jodhpur stood at 65.94 percent, with a gender disparity reflected in male and female literacy rates of 78.95 percent and 51.83 percent, respectively. Approximately 56 percent of the workforce is engaged in agriculture, underscoring the district's agricultural dependence.

Jaipur, the capital of Rajasthan and the most populous district in the state, also ranks first in terms of population density. As per the 2011 census, the district is divided into 13 tehsils and comprises 2,180 villages, with 2,126 inhabited and 54 uninhabited. The district's population in the 2011 census totaled 6,626,178 individuals, with 3,468,507 males and 3,157,671 females. The rural population accounted for 3,154,331 individuals, with 1,642,924 males and 1,511,407 females, while the urban population constituted 3,471,847 individuals, consisting of 1,825,583 males and 1,646,264 females. The literacy rate in Jaipur district stood at 75.51 percent, with males exhibiting a higher rate of 86.05 percent compared to females at 64.02 percent.

Ajmer, situated in the central region of Rajasthan, ranks eighth in population and eleventh in population density. The 2011 census divided the district into nine tehsils and 1,111 villages, of which 1,099 are inhabited and 12 are uninhabited. Prone to regular droughts, the district population, as per the 2011 census, totaled 2,583,052, with 1,324,085 males and 1,258,967 females. The rural population totaled 1,547,642, with 789,397 males and 758,245 females. While the urban population was 1,035,410, with 534,688 males and 500,722 females. The district literacy rate was 69.33 percent, with males exhibiting a higher rate of 82.44 percent compared to females at 55.68 percent.

Dausa, mainly reliant on agriculture, ranks third in population density. The 2011 census divides the districts into five tehsils. Further, the district comprises 1,109 villages, of which 1,079 are inhabited and 30 are uninhabited. According to the 2011 census, the district's population totaled 1,634,409, with 857,787 males and 776,622 females. The rural population accounted for 1,432,616, including 751,900 males and 680,716 females, while the urban population totaled 201,793, with 105,887 males and 95,906 females. The district's literacy rate stood at 68.16 percent, with a notable disparity observed between genders—82.98 percent for males and 51.93 percent for females.

Tonk is identified as one of the most underdeveloped districts and is designated for development under the Backward Regions Grant Fund. Similar to other districts in Rajasthan, agriculture constitutes the primary economic activity, with approximately 67.7 percent of the workforce engaged in agricultural activities. As per the 2011 census, the district population totaled 1,421,326, with 728,136 males and 693,190 females. The rural population totaled 1,103,603, with 568,045 males and 535,558 females. While the urban population was 317,723 of which 160,091 were males and 157,632 females. The literacy rate in Tonk district stands at 61.58 percent, with male literacy at 72.12 percent and female literacy at 45.45 percent. For administrative purposes, the 2011 census divides the district into seven tehsils and 1,183 villages, of which 1,116 are inhabited and 67 are uninhabited.

5.3 Data source

Both primary and secondary data were used for the study. The IMD gridded dataset was utilized to collect the data for the climatic variables. Precipitation data were obtained at a resolution of 0.25° × 0.25°, while temperature data were collected at a resolution of 1° × 1°. Moreover, data regarding the socio-economic status of households, their perceptions regarding water stress, as well as the adaptation strategies being implemented and the barriers hindering effective adaptation, was collected with the help of primary data. Using a structured interview schedule, a household survey was carried out to get the quantitative primary data. Based on a comprehensive literature review (CDC, 2008; Lamberts, 2012; M'Nyiri, 2014; Mwinzi, 2014; Tucker et al., 2014; Tabane, 2015; Rathnayaka et al., 2015; Zolnikov and Blodgett-Salafia, 2016; Adams, 2017; NABARD, 2017; Eichelberger, 2018; Meunier et al., 2019; Young et al., 2019; Ngarava et al., 2019; Tomaz et al., 2020) and questionnaire of the NSS on Drinking Water, Sanitation, Hygiene and Housing Condition survey (2012 and 2018), the interview schedule/questionnaire was constructed. The questionnaire was designed to comprehensively capture diverse socio-demographic, economic, and water-related facets of households.

5.4 Sampling strategy

The survey was conducted during two phases; in the first phase, in February 2021, a pilot survey was conducted in Jaipur in the Dudu tehsil to check the questionnaire. Following the pilot survey, essential adjustments were implemented in the questionnaire based on the feedback received. Subsequently, a finalized version of the questionnaire (refer to Appendix 5.1) was prepared. The final data collection was conducted between March 2021 and May 2021, utilizing face-to-face household surveys.

The sample size in each of the selected districts was determined using the Slovin formula (see Equation 5.1) (Cobbinah and Anane, 2016; Wulandari and Kurniasih, 2019)

$$n = \frac{N}{1 + N(\alpha)^2} \qquad \text{... (5.1)}$$

Here, n is the sample size, N represents the total number of households, and α is the margin of error. The total number of households within each district i.e., N, was determined from the Census 2011 data. Recognizing the greater prevalence of water poverty in rural areas compared to urban areas, as highlighted in Chapter 2, our study specifically targets the rural areas of each district. As per Census 2011, the total number of households in rural areas of Ajmer, Dausa, Jaipur, Jodhpur, Barmer, and Tonk were 293,744; 256,694; 507,803; 414,223; 418,990 and 212,126, respectively. Additionally, following Bestiantono et al. (2019) and Tran et al. (2022), the error margin was chosen as 0.1. Based on Equation 5.1, the sample size within each of the districts using the Slovin formula is given in Table 5.1. Approximately, the sample size within each district came out to be 100, giving us a total sample size of 600 in the six selected districts.

Table 5.1 Sample size determination

Districts	Number of Rural Households	Margin of Error (α)	Sample size
Ajmer	293744	0.1	99.97
Dausa	256694	0.1	99.96
Jaipur	507803	0.1	99.98
Jodhpur	414223	0.1	99.98
Barmer	418990	0.1	99.98
Tonk	212126	0.1	99.95

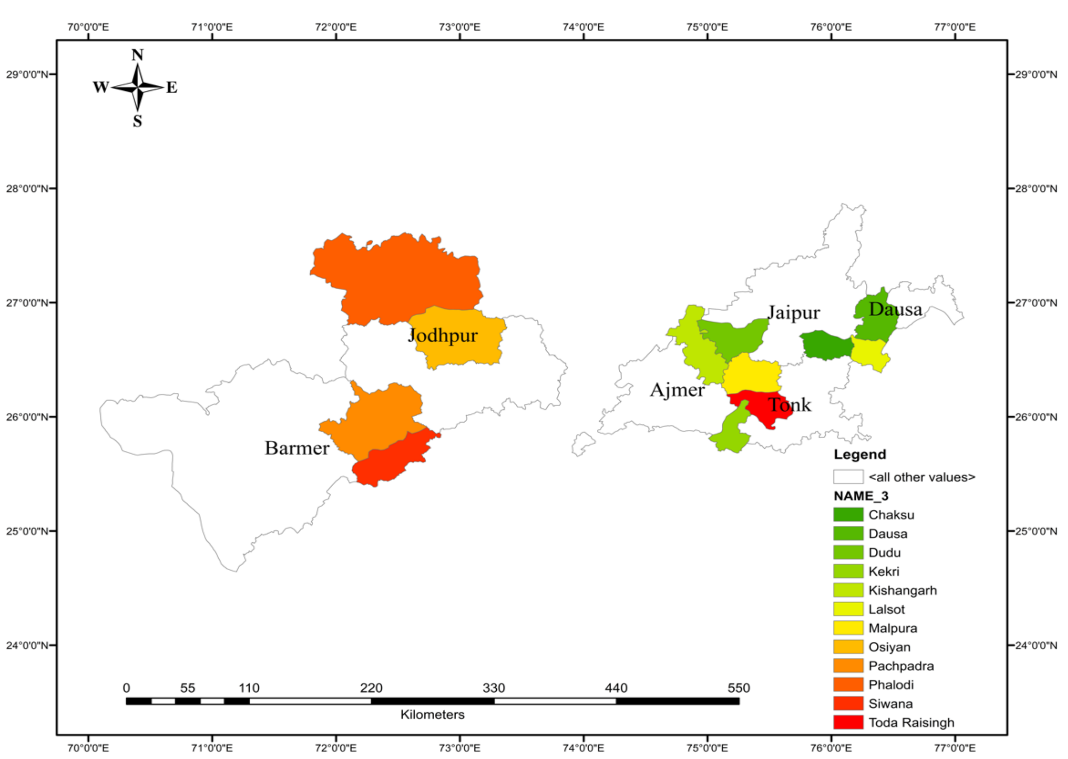
Source: Authors' construction

In order to collect the data on the 600 households from each of the districts, two tehsils were selected, and from each of the tehsils, five villages were selected. Then, from each of the villages, ten households were selected for the interview using the purposive random sampling technique. Previous studies have also employed the purposive sampling technique to extract the relevant household-level data (Singh et al., 2017; Chinwendu et al., 2017; Schlamovitz and Becker, 2021).

Figure 5.1. shows the location of the selected tehsils within each of the districts. In Barmer district, the two selected tehsils were Pachpadra and Siwana. From Pachpadra, the surveyed villages included Bithooja, Asotara, Sarana, Parloo, and Kitnod, while from Siwana, the selected villages were Padardi Kalan, Devandi, Arjiyana, Thanmata Hinglaj, and Kharantiya. In Jodhpur district, the two selected tehsils were Phalodi and Osian. From Phalodi Tehsil, the surveyed villages comprised Kheechan, Lohawat, Mokheri, Naneu, and Jagariya, whereas, from Osian Tehsil, the selected villages were Saraswati Nagar, Samrau, Mathaniya, Shivnagar, and Vishnu Nagar.

Jaipur district was represented by Dudu and Chaksu tehsils. From Dudu Tehsil, villages such as Morla, Ganeshpura, Chandpura, Gurha Kumawatan, and Kanwarpura were surveyed, while from Chaksu Tehsil, the selected villages included Mahachandpura, Bapugaon, Dragpalpura, Kanwarpura, and Kot Khawada. Ajmer district encompassed Kishangarh and Kekri tehsils. From Kishangarh, the surveyed villages comprised Kakalwara, Sandoliya, Seel, Balapura, and Goli, while from Kekri, the selected villages included Amali, Ambapura, Pratappura, Jooniya, and Kohra. In Dausa district, Lalsot and Dausa tehsils were sampled. From Lalsot Tehsil, the surveyed villages included Hodayali, Goodariya, Sanwasa, Daulatpura, and Samel, while from Dausa Tehsil, villages such as Lawan, Khanpura, Dugrawata, Singwara, and Jhoopariya were surveyed. Finally, in the Tonk district, Malpura and Todaraisingh tehsils were included in the study. From Malpura Tehsil, villages such as Peepliya, Kishanpura, Gopalpura, Chosla, and Bhagwanpura were selected, while from Todaraisingh Tehsil, the surveyed villages comprised Mor, Panwaliya, Bagri, Bassi, and Kankalwar.

Figure 5.1 Location of the selected tehsils



Source: Authors' construction

In the study, the primary respondent during data collection was the head of the household, both male and female. In instances where the head of the household was unavailable at the time of the interview, another adult[5] member possessing decision-making authority within the household was selected as the respondent.

5.5 Methodology

5.5.1 Data processing and analysis

A numerical coding system was generated to represent the various responses obtained from the questionnaire. This facilitated the data entry process, as instead of transcribing the entire response, we could input the corresponding numerical code. The coding process was conducted by a single individual to ensure consistency and accuracy across the dataset.

[5] A person who has completed eighteenth years of age.

Following the coding, district-wise compilation of the coded data was performed using Microsoft Excel. Subsequently, a unified data frame encompassing all districts was generated. The compiled data underwent thorough scrutiny to detect outliers and identify missing responses. Upon completion of the cleaning process, the final compiled data file was generated.

Basic descriptive analysis, including frequency tabulation, was conducted using statistical software such as SPSS and Stata. Moreover, gender differences within male and female-headed households were examined and interpreted through descriptive statistics, particularly percentages, concerning variables related to perceptions of water issues, adaptation strategies, and barriers to adaptation.

5.5.2 Vulnerability assessment

In this study, vulnerability is defined as a function of exposure (E), sensitivity (S), and adaptive capacity (AC) (IPCC, 2007). Following Patnaik et al. (2010), Ravindranath et al. (2011), and Swami and Parthasarathy (2021), the study used an indicator-based approach to assess district-wise vulnerability. The indicators for each exposure, sensitivity, and adaptive capacity were selected based on two criteria: 1) data availability and 2) literature review (see Table 5.2).

The vulnerability index encompasses 19 indicators, of which five were related to exposure, four were related to sensitivity, and ten were related to adaptive capacity (see Table 5.2). Further, to maintain consistency, the indicators were normalized (see Equation 5.2 and 5.3) using the standard min-max formula to get a uniform scale of 0 to 1.

Positive indicator

$$\mathrm{X}^{\mathrm{normalized}} = \left(\frac{\mathrm{X}^{\mathrm{i}} - \mathrm{X}^{\mathrm{minimum}}}{\mathrm{X}^{\mathrm{maximum}} - \mathrm{X}^{\mathrm{minimum}}}\right) \quad ..(5.2)$$

Negative indicator

$$\mathrm{X}^{\text{normalized}} = \left(\frac{\mathrm{X}^{\text{maximum}} - \mathrm{X}^{\mathrm{i}}}{\mathrm{X}^{\text{maximum}} - \mathrm{X}^{\text{minimum}}}\right) \quad ..(5.3)$$

After normalizing the indicators, the next step is assigning them weights. In the present study, following the paper of Inostroza et al. (2016), Zurovec et al. (2017), Maleki et al. (2018), and Khole et al. (2019), equal weights have been assigned to each component and indicators to avoid subjectivity and bias. The indicators, utilizing weighted additive mean methodology, were aggregated to derive the values of their respective components. Subsequently, the final vulnerability index was constructed from these components employing the weighted additive function. Equation 5.4 shows the mathematical formulation of the vulnerability index.

$$V\text{ulnerability index} = \left(\frac{\mathrm{E} + \mathrm{S} + (1 - \mathrm{AC})}{3}\right) \quad ..(5.4)$$

Table 5.2 Indicators for construction of vulnerability Index

Components (weight)	Indicators (weight)	Definition of indicators	Hypothesized relationship with vulnerability	Source
Exposure (1/3)	Change in annual average precipitation during the last 10 years (1/5)	Reflects availability of water	P	Moshizi et al. (2023)
	Change in annual average temperature during the last 10 years (1/5)	Determine the water loss due to evapo-transpiration as well as the demand for water	P	
	Household size (1/5)	Total number of household members	N	Maleki et al. (2018)
	Head of household	-	N	

	educational level (1/5)			
	Household economic status (1/5)	Income level of household.	N	
Sensitivity (1/3)	Damage to agriculture products (1/4)	-	P	Pandey et al. (2015)
	Damage to health (1/4)	-	P	
	Deteriorated quality of water (1/4)	Household with deteriorated quality of water (%)	P	
	Water scarcity (1/4)	Households with problem in availing water (%)	P	
Adaptive capacity (1/3)	House type (1/10)	The quality of the house i.e., kutcha, pucca or mixed	N	
	Migration (1/10)	Household with at least one migrated member.	N	
	Agriculture profession (1/10)	Household dependent solely on agriculture.	P	
	Change in livelihood strategies (1/10)	Household with change in livelihood strategies.	N	
	Change in crop variety (1/10)	Household with change in crop variety.	N	
	Adjustment in cultivation practices (1/10)	Household with change in sowing/planting/harvesting time.	N	
	Reduced water (1/10)	Household with reduced use of water.	N	
	Change in irrigation (1/10)	Household switching to low water intensive crop.	N	
	Water scarcity effects (1/10)	Household is aware of the	N	Maleki et al. (2018)

		consequences of water scarcity.		
	Government-initiated policies (1/10)	Households have awareness about or have access to government-initiated water policies.	N	

The final index value ranged from 0 to 1, with 0 indicating less vulnerability and 1 indicating high vulnerability. For interpretative purposes, the index was categorized into five distinct classifications following Mohapatra et al. (2022): households within the range of 0–0.2 were least vulnerable, those within 0.2–0.4 were classified as less vulnerable, while households ranging from 0.4–0.6 were considered moderately vulnerable. Further, households falling within the interval of 0.6–0.8 were classified as highly vulnerable, and those within 0.8–1 were categorized as extremely vulnerable.

Additionally, the reliability of the scale was evaluated using Cronbach's alpha, which is widely recognized in the literature as an indicator of reliability (Bujang et al., 2018; Maleki et al., 2018; Jamshidi et al., 2019; Chauhan et al., 2022). The obtained score of 0.61 confirms the reliability of the data (Chauhan et al., 2022).

5.5.3 Sensitivity analysis of vulnerability index

In the paper, to test the robustness of the index, PCA was employed as an alternative weighting scheme to equal weight. Using PCA, the vulnerability index was calculated. Before that, datasets were evaluated for sample adequacy and data reliability using the KMO and Bartlett sphericity tests. The KMO test value was 0.55, which is greater than 0.5, and the results of Bartlett's test were statistically significant, indicating that the data satisfied the minimum requirements for PCA.

5.5.4 Logistic regression

Binary logistic regression was employed to ascertain the determinants of household adaptation to water scarcity. In the study, both supply-side and demand-side management strategies were examined. Following the methodologies of Alam (2015), Inkani et al. (2020), and Ahsan et al. (2022), 11 distinct adaptation strategies were identified and subsequently classified into demand-side and supply-side categories. Supply-side strategies include: rainwater harvesting, water storage, diversification of water supply sources and purchasing additional water. Demand-side strategies encompass: diversification of livelihoods, migration, water conservation efforts, modifying cropping patterns, adoption of modern irrigation techniques, switching to less water-intensive crops and reducing livestock numbers.

The analytical approach was chosen due to the binary nature of the dependent variable, which represents the decision of households to either adopt or not adopt a specific adaptation strategy. Each adaptation strategy constitutes a binary outcome; consequently, binary logistic regression was individually applied to analyze all 11 identified adaptation strategies among the households.

According to Musafiri et al. (2022), the general equation of a binary logit model is as follows:

$$Ln\frac{P}{1-P} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n \quad \text{... (5.5)}$$

Here, Ln (P/(1-P)) is the odd ratio, α is the intercept, β1, β2, β3, …βn are the regression coefficients, and X_1, X_2, X_3, …X_n are the independent (explanatory) variables.

In the present study, based on data availability and literature review, 12 explanatory variables were selected. Household head age, household head gender, household head education level, household head marital status, household size, if the household has any secondary occupation, land size, the primary occupation of the household if the household has any external support/assistant, migration, annual income of the household, perception of the household to water scarcity are some of the important determinants of adaptation as cited in the literature (Chinwendu et al., 2017; Williams and Carrico, 2017; Inkani et al., 2021; Schlamovitz and Becker, 2021; Ahsan et al., 2022).

5.6 Results

5.6.1 Socioeconomic characteristics of households

Table 5.3 presents the socioeconomic characteristics of the households surveyed. Predominantly, 92.24 percent of the households were headed by males, with only 7.76 percent being headed by females, a consistent trend observed across all districts. Regarding the age distribution of household heads, the majority (46.21 percent) fell within the 55-75 age bracket. Notably, in Barmer and Jaipur, the majority of households (55 percent and 44 percent, respectively) belonged to the 35-55 age group. Almost all respondents were native to their respective districts, with a small percentage identified as migrants, primarily in Barmer, Ajmer, and Dausa. The majority (86.64 percent) of household heads were married. A majority proportion (57.40 percent) of households had resided in their communities for over 50 years. In all districts, excluding Tonk, the predominant household size fell within the range of 4-6 members, encompassing 51.99 percent of households. Additionally, Ajmer exhibited a significant proportion of households with 7-10 members. Conversely, in Tonk, the majority of households (37.14 percent) comprised 7-10 members.

In terms of literacy, districts such as Jodhpur, Tonk, Jaipur, and Ajmer exhibited higher rates of literacy among household heads (51.00 percent, 61.43 percent, 64.00 percent, and 50.00 percent, respectively), while in Barmer (67.00 percent) and Dausa (48.00 percent), the majority were illiterate. Moreover, a majority proportion of household heads across all districts had not received formal education. Occupationally, the majority (63 percent) were engaged in crop farming, with a smaller percentage involved in livestock farming (2.35 percent) and around 34.66 percent involved in both crop and livestock farming (34.66 percent). The annual income of the majority (64.80 percent) of households was less than 3 lakhs, except in Jaipur, where the majority (53 percent) earned between 3-5 lakhs annually. As observed from the table, a majority of households in Barmer (81.00 percent), Jodhpur (70.00 percent), Tonk (69.57 percent), Jaipur (71.43 percent), Ajmer (86.90 percent), and Dausa (86.00 percent) were engaged in secondary occupations. Regarding water scarcity, the majority of households in all the districts did not receive external assistance, except in Jaipur where 84 percent reported receiving aid. With respect to migration majority of households in all the districts did not practice migration. The district with the highest percentage of households practicing migration was Dausa, followed by Barmer, Jodhpur, Ajmer, Tonk, and Jaipur.

Table 5.3 Socioeconomic characteristics of the households.

Panel A (in percentage)								
Variables		Total	Barmer	Jodhpur	Tonk	Jaipur	Ajmer	Dausa
		n=554	n=100	n=100	n=70	n=100	n=84	n=100
Gender of household head	Male	92.24	90.00	91.00	91.43	94.00	91.67	95.00
	Female	7.76	10.00	9.00	8.57	6.00	8.33	5.00
Age of household head	15-35	3.61	2.00	3.00	7.00	8.00	0.00	0.00
	35-55	36.82	55.00	38.00	23.00	44.00	17.86	29.00
	55-75	46.21	35.00	49.00	34.00	43.00	63.10	42.00
	Above 75	13.36	8.00	10.00	6.00	5.00	19.05	29.00
Originality	Native	99.46	99.00	100.00	100.00	100.00	98.81	99.00
	Migrant	0.54	1.00	0.00	0.00	0.00	1.19	1.00
Marital status of household head	Married	86.64	80.00	86.00	97.14	98.00	75.00	85.00
	Unmarried	0.54	1.00	0.00	0.00	0.00	2.38	0.00
	Widowed	12.64	18.00	14.00	2.86	2.00	22.62	15.00
	Divorced	0.18	1.00	0.00	0.00	0.00	0.00	0.00
Number of years stayed in community	20-29	6.68	3.00	10.00	10.00	6.00	4.76	7.00
	30-49	35.92	33.00	47.00	32.86	39.00	30.95	31.00
	Above 50 years	57.40	64.00	43.00	57.14	55.00	64.29	62.00
Household Size	<3	3.79	1.00	2.00	17.14	6.00	0.00	0.00
	4-6	51.99	63.00	69.00	35.71	51.00	41.67	45.00
	7-10	35.92	33.00	27.00	37.14	38.00	41.67	40.00
	>10	8.30	3.00	2.00	10.00	5.00	16.67	15.00
Literacy status of household head	Neither Read or Write	46.03	67.00	45.00	32.86	32.00	47.62	48.00
	Read Only	3.43	2.00	4.00	5.71	2.00	2.38	5.00
	Write Only	0.36	0.00	0.00	0.00	2.00	0.00	0.00

	Read and write	50.18	31.00	51.00	61.43	64.00	50.00	47.00
Educational Status of household head	No Schooling	44.04	60.00	41.00	37.14	33.00	45.24	46.00
	Primary (1st-5th std)	29.06	27.00	25.00	24.29	25.00	35.71	37.00
	Upper Primary (6th – 8th std)	11.73	3.00	10.00	17.14	25.00	7.14	9.00
	Secondary (9th – 10th std)	7.40	3.00	10.00	11.43	14.00	4.76	2.00
	Senior Secondary (11th - 12th std)	6.50	6.00	13.00	2.86	3.00	7.14	6.00
	Vocational	0.36	1.00	0.00	1.43	0.00	0.00	0.00
	College/University	0.90	0.00	1.00	5.71	0.00	0.00	0.00
Occupational Status	Crop Farming	63.00	75.00	29.00	78.57	75.00	76.62	54.00
	Livestock Farming	2.35	3.00	7.00	0.00	0.00	0.00	3.00
	Both	34.66	22.00	64.00	21.43	25.00	27.38	43.00
Number of years farming	1-5 years	5.42	2.00	16.00	1.43	3.00	4.76	4.00
	5-10 years	11.73	19.00	24.00	5.71	2.00	9.52	8.00
	10-15years	5.05	8.00	13.00	0.00	0.00	3.57	4.00
	>15	77.80	71.00	47.00	92.86	95.00	82.14	84.00
Annual Income (in Lakhs)	<3	64.80	85.00	64.00	55.71	44.00	63.10	74.00
	3-5	31.23	12.00	36.00	35.71	53.00	32.14	20.00
	5-10	3.61	3.00	0.00	5.71	3.00	4.76	6.00
	>10	0.36	0.00	0.00	2.86	0.00	0.00	0.00
Secondary occupation	No	22.32	19.00	30.00	30.43	28.57	13.10	14.00
	Yes	77.68	81.00	70.00	69.57	71.43	86.90	86.00
Assistance	No	52.18	64.65	80.61	72.86	16.00	51.81	66.00
	Yes	47.82	35.35	19.39	27.14	84.00	48.19	34.00
Migration	No	68.61	63.92	65.98	75.36	81.00	73.91	55.00
	Yes	31.39	36.08	34.02	24.64	19.00	26.09	45.00

Source: Authors' calculation

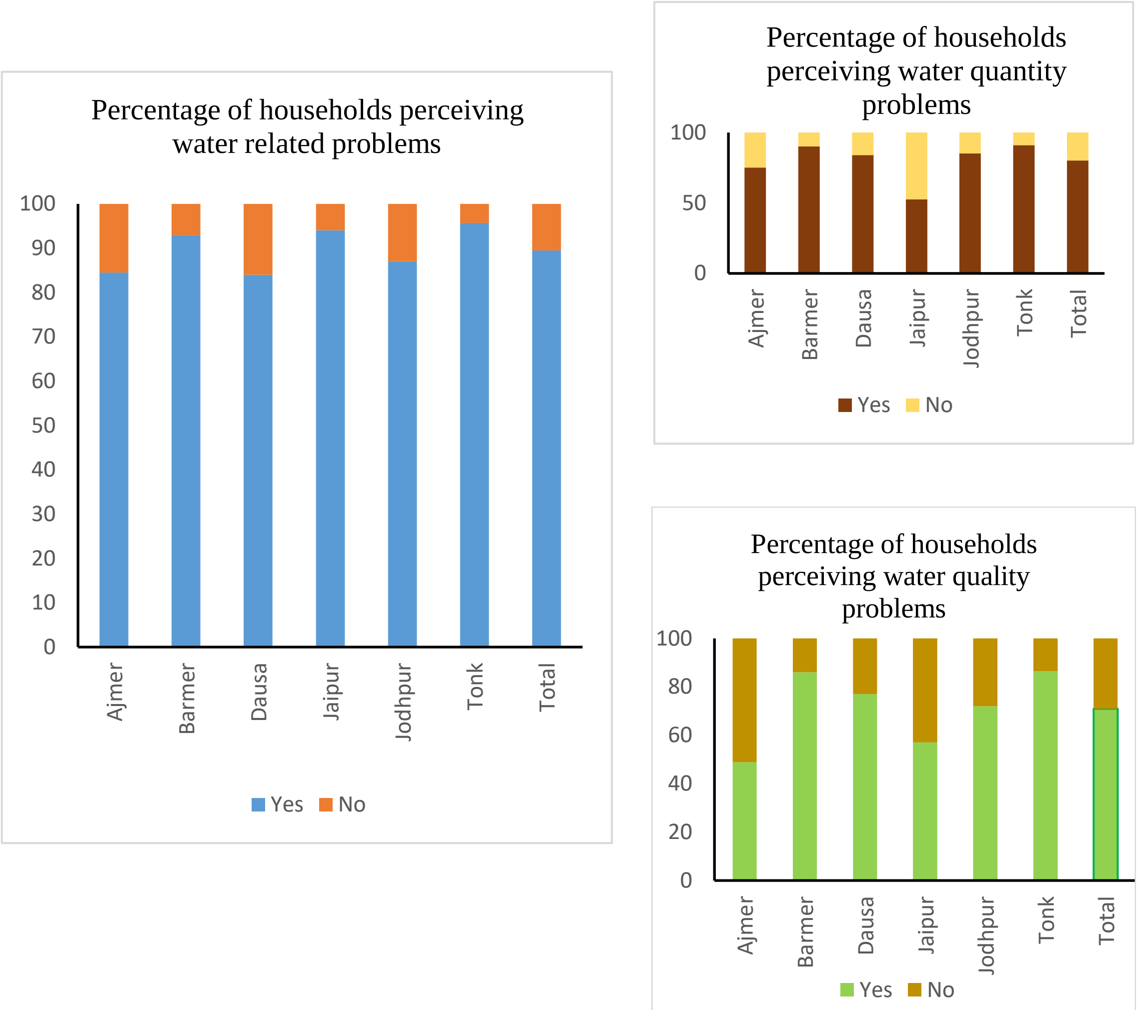
5.6.2 Households' perceptions of water issues

The preliminary findings of this study indicate that approximately 90.00 percent of the households surveyed (i.e., 495 households) perceive the presence of water-related issues in their respective locales (see Figure 5.2). Specifically, 80.00 percent of households (i.e., 424 households) perceive challenges related to the quantity of water, while 71 percent of households (i.e., 391 households) express concerns about the quality of water (see Figure 5.2).

When examined district-wise, the data reveals that, in Ajmer, Barmer, Dausa, Jaipur, Jodhpur, and Tonk, approximately 85.00, 93.00, 84.00, 94.00, 87.00, and 96.00 percent of the surveyed households, respectively, perceive water-related problems. Further, as evident from Figure 5.2, 75.00, 90.00, 84.00, 53.00, 85.00, and 91.00 percent of households in Ajmer, Barmer, Dausa, Jaipur, Jodhpur, and Tonk, respectively, express concern related to water quantity. Meanwhile, 49.00, 86.00, 77.00, 57.00, 72.00, and 58.00 percent of households in the corresponding districts perceive challenges associated with water quality. These initial findings highlight the widespread recognition of water-related challenges within the surveyed regions, with varying degrees of concern regarding both quantity and quality issues.

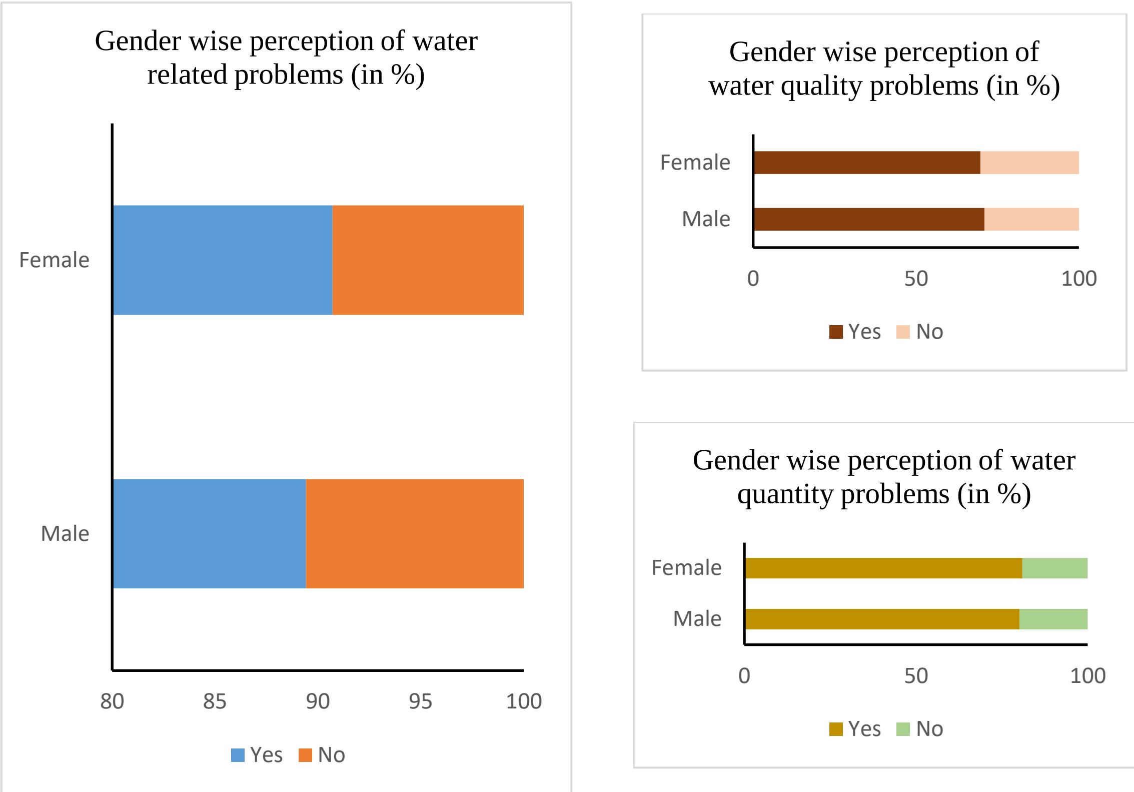
In addition, Figure 5.3 shows the disparity in the perception of water-related issues between male and female household heads. As evident, approximately 89 percent of male and 90 percent of female household heads perceive water-related problems in their locality, a non-significant difference. Likewise, about 80 percent of males and 81 percent of females perceive water quantity problems, and about 71 percent of males and 69 percent of females perceive water quality problems, a non-significant difference.

Figure 5.2 Perceptions of water-related problems in arid and semi-arid districts of Rajasthan, India.



Source: Authors' construction

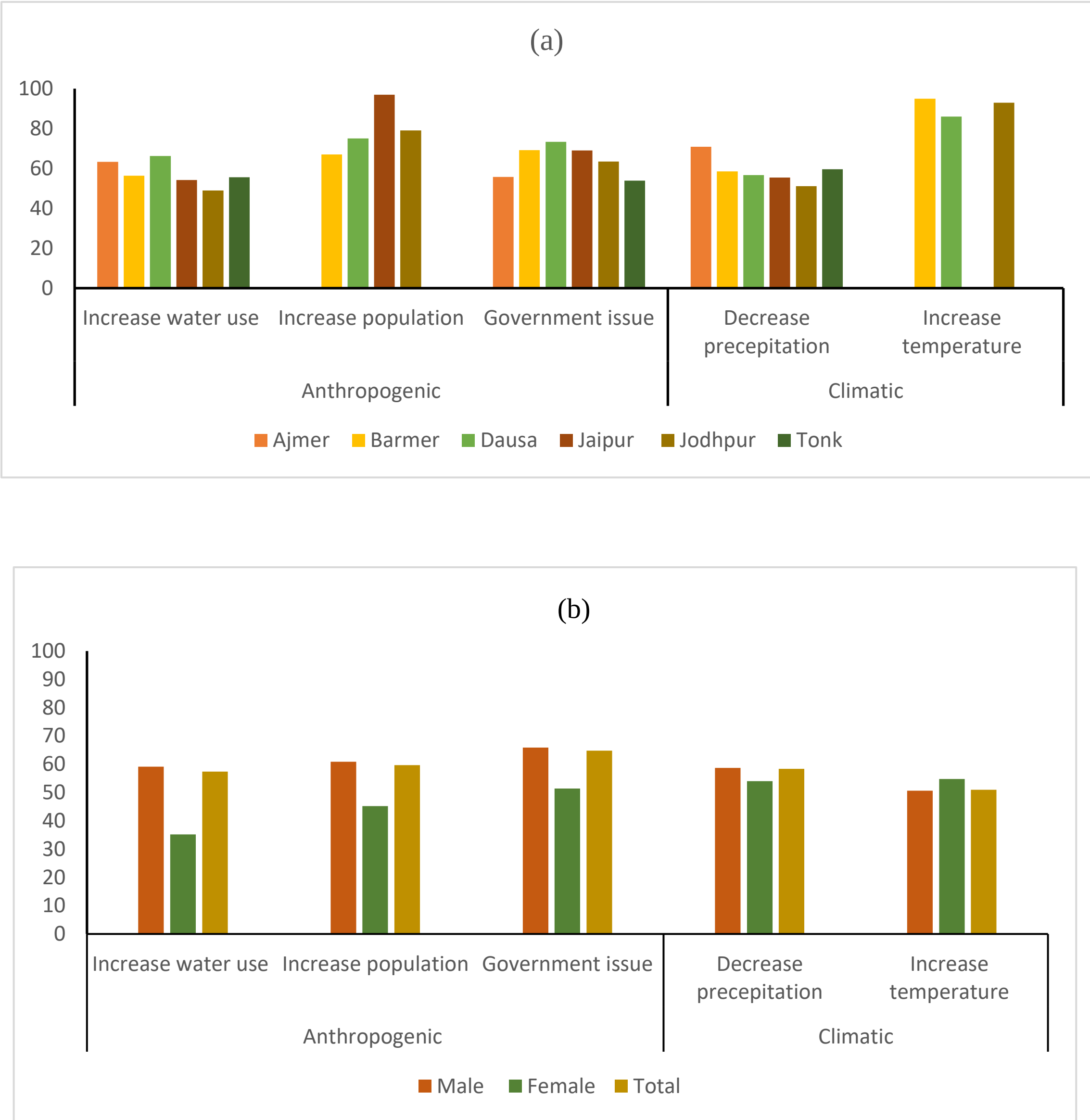
Figure 5.3 Gender differentiated perceptions of water related problems.



Source: Authors' construction

Moreover, households were also asked to identify the reasons associated with the water related problems in their locality. As evident from Figure 5.4, anthropogenic factors such as governmental issues, increase population and increase water use was identify to be major reason contributing to water problems by about 65.00, 60.00 and 57.00 percent of the households, respectively. Whereas, climatic factors such as decrease precipitation and increase temperature was identify to be major reason by approximately 58.00 and 51.00 percent of the households, respectively. District-wise, in Ajmer 71.00 percent and 63.00 percent of households identified decreased precipitation and increased water use, respectively, as the primary causes of water issues. Similarly, in Barmer, 95.00 percent and 69.00 percent of households attributed increased temperature and governmental issues as major factors, respectively. In Dusa and Jodhpur increased temperature identified by 86.00 percent and 93.00 percent, and population growth, identified by 75.00 percent and 79.00 percent of households, respectively, as the principal factors. While in Jaipur 97.00 percent of households identified population growth and 69.00 percent identified governmental issues as major contributors. In Tonk, 60.00 percent and 56.00 percent of households identified decreased precipitation and increased water usage as major contributing factors, respectively. Further, Figure 5.4 shows that compared to the male household heads who identified government issue (66.00 percent) and increase population (61.00 percent) as major reasons for water problem, female households' heads identified decrease precipitation (54.00 percent) and increase temperature (55.00 percent) as major reasons.

Figure 5.4 Natural and human causes for water relatd problems (in percent) (a) district-wise (b) gender wise.



Source: Authors' construction

5.6.3 Vulnerability to water scarcity

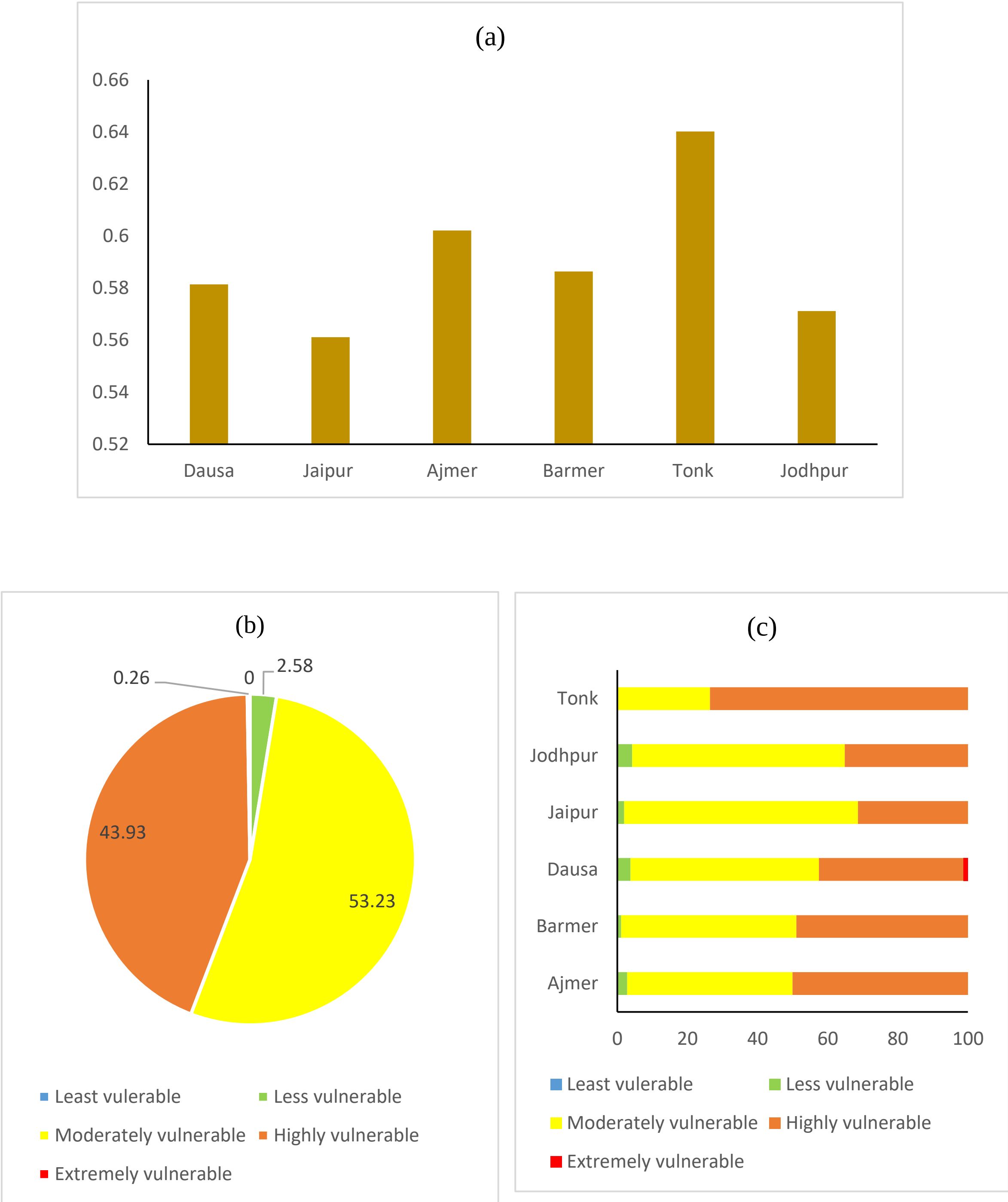
The mean vulnerability index score for water scarcity among households was found to be 0.5. Figure 5.5 shows the district-wise mean vulnerability scores, revealing Tonk as the most vulnerable district with a mean score of 0.64, followed by Ajmer with 0.60, Barmer with 0.59, Dausa with 0.58, Jodhpur with 0.57, and Jaipur with 0.56.

Additionally, Figure 5.5 shows the percentage of households categorized by different levels of vulnerability. As evident from the figure, none of the households were categorized as least vulnerable. Approximately 3.00 percent were classified as less vulnerable, around 53.00 percent as moderately vulnerable, nearly 43.00 percent as highly vulnerable, and 0.26 percent as extremely vulnerable. This suggests that majority of households in the study region face moderate to high level of vulnerability to water scarcity. At the district level also, a similar trend is observed (see Figure 5.5). As evident from the figure, the majority of households in Ajmer and Tonk (approximately 50.00 percent and 74 percent, respectively) fall into the highly vulnerable category. Whereas, in Barmer, Dausa, Jaipur, and Jodhpur, the majority of households (approximately 50.00 percent, 54.00 percent, 67.00 percent, and 60.00 percent, respectively) are classified as moderately vulnerable.

Also, as depicted in Figure 5.6, the vulnerability score for male-headed households is 0.58, whereas for female-headed households the vulnerability score is 0.59. Further, approximately 54.00 percent of male-headed households are categorized as moderately vulnerable, whereas the majority of female-headed households, approximately 52.00 percent, fall into the highly vulnerable category (see Figure 5.6).

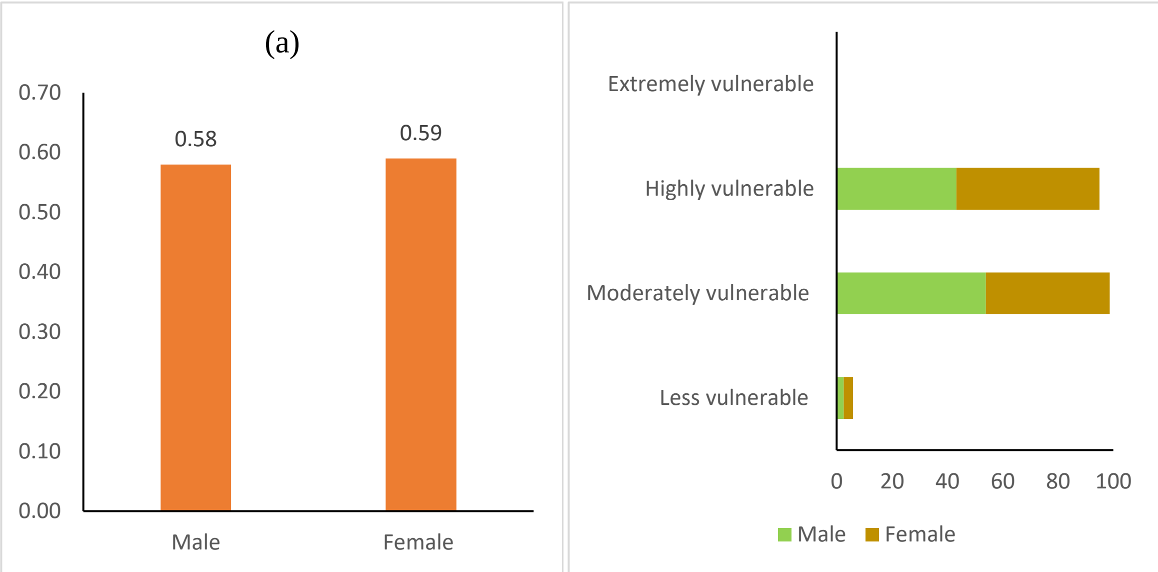
The component-wise scores of vulnerabilities are depicted in Figure 5.7. As evident from the figure, Barmer, with a mean score of 0.67, was found to be the most vulnerable district for exposure. At the same time, the sub-component scores indicate that Jaipur exhibits the highest exposure in terms of the change in annual average precipitation during 10 years. Meanwhile, Jodhpur demonstrates the highest exposure in terms of the change in annual average temperature during 10 years and household size. Additionally, Barmer has the highest exposure scores for the education level of the household head and the economic status of the household.

Figure 5.5 Vulnerability to water scarcity (a) district wise mean vulnerability score (b) percentage of households under different vulnerability level (overall) (c) district wise percentage of households under different vulnerability level.



Source: Authors' construction

Figure 5.6 Gender wise vulnerability to water scarcity (a) mean vulnerability score (b) percentage of households under different vulnerability level.

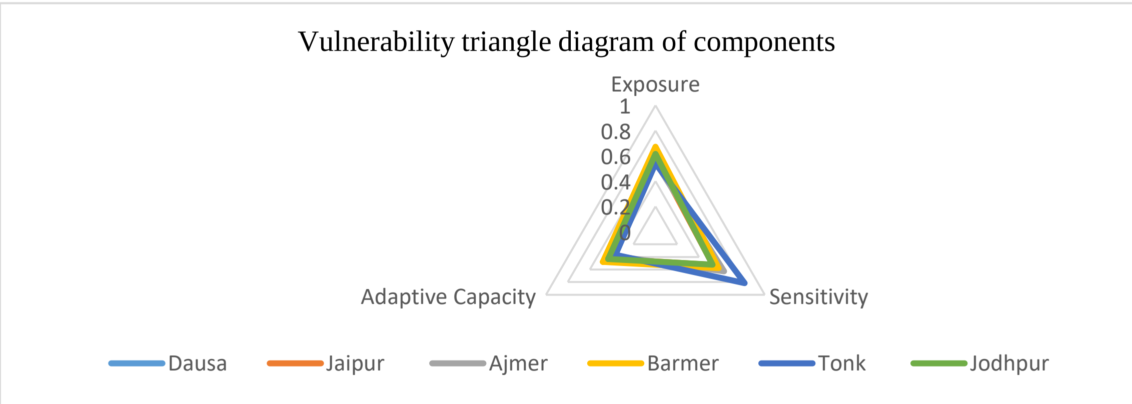


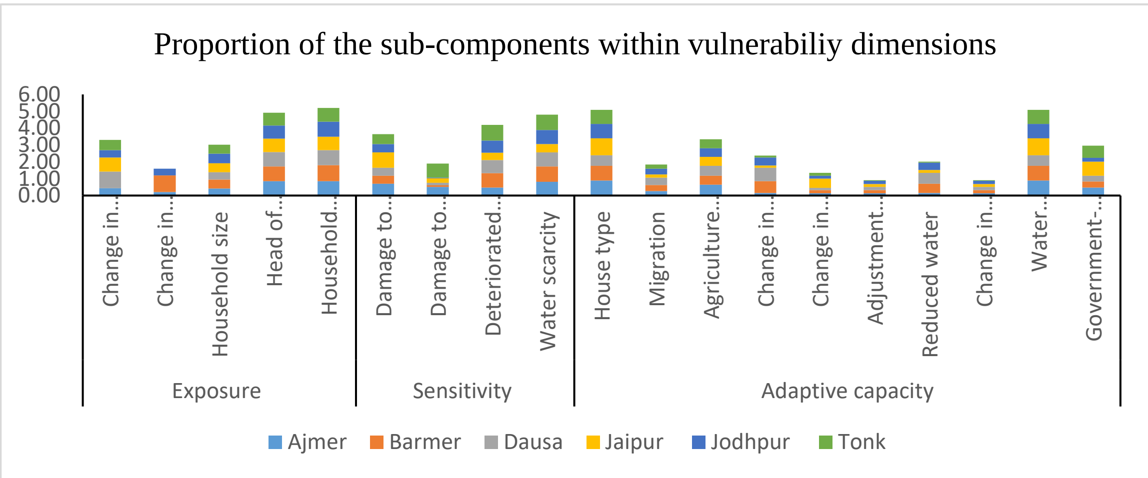
Source: Authors' construction

Further, Figure 5.7 depicts that Tonk, with a mean score of 0.81was the most vulnerable district for sensitivity. Moreover, the sub-component-wise score shows that Jaipur, with a mean score of 0.91, has the most vulnerability in terms of damage to agricultural products. Likewise, Tonk, with a mean score of 0.83 and 0.93, has the most vulnerability in terms of damage to health and households that receive deteriorated quality of water. Additionally, Tonk and Barmer with a mean score of 0.90 has the most vulnerability in terms of households that have problem in availing water.

Regarding the adaptive capacity, the results show that with a mean score of 0.48, Barmer has the highest adaptative capacity (see Figure 5.7). Further, the sub-component wise analysis reveals that Jaipur, with a mean score of 1.00, 0.55,1.00 and 0.84 has the highest adaptative capacity in terms of house type, households altering crop varieties, possessing awareness of water scarcity consequences, and having awareness/access to government-initiated water policies, respectively. Likewise, Dausa, with a mean score of 0.45 and Ajmer with a mean score of 0.65 has the highest adaptative capacity in terms of households with at least one migrated member and households whose income is not solely reliant on agriculture, respectively. Also, Dausa with a mean score of 0.80 and 0.64 has the most adaptive capacity regarding households implementing changes in livelihood strategies and reducing water usage. Simultaneously, Jodhpur and Barmer, with a mean score of 0.19, demonstrate the highest adaptive capacity concerning households adjusting cultivation practices and altering irrigation strategies.

Figure 5.7 Vulnerability to water scarcity (a) vulnerability triangle diagram of components (b) proportion of the sub-components within vulnerability dimensions.



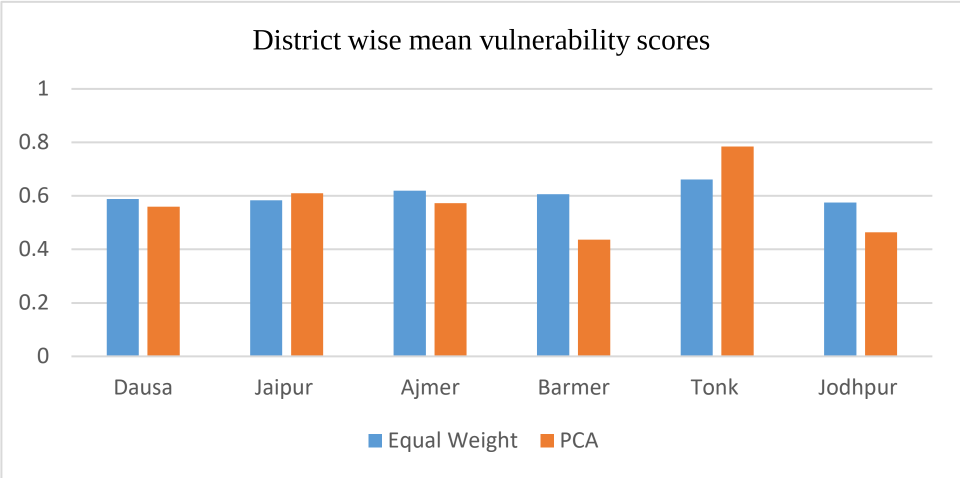


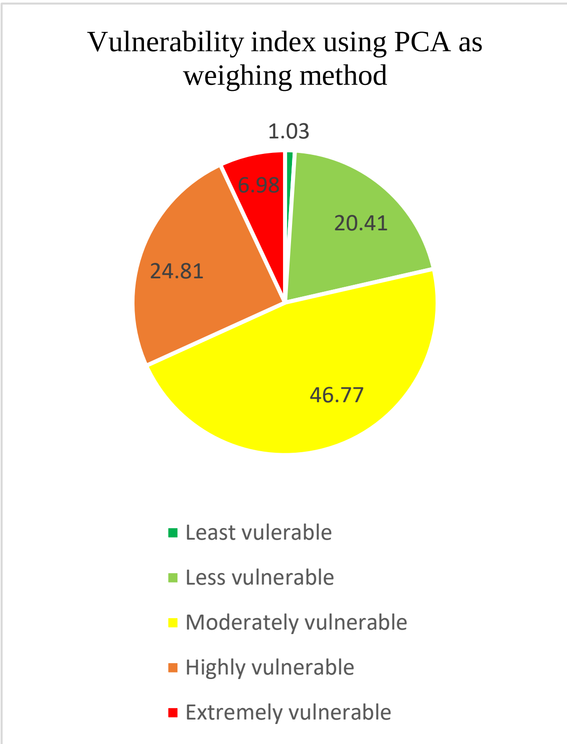
Source: Authors' construction

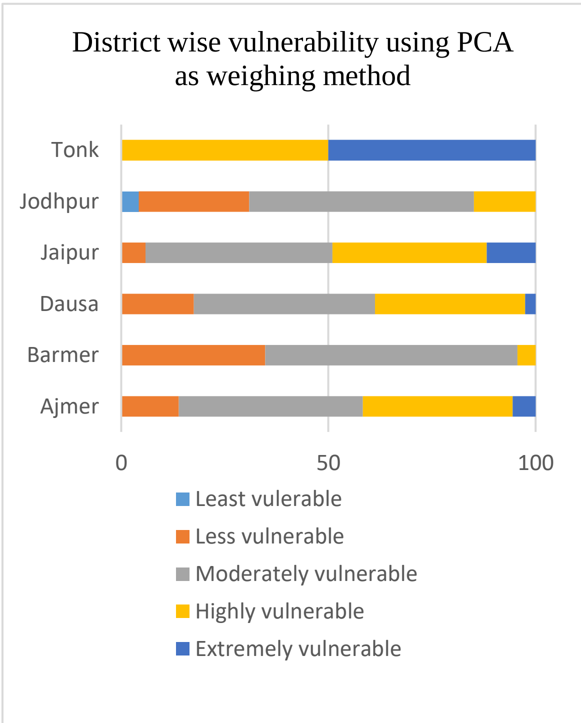
5.6.4 Sensitivity Analysis

Figure 5.8 illustrates the vulnerability index generated using an alternative weighting scheme based on PCA. Interestingly, employing PCA resulted in an increase in the average vulnerability score for Jaipur and Tonka, while scores decreased for Dausa, Ajmer, Barmer, and Jodhpur. Categorically, the majority of households categorized using PCA fell into the moderately vulnerable category, followed by the highly vulnerable category. Notably, approximately seven percent of households were classified as extremely vulnerable and roughly one percent as least vulnerable, diverging from the distribution observed with equal weighting. In terms of district-wise analysis, Ajmer exhibited approximately 14.00, 45.00, 36.00, and 6.00 percent of households categorized as less, moderate, highly, and extremely vulnerable, respectively, using PCA. Similarly, in Barmer, approximately 35.00, 61.00, 4.00, and 0.00 percent of households were categorized into these vulnerability categories, respectively. In Dausa, these percentages stood at approximately 18.00, 44.00, 36.00, and 3.00 percent. For Jaipur, approximately 6.00, 45.00, 37.00, and 12.00 percent of households fell into these vulnerability categories, respectively. In Jodhpur, these percentages were approximately 4.00, 27.00, 54.00, 15.00, and 0.00 percent, respectively. Lastly, in Tonk, 50.00 percent of households were categorized as highly and extremely vulnerable using PCA.

Figure 5.8 Vulnerability index using PCA







Source: Authors' construction

5.6.5 Household adaptation to water scarcity

Figure 5.9 illustrates the adaptation strategies employed by households to mitigate water scarcity, categorized into supply and demand-side management strategies (Inkani et al, 2021). The data reveals that the predominant strategy, adopted by 82.8 percent of households, is supply-side management through water storage.

District-wise analysis indicates that in Dausa and Jaipur, the majority of households opt for the supply-side strategy of water storage. Similarly, in Ajmer, Barmer, and Jodhpur, the predominant strategies are supply-side measures, with 92.6 percent, 99 percent, and 97 percent of households adopting water purchase and rainwater harvesting, respectively. Conversely, in Tonk, the majority of households (85.71 percent) employ demand-side strategies, particularly changing cropping patterns, to mitigate water scarcity.

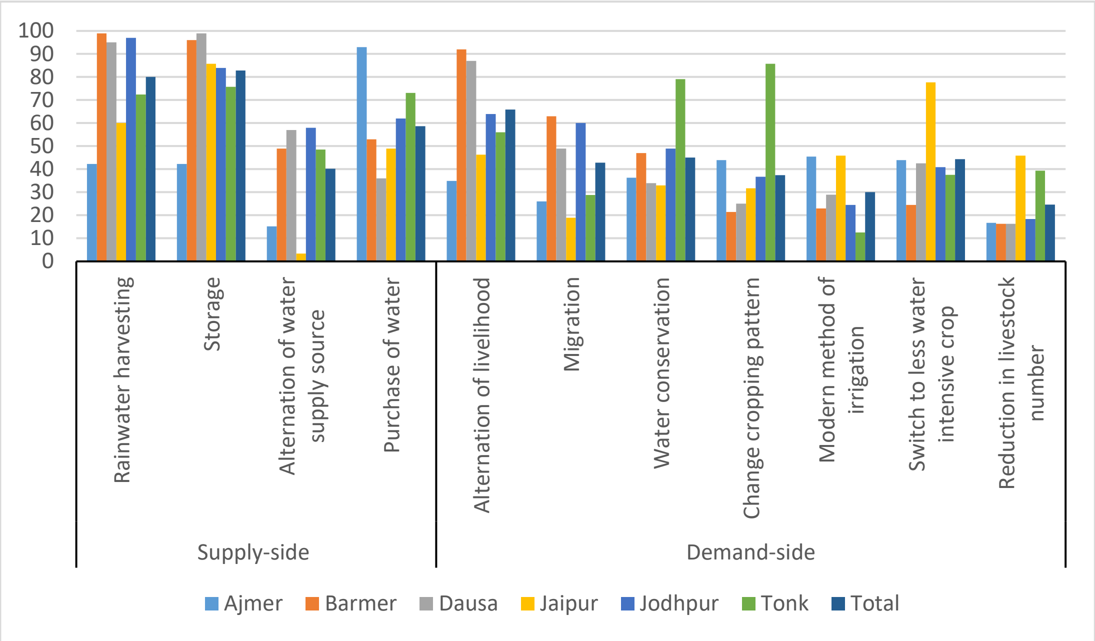
Among the supply-side strategies in Ajmer, the predominant strategy adopted by households is purchasing water, followed by storage, rainwater harvesting, and alteration of water sources, respectively. In Barmer, rainwater harvesting is the most prevalent strategy, followed by storage, purchasing water, and altering water sources. In Dausa, storage is the primary strategy, followed by rainwater harvesting, altering water sources, and purchasing water. Similarly, in Jaipur, storage is the leading strategy, followed by rainwater harvesting, purchasing water, and altering water sources. In Jodhpur, rainwater harvesting is the prevailing strategy, followed by storage, purchasing water, and altering water sources. Finally, in Tonk, storage is the predominant strategy, followed by purchasing water, rainwater harvesting, and altering water sources.

Similarly, for demand-side strategies, households in Ajmer predominantly adopted modern methods of irrigation, followed by changing cropping patterns and transitioning to less water-intensive crops. Other strategies included water conservation, altering livelihoods, migration, and reducing livestock numbers. In Barmer, the majority of households favoured altering livelihoods as the demand-side strategy, followed by migration, water conservation, transitioning to less water-intensive crops, adopting modern irrigation methods, changing cropping patterns, and reducing livestock numbers. Similarly, in Dausa, altering livelihoods was the primary strategy, followed by migration, transitioning to less water-intensive crops, water conservation, adopting modern irrigation methods, changing cropping patterns, and reducing livestock numbers.

In Jaipur, the majority of households opted for transitioning to less water-intensive crops as the demand-side strategy, followed by altering livelihoods, modern irrigation methods, reducing livestock numbers, water conservation, changing cropping patterns, and migration. In Jodhpur, altering livelihoods was the dominant demand-side strategy, followed by migration, water conservation, transitioning to less water-intensive crops, changing cropping patterns, adopting modern irrigation methods, and reducing livestock numbers. Finally, in Tonk, the primary demand-side strategy was changing cropping patterns, followed by water conservation, altering livelihoods, reducing livestock numbers, transitioning to less water-intensive crops, migration, and adopting modern irrigation methods.

Figure 5.10 illustrates the gender-wise adaptation strategies of households. As evident from the figure, households headed by males predominantly adopt the supply-side strategy of water storage, followed by rainwater harvesting. Subsequently, demand-side strategies such as altering livelihoods, purchasing water, water conservation, transitioning to less water-intensive crops, migration, altering water supply sources, changing cropping patterns, adopting modern irrigation methods, and reducing livestock numbers are observed.

Figure 5.9 Household adaptation strategies (in %)

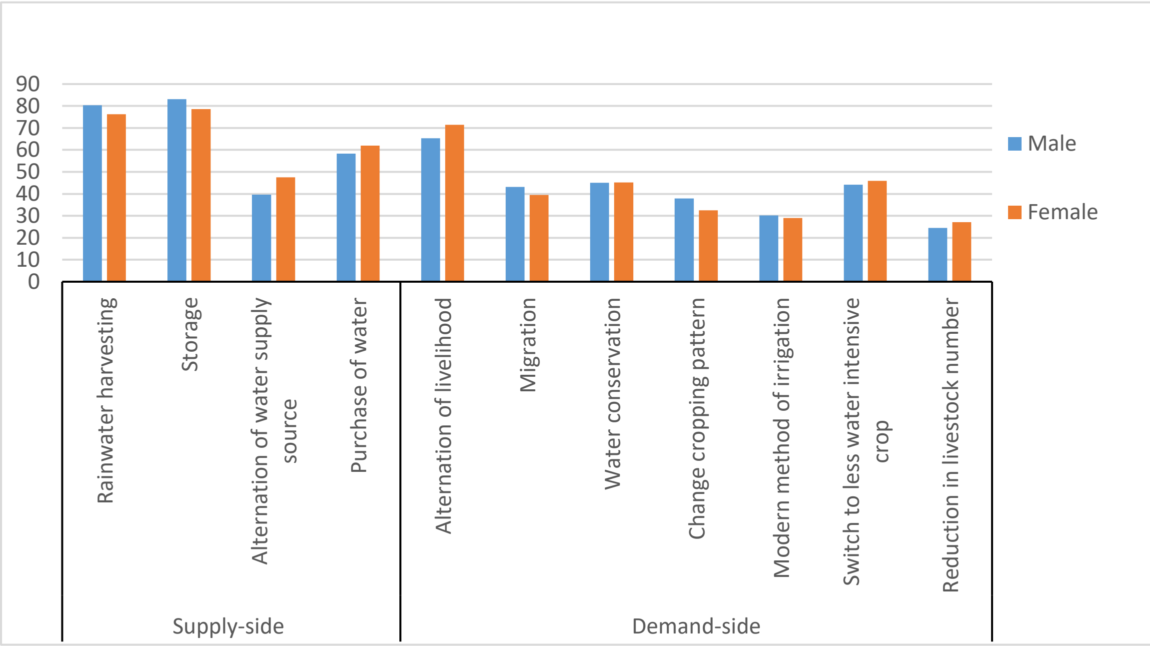


Source: Authors' construction

Likewise, households headed by females also predominantly adopt the supply-side strategy of water storage, followed by rainwater harvesting. Subsequently, demand-side strategies such as altering livelihoods, purchasing water, altering water supply sources, transitioning to less water-intensive crops, water conservation, migration, changing cropping patterns, adopting modern irrigation methods, and reducing livestock numbers are evident.

Figure 5.11 presents the barriers to the adaptation of strategies as identified by households, with 71.66 percent and 69.69 percent highlighting the lack of credit and inadequate income as major barriers, respectively. District-wise analysis in Ajmer reveals inadequate income as the primary barrier, followed by the lack of credit, lack of education, health, weak institutional support, and labor shortages. Similarly, in Barmer, the lack of credit emerges as the major barrier, followed by inadequate income, weak institutional support, lack of education, health, and labor shortages. In Dausa, inadequate income is identified as the primary barrier, followed by the lack of credit, educational deficiencies, weak institutional support, health, and labor shortages. Conversely, in Jaipur, lack of education is highlighted as the primary barrier, followed by the lack of credit, inadequate income, labor shortages, and health. In Jodhpur, the lack of credit is predominant, followed by inadequate income, educational deficiencies, health, weak institutional support, and labor shortages. In Tonk, lack of education emerges as the primary barrier, followed by the lack of credit, inadequate income, weak institutional support, labor shortages, and health.

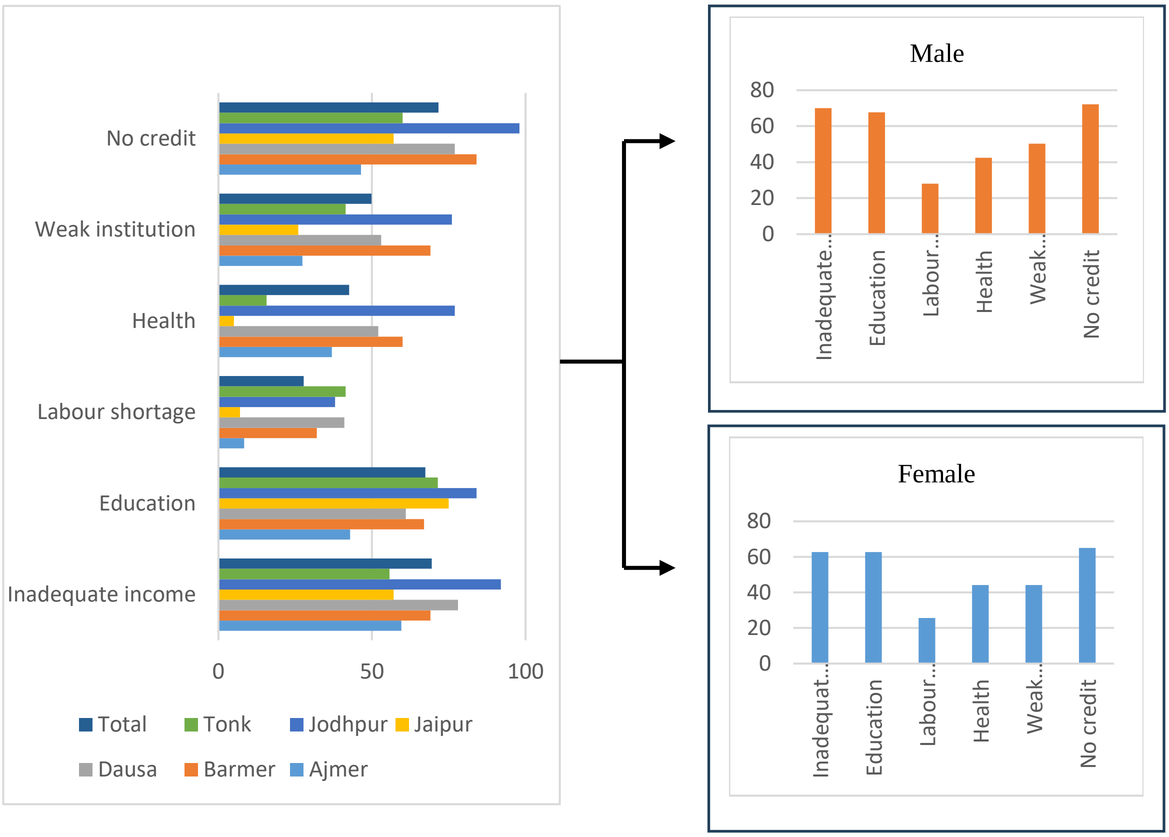
Figure 5.10 Gender wise adaptation strategies (in %)



Source: Authors' construction

The gender-wise analysis highlights the similarities in barriers to adaptation strategies between households headed by males and females (see Figure 5.11). The majority of households, regardless of gender, have identified the lack of credit and inadequate income as major barriers to adaptation.

Figure 5.11 Barriers to adaptation (in %)



Source: Authors' construction

5.6.6 Determinants of adaptation strategies

The household's decision to adapt to water scarcity is represented as a discrete variable (1,0) for all adaptation strategies, where 1 indicates adoption, and 0 indicates non-adoption. Table 5.4 presents the binary logit results for 11 adaptation strategies. As evident from the table, the result of Prob > chi2 indicated that models 1, 2, 3, 4, 5, 6, 8, and 9 are statistically significant at the 1% level, while models 7 and 11 are significant at the 5% level, and model 10 at the 10% level. Furthermore, the insignificant Prob > chi2 (Hosmer-Lemeshow chi-square) values across all models suggest good model fit (Archer and Lemeshow, 2006; Hosmer et al., 2013; Sahoo and Moharaj, 2022).

Migration emerges as a significant determinant influencing adaptation strategies such as rainwater harvesting, water storage, and migration itself. Positive and significant relationships are observed between migration and these strategies, indicating that households with migrated members are more inclined to adopt them to mitigate water stress. Conversely, migration shows a significant negative relationship with changing cropping patterns and reducing livestock, suggesting a lower adoption likelihood among households with migrated members. These findings resonate with previous research by Jha et al. (2018), Etana et al. (2022), and Ahsan et al. (2022), which underscore the pivotal role of migration as a determinant in adaptation dynamics. Notably, Jha et al. (2018) highlight a negative relationship between migration and livestock, while Etana et al. (2022) emphasizes a negative correlation between migration and crop diversification.

Households receiving external support are more likely to adopt rainwater harvesting, alternative water sources, migration, and modern irrigation methods, supported by positive and statistically significant coefficient values. Additionally, given that land serves as a fundamental asset for production and rural livelihood, it influences adaptation strategies. Previous studies, including those by Hisali et al. (2011) and Alam (2015), have underscored the significant impact of land on adaptation, particularly concerning long-term investments. Consistent with this, our study reveals a positive and statistically significant relationship between land ownership and the adoption of strategies like changing cropping patterns and modern irrigation methods. Furthermore, the data indicate that land size also correlates positively and significantly with water conservation and the alteration of water supply sources.

According to Padhan and Madheswaran (2022), secondary occupations are expected to enhance adaptive capacity due to diversified income streams. In our study, we found a positive and statistically significant relationship between secondary occupations and various adaptation strategies, including storage, alternative water sources, purchasing water, altering livelihoods, and changing cropping patterns. This suggests that households with secondary sources of income are more inclined to adopt these strategies to cope with water scarcity.

Moreover, the perception of water scarcity emerged as a significant determinant of adaptation strategies in our study. Specifically, households that perceive water scarcity exhibit a positive and statistically significant relationship with adaptation strategies such as altering water supply sources, purchasing water, and alternation of livelihoods.

Furthermore, certain household characteristics, including age, gender, education, marital status, household size, annual income, and occupation, have been identified as determinants in various adaptation strategies, as indicated in Table 5.4. Our findings suggest that households headed by individuals aged between 35 to 55 and those over 75 are less likely to resort to purchasing water as an adaptation measure. Similarly, households with heads aged between 55 to 75 and over 75 are less likely to opt for reducing livestock numbers as an adaptation strategy. Conversely, households with heads aged between 55 to 75 and above 75 are more likely to adopt changing cropping patterns as an adaptation strategy.

Regarding gender, our analysis reveals significant gender-related differences only in the adaptation strategy of altering water supply sources. Specifically, female-headed households exhibit a greater likelihood of adopting this adaptation strategy compared to male-headed households. The education status of the household head emerges as a crucial determinant in altering water supply sources and transitioning to less water-intensive crops. Our results indicate that household heads with upper primary education levels are less likely to adopt alterations in water supply sources, while those with upper primary and secondary schooling are more likely to switch to less water-intensive crops.

Occupation status also plays a pivotal role in adaptation strategies, particularly in the purchase of water and changing cropping patterns. Our findings suggest that households engaged in livestock farming occupations are less likely to purchase water, and those involved in both farming and livestock farming occupations are less likely to purchase water and alter cropping patterns. Annual household income serves as a significant determinant of water conservation adaptation strategies. Specifically, households with annual incomes ranging between 5 to 10 lakhs are more likely to adopt such strategies. Moreover, household size emerges as an important determinant in transitioning to less water-intensive crops. Larger households, with sizes exceeding 10 members, are less likely to adopt this strategy. Marital status of the household head also plays a significant role in various adaptation strategies. For instance, widowed household heads are more likely to migrate but less likely to adopt water conservation measures, modern irrigation methods, and reduce livestock numbers.

Table 5.4 Factors determining the adaptation strategies of the households (coefficient (β) values)											
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
	Rainwater harvesting	Storage	Alternation of water supply source	Purchase of water	Alternation of livelihood	Migration	Water conservation	Change cropping pattern	Modern method of irrigation	Switch to less water intensive crop	Reduction in livestock number
Age (Base<35 years)											
35 to <55 years	-1.28	-0.79	-0.46	(-)1.58*	-0.50	1.94	-0.86	1.15	1.42	-0.56	-0.59
55 to < 75 years	-1.50	-0.88	-0.62	-1.01	-0.87	4.52	-0.33	1.14**	1.15	-0.47	(-)1.28*
Above 75 years	-1.04	-0.47	-0.19	(-)1.55*	-0.63	1.36	-0.52	1.54*	1.78	-0.63	(-)1.27*
Gender	-0.28	-0.53	0.73*	0.44	-0.30	-0.40	0.47	-0.37	-0.40	(-)0.27	0.43
Education (Base: No formal schooling)											
Primary schooling	0.28	0.44	0.58	-0.79	-0.28	-0.06	-0.27	-0.34	-0.06	-0.16	-0.23
Upper primary schooling	-0.37	0.52	(-)0.73*	-0.05	-0.41	-0.75	0.00	0.74	0.48	0.91***	-0.48
Secondary schooling	0.79	1.23*	-0.13	0.29	-0.53	0.01	-0.03	0.43	-0.61	0.93**	-0.54
Senior secondary schooling	0.55	0.48	0.66	0.51	-1.10	0.47	0.09	0.44	0.26	0.25	-0.99

Vocational training				-2.15			0.57	2.00	1.75		0.68
College/University	0.00	-1.99	-0.89	0.32	-1.94		-1.34		0.15	-0.95	-1.10
Marital status (Base: Married)											
Unmarried											
Widowed	0.22	0.10	-0.44	-0.32	0.62	0.62*	(-)1.24***	-1.25	(-)0.91*	0.13	(-)0.83*
Household size (Base <3)											
4 to 6	-1.14	-0.83	-0.17	0.58	0.07	-0.51	-0.84	-0.04	0.85	-1.05	-0.21
7 to 10	-0.93	-1.04	-0.53	0.63	-0.33	0.22	-1.09	-0.78	0.68	-1.26	0.42
More than 10	-0.34	0.85	-0.78	1.13	-0.39	0.51	-1.32	-0.72	0.05	(-)1.12*	-0.73
Secondary occupation	0.38	0.94***	0.51**	0.68***	1.37***	0.32	0.06	0.41*	0.01	0.12	0.25
Land size (in Hectares)	0.01	-0.01	0.12*	0.00	0.00	0.00	0.02**	0.02**	0.03***	0.01	0.00
Occupation (Base: Farming)											
Livestock farming			2.84	(-)1.54**		0.11	-0.81		1.02		1.25
Both	0.24	-0.11	0.15	(-)0.42*	0.38	0.06	-0.24	(-)0.44*	-0.32	-0.19	0.11
External support/assistant	0.53**	0.39	1.07***	-0.04	0.23	0.47**	0.33	0.19	2.16***	0.24	(-)0.19
Migration	1.01***	0.94***	0.12	0.32	1.10	1.29***	0.09	(-)0.41*	-0.02	0.29	(-)0.67*

Annual Income (in Lakhs INR) (Base: <3)											
3 to < 5	0.27	0.03	0.28	-0.60	0.04	0.09	0.31	0.04	-0.21	0.28	0.54
5 to < 10	-0.28	0.55	0.74	-0.86	-0.84	0.65	1.13*	0.93	0.09	0.10	-0.06
Above 10											
Perceive water scarcity	0.26	0.04	0.91**	1.87***	0.67*	0.52	0.06	0.05	0.27	0.00	0.33
Constant	2.92**	2.98**	0.44	1.11	1.66*	1.92	0.94	1.49	16.45	1.45	0.16
Panel-B											
Pseudo R^2	0.13	0.12	0.12	0.14	0.23	0.24	0.14	0.22	0.19	0.12	0.28
Log likelihood	-204.10	-183.65	-267.62	-281.98	-249.62	-258.23	-297.46	-252.26	-208.68	-270.79	-226.98
Likelihood ratio chi-square	41.56	46.43	77.45	63.66	92.08	63.53	41.54	41.82	116.6	34.19	39.51
Prob > chi2	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.01**	0.00***	0.00***	0.05*	0.02**
Prob > chi2 (Hosmer-Lemeshow chi-square)	0.57	0.10	0.21	0.21	0.12	0.17	0.13	0.21	0.45	0.16	0.10
Correctly classified	86.88	85.63	68.93	69.18	73.13	80.00	67.50	77.17	76.87	69.57	80.58
Note: *** p<.01, ** p<.05, * p<.1											
Source: Authors' calculation											

5.7 Conclusion

The study investigates perceptions, vulnerabilities, and adaptation measures to water scarcity in arid and semi-arid districts of Rajasthan, focusing on gender differences. Results show varied perceptions among male and female household heads, with moderate to high vulnerability observed, particularly among female-headed households. Eleven distinct adaptation strategies were identified, with supply-side approaches predominating. Gender-wise analysis revealed no significant differences in adaptation approaches. Migration emerged as a significant determinant of adaptation strategies, along with external support, land size, secondary occupations, and perception of water scarcity.

Chapter 6

SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

This chapter summarizes the primary findings based on the empirical investigations and then offers policy recommendations. This chapter is divided into five sub-sections. The first section offers a summary of the findings and conclusions drawn from the research. The second section provides policy suggestions to the decision-makers based on the findings. The third sections talk about the novelty of the present study. The fourth section discusses the limitations of the study. Finally, section fifth outlines the direction for future research.

6.1 Summary and conclusions

6.1.1 Water and development

Water scarcity not only threatens livelihoods but also impacts health and education, underscoring its multifaceted significance across various dimensions of development. Additionally, beyond physical scarcity, factors like access to water, water quality, and time spent fetching water profoundly affect human well-being. Given this, in the context of India, which has shown remarkable progress in different dimensions of development, the worsening water situation raises concerns about the sustainability of this progress in the long term. This concern is exacerbated by institutional inefficiencies and delays, which cast doubt on the effectiveness of government-sponsored schemes aimed at mitigating water scarcity.

Against this background, the study sought to unravel and comprehend the nature of the relationship that exists between various dimensions of water and development in India. To measure development, the study has used MPI, which provides a holistic understanding of poverty and development by capturing various aspects of well-being. MPI offers a more comprehensive perspective on development by incorporating non-economic dimensions. In the study, MPI was constructed using the Alkire and Foster (2011) methodology. Further, to capture the multi-dimensional aspect of water WPI has been computed. Though earlier studies on the water poverty index have generally been applied at the macro level, in the study recognizing that there can be considerable variations between household water conditions, a household-level water poverty index (MWPI) has been created using the multivariate analysis technique of PCA. Kendall tau-b and Tobit regression were used to examine the relationship between MWPI and MPI.

Recognizing that the characteristics of poverty and the extent of the relationship between water and poverty may differ between urban and rural areas, the inter-relationship of water and poverty has been examined separately for rural and urban areas. According to the empirical findings, it is found that 14.93 percent of rural households and 2.98 percent of urban households are multidimensionally poor. Rural areas were also found to be having a higher level of water poverty compared to urban areas.

In terms of the inter-relationship between MPI and MWPI, the findings show a significant and negative correlation, indicating that poor households are water-poor and vice versa. Furthermore, the Tobit regression results reveal that compared to urban areas, the impact of MWPI on MPI is higher in rural areas. Similarly, MPI although found to be significantly impacting the MWPI in both rural and urban areas, its effect is more profound in the case of rural areas.

The study has also examined the impact of the drinking water policy on MPI using GSEM. The water policy variable was constructed from the NSSO data and it considered various drinking water policies like NRDWP, AMRUT, and SCM. The results reveal that only 3.28 percent of households in India have ever received any benefit from the drinking water policy. Furthermore, the analysis reveals that drinking water policies significantly influence MWPI and indirectly impact MPI through MWPI.

6.1.2 Temporal and spatial assessment of water scarcity

As a “common property,” natural capital is especially beneficial to the most vulnerable section of society. Water is one such natural resource that is critical to the ecosystem's proper functioning and central to all human activities. Given the immense importance of water, especially in a water-stressed country like India, the next step was to evaluate the water situation across the Indian states.

As evident from the literature, WPI is a holistic and comprehensive tool that expresses multifaceted water issues in a comprehensive manner. Accordingly, WPI has been calculated, and a comparison has been made between two points of data (2012 and 2018) to understand the spatiotemporal pattern of water scarcity in the country. The indirect aim is to highlight the lacking areas responsible for the deterioration in the water poverty status.

The WPI provided a detailed and valuable insight into the water situation prevailing in the states of India. Overall, the study shows that although the capacity and access component of WPI has increased, there has been a deterioration in the environment and resource components. The data also pointed to a marginal decrease in the use component in the given period. The results of the sub-component-wise analysis indicated a decline in groundwater resources per capita as well as in annual rainfall. Deterioration was also visible in the agricultural water usage evaluated as the percentage of NIA to NSA as well as in the generation of solid and liquid wastes. The amount of time and distance covered in fetching water saw a reduction in the given period; there was also an increase in the percentage of households having access to improved water sources as well as improved sanitation. A marginal increase was also visible in the percentage of land covered by forest. Also, all the sub-components of capacity, i.e., mortality rate, gross enrolment in higher education, as well as per capita NSDP, showed an improvement in 2018 when compared to 2012.

A comparison of the aggregate WPI across the time periods indicated a worsening of the water situation in the states of Andhra Pradesh, Arunachal Pradesh, Chandigarh, Delhi, Goa, Haryana, Meghalaya, Nagaland and Tripura. The result indicated that there is no single state that topped all the dimensions of the WPI. Whereas resource and environment components were found to be most favorable in Arunachal Pradesh, Chandigarh scored the highest value in the use and capacity component, and for access, Delhi was the best compared to the other states in our analysis in 2012. In 2018 while Arunachal Pradesh continued to be the best performer in the environment component, the resource component was highest in the state of Karnataka. Chandigarh has the highest value in the use and capacity component in 2018 as well but access was the best in Goa in 2018. Among all the states, Chandigarh topped the overall WPI score, but it performed poorly in the resource component, being the worst performer in 2012 and the third-worst in 2018. From the analysis, it was also found that Jharkhand, Rajasthan, Odisha, and Chhattisgarh continued to occupy the bottom positions in 2012 as well as in 2018, implying a continuous prevalence of extremely unsafe water situations in these states.

Rajasthan, known for its low water resource base, stands as the driest state in India, marked by persistent water scarcity and a significant likelihood of drought occurrences. Additionally, it was observed that Rajasthan was one of the worst performers in WPI during both time periods. This let us delve deeper into the water situation of Rajasthan in the subsequent analysis, to better understand its challenges and explore potential avenues for improvement.

Based on the availability of data, a household-level (microscale) WPI, referred to as the MWPI, was calculated for the state. The MWPI was created for 2012 and 2018 using five components containing 10 indicators. A spatial and temporal analysis using simple descriptive statistics was performed to clearly understand whether the state's water situation is improving or deteriorating.

The study found that the state's water poverty situation improved between 2012 and 2018. Data revealed that environment, secondary sources, access, and capacity components mainly drove this improvement. The resource component during this period witnessed a decline. A region-wise assessment of water poverty revealed that the western region is the most water-poor in both periods. Furthermore, all regions' water poverty situations improved between 2012 and 2018, but the western and northern regions saw the least improvement compared to the others. The district-wise water poverty analysis revealed that the most water-poor districts are in the Western and North eastern regions.

Further, among the 33 districts, leaving Churu, Karauli, Nagaur, Barmer, Sirohi, Tonk, and Pratapgarh, the score of MWPI improved in all other districts from 2012 to 2018. The component-wise analysis revealed that the decline in the water status (decline in MWPI score) in these districts is primarily attributed to the deterioration of water supply frequency, the increase in water-related diseases, the percentage of households lacking access to improved sanitation, the proportion of households without access to safe water, and the percentage of households experiencing water insufficiency. Also, during the given period of all the five components of MWPI, resources deteriorated in most districts. Notably, policies such as canal-based water supply schemes in Sri Ganganagar, Bhilwara, and Jaisalmer, along with community-based water management initiatives in Churu and Jhalawar, have led to improvements in these districts' resource component, driven by enhanced water availability and consequent reduction in the percentage of households experiencing water insufficiency.

6.1.3 Impact of climatic and anthropogenic factors on water resources in Rajasthan

As per UNESCO (2022), groundwater resources account for about 99 percent of all liquid freshwater on earth, making them an essential component of the global water supply. Particularly, Rajasthan heavily depends on groundwater to meet its needs, especially in arid and semi-arid regions where surface water is scarce. However, this reliance, coupled with inadequate natural recharge, places significant strain on groundwater resources. Additionally, groundwater is often mismanaged and undervalued. Mismanagement, compounded by the 'tragedy of the commons,' results in unsustainable groundwater abstraction. Furthermore, groundwater quality has deteriorated over time, making it unsuitable for consumption and use.

With the intensification of anthropogenic activities and climate change predicted to further exacerbate the deterioration of groundwater, the study explores how climate change and anthropogenic activities are affecting groundwater in the arid and semi-arid regions of Rajasthan. In the study, six districts of Rajasthan, two (Barmer and Jodhpur) arid and four (Ajmer, Jaipur, Dausa, and Tonk) semi-arid were considered for the analysis. Statistical methods such as descriptive test statistics, MK test, and Sen's slope estimation were used to examine the annual and seasonal patterns in groundwater level, precipitation, and temperature at 113 monitoring sites between 1994 and 2020. In addition, at the district level, trends in anthropogenic factors like DGDP, population, and NIA were also analyzed. Further, the general additive model (GAM) was utilized to analyze the influence of climatic and anthropogenic factors on groundwater level.

The results indicate that, during the 26 years, the groundwater level exhibited both increasing and declining trends in the study area. However, in Dausa and Jaipur districts, most observation wells/piezometers showed a significant positive trend. All monitoring wells in Dausa and approximately 56 percent of all monitoring wells in Jaipur exhibited a significant positive trend in annual groundwater levels. In the post-monsoon, monsoon, pre-monsoon, and winter seasons, 67 percent, 61 percent, 56 percent, and 50 percent of observation wells in Jaipur and 89percent, 100 percent, 100 percent, and 89 percent of observation wells in Dausa were characterized by a significant positive trend of groundwater level. In contrast, the districts of Tonk and Barmer have the highest proportion of wells with a negative trend in annual groundwater level. Also, the districts experienced a rise in DGDP and population from 1999 to 2020. The NIA, despite exhibiting a fluctuating pattern, has increased in all districts from 1994 to 2020. Also, during the study period all the monitoring stations witnessed an increasing trend in both minimum and maximum temperature. The precipitation witnessed an increasing trend in 63% and decreasing trend in 29% of stations.

The univariate and multivariate GAM have been used to effectively analyze the influence of climatic and anthropogenic factors on groundwater levels. Univariate GAM analysis revealed both linear and nonlinear relationships between groundwater levels and explanatory variables in each district. Moreover, multivariate GAMs provided deeper insights by examining the combined effects of multiple variables on groundwater levels, with the best-fit models identified based on the AIC values. The district-wise optimal/best-fit GAM result showed that climatic factor such as precipitation significantly affects the groundwater level in the arid district of Barmer. In all other districts, it is influenced by a combination of different anthropogenic variables, such as DGDP and NIA (Ajmer and Tonk), NIA, and population (Jaipur). At the same time, population emerged as a key factor in Dausa and NIA in Jodhpur. Due to district-specific variances in geographical locations, population, lifestyle, policy, etc., it was observed that the factors influencing the groundwater level vary.

Additionally, the study attempts to assess the hydrochemical characteristics of groundwater, its temporal trend, and suitability for domestic and irrigation use using non-parametric MK and Sen's slope estimator test and USSL diagram. Also, it identifies the influence of anthropogenic and climatic variables on groundwater quality at 84 stations in arid (Barmer and Jodhpur) and semi-arid (Ajmer, Jaipur, Dausa, and Tonk) districts of Rajasthan for the period 2000 to 2018 using GAM.

Results reveal that groundwater in the examined districts is generally neutral to slightly alkaline. On average, Na^+ + K^+ were the dominating cations, while Cl^- and HCO_3^- were the dominating anions. During the study period, the order of water type in the districts was: Na-Cl > Ca-Na-HCO_3> Na-HCO_3> Ca-Mg-Cl> Ca-HCO_3. In general, MK and Sen's trend analysis reveals that cations Ca^{2+}, Mg^{2+}, Na^+, and anions Cl^-, HCO_3^-, and SO_4^{2-} witnessed an increasing trend in a comparatively higher percentage of observation stations. In contrast, for cation K^+ and anion F^- and NO_3^-, a comparatively higher percentage of observation stations witnessed a decreasing trend. The district-wise analysis indicates that the majority of observation stations with an increasing trend in EC, Ca^{2+}, K^+, Cl^-, and SO_4^{2-} were located in Jaipur, whereas the majority of stations with an increasing trend in pH and F^- were situated in Barmer and Dausa, respectively. Similarly, stations with an increasing trend in Na^+ and NO_3^- were primarily located in Jodhpur, while stations with an increasing trend in TA, TH, Mg^{2+}, and HCO_3^- were primarily in Tonk. Moreover, 30 percent of monitoring stations, primarily in Barmer, Jodhpur, Tonk, and Ajmer, observed a significant increasing trend in Fe.

Based on the BIS (2012) and WHO (2011) guidelines, groundwater in the examined districts exceeded the acceptable limit in Cl^-, F^-, and Na^+ at most of the stations. From the human health perspective, the suitability of groundwater, particularly in Dausa, raises considerable apprehension. Consuming water with such a high concentration of these ions can lead to several adverse health effects, including bone and skeletal damage, tooth discoloration, high blood pressure, and heart disease. The irrigation indices, such as EC, were found to be between 750-2000 (Permissible limit) in 29 percent and >3000 (Unsuitable) in 23 percent of the stations in 2018. Furthermore, the results show that the SAR values were less than 10 (Excellent) for the majority of stations during the period from 2000 to 2018. Moreover, the USSL diagram reveals that most observation stations fall into the C3S2 category, indicating that the water would be suitable for irrigation if salinity control measures can be implemented.

GAM analysis reveals that in the examined districts, compared to the climatic variables, various anthropogenic variables significantly influence the groundwater quality parameters. From the district-wise analysis, it can be stated that industrialization in Ajmer, population and NIA in Barmer, NIA and fertilizer usage in Jodhpur, population and industrialization in Jaipur and Dausa, and NIA, population, fertilizer usage in Tonk were the key factors in explaining the groundwater quality parameters. However, climatic factor such as precipitation was found to have a significant influence on TA and HCO_3^- at Tonk, while both temperature and precipitation significantly influence K^+ at Dausa,

6.1.4 Water Scarcity in Rural Rajasthan: Perception, Adaptation, and Vulnerability

Given the prevalence of water poverty in Rajasthan, particularly in rural areas, it is imperative to comprehensively understand the vulnerability of rural households to water scarcity, their perceptions regarding it, and how they adapt to this challenge. In this context, the study employs a comprehensive approach utilizing both primary and secondary data to investigate the vulnerability, perception, and adaptation to water scarcity among rural households in the arid and semi-arid districts of Rajasthan. Furthermore, the research identifies factors that influence adaptation and illuminates the barriers to adaptation within these districts.

Additionally, given the extreme importance of water for poverty alleviation and its gendered impact, in the study, the gender disparities in perception, vulnerability, and adaptation to water scarcity have been highlighted. To quantify vulnerability, using the IPCC framework, a vulnerability index at the household level was constructed. Further, binary logit regression was utilized to analyze determinants of adaptation strategies.

The results reveal that the perceptions of water-related challenges vary, with male household heads often citing anthropogenic factors while female heads attribute issues to climatic factors. Vulnerability assessment shows moderate to high vulnerability, with the majority of female-headed households falling into the highly vulnerable category. Regarding adaptation strategies, 11 distinct approaches categorized into supply and demand management were identified. Notably, supply-side strategies predominated across districts, except in Tonk, where demand-side methods, particularly altering cropping patterns, were more prevalent. Gender-wise analysis revealed no significant differences in adaptation approaches between male and female-headed households. Moreover, both genders identified lack of credit and insufficient income as primary barriers to adaptation.

Further, the study found that migration is a significant determinant of adaptation strategies such as rainwater harvesting, water storage, changing cropping patterns, and reducing livestock. External support was a significant determinant in rainwater harvesting, alternative water sources, migration, and modern irrigation methods. Also land size was found to be a significant determinant in cropping patterns and water conservation. Secondary occupations and perception of water scarcity also shape adaptation decisions, alongside household characteristics like age, gender, education, income, household size, and marital status, influencing strategies such as purchasing water, altering livelihoods, and changing cropping patterns.

6.2 Policy recommendations

- The study highlights important policy recommendations. The study uncovers that water and poverty are positively and significantly related. In this context, the study concludes that for pertinent poverty targeting, proper management of water resources is a must. Investing in water is critical because it directly reduces disease burdens while indirectly increasing productivity and growth.
- Notably, the study found that drinking water policies significantly influence water poverty as well as multidimensional poverty. We can say that policies in the Indian context if properly implemented, could increase household well-being. However, the coverage of these policies is meager. Also, even though various poverty relief programs have been launched in India, they rarely address the issue of drinking water availability. Although government policies and programs like the National Water Mission, Jal Jeevan Mission, Mukhya Mantri Jal Swavlambhan Abhiyan, Neeru-Chettu program, and Sujalam Sufalam Yojana, to name a few, are commendable efforts to address the country's water woes. Given the country's rising water demand and decreasing water availability, these schemes must be aggressively implemented and integrated with the various anti-poverty schemes if India is to maintain its remarkable performance in various aspects of development in the long run.
- Owing to the efforts of various state governments and policies at the central level, access to safe water in India over the years has increased. From recognizing the right to water in

early 2000 to signing MOU with different nations like Israel and Japan to leverage their expertise in water conservation in 2018 and 2021, respectively, India has made significant efforts to combat the worsening water crisis. Also, to address the problem of rising waste generation programs like Jawaharlal Nehru National Urban Renewal Mission, Swacch Bharat Abhiyan is doing a commendable job. However, owing to a lack of monitoring and improper implementation of various programs, the results remain dismal. The study found that over the years, the major reasons for the worsening of the water situation in the majority of the states were declining resource and environmental components. Hence, the study recommends taking such policy initiatives that focus on improving the environment and augmenting the resource base of the nation.

- In Rajasthan, the study found that each district has a distinct characteristic. Hence, it is advisable to formulate tailored policies targeting specific components to mitigate water poverty. Based on the findings, particular emphasis should be placed on enhancing the resource component. Accordingly, policies that increase water availability and reliability, such as MJSA and drinking water projects like the Bisalpur project and the Bhilwara project, should be encouraged and effectively implemented. In addition, it is recommended to promote community-based water management, which reduces the state's resource burden and enables behavioral change that supports water conservation and sustainable utilization. Also, given the multidimensional nature of water poverty, Integrated Water Resources Management could be an effective tool for addressing it.
- While acknowledging the state's efforts in water management, still a lot has to be done. Although the state has implemented various policy measures in water management, it is noteworthy that it ranks among the lowest in India, as highlighted by the NITI Aayog. Our

research suggests that if states' water woes are to be addressed, more policy actions/initiatives explicitly addressing access and ensuring water sufficiency and reliability for households are needed.

- According to the findings, the study recommends prioritizing effective municipal solid and liquid waste disposal and managing industrial pollutants in policy interventions. Additionally, stringent regulations should control the excessive use of chemical-based fertilizers while promoting organic farming among agricultural households. Efforts to reduce reliance on groundwater for irrigation are crucial to prevent over-exploitation and deterioration of water quality. Initiatives such as the Indira Gandhi Nahar Pariyojana (IGNP) should focus on increasing surface water irrigation. Encouraging traditional water harvesting methods like Khadin, Baori, and Tanka can help decrease dependence on groundwater for irrigation. Moreover, raising awareness about water disinfection before domestic use is essential, particularly in rural areas, to protect public health.
- Urgent enforcement of regulations is necessary to curb excessive groundwater extraction, especially in districts where anthropogenic factors drive groundwater depletion. Effective management of agricultural water demand through mechanisms like groundwater pricing and agricultural power supply rationing can mitigate groundwater depletion. Initiatives like the 'Deen Dayal Upadhyaya Gram Jyoti Yojana' should be pursued to improve agricultural water management. Promoting water-efficient practices such as drip irrigation and utilizing treated wastewater for agricultural irrigation can conserve freshwater resources. Encouraging advanced wastewater treatment technologies and promoting safe water reuse practices are recommended for ensuring the safe reuse of water.

- Implementing proactive artificial aquifer recharge programs can increase natural recharge rates, particularly in districts where precipitation significantly influences groundwater dynamics.
- Further, based on the findings, the study recommends facilitating access to credit and financial support for households to implement adaptation strategies, particularly for vulnerable groups like female-headed households. Promote livelihood diversification and secondary occupations to enhance adaptive capacity and reduce reliance on agriculture in water-stressed regions.
- Develop policies that support environmentally sustainable migration, considering the positive role migration plays in facilitating adaptation strategies like rainwater harvesting and water storage. Provide assistance and resources to households with migrated members to help them implement adaptation measures effectively.
- Districts like Ajmer, Barmer, and Jodhpur exhibit high adoption rates of supply-side measures such as water purchase and rainwater harvesting. Policy interventions should focus on further promoting these strategies through incentives, subsidies for rainwater harvesting infrastructure, and public awareness campaigns highlighting their benefits.
- Given the prevalence of demand-side strategies, particularly changing cropping patterns, in Tonk, policies should incentivize and support farmers in adopting water-efficient cropping patterns. This can include providing technical assistance, promoting drought-resistant crop varieties, and offering financial incentives for sustainable agricultural practices.
- In districts where modern irrigation methods are underutilized, such as Ajmer and Barmer, capacity-building programs should be initiated to train farmers in the efficient use of

irrigation technologies. Extension services, demonstration farms, and farmer field schools can help disseminate knowledge and skills related to modern irrigation practices.

- Since altering livelihoods emerged as a primary demand-side strategy, especially in Barmer and Dausa, policies should support livelihood diversification initiatives. This can involve vocational training programs, entrepreneurship development, and support for non-farm income-generating activities to reduce dependence on water-intensive agriculture.
- Given the positive relationship between external support and the adoption of adaptation strategies, policies should facilitate access to external assistance for vulnerable households. This can include strengthening partnerships with NGOs, civil society organizations, and development agencies to provide technical and financial support for water-related projects.
- Considering the gender-specific adaptation patterns identified, policies should incorporate gender-sensitive approaches to water management. This involves ensuring women's participation in decision-making processes, providing access to resources and technologies, and addressing gender disparities in access to water and sanitation services.

6.3 Contribution of the present study

- To the best of our knowledge, there is a paucity of studies that use WPI to access water situations for the entire India. The studies mostly focused on a limited number of states except for Kaur (2016) and Goel et al. (2020). Further, the datasets that the authors used were relatively old and also were not done over different time periods. The current study adds to the existing literature by calculating the WPI score for all Indian states for two different time periods (2012 and 2018). Further, a component-wise analysis is performed to obtain a picture of state-wise water poverty progress as well as to examine the major areas of deficiency.

- The novelty of the present study is that for the first time within Rajasthan, WPI is applied to evaluate the temporal changes in the water poverty situation of the state.
- Also, although WPI can be applied at different scales, research measuring household-level WPI is scarce. Given that there can be considerable variation between households' water status, the present study modifies the traditional WPI to account for the micro-level differences and has created a household-level WPI (MWPI).
- Previous studies investigating anthropogenic and climate factors' effects on groundwater levels have addressed the issue, considering the impact of climate change or anthropogenic activities separately (Li et al., 2020; Panda et al., 2012; Tabari et al., 2012). Only recently, the emphasis shifted to evaluating groundwater resources' response to climate change coupled with anthropogenic activities(Li et al., 2020). In this context, correlation analysis (Muhammad et al., 2022), multivariate statistical analysis (Wang et al., 2018), local regression (LOESS) (Sishodia et al., 2016), as well as integrated hydrological modeling (Feng et al., 2018), have been used to assess the influence of climate change and anthropogenic activities on the groundwater system. But in recent years, multivariate techniques, such as generalized additive models (GAM), have seen increased application (Hwang et al., 2016; Wang et al., 2022). Though GAM is similar to LOESS, it has an efficient method for analyzing non-linear relationships (Simpson, 2018). Except for Liu et al. (2021), GAM has not been widely used to assess the quantity of groundwater resources. Further, though there are some studies analyzing the trends of groundwater level in Rajasthan (Saikia and Chetry, 2020; Singh and Bhakar, 2022), few studies, such as Chinnasamy et al. (2015) and Tembhurne et al. (2022), have comprehensively looked at the factors that influence groundwater fluctuations in Rajasthan as a whole. However,

studies exclusively related to the arid and semi-arid regions are limited. The study adds to the limited literature.

- Also, numerous studies have previously been conducted to assess groundwater quality across different districts of Rajasthan, particularly regarding F^- and NO_3^- (Chaudhary & Satheeshkumar, 2018; Tiwari et al., 2020; Aggarwal et al., 2021; Singh and Bhakar, 2021; Choubisa et al., 2022; Tanwer et al., 2023). However, particularly for the districts of Jaipur and Dausa, studies on water quality and availability are scarce (Tiwari et al., 2020; Pandit and Kateja, 2023). In addition, the literature on the effects of climate change on water quality is limited (Barbieri et al., 2021). Also, to the best of our knowledge, a comprehensive assessment of climatic and anthropogenic activities influencing the groundwater quality in the selected districts is sparse, although notable exceptions include Coyte et al. (2019). The novelty of the present study is that it presents a comprehensive analysis of the hydro-chemistry and factors that influence it in the selected districts. The study results can be used to formulate appropriate strategies for managing groundwater resources and highlighting potential risks associated with using groundwater.

6.4 Limitations of the study

The following limitations are observed in the context of the present study:

- Due to data constraints, the study primarily focuses on the impact of a limited set of anthropogenic variables, such as DGDP, NIA, and population, on groundwater level. However, it is essential to acknowledge that factors like land use, vegetation changes, and government policies also play crucial roles in influencing groundwater levels.
- Additionally, the study has explored data related to precipitation and temperature to gauge the potential effects of climate change on groundwater resources. Nevertheless, exploring

extreme weather conditions and their specific influence on groundwater levels could provide valuable insights, particularly in the context of Rajasthan.

- For the groundwater quality analysis only 15 water quality parameters have been considered in the study. An investigation into other quality parameters will further enhance our understanding of the groundwater quality of the state.
- Due to data constraints, this study used a limited set of variables to construct the MWPI and MPI. However, it is essential to acknowledge that factors such as nutrition, child mortality, antenatal care, household asset ownership, and bank accounts are also crucial in defining the multidimensional poverty status of households. Similarly, water quality and conflict over water sources also play a vital role in influencing households' water poverty status.
- Additionally, the study did not detail the district-specific influence on MWPI, MPI, and various factors of MWPI. Nevertheless, exploring district-specific effects could provide valuable insights.

6.5 Direction of the future research

There are a number of concerns and potential scopes that require empirical investigation. Hence, the future scope of the study is:

- Firstly, extending the study to examine the groundwater situation in other agroecological zones of Rajasthan would provide valuable insights into regional variations in water availability and usage patterns.
- Broadening the scope of the study to include other agroecological zones in India would allow for a comprehensive assessment of the impact of climate and anthropogenic factors on water resources at the national level.

- Addressing data limitations by incorporating additional variables that may influence the MPI and WPI would enhance the robustness and accuracy of these indices. A more comprehensive index that accounts for a wider range of socio-economic, environmental, and institutional factors could provide a more nuanced understanding of poverty and water scarcity dynamics.
- Expanding the study to consider other climatic variables such as extreme weather conditions, land use changes, vegetation dynamics, and government policies could enrich our understanding of groundwater dynamics. By examining the specific influence of these factors on groundwater levels and quality, policymakers can develop targeted interventions to mitigate the impacts of climate change and anthropogenic activities on water resources.

REFERENCES

Adimalla, N., Li, P., and Qian, H. (2018). Evaluation of groundwater contamination for fluoride and nitrate in semi-arid region of Nirmal Province, South India: A special emphasis on human health risk assessment (HHRA). Human and Ecological Risk Assessment: An International Journal. 25, 1107–1124. https://doi.org/10.1080/10807039.2018.1460579

Aravinthasamy, P., Karunanidhi, D., Subba Rao, N., Subramani, T., and Srinivasamoorthy, K. (2020). Irrigation risk assessment of groundwater in a non-perennial river basin of South India: implication from irrigation water quality index (IWQI) and geographical information system (GIS) approaches. Arabian Journal of Geosciences. 13, 1–14. https://doi.org/10.1007/S12517-020-06103-1/FIGURES/5

Asongu, S. A., and Kodila-Tedika, O. (2017). Is Poverty in the African DNA (Gene)? South African Journal of Economics.85(4), 533–552. https://doi.org/10.1111/SAJE.12165

Abascal, E., Gómez-Coma, L., Ortiz, I., and Ortiz, A. (2022). Global diagnosis of nitrate pollution in groundwater and review of removal technologies. Science of The Total Environment. 810, 152233.

Adimalla, N. (2020). Controlling factors and mechanism of groundwater quality variation in the semi-arid region of South India: an approach of water quality index (WQI) and health risk assessment (HRA). Environmental Geochemistry and Health. 426, 1725–1752.

Aggarwal, A., Soni, J., Sharma, K., Sapra, M., Chitrakshi, Karaca, O., and Haritash, A. K. (2021). Hydrogeochemical Assessment of Groundwater for Drinking and Agricultural Use: A Case Study of Rural Areas of Alwar, Rajasthan. Environmental Management. 67, 513–521.

Aggarwal, R., Kaushal, M., Kaur, S., and Farmaha, B. (2009). Water resource management for sustainable agriculture in Punjab, India. Water Science and Technology. 60, 2905–2911.

Ahmad, Q. K. (2003). Towards Poverty Alleviation: The Water Sector Perspectives. International Journal of Water Resources Development. 19(2), 263-277. https://doi.org/10.1080/0790062032000089356

Akhundzadah, N. A., Soltani, S., and Aich, V. (2020). Impacts of Climate Change on the Water Resources of the Kunduz River Basin, Afghanistan. Climate. 8(10),102. https://doi.org/10.3390/CLI8100102

Akter, S. (2019). Impact of drinking water salinity on children's education: Empirical evidence from coastal Bangladesh. Science of the Total Environment. 690(10), 1331-1341. https://doi.org/10.1016/j.scitotenv.2019.06.458

Alcamo, J., and Henrichs, T. (2002). Critical regions: A model-based estimation of world water resources sensitive to global changes. Aquatic Sciences. 64(4), 352–362. https://doi.org/10.1007/PL00012591

Ali, S. A., and Ali, U. (2018). Hydrochemical characteristics and spatial analysis of groundwater quality in parts of Bundelkhand Massif, India. Applied Water Science. 81, 1–15.

Alkire, S., Foster, J. E., Seth, S., Santos, M. E., Roche, J. M., and Ballon, P. (2015). Multidimensional Poverty Measurement and Analysis, Oxford: Oxford University Press, USA.

Alqatarneh, G., and Al-Zboon, K. K. (2022). Water Poverty Index: A Tool for Water Resources Management in Jordan. Water, Air, and Soil Pollution. 233(11), 1–10.

Amrani, S., Hinaje, S., El Fartati, M., Gharmane, Y., and Yaagoub, D. (2022). Assessment of groundwater quality for drinking and irrigation in the Timahdite–Almis Guigou area (Middle Atlas, Morocco). Applied Water Science. 12, 1–12.

Arfanuzzaman, M., and Atiq Rahman, A. (2017). Sustainable water demand management in the face of rapid urbanization and ground water depletion for social–ecological resilience building. Global Ecology and Conservation. 10, 9–22.

Arku, F. S. (2010). Time savings from easy access to clean water: Implications for rural men's and women's well-being. Progress in Development Studies. 10(3), 233–246.

Bahir, M., Ouhamdouch, S., Ouazar, D., and Chehbouni, A. (2020). Assessment of groundwater quality from semi-arid area for drinking purpose using statistical, water quality index (WQI) and GIS technique. Carbonates and Evaporites. 35, 1–24.

Barbieri, M., Barberio, M. D., Banzato, F., Billi, A., Boschetti, T., Franchini, S., Gori, F., and Petitta, M. (2021). Climate change and its effect on groundwater quality. Environmental Geochemistry and Health. 45, 1133–1144.

Bera, B., Shit, P. K., Sengupta, N., Saha, S., and Bhattacharjee, S. (2022). Steady declining trend of groundwater table and severe water crisis in unconfined hard rock aquifers in extended part of Chota Nagpur Plateau, India. Applied Water Science. 12, 1–19.

Bisung, E., and Elliott, S. J. (2018). Improvement in access to safe water, household water insecurity, and time savings: A cross-sectional retrospective study in Kenya. Social Science and Medicine. 200, 1–8. https://doi.org/10.1016/J.SOCSCIMED.2018.01.001

Buor, D. (2004). Water needs and women's health in the Kumasi metropolitan area, Ghana. Health and Place. 10(1), 85–103. https://doi.org/10.1016/S1353-8292(03)00050-9

CAG. (2018). Comptroller and Auditor General of India on Performance Audit of National Rural Drinking Water Programme Union Government (Civil) Ministry of Drinking Water and Sanitation Report No. 15 of 2018 (Performance Audit).

CAG. (2018). Report of the Comptroller and Auditor General of India on National Projects Union

Government Ministry of Water Resources, River Development and Ganga Rejuvenation Report No. 6 of 2018 (Performance Audit).

Carrard, N., Foster, T., and Willetts, J. (2019). Groundwater as a Source of Drinking Water in Southeast Asia and the Pacific: A Multi-Country Review of Current Reliance and Resource Concerns. Water. 11, 1605.

Central Ground Water Board (CGWB). (2009). Dynamic groundwater resources of India. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/National%20Report%20(Dynamic%20Ground%20Water%20Resources%20of%20India_2009).pdf

Central Ground Water Board (CGWB). (2013). Groundwater information Jaipur district. http://cgwb.gov.in/sites/default/files/2022-10/jaipur.pdf

Central Ground Water Board (CGWB). (2017). Aquifer mapping and groundwater management-Jodhpur district, Rajasthan. http://cgwb.gov.in/cgwbpnm/publication-detail/478

Central Ground Water Board (CGWB). (2020). Groundwater yearbook Rajasthan 2019-20. http://cgwb.gov.in/Regions/WR/Reports/Year%20Book%202019-20_English%20corrected%203-11-20%20sent.pdf

Central Ground Water Board (CGWB) (2020). Aquifer mapping and groundwater management-Barmer district, Rajasthan. http://cgwb.gov.in/cgwbpnm/publication-detail/544

Central Ground Water Board (CGWB) (2020). Dynamic groundwater resources, Rajasthan. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/Reports/assessment_reports/GWRE_FINAL_11.10.21_state.pdf

Central Ground Water Board (CGWB). (2021). Groundwater year book 2020-2021 Rajasthan. http://cgwb.gov.in/cgwbpnm/public/uploads/documents/16881055672087557557file.pdf

Central Ground Water Board (CGWB) (2022). Dynamic groundwater resources of India. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Public-Health-Engineering-Department/PDF2022/2022-11-10-Final-Report-GWRA2022-Compressed.pdf

Central Ground Water Board (CGWB) (2022). Aquifer mapping and groundwater management-Tonk district, Rajasthan. http://cgwb.gov.in/cgwbpnm/publication-detail/562

Chaudhary, V., and Satheeshkumar, S. (2018). Assessment of groundwater quality for drinking and irrigation purposes in arid areas of Rajasthan, India. Applied Water Science. 8, 1–17.

Chen, Z., Grasby, S. E., and Osadetz, K. G. (2004). Relation between climate variability and groundwater levels in the upper carbonate aquifer, southern Manitoba, Canada. Journal of Hydrology. 290, 43–62.

Chinnasamy, P., Maheshwari, B., and Prathapar, S. (2015). Understanding Groundwater Storage Changes and Recharge in Rajasthan, India through Remote Sensing. Water. 7, 5547–5565.

Chopra, A., and Ramachandran, P. (2021). Multidimensional analysis of water sector performance in India: an index approaches. OPSEARCH, 58(1), 109–124. https://doi.org/10.1007/S12597-020-00476-3

Choubisa, S. L., Choubisa, D., and Choubisa, A. (2022). Fluoride contamination of groundwater and its threat to health of villagers and their domestic animals and agriculture crops in rural Rajasthan, India. Environmental Geochemistry and Health. 45, 607–628.

Choudhary, N., Schuster, R., Brewis, A., and Wutich, A. (2020). Water insecurity potentially undermines dietary diversity of children aged 6-23 months: Evidence from India. Maternal and Child Nutrition. 16(2). https://doi.org/10.1111/MCN.12929

Choudhuri, P., and Desai, S. (2021). Lack of access to clean fuel and piped water and children's educational outcomes in rural India. World Development. 145, 105535.

Coyte, R. M., Singh, A., Furst, K. E., Mitch, W. A., and Vengosh, A. (2019). Co-occurrence of geogenic and anthropogenic contaminants in groundwater from Rajasthan, India. Science of the Total Environment. 688, 1216–1227.

Das, P., Ghosh, S. and Paria, B. (2021). Multidimensional poverty in India: a study on regional disparities. GeoJournal. https://doi.org/10.1007/s10708-021-10483-6

Dehury, B., and Mohanty, S. K. (2015). Regional estimates of multidimensional poverty in India. Economics. 9. https://doi.org/10.5018/ECONOMICS-EJOURNAL.JA.2015-36

Dey, S., Bhatt, D., Haq, S., and Mall, R. K. (2020). Potential impact of precipitation variability on groundwater resources: a case study in Uttar Pradesh, India. Arabian Journal of Geosciences. 13.

Dhal, L., and Swain, S. (2022). Understanding and modeling the process of seawater intrusion: a review. Advances in Remediation Techniques for Polluted Soils and Groundwater. 269–290.

Dhillon, M. S., Kaur, S., and Aggarwal, R. (2019). Delineation of critical regions for mitigation of carbon emissions due to groundwater pumping in central Punjab. Groundwater for Sustainable Development. 8, 302–308.

Döll, P. (2009). Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment. Environmental Research Letters. 4.

Dutta Roy, A. (2015). Trend detection in Temperature and Rainfall over Rajasthan during the Last Century Extent. Asian Journal of Research in Social Sciences and Humanities. 5(2), 12–26. https://doi.org/10.5958/2249-7315.2015.00022.2

Esmeray, E., and Gökcekli, C. (2020). Assessment of groundwater quality for drinking and irrigation purposes in Karabuk province, Turkey. Environmental Earth Sciences. 79, 1–17.

Fatimatuzzahro, Raharjo, M., and Nurjazuli. (2020). Water Pollution Index (WPI) and Incidence of Diarrhea among Children under Five Years Old in Coastal Area of Semarang City, Indonesia. In E3S Web of Conferences (Vol. 202).

FE Bureau. (2019). India's per capita water availability to fall further - The Financial Express. https://www.financialexpress.com/economy/indias-per-capita-water-availability-to-fall-further/1697647/

Feitelson, E., and Chenoweth, J. (2002). Water poverty: towards a meaningful indicator. Water Policy. 4, 263–281. https://doi.org/10.1016/S1366-7017(02)00029-6

Foster, S., Pulido-Bosch, A., Vallejos, Á., Molina, L., Llop, A., and MacDonald, A. M. (2018). Impact of irrigated agriculture on groundwater-recharge salinity: a major sustainability concern in semi-arid regions. Hydrogeology Journal. 26, 2781–2791.

Gao, Y., Qian, H., Zhou, Y., Chen, J., Wang, H., Ren, W., and Qu, W. (2022). Cumulative health risk assessment of multiple chemicals in groundwater based on deterministic and Monte Carlo models in a large semiarid basin. Journal of Cleaner Production. 352, 131567. https://doi.org/10.1016/J.JCLEPRO.2022.131567

Garriga, R. G., and Foguet, A. P. (2010). Improved Method to Calculate a Water Poverty Index at Local Scale. https://doi.org/10.1061/ASCEEE.1943-7870.0000255

Gibrilla, A., Anornu, G., and Adomako, D. (2018). Trend analysis and ARIMA modelling of recent groundwater levels in the White Volta River basin of Ghana. Groundwater for Sustainable Development. 6, 150–163.

Goel, I., Sharma, S., and Kashiramka, S. (2020). The Water Poverty Index: An application in the

Indian context. Natural Resources Forum. 44(3), 195–218. https://doi.org/10.1111/1477-8947.12192

Goswami, T., and Ghosal, S. (2022). Domestic water poverty in a semi-arid district of eastern India: Multiple dimensions, regional pattern, and association with human development. Environmental Development, 44, 100742. https://doi.org/10.1016/J.ENVDEV.2022.100742

Goudie, A. (1998). Eliminating world poverty: A challenge for the 21st century. An overview of the 1997 white paper on international development. Journal of International Development. 10, 167-183.

GOR. (2013). Hydrogeological atlas of Rajasthan-Jodhpur district. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Jodhpur.pdf

GOR. (2013). Hydrogeological atlas of Rajasthan-Barmer district. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Barmer.pdf

GOR. (2013). Hydrogeological atlas of Rajasthan-Jaipur district. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Jaipur.pdf

GOR. (2013). Hydrogeological atlas of Rajasthan-Tonk district. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Tonk.pdf

GOR. (2013). Hydrogeological atlas of Rajasthan-Dausa district.

https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Dausa.pdf

GOR. (2013). Hydrogeological atlas of Rajasthan-Ajmer district. https://phedwater.rajasthan.gov.in/content/dam/doitassets/water/Ground%20Water/Pdf/PublicReports/Groundwater_Atlas/Districts/Districtwise%20Atlas%20-%20Ajmer.pdf

GOR. 2013. Agricultural statistics 2017-18. https://rajas.raj.nic.in/PDF/99202145052PMAgricultureStatistics201718.pdf

GOR. (2017). District survey report. https://environmentclearance.nic.in/DownloadPfdFile.aspx?FileName=7ZD1sLlra2CiyGBcN9iCEvkn1LONOzLM/uUuh6zRQgmdLLS+RkUzMkYBEqYfzNLwszY+yF/W5YhcExcTsMFjJZu14lAOkTESuq4GAdxF0gxjiRq2vtAQI/akJ1kyDgG7andFilePath=93ZZBm8LWEXfg+HAlQix2fE2t8z/pgnoBhDlYdZCxzVPEh4a7F53Cae7tleKGoXIDiA7chYePNgRJpehWx3dLsaLaee8RS5VxBvVdCAnIMg=

GOR. (2022). Sustainable development index- 2022. https://sdg.rajasthan.gov.in/Upload%20Attachment/fe0c6e45-0300-4124-90ce-eb4b1da7c63e/Rajasthan%20SDG%20Index.pdf

Gulati, M., Jacobs, I., Jooste, A., Naidoo, D., and Fakir, S. (2013). The Water–energy–food Security Nexus: Challenges and Opportunities for Food Security in South Africa. Aquatic Procedia. 1, 150–164. https://doi.org/10.1016/J.AQPRO.2013.07.013

Guppy, L. (2014). The Water Poverty Index in rural Cambodia and Viet Nam: A holistic snapshot to improve water management planning. 38, 203-219. 10.1111/1477-8947.12051

Gupta, P. K., and Sharma, D. (2019). Assessment of hydrological and hydrochemical vulnerability of groundwater in semi-arid region of Rajasthan, India. Sustainable Water Resources Management. 5, 847–861.

Guptha, G. C., Swain, S., Al-Ansari, N., Taloor, A. K., and Dayal, D. (2021). Evaluation of an urban drainage system and its resilience using remote sensing and GIS. Remote Sensing Applications: Society and Environment. 23, 100601.

Halder, S., Roy, M. B., and Roy, P. K. (2020). Analysis of groundwater level trend and groundwater drought using Standard Groundwater Level Index: a case study of an eastern river basin of West Bengal, India. SN Applied Sciences. 2, 1–24.

Handbook of Statistics on Indian Economy. (2018). Reserve Bank of India. https://www.rbi.org.in/scripts/PublicationsView.aspx?id=18621

Hanjra, M. A., and Qureshi, M. E. (2010). Global water crisis and future food security in an era of climate change. Food Policy. 35(5), 365–377.

Helmecke, M., Fries, E., and Schulte, C. (2020). Regulating water reuse for agricultural irrigation: risks related to organic micro-contaminants. Environmental Sciences Europe. 32, 1–10.

Hooda, B. K., and Tanwar, N. (2018). Aspect based multidimensional poverty status of households in rural and urban Haryana. Int. J. Agricult. Stat. Sci. 14(1), 339–348.

Hoogesteger, J. (2022). Regulating agricultural groundwater use in arid and semi-arid regions of the Global South: Challenges and socio-environmental impacts. Current Opinion in Environmental Science and Health. 27.

Hunter, P. R., Risebro, H., Yen, M., Lefebvre, H., Lo, C., Hartemann, P., Longuet, C., and Jaquenoud, F. (2014). Impact of the provision of safe drinking water on school absence rates in Cambodia: A quasi-experimental study. PLoS ONE. 9(3).

Huynh, P. T. A., and Resurreccion, B. P. (2014). Women's differentiated vulnerability and adaptations to climate-related agricultural water scarcity in rural Central Vietnam. Climate and Development. 6(3), 226–237. https://doi.org/10.1080/17565529.2014.886989

Hwang, S. A., Hwang, S. J., Park, S. R., and Lee, S. W. (2016). Examining the Relationships between Watershed Urban Land Use and Stream Water Quality Using Linear and Generalized Additive Models. Water. 8, 155.

IBEF. (2021). Retrieved May 16, 2022, from https://www.ibef.org/states/rajasthan-infographic

Indiastat. Damage Due to Flood and Heavy Rainfall in India (1953 to 2018). Retrieved November 30, 2021, from https://www.indiastat.com/table/meteorological-data/damage-due-flood-heavy-rainfall-india-1953-2018/14384

IUCN. (2004). Environmental Law Programme Water as a Human Right? Retrieved May 10, 2022, from www.iucn.org/themes/law

Jemmali, H., and Sullivan, C. A. (2014). Multidimensional Analysis of Water Poverty in MENA Region: An Empirical Comparison with Physical Indicators. Social Indicators Research. 115(1),253–277.

Jeon, C., Raza, M., Lee, J. Y., Kim, H., Kim, C. S., Kim, B., Kim, J. W., Kim, R. H., and Lee, S. W. (2020). Countrywide Groundwater Quality Trend and Suitability for Use in Key Sectors of Korea. Water. 12, 1193.

Jiménez-Martínez, J., Skaggs, T. H., van Genuchten, M. T., and Candela, L. (2009). A root zone modelling approach to estimating groundwater recharge from irrigated areas. Journal of Hydrology. 367, 138–149.

John, B., Das, S., and Das, R. (2023). Natural groundwater level fluctuations of Kolkata City based on seasonal field data and population growth using geo-spatial application and characterized statistical techniques. Environment, Development and Sustainability. 25, 6503–6528.

Jun, X., and Chen, Y. D. (2001). Water problems and opportunities in the hydrological sciences in China. Hydrological Sciences Journal. 46, 907–921.

Juran, L., MacDonald, M. C., Basu, N. B., Hubbard, S., Rajagopal, R., Rajagopalan, P., and Philip, L. (2017). Development and application of a multi-scalar, participant-driven water poverty index in post-tsunami India. International Journal of Water Resources Development. 33(6), 955–975. https://doi.org/10.1080/07900627.2016.1253543

Kaur, J. (2016). Water poverty index an interstate analysis of India. http://hdl.handle.net/10603/209509

Keerthana, A., and Nair, A. (2022). Trend Analysis of Hydro-Climatological Factors Using a Bayesian Ensemble Algorithm with Reasoning from Dynamic and Static Variables. Atmosphere. 13.

Khalaj, M., Kholghi, M., Saghafian, B., and Bazrafshan, J. (2019). Impact of climate variation and anthropogenic activities on groundwater quality in northwest of Iran. Journal of Water Supply: Research and Technology-Aqua. 68, 121–135.

Kim, C. S., Raza, M., Lee, J. Y., Kim, H., Jeon, C., Kim, B., Kim, J. W., and Kim, R. H. (2020). Factors Controlling the Spatial Distribution and Temporal Trend of Nationwide Groundwater Quality in Korea. Sustainability.12, 9971.

Kirby, J. M., Ahmad, M. D., Mainuddin, M., Palash, W., Quadir, M. E., Shah-Newaz, S. M., and Hossain, M. M. (2015). The impact of irrigation development on regional groundwater resources in Bangladesh. Agricultural Water Management. 159, 264–276.

Kong, F., Xu, W., Mao, R., and Liang, D. (2022). Dynamic Changes in Groundwater Level under Climate Changes in the Gnangara Region, Western Australia. Water. 14, 162.

Kookana, R. S., Maheshwari, B., Dillon, P., Dave, S. H., Soni, P., Bohra, H., Dashora, Y., Purohit, R. C., Ward, J., Oza, S., Katara, P., Yadav, K. K., Varua, M. E., Grewal, H. S., Packham, R., Jodha, A. S., and Patel, A. (2016). Groundwater scarcity impact on inclusiveness and women empowerment: Insights from school absenteeism of female students in two watersheds in India. International Journal of Inclusive Education. 20(11), 1155-1171.

Ladi T., Mahmoudpour A. and Sharifi A. (2021). Assessing impacts of the water poverty index components on the human development index in Iran. Habitat International, 113.

Lalnunmawia, C., and Lalhriatpuii, P. (2021). Assessment of Multidimensional Poverty in Aizawl District Mizoram, India. EPRA International Journal of Agriculture and Rural Economic Research (ARER)-Peer-Reviewed Journal. 9(7),13-20. https://doi.org/10.36713/epra0813

Leng, G., Huang, M., Tang, Q., Gao, H., and Leung, L. R. (2014). Modeling the Effects of Groundwater-Fed Irrigation on Terrestrial Hydrology over the Conterminous United States. Journal of Hydrometeorology. 15, 957–972.

Lin, X., Liao, Y., and Hao, Y. (2018). The burden associated with ambient PM2.5 and meteorological factors in Guangzhou, China, 2012–2016: A generalized additive modeling of temporal years of life lost. Chemosphere. 212, 705–714.

Liu, J., Gao, Z., Wang, M., Li, Y., Ma, Y., Shi, M., and Zhang, H. (2018). Study on the dynamic characteristics of groundwater in the valley plain of Lhasa City. Environmental Earth Sciences. 77, 1–15.

Liu, J., Yang, H., Gosling, S. N., Kummu, M., Flörke, M., Pfister, S., Hanasaki, N., Wada, Y., Zhang, X., Zheng, C., Alcamo, J., and Oki, T. (2017). Water scarcity assessments in the past, present, and future. Earth's Future. 5(6), 545–559. https://doi.org/10.1002/2016EF000518

Liu, W., Zhao, M., Cai, Y., Wang, R., and Lu, W. (2019). Synergetic Relationship between Urban and Rural Water Poverty: Evidence from Northwest China. International Journal of Environmental Research and Public Health. 16(9). https://doi.org/10.3390/IJERPH16091647

Liu, Z., and Liu, W. (2021). Spatial-Temporal Relationship between Water Resources and Economic Development in Rural China from a Poverty Perspective. J. Environ. Res. Public Health. 18. https://doi.org/10.3390/ijerph18041540

Lwimbo, Z. D., Komakech, H. C., and Muzuka, A. N. N. (2019). Impacts of Emerging Agricultural Practices on Groundwater Quality in Kahe Catchment, Tanzania. Water. 11, 2263.

Magombeyi, M. S., Taigbenu, A. E., and Barron, J. (2016). Rural food insecurity and poverty mappings and their linkage with water resources in the Limpopo River Basin. Physics and Chemistry of the Earth. 92, 20–33. https://doi.org/10.1016/J.PCE.2015.10.020

Mahanta, A. R., Rawat, K. S., Singh, S. K., Sanjeevi, S., and Mishra, A. K. (2022). Evaluation of long-term nitrate and electrical conductivity in groundwater system of Peninsula, India. Applied Water Science. 12, 1–20.

Marghade, D., Malpe, D. B., Duraisamy, K., Patil, P. D., and Li, P. (2021). Hydrogeochemical evaluation, suitability, and health risk assessment of groundwater in the watershed of Godavari basin, Maharashtra, Central India. Environmental Science and Pollution Research. 28, 18471–18494.

Masroor, M., Rehman, S., Sajjad, H., Rahaman, M. H., Sahana, M., Ahmed, R., and Singh, R.

(2021). Assessing the impact of drought conditions on groundwater potential in Godavari Middle Sub-Basin, India using analytical hierarchy process and random forest machine learning algorithm. Groundwater for Sustainable Development. 13.

Merz, C., and Lischeid, G. (2019). Multivariate analysis to assess the impact of irrigation on groundwater quality. Environmental Earth Sciences. 78, 1–11.

Ministry of Finance (2020) Economic Survey 2020-21. https://www.indiabudget.gov.in/economicsurvey/

Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation. (2020). Annual Report 2019-20.256. http://jalshaktidowr.gov.in/sites/default/files/AR_DoWR_RD_GR_2019-20_English.pdf

Mohanty, S. K. (2011). Multidimensional Poverty and Child Survival in India. PLoS ONE. 6(10). https://doi.org/10.1371/JOURNAL.PONE.0026857

Molle, F., and Mollinga, P. (2003). Water poverty indicators: conceptual problems and policy issues. Water Policy. 5, 529–544.

Mothkoor, V. and Badgaiyan, N. (2021). Estimates of multidimensional poverty for India using NSSO-71 and -75. WIDER Working Paper 2021/1. Helsinki: UNU-WIDER. https://doi.org/10.35188/UNU-WIDER/2021/935-8

Muenratch, P., Nguyen, T. P. L., Shrestha, S., Chatterjee, J. S., and Virdis, S. G. P. (2022). Governance and policy responses to anthropogenic and climate pressures on groundwater resources in the Greater Mekong Subregion urbanizing cities. Groundwater for Sustainable Development.18, 100791.

Nadeem, A. M., Cheo, R., and Shaoan, H. (2017). Multidimensional Analysis of Water Poverty and Subjective Well-Being: A Case Study on Local Household Variation in Faisalabad, Pakistan. Social Indicators Research. 138(1), 207–224.

Narayanamoorthy, A. (2007). Does groundwater irrigation reduce rural poverty? Evidence from Indian states. Irrigation and Drainage, 56(2–3), 349–362. https://doi.org/10.1002/IRD.307

Narjary, B., Kumar, S., Kamra, S. K., Bundela, D. S., and Sharma, D. K. (2014). Impact of precipitation variability on groundwater resources and opportunities of artificial recharge structure to reduce its exploitation in fresh groundwater zones of Haryana. Current Science. 107, 161–170.

Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., Spinoni, J., Vogt, J., and Feyen, L. (2018). Global Changes in Drought Conditions Under Different Levels of Warming. Geophysical Research Letters. 45, 3285–3296.

Nemčić-Jurec, J., Singh, S. K., Jazbec, A., Gautam, S. K., and Kovač, I. (2019). Hydrochemical investigations of groundwater quality for drinking and irrigational purposes: two case studies of Koprivnica-Križevci County (Croatia) and district Allahabad (India). Sustainable Water Resources Management. 5, 467–490.

Nishimwe-Niyimbanira, R. (2020). Income poverty versus multidimensional poverty: Empirical insight from Qwaqwa. African Journal of Science, Technology, Innovation and Development. 12(5), 631–641. https://doi.org/10.1080/20421338.2019.1638585

NITI Aayog. (2019). Composite Water Management Index In association with Ministry of Jal Shakti and Ministry of Rural Development.

Okafor, G. C., and Ogbu, K. N. (2018). Assessment of the impact of climate change on the freshwater availability of Kaduna River basin, Nigeria. Journal of Water and Land Development. 38(1), 105–114. https://doi.org/10.2478/JWLD-2018-0047

Okello, C., Tomasello, B., Greggio, N., Wambiji, N., and Antonellini, M. (2015). Impact of Population Growth and Climate Change on the Freshwater Resources of Lamu Island, Kenya. Water.7, 1264–1290.

Panda, D. K., Mishra, A., and Kumar, A. (2012). Quantification of trends in groundwater levels of Gujarat in western India. Hydrological Sciences Journal. 57, 1325–1336.

Panthi, J., Khatiwada, K. R., and Shrestha, M. (2018). Water poverty in the context of climate change: a case study from Karnali river basin in Nepal Himalaya Runoff Scenario and Water Based Adaptation Strategies in South Asia. International Journal of River Basin Management. https://doi.org/10.1080/15715124.2018.1531421

Pickering, A. J., and Davis, J. (2012). Freshwater availability and water fetching distance affect child health in sub-Saharan Africa. Environmental Science and Technology. 46(4), 2391–2397. https://doi.org/10.1021/es203177v

Popkin, B. M., D'Anci, K. E., and Rosenberg, I. H. (2010). Water, Hydration and Health. Nutrition Reviews. 68(8), 439. https://doi.org/10.1111/J.1753-4887.2010.00304.X

Portmann, F. T., Döll, P., Eisner, S., and Flörke, M. (2013). Impact of climate change on renewable groundwater resources: assessing the benefits of avoided greenhouse gas emissions using selected CMIP5 climate projections. Environmental Research Letters. 8, 024023.

Prabha, A. S., Ram, A., and Irfan, Z. B. (2020). Exploring the relative water scarcity across the Indian million-plus urban agglomerations: An application of the Water Poverty Index. HydroResearch. 3, 134–145. https://doi.org/10.1016/J.HYDRES.2020.10.001

Prajapati, R., Upadhyay, S., Talchabhadel, R., Thapa, B. R., Ertis, B., Silwal, P., and Davids, J. C. (2021). Investigating the nexus of groundwater levels, precipitation and land-use in the Kathmandu Valley, Nepal. Groundwater for Sustainable Development. 14, 100584.

PRS Legislative Research. Demand for Grants 2021-22 Analysis: Jal Shakti. Retrieved November 30, 2021, from https://prsindia.org/budgets/parliament/demand-for-grants-2021-22-analysis-jal-shakti

Rahman, A., Mondal, N. C., and Tiwari, K. K. (2021). Anthropogenic nitrate in groundwater and its health risks in the view of background concentration in a semi-arid area of Rajasthan, India. Scientific Reports.11, 1–13.

Rao, N. S , Dinakar, A., and Sun, L. (2022). Estimation of groundwater pollution levels and specific ionic sources in the groundwater, using a comprehensive approach of geochemical ratios, pollution index of groundwater, unmix model and land use/land cover – A case study. Journal of Contaminant Hydrology. 248, 103990. https://doi.org/10.1016/J.JCONHYD.2022.103990

Raskin, P., Gleick, P., Kirshen, P., Pontius, G., and Strzepek, K. (1997). Water futures: Assessment of long-range patterns and problems. Stockholm: Swedish Environment Institute/United Nations

Rijsberman, F. R. (2006). Water scarcity: Fact or fiction? Agricultural Water Management. 80(1-3), 5–22. https://doi.org/10.1016/J.AGWAT.2005.07.001

Ritchie H. and Roser M. (2017). Water Use and Stress. https://ourworldindata.org/water-use-stress

Rosinger, A. Y., Young, S. L., Asher, C., and Rosinger, Y. (2020). The toll of household water insecurity on health and human biology: Current understandings and future directions. Wiley Interdisciplinary Reviews: Water. 7(6), e1468. https://doi.org/10.1002/WAT2.1468

Rotiroti, M., Bonomi, T., Sacchi, E., McArthur, J. M., Stefania, G. A., Zanotti, C., Taviani, S., Patelli, M., Nava, V., Soler, V., Fumagalli, L., and Leoni, B. (2019). The effects of irrigation on groundwater quality and quantity in a human-modified hydro-system: The

Oglio River basin, Po Plain, northern Italy. Science of The Total Environment. 672, 342–356.

Roy, S. , Rahman, A., Ahmed, S., Shahfahad, and Ahmad, I. A. (2022). Long-term trends of groundwater level variations in response to local level land use land cover changes in Mumbai, India. Groundwater for Sustainable Development.18.

Sachs, J. D., Kroll, C., Lafortune, G., Fuller, G., and Woelm, F. (2021). Sustainable Development Report 2021. https://doi.org/10.1017/9781108992411

Sadath, A. C., and Acharya, R. H. (2017). Assessing the extent and intensity of energy poverty using Multidimensional Energy Poverty Index: Empirical evidence from households in India. Energy Policy. 102, 540–550. https://doi.org/10.1016/j.enpol.2016.12.056

Sahoo, S., Swain, S., Goswami, A., Sharma, R., and Pateriya, B. (2021). Assessment of trends and multi-decadal changes in groundwater level in parts of the Malwa region, Punjab, India. Groundwater for Sustainable Development.14, 100644.

Sarkar, T., Kannaujiya, S., Taloor, A. K., Champati Ray, P. K., and Chauhan, P. (2020). Integrated study of GRACE data derived interannual groundwater storage variability over water stressed Indian regions. Groundwater for Sustainable Development. 10, 100376.

Savenije, H. H. G. (2000). Water scarcity indicators; the deception of the numbers. Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere. 25(3), 199–204. https://doi.org/10.1016/S1464-1909(00)00004-6

Schewe, J., Heinke, J., Gerten, D., Haddeland, I., Arnell, N. W., Clark, D. B., Dankers, R., Eisner, S., Fekete, B. M., Colón-González, F. J., Gosling, S. N., Kim, H., Liu, X., Masaki, Y., Portmann, F. T., Satoh, Y., Stacke, T., Tang, Q., Wada, Y., … Kabat, P. (2014). Multimodel assessment of water scarcity under climate change. Proceedings of the

National Academy of Sciences of the United States of America. 111(9), 3245–3250. https://doi.org/10.1073/PNAS.1222460110/SUPPL_FILE/SAPP.PDF

Sen, A. (2000). Social Exclusion: Concept, Application and Scrutiny. Asian Development Bank. http://hdl.handle.net/11540/2339.

Shah, T. (2009). Climate change and groundwater: India's opportunities for mitigation and adaptation. Environmental Research Letters. 4.

Shalamzari, M. J., and Zhang, W. (2018). Assessing Water Scarcity Using the Water Poverty Index (WPI) in Golestan Province of Iran. Water .10(8), 1079. https://doi.org/10.3390/W10081079

Sharan, A., Lal, A., and Datta, B. (2023). Evaluating the impacts of climate change and water over-abstraction on groundwater resources in Pacific Island country of Tonga. Groundwater for Sustainable Development. 20, 100890.

Sheffield, J., Wood, E. F., Pan, M., Beck, H., Coccia, G., Serrat-Capdevila, A., and Verbist, K. (2018). Satellite Remote Sensing for Water Resources Management: Potential for Supporting Sustainable Development in Data-Poor Regions. Water Resources Research. 54(12), 9724–9758. https://doi.org/10.1029/2017WR022437

Silva, M. M. V. G., Gomes, E. M. C., Isaías, M., Azevedo, J. M. M., and Zeferino, B. (2017). Spatial and seasonal variations of surface and groundwater quality in a fast-growing city: Lubango, Angola. Environmental Earth Sciences.76, 1–17.

Singh, A. P., and Bhakar, P. (2021). Development of groundwater sustainability index: a case study of western arid region of Rajasthan, India. Environment, Development and Sustainability. 23, 1844–1868.

Singh, R. B., and Kumar, A. (2015). Climate variability and water resource scarcity in drylands of

Rajasthan, India. Geo-environmental Disasters. 2, 1–10.

Sishodia, R. P., Shukla, S., Graham, W. D., Wani, S. P., and Garg, K. K. (2016). Bi-decadal groundwater level trends in a semi-arid south indian region: Declines, causes and management. Journal of Hydrology: Regional Studies. 8, 43–58.

Streeten P., Burki S.J., Ul-Haq M., Hicks N., and Stewart F. (1981). First Things First: Meeting Basic Human Needs in Developing Countries. OUP Catalogue, Oxford University Press, number 9780195203691.

Sullivan, C. (2002). Calculating a Water Poverty Index. World Development. 30(7), 1195–1210. https://doi.org/10.1016/S0305-750X(02)00035-9

Sullivan, C. A., Meigh, J. R., and Giacomello, A. M. (2003). The Water Poverty Index: Development and application at the community scale. Natural Resources Forum. 27(3), 189–199. https://doi.org/10.1111/1477-8947.00054

Sullivan, C., Meigh, J., and Lawrence, P. (2009). Application of the Water Poverty Index at Different Scales: A Cautionary Tale. Water International. 31(3), 412–426. https://doi.org/10.1080/02508060608691942

Swain, S., Dayal, D., Pandey, A., and Mishra, S. K. (2019). Trend analysis of precipitation and temperature for Bilaspur District, Chhattisgarh, India. World environmental and water resources congress 2019: groundwater, sustainability, Hydro-climate/climate change, and environmental engineering. Reston, VA: American Society of Civil Engineers, 193-204.

Swain, S., Mishra, S. K., and Pandey, A. (2021). A detailed assessment of meteorological drought characteristics using simplified rainfall index over Narmada River Basin, India. Environmental Earth Sciences. 80, 221.

Swain, S., Mishra, S. K., and Pandey, A. (2022). Assessing spatiotemporal variation in drought characteristics and their dependence on timescales over Vidarbha Region, India. Geocarto International. 37, 17971-17993.

Swain, S., Mishra, S. K., Pandey, A., and Dayal, D. (2022). Assessment of drought trends and variabilities over the agriculture-dominated Marathwada Region, India. Environmental Monitoring and Assessment. 194, 883.

Swain, S., Mishra, S. K., Pandey, A., and Dayal, D. (2022). Spatiotemporal assessment of precipitation variability, seasonality, and extreme characteristics over a Himalayan catchment. Theoretical and Applied Climatology. 147, 817-833.

Swain, S., Mishra, S. K., Pandey, A., and Kalura, P. (2022). Inclusion of groundwater and socio-economic factors for assessing comprehensive drought vulnerability over Narmada River Basin, India: A geospatial approach. Applied Water Science. 12, 14.

Swain, S., Mishra, S. K., Pandey, A., Dayal, D., and Srivastava, P. K. (2022). Appraisal of historical trends in maximum and minimum temperature using multiple non-parametric techniques over the agriculture-dominated Narmada Basin, India. Environmental Monitoring and Assessment. 194, 893.

Swain, S., Mishra, S. K., Pandey, A., Srivastava, P. K., and Nandi, S. (2023). Characterization and assessment of hydrological droughts using GloFAS streamflow data for the Narmada River Basin, India. Environmental Science and Pollution Research. 1-14.

Swain, S., Sahoo, S., and Taloor, A. K. (2022). Groundwater quality assessment using geospatial and statistical approaches over Faridabad and Gurgaon districts of National Capital Region, India. Applied Water Science. 12, 75.

Swain, S., Sahoo, S., Taloor, A. K., Mishra, S. K., and Pandey, A. (2022). Exploring recent groundwater level changes using Innovative Trend Analysis (ITA) technique over three districts of Jharkhand, India. Groundwater for Sustainable Development. 18, 100783.

Swain, S., Taloor, A. K., Dhal, L., Sahoo, S., and Al-Ansari, N. (2022). Impact of climate change on groundwater hydrology: a comprehensive review and current status of the Indian hydrogeology. Applied Water Science. 12, 120.

Swain, S., Taloor, A. K., Dhal, L., Sahoo, S., and Al-Ansari, N. (2022). Impact of climate change on groundwater hydrology: a comprehensive review and current status of the Indian hydrogeology. Applied Water Science. 12, 1–25.

Tanwer, N., Deswal, M., Khyalia, P., Laura, J. S., and Khosla, B. (2023). Assessment of groundwater potability and health risk due to fluoride and nitrate in groundwater of Churu District of Rajasthan, India. Environmental Geochemistry and Health. 1–23.

Taşan, M., Demir, Y., and Taşan, S. (2022). Groundwater quality assessment using principal component analysis and hierarchical cluster analysis in Alaçam, Turkey. Water Supply. 22, 3431–3447.

Thakur J.K., Neupane M. and Mohanan A. A. (2017). Water poverty in upper Bagmati River Basin in Nepal. Water Science. 31 (1), 93-108. https://doi.org/10.1016/j.wsj.2016.12.

The Hindu. (2021). Data | Floods, droughts, and cyclones have become more frequent in India since 2000.The Hindu. https://www.thehindu.com/data/floods-droughts-and-cyclones-have-become-more-frequent-in-india-since-2000/article33521312.ece

Tian, L., Zhu, X., Wang, L., Du, P., Peng, F., and Pang, Q. (2020). Long-term trends in water quality and influence of water recharge and climate on the water quality of brackish-water lakes: A case study of Shahu Lake. Journal of Environmental Management. 276, 111290. https://doi.org/10.1016/J.JENVMAN.2020.111290

Tirogo, J., Jost, A., Biaou, A., Valdes-Lao, D., Koussoubé, Y., and Ribstein, P. (2016). Climate Variability and Groundwater Response: A Case Study in Burkina Faso (West Africa). Water. 8, 171.

Tiwari, K. K., Krishan, G., Anjali, Prasad, G., Mondal, N. C., and Bhardwaj, V. (2020). Evaluation of fluoride contamination in groundwater in a semi-arid region, Dausa District, Rajasthan, India. Groundwater for Sustainable Development. 11.

Touhami, I., Chirino, E., Andreu, J. M., Sánchez, J. R., Moutahir, H., and Bellot, J. (2015). Assessment of climate change impacts on soil water balance and aquifer recharge in a semiarid region in south east Spain. Journal of Hydrology. 527, 619–629.

Tran, Q. K., Schwabe, K. A., and Jassby, D. (2016). Wastewater reuse for agriculture: Development of a regional water reuse decision-support model (RWRM) for cost-effective irrigation sources. Environmental Science and Technology. 50, 9390–9399.

Tripathi, S. S., and Issac, R. K. (2016). Precipitation Pattern and Groundwater Fluctuation in Ramganga River Basin at Bareilly District, Uttar Pradesh, India. International Journal of Advanced Engineering, Management and Science. 2.

UN. (2021). The United Nations World Water Development Report 2021: Valuing water. UNESCO, Paris. https://unesdoc.unesco.org/ark:/48223/pf0000375724

UNDP (2015). Water Governance for Poverty Reduction. Retrieved March 11, 2022, from https://www.undp.org/publications/water-governance-poverty-reduction

UNESCO. (2019). The United Nations world water development report 2019: leaving no one behind. UNESCO Digital Library, 201.

UNESCO. (2020). Water and climate change - UNESCO Digital Library. Retrieved May 10, 2022, from https://unesdoc.unesco.org/ark:/48223/pf0000372985.locale=en

UNESCO. (2020). Water resources an essential part of the solution to climate change. Retrieved May 19, 2022, from https://en.unesco.org/news/water-resources-essential-part-solution-climate-change

UNESCO. (2021). Valuing water - The United Nations World Water Development Report 2021. Water Politics, 206. https://unesdoc.unesco.org/ark:/48223/pf0000375724

United Nations (UN). (2023). Water-related diseases responsible for 80 percent of all illnesses, deaths in the developing world. https://press.un.org/en/2003/sgsm8707.doc.htm#:~:text=Water%2Drelated%20diseases%20kill%20a,these%20diseases%20are%20easily%20preventable. (accessed 13 July 2023).

United Nations Office for Disaster Risk Reduction (UNDRR). (2021). GAR Special Report on Drought 2021. UNDRR. https://www.undrr.org/publication/gar-special-report-drought-2021

Usman, M. A., Gerber, N., and von Braun, J. (2019). The Impact of Drinking Water Quality and Sanitation on Child Health: Evidence from Rural Ethiopia. Journal of Development Studies. 55(10), 2193–2211. https://doi.org/10.1080/00220388.2018.1493193

Wakejo, W. K., Meshesha, B. T., Habtu, N. G., and Mekonnen, Y. G. (2022). Anthropogenic nitrate contamination of water resources in Ethiopia: an overview. Water Supply. 22, 8157–8172.

Wang, L., Zeng, X., and Yu, H. (2022). Association between Lake Sediment Nutrients and Climate Change, Anthropogenic Activities: A Time-Series Analysis. Environmental Management. 70, 117–133.

Wu, J., Wang, L., Wang, S., Tian, R., Xue, C., Feng, W., and Li, Y. (2017). Spatiotemporal variation of groundwater quality in an arid area experiencing long-term paper wastewater irrigation, northwest China. Environmental Earth Sciences. 76, 1–14.

Yadav, V., and Ibrar, Z. (2022). Relationship of Water Stress and Flood Damage for Sustainable Development. Water Resources Management. 36, 1323-1338. https://doi.org/10.1007/S11269-022-03083-7

Zacchaeus, O. O., Adeyemi, M. B., Azeem Adedeji, A., Adegoke, K. A., Anumah, A. O., Taiwo, A. M., and Ganiyu, S. A. (2020). Effects of industrialization on groundwater quality in Shagamu and Ota industrial areas of Ogun state, Nigeria. Heliyon. 6, e04353.

Zavareh, M., Maggioni, V., and Sokolov, V. (2021). Investigating Water Quality Data Using Principal Component Analysis and Granger Causality. Water. 13, 343.

Zhang, J., and Xu, L. C. (2016). The long-run effects of treated water on education: The rural drinking water program in China. Journal of Development Economics. 122, 1–15.

Zhang, J., Zhi, M., and Zhang, Y. (2021). Combined Generalized Additive model and Random Forest to evaluate the influence of environmental factors on phytoplankton biomass in a large eutrophic lake. Ecological Indicators. 130, 108082.

Zhao, Z., Jia, Z., Guan, Z., and Xu, C. (2019). The Effect of Climatic and Non-climatic Factors on Groundwater Levels in the Jinghuiqu Irrigation District of the Shaanxi Province, China. Water. 11, 956.

Zhou, S., Huang, Y., Yu, B., and Wang, G. (2015). Effects of anthropogenic activities on the eco-environment in the middle Heihe River Basin based on an extended environmental Kuznets curve model. Ecological Engineering. 76, 14–26.

APPENDIX

Chapter 3

Table 3.1: Region-wise Specification of Districts in Rajasthan				
North-Eastern	Western	South-Eastern	Northern	Southern
Alwar	Bikaner	Bundi	Sri Ganganagar	Rajsamand
Bharatpur	Jodhpur	Chittaurgarh	Hanumangarh	Dungarpur
Dhaulpur	Jaisalmer	Kota	Churu	Banswara
Karauli	Barmer	Baran	Jhunjhunun	Udaipur
Sawai Madhopur	Jalor	Jhalawar	Sikar	
Dausa	Sirohi	Pratapgarh	Nagaur	
Jaipur	Pali			
Ajmer				
Tonk				
Bhilwara				

Table 3.2: District wise Resource component score						
District	Resource (Index value)		Frequency of water supply (Index value)		Water insufficiency (in percentage)	
	2012	2018	2012	2018	2012	2018
Ajmer	0.89	0.55	0.92	0.41	15.10	27.91
Alwar	0.86	0.82	0.97	0.72	13.95	6.82
Banswara	0.85	0.71	0.97	0.43	25.83	0.69
Baran	0.81	0.71	1.00	0.46	26.39	3.13
Barmer	0.80	0.53	0.76	0.39	33.33	32.14
Bharatpur	1.00	0.75	1.00	0.51	2.08	2.60
Bhilwara	0.55	0.71	0.81	0.63	47.62	19.05
Bikaner	0.92	0.73	0.97	0.79	20.14	30.73
Bundi	0.74	0.65	0.97	0.56	48.61	29.17
Chittaurgarh	0.88	0.54	0.98	0.60	23.81	47.50
Churu	0.73	0.82	0.97	0.80	50.83	15.57
Dausa	0.85	0.69	0.95	0.38	22.11	0.83
Dhaulpur	1.00	0.74	0.99	0.54	1.04	6.25
Dungarpur	0.82	0.34	0.97	0.38	19.79	60.83
Hanumangarh	0.89	0.74	0.98	0.83	14.58	36.81
Jaipur	0.92	0.79	0.99	0.76	16.67	15.37
Jaisalmer	0.53	0.55	0.72	0.50	28.13	36.11
Jalor	0.93	0.74	0.87	0.52	0.83	4.17
Jhalawar	0.61	0.64	0.98	0.56	67.71	28.13
Jhunjhunun	0.94	0.87	1.00	0.76	10.83	2.98
Jodhpur	0.89	0.65	0.88	0.51	6.51	20.83
Karauli	0.63	0.48	0.91	0.59	59.38	62.50
Kota	0.84	0.79	0.99	0.77	25.69	15.63
Nagaur	0.74	0.62	0.86	0.53	34.72	30.00
Pali	0.78	0.71	0.83	0.56	22.50	13.19
Pratapgarh	0.72	0.43	0.87	0.19	36.11	31.94

Rajsamand	0.79	0.66	0.93	0.59	16.13	25.00
Sawai Madhopur	0.78	0.32	1.00	0.40	48.61	75.00
Sikar	0.94	0.79	1.00	0.70	9.52	11.46
Sirohi	0.93	0.54	0.91	0.39	4.17	29.17
Sri Ganganagar	0.75	0.77	0.93	0.63	40.83	9.03
Tonk	0.86	0.82	0.98	0.73	19.79	7.29
Udaipur	0.91	0.51	0.91	0.31	17.59	27.08
Source: Authors' calculation						

Table 3.3: Index value of MWPI components

District	Access to secondary sources of water (in percentage)		Presence of stagnant water around the source of drinking water (in percentage)		Access (Index value)	
	2012	2018	2012	2018	2012	2018
Ajmer	45.31	59.07	33.87	10.23	0.69	0.89
Alwar	14.42	62.50	8.06	23.86	0.78	0.87
Banswara	25.83	38.89	15.48	0.69	0.87	0.95
Baran	27.78	47.92	45.10	40.63	0.72	0.88
Barmer	44.17	42.26	25.71	1.19	0.46	0.62
Bharatpur	0.00	52.60	32.46	7.81	0.66	0.80
Bhilwara	54.76	70.24	30.23	16.67	0.80	0.86
Bikaner	17.36	45.83	0.00	0.52	0.56	0.82
Bundi	50.00	66.67	45.28	43.06	0.85	0.78
Chittaurgarh	40.48	70.00	48.57	13.33	0.62	0.93
Churu	55.00	30.54	19.05	7.19	0.72	0.74
Dausa	21.05	40.83	50.82	5.00	0.73	0.85
Dhaulpur	0.00	87.50	39.34	29.17	0.76	0.87
Dungarpur	30.21	85.00	30.99	20.00	0.90	0.96
Hanumangarh	27.08	43.06	6.67	0.69	0.85	0.89
Jaipur	14.58	33.07	21.43	14.59	0.69	0.93
Jaisalmer	32.29	25.00	31.58	29.17	0.66	0.76
Jalor	19.17	6.25	73.68	17.36	0.51	0.67
Jhalawar	67.71	44.79	77.11	27.08	0.72	0.84
Jhunjhunun	20.00	33.93	0.00	7.74	0.78	0.82
Jodhpur	16.28	36.11	47.27	0.69	0.77	0.85
Karauli	61.46	100.00	30.77	13.54	0.78	0.87
Kota	23.61	36.98	64.81	12.50	0.83	0.95
Nagaur	58.80	61.67	47.50	5.00	0.73	0.81
Pali	39.17	31.94	71.15	6.94	0.50	0.68
Pratapgarh	47.22	50.00	18.52	0.00	0.79	0.84
Rajsamand	41.94	78.13	54.55	6.25	0.51	0.88
Sawai Madhopur	61.11	97.92	55.10	31.25	0.88	0.74

Sikar	10.71	51.56	4.35	1.04	0.81	0.90
Sirohi	20.83	25.00	17.14	12.50	0.86	0.96
Sri Ganganagar	52.50	17.36	0.00	0.69	0.64	0.80
Tonk	21.88	77.08	71.19	13.54	0.82	0.82
Udaipur	43.52	61.25	8.40	3.75	0.73	0.90
Source: Authors' calculation						

Table 3.4: Index value of Access components

District	Distance travelled to fetch water (Index value)		Time taken to fetch water (index value)		Access to safe water source (in percentage)		Access to improve sanitation (in percentage)	
	2012	2018	2012	2018	2012	2018	2012	2018
Ajmer	0.79	0.88	0.82	0.96	84.38	83.72	96.00	87.71
Alwar	0.78	0.91	0.88	0.95	95.35	95.83	78.13	67.03
Banswara	0.72	0.85	0.84	0.96	89.17	99.31	100.00	89.19
Baran	0.74	0.88	0.78	0.94	83.33	96.88	54.17	70.93
Barmer	0.68	0.78	0.81	0.89	54.17	74.40	2.78	8.85
Bharatpur	0.69	0.87	0.79	0.91	79.86	82.81	57.14	63.85
Bhilwara	0.68	0.89	0.85	0.97	69.64	89.88	75.38	68.83
Bikaner	0.87	0.95	0.83	0.97	82.64	84.90	92.68	50.28
Bundi	0.75	0.82	0.73	0.94	100.00	83.33	90.91	60.38
Chittaurgarh	0.79	0.73	0.89	0.90	96.43	96.67	96.88	95.71
Churu	0.77	0.93	0.81	0.97	96.67	83.23	62.16	29.03
Dausa	0.74	0.92	0.88	0.98	96.84	95.00	60.00	47.89
Dhaulpur	0.76	0.82	0.81	0.86	90.63	100.00	81.82	71.19
Dungarpur	0.70	0.85	0.82	0.93	94.79	94.17	97.06	100.00
Hanumangarh	0.74	0.96	0.84	0.94	76.04	91.67	86.36	75.00
Jaipur	0.82	0.95	0.85	0.98	90.28	96.50	79.14	79.65
Jaisalmer	0.56	0.85	0.85	0.89	64.58	100.00	50.00	29.27
Jalor	0.78	0.87	0.84	0.92	85.83	91.67	76.47	0.00
Jhalawar	0.61	0.85	0.80	0.93	93.75	88.54	69.23	62.69
Jhunjhunun	0.81	0.93	0.80	0.97	82.50	91.07	44.59	39.06
Jodhpur	0.67	0.95	0.85	0.98	72.09	88.54	83.33	54.79
Karauli	0.67	0.88	0.84	0.92	82.29	96.88	81.25	60.00
Kota	0.83	0.96	0.86	0.97	100.00	98.96	92.86	82.61
Nagaur	0.76	0.91	0.83	0.98	64.35	67.08	99.12	59.57
Pali	0.59	0.81	0.80	0.90	69.17	90.28	39.47	4.24
Pratapgarh	0.61	0.79	0.80	0.91	62.50	80.56	81.82	71.43
Rajsamand	0.72	0.88	0.89	0.93	83.87	98.96	100.00	65.63

Sawai Madhopur	0.70	0.86	0.85	0.92	100.00	80.21	58.82	32.88
Sikar	0.86	0.97	0.89	0.99	98.81	96.88	70.00	64.08
Sirohi	0.78	0.83	0.89	0.96	97.22	94.44	81.08	100.00
Sri Ganganagar	0.84	1.00	0.89	1.00	96.67	75.00	35.19	45.77
Tonk	0.75	0.86	0.89	0.93	98.96	100.00	96.30	50.00
Udaipur	0.74	0.82	0.84	0.95	81.94	78.75	100.00	88.41
Source: Authors' calculation								

Table 3.5: District wise Capacity component score

District	Capacity (Index value)		Income (Index value)		Water-related illness (in percentage)	
	2012	2018	2012	2018	2012	2018
Ajmer	0.19	0.22	0.01	0.02	63.02	59.07
Alwar	0.24	0.19	0.01	0.02	53.95	62.12
Banswara	0.09	0.02	0.01	0.01	83.33	96.53
Baran	0.16	0.17	0.01	0.02	68.06	63.54
Barmer	0.39	0.46	0.01	0.02	22.50	8.93
Bharatpur	0.18	0.23	0.01	0.02	65.28	49.48
Bhilwara	0.10	0.26	0.01	0.02	80.36	47.02
Bikaner	0.09	0.21	0.01	0.02	81.94	52.60
Bundi	0.16	0.14	0.01	0.02	68.06	70.83
Chittaurgarh	0.29	0.15	0.01	0.02	42.86	66.67
Churu	0.28	0.28	0.01	0.03	44.17	40.72
Dausa	0.16	0.08	0.01	0.02	69.47	84.17
Dhaulpur	0.19	0.17	0.01	0.02	63.54	63.54
Dungarpur	0.15	0.13	0.01	0.02	70.83	71.67
Hanumangarh	0.15	0.23	0.01	0.02	70.83	55.56
Jaipur	0.26	0.21	0.01	0.03	48.26	60.12
Jaisalmer	0.22	0.41	0.01	0.02	56.25	16.67
Jalor	0.24	0.45	0.01	0.02	52.50	12.50
Jhalawar	0.14	0.11	0.00	0.02	72.92	78.13
Jhunjhunun	0.25	0.38	0.01	0.02	50.83	25.00
Jodhpur	0.29	0.42	0.01	0.03	42.33	18.86
Karauli	0.06	0.08	0.01	0.02	88.54	83.33
Kota	0.25	0.18	0.01	0.03	51.39	59.38
Nagaur	0.30	0.20	0.01	0.02	40.28	58.33
Pali	0.24	0.30	0.01	0.02	53.33	41.26
Pratapgarh	0.23	0.18	0.01	0.02	54.17	58.33
Rajsamand	0.30	0.16	0.01	0.02	40.32	66.67
Sawai Madhopur	0.09	0.14	0.01	0.02	83.33	71.88
Sikar	0.30	0.22	0.01	0.02	41.67	58.85
Sirohi	0.22	0.03	0.01	0.02	56.94	94.44

Sri Ganganagar	0.22	0.20	0.01	0.02	56.67	54.86
Tonk	0.17	0.06	0.01	0.02	67.71	86.32
Udaipur	0.22	0.09	0.01	0.02	56.48	80.42
Source: Authors' calculation						

Figure 3.6: District-wise MWPI score (average) using PCA

District	2012	2018
Ajmer	0.63	0.70
Alwar	0.62	0.74
Banswara	0.51	0.73
Baran	0.58	0.69
Barmer	0.69	0.60
Bharatpur	0.51	0.69
Bhilwara	0.58	0.73
Bikaner	0.43	0.69
Bundi	0.61	0.63
Chittaurgarh	0.51	0.71
Churu	0.62	0.68
Dausa	0.51	0.66
Dhaulpur	0.44	0.75
Dungarpur	0.65	0.74
Hanumangarh	0.63	0.71
Jaipur	0.62	0.72
Jaisalmer	0.49	0.65
Jalor	0.45	0.63
Jhalawar	0.49	0.63
Jhunjhunun	0.73	0.72
Jodhpur	0.64	0.72
Karauli	0.61	0.67
Kota	0.63	0.75
Nagaur	0.71	0.67
Pali	0.55	0.62
Pratapgarh	0.63	0.66
Rajsamand	0.51	0.73
Sawai Madhopur	0.47	0.62
Sikar	0.63	0.74
Sirohi	0.69	0.65
Sri Ganganagar	0.59	0.66
Tonk	0.67	0.70
Udaipur	0.64	0.69
Source: Authors' calculation		

Chapter 4

Table 4.1: Location of selected wells/piezometers for groundwater level		
	Longitude	Latitude
Tonk		
Arniyalmal	75.8083	26.0583
Bantholi	75.5667	25.8833
Dewal1	75.1875	26.2383
Dikoliya	75.9661	25.975
Hamirpur	75.575	26.1833
Jaisinghpur	75.4875	26.3917
Mahuva	75.6833	25.9986
Malpura	75.3833	26.2833
Nayagaon	75.8889	26.0408
Ramthala	75.2806	25.8639
Sohela	75.85	26.2417
Todarsingh	75.4889	26.0139
Jaipur		
Durgapura	75.7889	26.8417
Chaksu	75.95	26.6
Amber	75.8667	26.9833
Kalwad	75.6	26.975
Jhotwara	75.7444	26.9433
Mozmabad	75.3625	26.6833
Mes Jaipur	75.7792	26.9333
Dawach	75.7542	26.5672
Mangarwara	75.2778	26.61
Rasala	76.205	27.1167

Nasnota	75.4333	26.8
Tigaria	75.7733	27.2919
Thalli	75.8861	26.6125
Goner	75.9083	26.6792
Sirohikhurd	75.15	26.7917
Shivdaspura	75.9006	26.7136
Pallukhurd	75.3	26.7361
Jodhpur		
Bujawar	72.9083	26.225
Karani	72.825	26.2722
Mandore	73.0417	26.35
Raron Ki Dhani	72.775	26.1944
Devatra	73.3778	26.5103
Jodhpur	73.0333	26.3
Bhawi	73.1792	26.1078
Chopasni Nath	72.9333	26.275
Cazri	73	26.2667
Bhimkam Kaur	72.7936	26.8
Benan	73.4208	26.3167
Naran Ki Dhani	72.9083	26.2444
Dangiwas	73.2833	26.2667
Bap	72.35	27.3667
Bari Dhani	72.3194	27.3417
Dhawa	72.7417	26.0583
Ramrawas	73.3458	26.3694
Sajjara	73.2472	26.1139
Kalpan	72.2458	27.0667

Kapuria	73.0589	26.9367
Lordi	72.8333	26.3111
Kolu	72.3	26.9167
Kangik Sirdi	72.475	27.4875
Jatyansani	72.8333	26.0917
Ajmer		
Ajagara	75.1	26.0333
Arian	75.0667	26.45
Baglias	74.2	25.9083
Jawaja	74.2	25.9333
Jhopadiyan	74.6583	26.025
Kanpur	74.8667	26.4
Ludiyana	74.5833	25.9972
Masuda	74.5125	26.0917
Narbadkhera	74.2833	26.05
Nasirabad	74.7403	26.2867
Sanpla	75.0417	25.9111
Taragarh	74.15	25.8833
Pakhriawas	74.4167	26.1
Ramsar	74.8333	26.2667
Bogla	75.2333	25.8333
Kalyanpura	74.8022	26.1411
Ghugra	74.6917	26.5042
Dausa		
Bapi	76.2917	26.975
Lawan	76.2167	26.7833
Mahuwa	76.95	27.075

Sikandara	76.5792	26.9667
Prahladpura	76.2	26.6833
Bhandarej	76.4	26.9167
Garh Ranoli	76.5097	26.8125
Dausa	76.325	26.8958
Gijgarh	76.6431	26.8847
Barmer		
Bachhbar	70.9583	25.7417
Balewa	70.875	25.9153
Barmer	71.3972	25.7361
Bisala	71.2417	25.9083
Bisukalan	71.3056	26.275
Chohtan	71.0667	25.475
Derasar	70.1583	25.9181
Devra	72.5167	25.7333
Doli	72.6667	26.0667
Hathitala	71.3986	25.5744
Jasai	71.2556	25.7167
Jawansingh Ki Ber	70.9833	26.0667
Kateria	71.4542	25.1583
Matasar	71.6	25.7917
Nand	71.1167	25.9833
Nimri	71.2833	25.6083
Padmaniyon	71.4	25.3458
Panavada	71.7792	26.0292
Panchla	70.1667	25.9917
Patrasar	71.2236	25.6778

Redana	70.9389	25.8458
Sanawara	71.4	25.4833
Sanlor	71.2333	25.5958
Sasion Ka Kua	71.4125	25.7042
Saupadamsingh	71.825	26.2
Sihani	71.0833	25.775
Siyaga Tala	70.8653	25.3375
Sutharon ki dha	71.0389	25.8083
Thob	72.3583	26.05
Gujro ka Bera	71.5556	26.3383
Kashmir	71.6056	26.2597
Sindari	71.9	25.5667
Piparli Gaon	71.5889	25.1222
Adel	71.7083	25.425
Source: Authors' construction		

Table 4.2: Location of selected wells/piezometers for groundwater quality		
	Longitude	Latitude
Ajmer		
Ajagara	75.1	26.03333
Arian	75.06667	26.45
Baglias	74.2	25.90833
Barora	75.03611	26.2125
Bogla	75.23333	25.83333
Dasuk	75.13333	26.41667
Goelo	74.92778	26.12917
Jawaja1	74.2	25.93333

Jhopadiyan	74.65833	26.025
Kanpur1	74.86667	26.4
Kekri1	75.15	25.98333
Lamana	74.49167	26.23333
Ludiyana	74.58333	25.99722
Masuda1	74.5125	26.09167
Nasirabad	74.74028	26.28667
Pakhriawas	74.41667	26.1
Ramgarh2	74.83333	26.26667
Sanpla	75.04167	25.91111
Sarwad	75	26.05
Tabiji	74.61667	26.4
Taragarh	74.15	25.88333
Jaipur		
Amber	75.86667	26.98333
Bassi2	76.06667	26.83333
Chaksu	75.95	26.6
Dawach	75.75417	26.56722
Goner	75.90833	26.67917
Kalwad	75.6	26.975
Mangarwara	75.27778	26.61
Mozmabad	75.3625	26.68333
Nasnota	75.43333	26.8
Rasala	76.205	27.11667
Shivdaspura	75.90056	26.71361
Thalli	75.88611	26.6125
Tigaria	75.77333	27.29174

Barmer		
Panchla	70.16667	25.99167
Bachhbar	70.95833	25.74167
Balewa	70.875	25.91528
Balotra1	72.25833	25.82917
Barmer1	71.39722	25.73611
Bisala	71.24167	25.90833
Chohtan	71.06667	25.475
Devra	72.51667	25.73333
Doli	72.66667	26.06667
Gadra Road	70.63889	25.74028
Jasai	71.25556	25.71667
Kuri2	72.36861	25.94167
Nand	71.11667	25.98333
Patrasar	71.22361	25.67778
Redana	70.93889	25.84583
Sanawara	71.4	25.48333
Sanlor	71.23333	25.59583
Sihani	71.08333	25.775
Sihaniya	71.15	24.92222
Tarla	71.21667	24.88333
Jodhpur		
Bap1	72.35	27.36667
Cazri	73	26.26667
Chopasni Nath	72.93333	26.275
Dangiwas	73.28333	26.26667
Devatra	73.37778	26.51028

Dharmi	73.64167	26.7375
Dhawa	72.74167	26.05833
Jatyasani	72.83333	26.09167
Jodhpur	73.03333	26.3
Karani	72.825	26.27222
Kumbhariya	73.5375	26.7375
Mandawar1	73.04167	26.35
Osian1	72.91667	26.725
Piparcity	73.53	26.388
Tonk		
Aligarh	76.08333	25.96667
Arniyalmal	75.80833	26.05833
Bantholi	75.56667	25.88333
Dikoliya	75.96611	25.975
Hamirpur	75.575	26.18333
Jainagar	76.23278	25.81667
Mahuva	75.68333	25.99861
Malpura1	75.38333	26.28333
Nayagaon	75.88889	26.04083
Niwai1	75.93333	26.36667
Ramthala	75.28056	25.86389
Sohela	75.85	26.24167
Dausa		
Mahuwa	76.95	27.075
Dausa1	76.325	26.89583
Bhandarej	76.4	26.91667
Bapi	76.29167	26.975

Source: Authors' construction

Table 4.3: Descriptive statistics of wells/piezometers (mbgl) : DGWL

Annual	Mean	SD	CV	Kurtosis	Skewness	**Winter**	Mean	SD	CV	Kurtosis	Skewness
Kalpan	82.2	12.9	15.7	-0.9	0.9	Kalpan	78.3	9.7	12.4	2.7	1.6
Gujro ka Bera	75.7	8.3	10.9	-1.1	0.4	Gujroka bera	75.5	8.4	11.1	-1.1	0.6
Kapuria	72.9	2.8	3.8	-1.1	0.9	Kapuria	72.3	2.7	3.8	0.1	1.4
Siyaga Tala	66.5	2.5	3.7	1.0	-0.1	Siyaga	66.0	1.8	2.8	0.7	-0.2
Padmaniyon	58.8	10.7	18.2	22.0	-4.3	Padmaniyon	60.2	4.0	6.7	9.5	1.9
Jhotwara	57.1	12.9	22.5	-1.4	-0.4	Jhotwara	55.8	13.8	24.7	-1.6	-0.3
Kashmir	53.6	6.2	11.6	-1.0	0.5	Kashmir	52.5	5.6	10.6	-1.0	0.6
Hathitala	50.6	1.1	2.2	3.8	1.8	Hathitala	50.5	0.7	1.4	2.0	1.2
Chohtan	50.2	2.6	5.2	-0.2	0.4	Chohtan	48.8	3.9	8.0	1.7	-0.5
Kolu	48.7	13.1	27.0	-0.4	1.0	Kolu	45.8	10.6	23.1	1.3	1.4
Prahladpura	46.7	12.3	26.4	-1.0	-0.1	Sanawara	45.2	1.1	2.4	0.6	0.5
Karani	46.0	3.4	7.4	-1.4	0.4	Karani	44.4	3.2	7.3	1.1	1.4
Sanawara	45.8	2.0	4.4	1.5	1.0	Prahlad pura	44.0	13.7	31.1	-1.0	-0.4
Mes Jaipur	44.4	9.4	21.2	-0.4	0.8	Panchla	43.7	2.4	5.4	-1.4	-0.3
Panchla	43.6	2.6	5.9	-1.4	-0.1	Mesjaipur	42.2	6.7	15.9	-1.2	0.5
Durgapura	42.4	17.2	40.6	-1.8	-0.2	Durgapura	40.1	16.3	40.6	-1.9	-0.1

Naran Ki Dhani	38.5	4.2	10.9	1.1	-0.1	Naranki dhani	37.7	3.7	9.8	-0.6	-0.6
Raron Ki Dhani	35.1	1.5	4.4	3.1	1.6	Matasar	35.2	1.5	4.3	1.4	-1.1
Matasar	35.0	2.4	6.9	9.0	-2.6	Raronki dhani	35.1	1.7	4.8	-0.2	0.6
Cazri	34.1	8.1	23.8	-1.1	0.1	Bisukalan	34.0	0.4	1.0	-1.0	-0.2
Bisukalan	34.0	0.8	2.4	14.4	-3.5	Cazri	33.0	7.6	23.0	-0.6	0.5
Tigaria	32.7	17.4	53.2	-1.4	0.4	Tigaria	31.1	16.6	53.5	-1.2	0.4
Kalwad	31.5	13.8	43.9	-1.6	-0.2	Panavada	29.8	1.0	3.5	-0.5	0.5
Lordi	30.4	3.8	12.6	0.8	1.0	Lordi	29.0	2.8	9.5	9.1	2.8
Lawan	29.8	8.5	28.4	-1.4	0.3	Mahuwa	28.9	16.5	57.0	-0.5	0.7
Panavada	29.7	1.2	4.2	0.2	0.4	Lawan	28.8	8.5	29.3	-1.0	0.6
Garh Ranoli	28.8	8.5	29.4	-1.7	0.0	Kalwad	28.6	13.6	47.4	-1.7	0.0
Sanlor	28.2	4.0	14.2	11.6	-2.0	Sanlor	28.5	4.1	14.3	10.8	1.7
Mahuwa	27.6	16.7	60.3	0.6	1.1	Garhranoli	27.3	8.9	32.7	-1.7	0.3
Sikandara	26.6	11.0	41.2	-0.9	0.5	Bhimkamkaur	27.2	5.8	21.1	18.4	4.2
Gijgarh	26.5	13.4	50.7	0.0	1.0	Sikandara	26.6	12.6	47.4	-1.0	0.7
Bhimkam Kaur	26.2	1.9	7.2	3.1	1.9	Devra	25.7	3.7	14.5	0.2	0.1
Devra	26.0	3.2	12.4	1.5	0.4	Gajjgarh	25.6	11.5	44.9	-0.6	0.7

Saupadamsingh	25.0	2.7	11.0	-0.9	-0.4	Saupadamsingh	24.4	3.2	13.3	-1.5	0.0
Barmer	24.8	6.7	27.2	-1.3	-0.6	Barmer	24.3	5.7	23.5	-1.2	-0.6
Adel	24.4	1.3	5.4	0.0	0.9	Kangiksirdi	24.1	4.4	18.1	1.1	1.3
Devatra	24.0	4.6	19.3	-1.1	0.0	Adel	23.9	0.8	3.5	3.9	-0.5
Kangik Sirdi	23.8	3.4	14.4	4.5	2.2	Devatra	23.8	4.9	20.8	0.2	-0.4
Balewa	23.8	4.9	20.8	-1.7	0.2	Balewa	23.6	4.9	20.6	-1.5	0.2
Bujawar	23.3	3.3	13.9	-0.9	0.4	Bujawar	21.8	4.6	20.9	-0.4	0.3
Redana	21.7	6.9	32.0	2.3	1.5	Bhandarej	20.9	4.7	22.2	-0.9	-0.2
Sasion Ka Kua	20.8	2.9	13.9	2.8	0.7	Jatyasani	19.7	3.4	17.5	6.3	-1.5
Bhandarej	20.7	5.2	25.1	-1.2	-0.4	Sasion	19.4	3.6	18.6	1.7	0.0
Jatyansani	20.7	2.1	10.0	2.3	0.7	Shivdaspura	18.9	7.8	41.1	-0.8	-0.9
Shivdaspura	20.1	6.7	33.4	0.0	-1.1	Dhawa	18.9	7.2	38.0	-0.6	-0.9
Thob	20.1	6.1	30.4	5.7	1.6	Redana	18.1	6.7	36.7	3.8	1.3
Dhawa	18.9	7.4	39.0	-0.7	-0.9	Bachhbar	17.2	5.0	28.9	0.3	0.0
Bachhbar	18.5	3.3	17.8	-0.9	-0.7	Thob	16.8	4.9	28.8	-0.4	0.6
Ramrawas	17.4	3.1	17.8	21.5	4.5	Ramrawas	16.7	0.8	4.7	2.1	1.4
Sihani	17.2	5.2	30.1	-0.7	-0.4	Doli	16.7	9.2	55.0	-1.4	-0.3

Benan	17.2	2.6	15.0	1.0	-0.8	Chaksu	16.4	4.3	26.4	-0.2	0.3
Doli	17.0	8.9	52.5	-1.2	0.0	Benan	16.3	3.7	22.8	0.0	0.0
Chaksu	16.8	3.8	22.6	-0.5	0.1	Bisala	16.2	2.5	15.3	-0.7	-0.6
Sutharon ki dha	16.4	4.0	24.3	0.3	-0.7	Sihani	15.8	7.2	45.5	1.1	0.9
Sindari	15.7	1.0	6.3	6.0	1.7	Sindari	15.8	1.1	7.2	1.5	1.3
Bisala	15.6	3.7	23.8	0.7	-1.1	Kateria	15.3	1.3	8.7	6.3	2.0
Dausa	15.6	12.7	81.8	5.0	2.3	Sutharon ki dha	15.0	4.7	31.8	-0.8	-0.5
Narbadkhera	15.5	4.7	30.0	1.4	0.4	Jasai	14.8	4.4	29.4	-0.7	-0.4
Kateria	15.2	1.0	6.9	16.9	3.6	Narbadkhera	13.9	5.2	37.1	-0.4	0.3
Jasai	15.0	5.3	35.5	2.0	-1.3	Derasar	13.0	4.2	32.7	0.7	0.3
Jhopadiyan	14.8	4.3	28.9	-0.9	-0.3	Ghugra	12.9	6.7	51.8	-0.3	0.3
Mandore	14.5	6.3	43.8	0.9	1.3	Jhopadiyan	12.1	5.0	41.3	-1.3	0.1
Ghugra	14.1	6.6	47.1	-1.4	0.1	Jodhpur	12.1	6.6	54.9	-0.4	1.1
Rasala	13.5	2.8	21.0	-0.4	0.3	Rasala	11.8	3.0	25.2	0.3	0.5
Derasar	12.8	4.3	33.4	0.5	-0.9	Mandore	11.6	4.5	38.4	6.7	2.1
Masuda	12.6	4.7	37.8	0.0	0.1	Goner	11.0	2.5	23.2	-1.1	-0.2
Goner	12.3	3.3	26.9	10.0	2.5	Baridhani	10.9	2.0	18.0	9.7	2.4

Thalli	12.1	3.2	26.2	-0.7	-0.6	Pakhriawas	10.9	4.0	36.3	-0.9	0.2
Ludiyana	11.8	2.6	21.8	-0.6	-0.8	Thalli	10.9	3.5	32.5	-1.2	-0.3
Pakhriawas	11.4	3.4	29.9	-0.5	0.0	Jawansingh	10.6	5.1	48.6	-1.7	0.1
Jodhpur	11.3	6.0	53.3	1.3	1.6	Ludiyana	10.5	2.8	27.1	-0.9	-0.1
Amber	11.2	1.9	16.7	10.6	-2.9	Nasnota	10.4	2.7	25.5	0.4	-0.1
Patrasar	10.9	2.7	24.4	-0.9	-0.1	Nand	10.4	3.7	35.9	0.0	-0.6
Dikoliya	10.8	4.5	41.2	1.0	0.3	Patrasar	10.1	2.4	23.8	0.0	-0.1
Jawansingh Ki Ber	10.8	4.9	45.2	-1.5	0.1	Dausa	10.0	5.1	51.3	-0.5	0.5
Nasnota	10.6	2.1	19.7	-0.3	0.0	Amber	10.0	2.1	21.2	2.8	-1.7
Bari Dhani	10.2	2.0	20.0	3.3	-1.8	Nimri	9.7	3.1	31.9	4.6	1.4
Ramsar	10.2	2.7	26.3	-1.3	0.1	Dikoliya	9.7	5.3	54.7	0.1	0.2
Bapi	10.0	2.6	26.4	-1.1	0.1	Dangiwas	9.4	1.9	20.0	-0.7	-0.1
Nimri	10.0	1.2	12.4	0.2	-0.9	Bantholi	9.4	1.3	13.4	0.6	0.6
Dangiwas	9.9	1.7	16.8	-0.7	-0.1	Masuda	9.2	4.6	50.4	0.4	0.7
Pallukhurd	9.9	3.6	35.9	-1.6	0.1	Bapi	9.0	2.6	29.3	-0.4	0.7
Jawaja	9.9	3.6	36.3	-0.5	0.1	Piparli	8.9	1.9	21.0	9.9	2.6
Nand	9.8	6.8	69.2	3.9	-1.7	Pallukhurd	8.9	4.0	45.1	-1.6	0.1

Bantholi	9.5	0.9	9.7	2.1	0.7	Dawach	8.6	3.4	39.7	-0.6	-0.1
Dawach	9.5	3.0	31.9	0.0	-0.2	Kalyanpura	8.3	3.4	40.5	1.9	1.1
Bhawi	9.3	3.6	38.4	-0.1	-0.1	Ramsar	8.2	3.1	38.0	-0.5	0.2
Piparli Gaon	8.7	1.1	13.0	-0.8	0.1	Jawaja	8.1	3.6	44.5	-0.5	0.4
Kalyanpura	8.6	3.1	35.9	-1.7	-0.1	Mahuva	7.7	3.2	41.3	0.5	0.5
Sohela	8.4	4.1	48.4	-0.8	0.5	Hamirpur	7.4	3.2	43.1	-1.5	0.2
Malpura	8.3	4.0	47.6	-1.2	0.2	Malpura	7.4	3.1	42.2	-0.9	0.3
Baglias	8.1	3.3	40.5	-0.3	0.7	Mozmabad	7.3	3.5	47.5	-1.5	0.1
Mahuva	8.0	2.4	29.7	-0.3	-0.1	Bhawi	7.2	2.5	35.2	-0.5	-0.1
Hamirpur	7.9	2.8	35.2	-0.9	0.1	Chopasninath	6.8	2.0	29.1	-0.8	-0.4
Kanpur	7.9	4.6	58.4	0.9	1.0	Kanpur	6.8	4.3	63.5	2.9	1.5
Mozmabad	7.8	3.2	41.0	-1.5	0.0	Sohela	6.7	3.7	55.2	-0.7	0.7
Sanpla	7.7	2.6	33.2	0.1	0.1	Sanpla	6.7	2.3	34.5	-1.1	-0.2
Arniyalmal	7.5	3.5	47.3	-0.9	0.4	Baglias	6.4	3.3	51.1	0.4	0.8
Chopasni Nath	7.3	1.8	24.4	-1.2	0.0	Arniyalmal	6.4	3.6	56.9	-0.4	0.7
Bogla	7.2	1.8	24.5	-1.3	0.1	Arian	6.2	8.4	135.9	21.0	4.4
Taragarh	6.2	3.1	49.4	-1.1	0.0	Nayagaon	5.8	2.2	37.8	-1.0	0.2

Nayagaon	6.2	2.3	37.6	-0.2	-0.1	Bogla	5.5	2.0	37.0	-0.7	0.5
Sirohikhurd	6.2	1.8	29.3	3.9	1.4	Sirohikhurd	5.0	1.5	29.9	-0.6	-0.2
Arian	5.7	3.7	64.7	-0.1	1.0	Mangarwara	4.7	3.3	70.6	3.4	1.4
Nasirabad	5.5	4.6	82.5	1.6	1.6	Jaisinghpur	4.3	2.6	59.7	0.8	1.3
Dewal1	5.5	2.3	41.7	2.9	1.5	Sajjara	4.3	1.0	23.7	0.9	-0.8
Ajagara	5.1	2.0	40.0	-1.0	0.3	Dewal	4.3	2.1	49.7	2.5	1.2
Jaisinghpur	5.0	2.0	39.1	-0.5	0.9	Bap1	3.9	1.4	36.0	-0.5	0.0
Mangarwara	4.9	2.4	48.7	-0.8	0.3	Taragarh	3.8	3.2	82.1	-0.9	0.8
Todarsingh	4.9	4.2	85.9	0.1	1.2	Ajagara	3.8	1.5	39.0	-0.7	0.5
Ramthala	4.7	2.3	47.5	2.5	0.9	Ramthala	3.6	1.7	46.6	-1.1	-0.4
Bap	4.5	1.6	35.3	-0.5	-0.3	Todarsingh	3.2	1.7	53.6	-0.8	0.4
Sajjara	4.3	0.9	20.5	0.2	-0.7	Nasirabad	3.1	2.0	64.3	0.5	0.7
Pre-monsoon						**Monsoon**					
Kalpan	77.4	8.0	10.3	7.4	2.4	Gujrokabera	75.1	7.9	10.5	-0.9	0.7
Gujrokabera	74.2	7.4	9.9	-0.7	0.6	Kalpan	73.0	5.1	7.0	4.5	-1.3
Kapuria	71.5	1.8	2.6	9.6	3.0	Kapuria	71.3	1.9	2.6	10.7	3.2
Siyaga	66.8	2.6	3.9	0.8	-0.1	Siyaga	65.5	1.7	2.6	-1.3	-0.1

Padmaniyon	59.0	10.7	18.2	21.9	-4.4	Padmaniyon	59.0	3.4	5.7	5.5	-1.3
Jhotwara	55.0	12.9	23.5	-1.5	-0.3	Jhotwara	56.0	13.2	23.5	-1.5	-0.3
Kashmir	52.3	5.4	10.2	-0.9	0.6	Kashmir	52.5	5.7	10.9	-0.6	0.8
Hathitala	50.7	1.1	2.2	2.2	1.5	Kolu	52.2	16.7	32.1	-0.7	0.8
Chohtan	49.9	2.4	4.8	-0.6	0.2	Hathitala	49.7	6.2	12.5	25.0	-4.9
Kolu	47.6	10.5	22.0	0.5	1.1	Chohtan	48.1	3.9	8.1	3.9	0.2
Karani	46.1	3.2	6.9	-1.2	0.4	Sanawara	46.1	2.3	5.1	-0.9	0.3
Mesjaipur	46.1	10.4	22.5	-1.0	0.7	Karani	44.4	3.1	7.1	0.8	1.4
Sanawara	45.9	2.0	4.4	1.1	0.8	Prahladpura	44.3	11.3	25.5	-1.3	-0.3
Prahladpura	44.5	11.2	25.1	-1.3	-0.4	Panchla	43.6	2.2	5.1	-0.9	-0.4
Panchla	43.8	2.6	5.9	-1.3	-0.3	Mesjaipur	43.3	7.4	17.2	-1.0	0.5
Durgapura	41.2	17.2	41.7	-1.8	-0.1	Durgapura	41.4	16.2	39.0	-1.8	-0.3
Narankidhani	37.6	3.6	9.5	-0.1	-0.9	Narankidhani	37.0	3.6	9.7	-1.0	-0.5
Raronkidhani	35.2	1.7	4.8	1.4	1.3	Matasar	35.4	1.9	5.5	1.5	0.6
Matasar	35.1	2.5	7.0	9.2	-2.6	Raronkidhani	34.8	1.6	4.5	2.5	1.6
Bisukalan	34.0	0.8	2.4	13.9	-3.4	Bisukalan	34.0	1.1	3.2	2.9	1.0
Cazri	33.7	7.2	21.3	-0.6	0.3	Cazri	32.6	7.9	24.4	-0.8	0.4

Tigaria	31.8	17.5	55.1	-1.3	0.4	Kalwad	30.1	13.6	45.3	-1.7	0.0
Lawan	30.3	10.4	34.3	0.3	1.0	Tigaria	30.1	15.9	53.0	-1.3	0.4
Kalwad	30.0	13.3	44.2	-1.7	-0.1	Panavada	29.7	1.0	3.4	-0.4	-0.6
Panavada	29.8	1.2	3.9	0.2	0.7	Lordi	29.5	4.0	13.6	2.5	1.3
Lordi	28.8	2.0	7.1	1.0	-0.4	Garhranoli	29.5	11.7	39.6	-0.9	0.6
Garhranoli	28.6	9.3	32.6	-1.2	0.4	Sanlor	29.4	4.7	15.9	6.9	-1.3
Sanlor	28.2	4.0	14.2	11.6	-2.0	Lawan	28.2	9.9	35.2	-1.4	0.2
Sikandara	28.1	14.4	51.2	-0.3	0.9	Gajjgarh	27.0	11.8	43.9	-0.2	0.7
Bhimkamkaur	26.4	2.0	7.4	2.8	1.9	Bhimkamkaur	26.6	2.2	8.3	11.9	3.2
Mahuwa	26.4	14.4	54.6	0.5	1.0	Devra	24.8	4.0	16.0	1.5	-0.8
Devra	25.9	3.4	12.9	0.8	0.6	Sikandara	24.6	9.4	38.2	-1.8	0.0
Barmer	25.2	6.5	25.7	-1.0	-0.7	Saupadamsingh	24.4	3.2	13.1	-1.7	0.1
Saupadamsingh	25.1	2.9	11.5	-1.0	-0.3	Mahuwa	24.4	14.3	58.8	0.2	1.0
Adel	24.3	1.3	5.2	0.6	1.0	Barmer	24.3	6.4	26.2	-1.3	-0.5
Balewa	24.2	5.0	20.7	-1.8	0.1	Adel	23.8	1.1	4.6	6.4	-1.6
Gajjgarh	24.0	11.5	47.9	2.4	1.5	Balewa	23.8	4.7	19.9	-1.7	0.0
Devatra	23.5	4.6	19.7	-1.2	0.0	Kangiksirdi	23.1	3.6	15.4	2.5	1.9

Bujawar	23.0	3.3	14.1	-0.6	0.6	Bujawar	20.7	4.2	20.5	-0.8	-0.4
Kangiksirdi	22.9	2.6	11.3	3.8	1.5	Sasion	19.6	4.3	22.1	2.7	-0.6
Thob	21.5	5.6	25.9	6.6	2.2	Jatyasani	19.0	2.5	13.4	-0.9	-0.5
Redana	21.4	7.0	32.9	2.3	1.5	Devatra	18.9	6.0	31.8	0.2	0.5
Sasion	20.9	3.2	15.1	1.6	0.7	Doli	17.8	9.5	53.6	-1.1	-0.1
Jatyasani	20.3	1.5	7.3	-0.3	-0.5	Shivdaspura	17.6	8.0	45.7	-0.8	-0.8
Shivdaspura	20.2	6.3	31.3	-0.7	-0.9	Redana	17.3	4.1	23.8	-0.6	0.5
Bhandarej	20.1	5.2	25.7	-1.3	-0.2	Dhawa	17.1	7.3	42.7	-1.3	-0.6
Dhawa	19.4	6.7	34.5	-0.8	-0.8	Bhandarej	16.6	9.3	56.2	1.3	1.1
Bachhbar	18.7	4.0	21.4	1.2	0.5	Ramrawas	16.3	0.6	4.0	-0.2	-0.3
Doli	18.4	8.4	45.8	-1.0	-0.3	Bachhbar	16.1	3.9	24.3	-1.4	-0.1
Ramrawas	17.7	3.8	21.2	14.7	3.8	Thob	15.7	6.8	43.6	9.8	2.9
Sihani	17.2	5.6	32.7	0.3	-0.8	Bisala	15.7	4.7	30.2	3.8	-1.9
Benan	17.0	2.8	16.8	0.5	-0.8	Kateria	15.6	2.4	15.3	8.0	2.7
Chaksu	16.7	3.4	20.3	-0.8	0.0	Sindari	15.5	0.5	3.0	1.8	-0.7
Sutharon ki dha	16.6	3.9	23.2	0.9	-0.9	Chaksu	14.7	3.5	23.5	-1.4	0.1
Bisala	16.1	3.2	20.1	0.3	-0.9	Benan	14.3	3.9	27.4	-0.1	0.3

Jasai	15.9	4.0	25.4	1.0	-0.9	Derasar	14.1	6.0	42.4	3.2	1.6
Sindari	15.7	1.0	6.5	5.5	1.6	Jasai	14.0	4.6	32.9	1.7	-1.0
Jhopadiyan	15.7	3.7	23.9	-0.9	-0.4	Sutharon ki dha	13.7	4.7	34.7	0.5	-0.8
Narbadkhera	15.2	3.2	21.0	-0.9	-0.5	Mandore	12.5	6.1	49.0	3.1	1.7
Kateria	15.0	0.4	2.5	1.0	-0.4	Dausa	12.5	16.7	134.4	5.5	2.4
Ghugra	14.9	6.5	43.6	-1.3	0.0	Jhopadiyan	12.1	4.4	36.1	-0.1	0.2
Mandore	14.7	6.3	43.0	1.1	1.3	Ghugra	12.1	5.7	47.2	-0.9	0.5
Rasala	13.7	2.8	20.3	-0.4	0.0	Sihani	11.8	5.5	46.3	-1.0	-0.4
Masuda	13.3	4.0	30.1	-0.1	0.6	Narbadkhera	11.3	7.3	64.6	0.1	0.8
Derasar	13.2	3.7	27.7	0.1	-0.7	Thalli	10.9	3.5	32.1	-0.7	-0.5
Dausa	12.9	6.6	51.1	1.2	1.2	Ludiyana	10.8	2.3	21.0	0.0	0.1
Jodhpur	12.5	7.1	57.0	0.5	1.3	Goner	10.8	2.7	25.2	-0.6	-0.7
Ludiyana	12.4	2.4	19.4	0.9	-1.3	Jodhpur	10.5	5.4	51.4	0.3	1.3
Goner	12.1	3.2	26.4	11.8	2.8	Pakhriawas	10.5	4.2	39.8	0.1	0.4
Thalli	12.1	3.1	25.7	-0.6	-0.6	Rasala	10.5	2.9	28.0	-0.9	-0.1
Amber	11.7	0.8	7.0	0.5	0.5	Baridhani	10.4	1.5	14.7	0.8	-1.2
Nand	11.4	4.1	35.9	-0.3	-0.5	Nasnota	10.3	2.8	27.1	-0.6	0.2

Pakhriawas	11.2	3.0	26.6	-0.3	-0.4	Jawansingh	9.9	5.7	58.2	-1.7	0.1
Jawansingh	11.2	5.1	45.6	-1.7	0.0	Patrasar	9.8	2.2	22.6	0.0	-0.2
Patrasar	10.8	2.6	24.4	-0.5	0.1	Dangiwas	9.2	1.7	19.0	-1.4	-0.3
Nasnota	10.7	2.1	19.4	-0.3	-0.1	Amber	8.7	3.0	34.2	-0.7	-0.7
Jawaja	10.4	3.0	28.5	-0.6	0.1	Nimri	8.5	2.9	33.6	1.5	-1.2
Ramsar	10.3	2.6	25.4	-1.5	-0.2	Masuda	8.4	4.1	48.2	-1.2	-0.1
Baridhani	10.3	2.1	20.0	3.3	-1.8	Malpura	8.2	4.4	53.3	-1.4	0.0
Dikoliya	10.1	3.2	31.7	-1.0	-0.4	Nand	8.1	3.9	47.6	-0.9	0.1
Bapi	10.1	2.7	26.3	-1.2	0.0	Piparli	8.1	1.2	14.7	-0.3	-0.8
Dangiwas	10.0	1.7	17.1	-0.7	-0.2	Pallukhurd	8.0	4.1	52.0	-1.6	0.0
Nimri	9.9	1.2	11.9	0.3	-0.9	Bantholi	7.9	1.6	19.8	2.1	-1.0
Bhawi	9.8	3.0	30.9	0.1	0.3	Kalyanpura	7.9	4.0	51.3	0.5	0.9
Pallukhurd	9.8	3.5	36.3	-1.6	0.2	Dawach1	7.7	3.5	45.7	-0.9	0.0
Sohela	9.7	4.4	45.8	-0.8	0.3	Dawach	7.7	3.5	45.7	-0.9	0.0
Bantholi	9.5	0.7	7.8	1.0	-0.3	Ramsar	7.7	2.6	33.6	-0.9	-0.2
Dawach1	9.4	3.2	33.8	-0.4	0.0	Mozmabad	7.4	7.6	103.7	17.9	3.9
Dawach	9.4	3.2	33.8	-0.4	0.0	Sanpla	7.2	3.0	41.8	6.8	1.9

Piparli	8.7	1.1	12.2	-0.3	0.0	Dikoliya	7.1	5.0	69.7	1.1	0.7
Kalyanpura	8.7	3.0	34.7	-1.6	-0.1	Bapi	6.9	2.9	42.2	-0.5	0.3
Sanpla	8.4	2.2	25.9	-0.2	0.5	Bhawi	6.4	4.1	64.3	2.2	1.3
Malpura	8.3	3.6	43.3	-0.9	-0.1	Mahuva	6.4	2.7	42.0	-0.6	0.1
Hamirpur	8.1	2.5	30.6	-0.9	0.0	Jawaja	5.9	2.7	46.2	0.5	0.7
Mahuva	8.1	2.4	29.7	-0.3	-0.3	Arian	5.8	3.8	66.4	0.8	1.1
Kanpur	8.0	3.1	38.6	0.0	0.8	Chopasninath	5.6	1.6	28.5	-0.6	0.6
Baglias	7.9	2.6	32.7	-0.8	0.2	Bogla	5.4	2.1	38.6	-0.1	0.5
Mozmabad	7.7	3.2	41.8	-1.5	0.0	Hamirpur	5.3	2.2	41.5	0.6	0.4
Arniyalmal	7.6	3.5	45.7	-1.0	0.3	Kanpur	5.3	2.6	48.5	-1.1	0.0
Chopasninath	7.5	1.8	24.5	-0.8	0.3	Sohela	5.1	3.9	75.8	0.3	1.2
Bogla	7.1	1.6	22.7	-1.4	0.0	Baglias	5.1	2.9	57.3	-0.5	0.4
Sirohikhurd	6.8	2.2	31.9	0.8	0.8	Arniyalmal	5.0	2.5	50.1	0.8	0.6
Nasirabad	6.7	4.8	72.0	-0.2	0.9	Sirohikhurd	4.4	1.9	42.6	0.3	0.5
Taragarh	6.6	2.9	43.4	-1.0	-0.1	Mangarwara	4.1	2.3	55.3	0.3	0.6
Nayagaon	6.4	2.2	33.8	0.1	0.0	Dewal	4.1	1.8	44.1	5.9	1.8
Arian	5.9	3.7	62.1	-0.1	0.9	Sajjara	4.0	0.9	22.4	0.8	-1.1

Dewal	5.8	2.0	34.6	4.0	1.7	Ajagara	3.9	1.4	37.1	-0.6	0.4
Ajagara	5.3	1.8	34.1	-1.1	0.5	Bap1	3.8	1.4	37.1	-0.7	0.8
Ramthala	5.2	2.0	38.7	3.5	1.1	Taragarh	3.7	2.5	67.8	-1.5	0.1
Mangarwara	5.1	2.2	43.6	-0.7	0.4	Nayagaon	3.7	1.8	49.7	0.9	0.9
Todarsingh	5.0	4.3	85.0	-0.4	1.0	Ramthala	3.3	1.7	50.7	-0.7	-0.2
Jaisinghpur	5.0	1.9	38.2	-0.4	0.9	Jaisinghpur	3.3	2.2	68.6	-0.2	0.9
Sajjara	4.5	0.9	20.7	1.0	-1.1	Nasirabad	3.2	2.3	71.2	3.1	1.4
Bap1	4.4	1.6	36.5	-0.5	-0.3	Todarsingh	2.1	1.8	88.4	6.0	2.5

Post-monsoon	Mean	SD	CV	Kurtosis	Skewness
Gujrokabera	75.5	7.8	10.3	-1.1	0.5
Kalpan	74.3	6.7	9.0	2.2	-1.2
Kapuria	71.8	2.4	3.4	3.0	2.0
Siyaga	66.4	1.9	2.8	0.6	0.5
Padmaniyon	59.6	1.2	1.9	0.6	0.6
Jhotwara	57.8	14.0	24.2	-1.4	-0.4
Kashmir	52.9	5.7	10.7	-0.8	0.6
Kolu	51.7	18.1	34.9	2.6	1.7
Hathitala	50.5	0.7	1.4	0.9	0.7
Chohtan	47.9	3.2	6.7	-1.1	0.0
Sanawara	45.8	2.2	4.8	1.6	1.2
Prahladpura	45.7	11.3	24.7	-1.5	-0.3
Karani	45.2	3.5	7.7	-0.5	0.7

Panchla	44.0	2.4	5.5	-1.5	-0.4
Mesjaipur	42.5	4.9	11.7	-1.4	0.1
Durgapura	41.8	16.5	39.4	-1.8	-0.3
Narankidhani	38.0	4.4	11.7	0.8	0.2
Matasar	35.8	1.8	5.0	2.4	1.6
Raronkidhani	34.4	1.1	3.3	-0.1	0.3
Bisukalan	34.0	0.4	1.1	0.3	-0.1
Garhranoli	33.5	19.9	59.6	1.3	1.5
Cazri	32.7	7.6	23.4	-0.2	0.7
Kalwad	30.7	13.6	44.2	-1.7	-0.2
Tigaria	30.1	15.7	52.4	-1.2	0.4
Lawan	29.9	9.1	30.6	-1.6	0.3
Panavada	29.8	1.3	4.4	0.4	1.1
Lordi	28.3	3.1	11.0	-0.9	-0.1
Sanlor	28.0	4.1	14.6	5.8	-1.4
Gajjgarh	27.4	11.6	42.5	0.2	0.7
Sikandara	26.9	13.8	51.2	0.1	0.9
Kangiksirdi	26.0	6.2	23.6	-0.8	0.9
Bhimkamkaur	25.8	1.1	4.3	-0.2	0.6
Mahuwa	25.3	13.8	54.5	-0.6	0.6
Barmer	25.0	6.6	26.4	-0.9	-0.5
Devra	24.9	3.1	12.2	1.1	-1.4
Adel	24.4	1.5	6.3	3.0	1.7
Saupadamsingh	24.1	3.2	13.2	-1.5	0.0
Balewa	23.4	5.0	21.6	-1.6	0.1
Devatra	20.7	4.8	23.4	0.1	0.2
Sasion	19.8	2.6	13.3	-0.3	-0.2

Bujawar	19.8	4.0	20.3	0.7	0.8
Jatyasani	18.7	3.9	20.6	3.0	-1.8
Bhandarej	18.3	6.0	33.0	0.0	0.8
Bachhbar	18.2	3.9	21.3	-0.4	-0.8
Shivdaspura	18.2	8.1	44.7	-0.9	-0.9
Dhawa	17.8	7.6	42.8	-1.0	-0.8
Redana	17.7	4.4	24.7	-0.2	-0.4
Dausa	17.6	22.0	124.6	2.8	1.9
Ramrawas	16.6	1.2	7.0	8.6	2.5
Doli	16.0	9.6	60.3	-1.5	-0.1
Bisala	15.8	2.8	17.7	0.3	-1.0
Sindari	15.6	0.8	5.1	2.1	0.6
Chaksu	15.2	2.8	18.7	-0.3	0.3
Kateria	15.1	0.7	4.3	1.1	1.1
Benan	15.0	3.9	26.2	-0.5	0.2
Jasai	14.4	4.1	28.2	0.4	-0.7
Thob	13.2	4.1	31.1	5.5	2.1
Sutharon ki dha	12.7	4.6	36.0	0.3	-0.4
Sihani	12.5	6.2	49.4	-1.5	0.2
Ghugra	12.2	5.9	48.6	-1.0	0.3
Derasar	12.2	4.4	35.8	1.2	-0.3
Goner	11.7	6.8	57.9	17.4	3.9
Rasala	11.5	3.6	31.6	0.6	0.4
Mandore	11.3	5.3	47.2	9.4	2.7
Narbadkhera	10.9	4.7	43.3	-0.9	0.2
Thalli	10.8	3.7	34.5	-1.4	-0.4
Jodhpur	10.6	5.8	54.9	0.7	1.4

Nasnota	10.5	2.1	19.8	0.5	-0.3
Nimri	10.5	7.1	68.2	8.0	2.7
Jawansingh	10.4	5.1	48.9	-1.5	0.1
Patrasar	10.3	2.9	27.8	0.2	0.7
Baridhani	10.3	1.6	16.0	0.0	-0.7
Jhopadiyan	10.2	4.4	43.1	-0.7	0.1
Ludiyana	10.1	2.5	24.9	-0.6	-0.5
Amber	9.8	2.3	23.8	1.1	-1.4
Pakhriawas	9.3	4.5	48.8	0.3	0.9
Nand	9.3	3.9	42.5	0.5	0.0
Dangiwas	9.0	1.7	19.0	-1.1	-0.1
Dikoliya	8.8	5.2	58.9	0.4	0.4
Bantholi	8.8	1.1	12.6	-0.1	0.4
Dawach1	8.6	3.4	39.5	-0.6	-0.6
Dawach	8.6	3.4	39.5	-0.6	-0.6
Pallukhurd	8.6	4.1	48.3	-1.6	0.1
Bapi	8.5	3.0	35.0	-0.2	0.4
Malpura	8.2	3.9	47.1	-1.4	0.0
Ramsar	8.2	3.6	44.3	0.3	0.7
Piparli	8.2	1.2	14.1	-1.1	0.0
Kalyanpura	7.4	3.3	45.0	-1.7	-0.1
Masuda	7.3	4.3	59.9	-1.0	0.5
Hamirpur	6.7	3.0	44.5	-1.7	0.0
Bhawi	6.7	4.7	70.6	7.4	2.4
Mahuva	6.7	2.6	39.1	-1.0	-0.2
Jawaja	6.6	3.3	50.3	0.1	0.8
Mozmabad	6.6	3.2	48.4	-1.6	0.2

Sanpla	6.5	2.1	32.5	-1.1	-0.2
Chopasninath	6.0	2.1	34.9	-1.0	0.3
Sohela	6.0	3.6	60.0	-0.2	1.0
Arniyalmal	5.9	3.7	62.4	-1.2	0.7
Baglias	5.8	2.9	50.3	3.6	1.6
Kanpur	5.5	2.8	50.2	-1.4	0.0
Bogla	5.4	2.0	36.9	-1.4	0.0
Arian	5.4	4.4	81.4	5.5	2.0
Nayagaon	5.1	2.3	44.5	-1.4	0.1
Sirohikhurd	4.9	1.9	38.1	-1.2	-0.1
Mangarwara	4.5	3.0	65.5	5.4	1.8
Sajjara	4.1	1.2	29.8	1.5	-0.4
Jaisinghpur	4.0	2.4	58.8	0.5	1.0
Ajagara	4.0	1.6	39.4	-0.9	0.5
Bap1	3.7	1.5	41.3	0.4	-0.1
Dewal	3.7	1.3	34.7	-0.5	0.2
Ramthala	3.5	1.6	44.6	-0.6	-0.1
Taragarh	3.1	2.8	90.3	-0.3	0.9
Todarsingh	2.9	1.5	52.9	-0.3	0.5
Nasirabad	2.7	1.5	55.9	-1.1	0.4
Source: Authors' calculation					

Table 4.4: Annual and Seasonal groundwater level trends in wells/piezometers

	Winter			Pre-Monsoon			Monsoon			Post- Monsoon			Annual		
Tonk	Z	p-value	Sen	Z	p-value	Sen	Z	p-value	Sen	Z	p-value	Sen	Z	p-value	Sen
Arniyalmal	-1.07	0.29	-0.1	-3.83	0	-0.3	-1.85	0.06	-0.1	-1.39	0.16	-0.1	-4.02	0	-0.2
Bantholi	-1.09	0.28	-0	-1.76	0.08	-0	-1.35	0.18	-0	-3.6	0	-0.1	-1.33	0.18	-0
Dewal1	-0.73	0.46	-0	0.58	0.56	0.02	0	1	0	0	1	0	0.99	0.32	0.03
Dikoliya	-2.04	0.04	-0.3	-6.07	0	-0.3	-3.14	0	-0.3	-1.93	0.05	-0.3	-4.09	0	-0.3
Hamirpur	-2.59	0.01	-0.2	-2.62	0.01	-0.1	-2.86	0	-0.1	-2.63	0.01	-0.2	-2.96	0	-0.2
Jaisinghpur	-0.43	0.67	-0	0.11	0.91	0.01	-0.08	0.93	-0	-0.05	0.96	-0	0.29	0.77	0.01
Mahuva	-1.49	0.14	-0.1	-0.94	0.35	-0.1	-0.81	0.42	-0.1	-1.98	0.05	-0.2	-0.97	0.33	-0.1
Malpura	-1.5	0.13	-0.1	-1.11	0.27	-0.1	0	1	0	-1.03	0.3	-0.1	-1.27	0.2	-0.1
Nayagaon	-1.4	0.16	-0.1	-2.39	0.02	-0.1	-1.62	0.11	-0.1	-1.87	0.06	-0.1	-2.67	0.01	-0.1
Ramthala	-2.93	0	-0.1	-4.67	0	-0.1	-0.49	0.62	-0	-2.52	0.01	-0.1	-6.14	0	-0.1
Sohela	-0.48	0.63	-0	-0.42	0.68	-0	-1.15	0.25	-0.1	-1.33	0.18	-0.1	-0.36	0.72	-0
Todarsingh	-8.22	0	-0.2	-4.59	0	-0.4	-6.13	0	-0.1	-3.28	0	-0.1	-4.55	0	-0.4
Jaipur															
Durgapura	6.41	0	1.92	6.83	0	2.09	6.67	0	1.98	5.87	0	1.94	6.54	0	1.99
Chaksu	-2.65	0.01	-0.2	-1.43	0.15	-0.1	-2.54	0.01	-0.2	-2.19	0.03	-0.1	-1.58	0.11	-0.1

•

Amber	0.38	0.7	0.01	-0.55	0.58	-0	0.89	0.37	0.04	1.26	0.21	0.04	-0.92	0.35	-0
Kalwad	8.76	0	1.68	7.84	0	1.69	7.92	0	1.68	7.62	0	1.75	8.19	0	1.67
Jhotwara	7.62	0	1.72	7.05	0	1.7	6.16	0	1.69	6.32	0	1.72	6.31	0	1.62
Mozmabad	0.79	0.42	0.1	0.55	0.59	0.08	0.21	0.83	0.01	0.06	0.95	0.01	0.46	0.64	0.05
Mes Jaipur	1.79	0.07	0.36	3.76	0	0.78	1.69	0.09	0.49	1.93	0.05	0.46	1.42	0.15	0.37
Dawach	4.95	0	0.28	5.04	0	0.25	6.07	0	0.34	4.25	0	0.27	4.98	0	0.24
Mangarwara	-0.46	0.64	-0	1.31	0.19	0.07	-0.32	0.75	-0	-1.9	0.06	-0.1	0.05	0.96	0.01
Rasala	1.61	0.11	0.09	2.49	0.01	0.11	2.37	0.02	0.19	2.76	0.01	0.22	2.96	0	0.13
Nasnota	-1.55	0.12	-0.1	0.84	0.4	0.03	1.07	0.29	0.12	0	1	0	0.83	0.41	0.03
Tigaria	7.53	0	2.22	7.3	0	2.26	7.01	0	2.17	8.2	0	2.16	7.62	0	2.34
Thalli	1.69	0.09	0.11	1.92	0.06	0.15	1.95	0.05	0.23	2.58	0.01	0.16	1.92	0.05	0.15
Goner	10.09	0	0.26	5.55	0	0.18	7.27	0	0.24	3.42	0	0.27	5.93	0	0.21
Sirohikhurd	3.2	0	0.09	6.29	0	0.27	8.12	0	0.18	5.49	0	0.15	4.85	0	0.09
Shivdaspura	2.39	0.02	0.61	1.75	0.08	0.42	4.89	0	0.8	3.39	0	0.58	1.41	0.16	0.4
Pallukhurd	0.49	0.62	0.05	0.32	0.75	0.03	0.12	0.9	0.04	0	1	0	0.05	0.96	0.01
Dawach	4.95	0	0.28	5.04	0	0.25	6.07	0	0.34	4.25	0	0.27	2.67	0.01	0.08
Jodhpur															
Bujawar	0.15	0.88	0.02	-0.46	0.64	-0.1	1.13	0.26	0.09	-0.92	0.36	-0.1	0.03	0.98	0
Karani	4.59	0	0.25	1.8	0.07	0.14	5.01	0	0.23	6.44	0	0.29	3.52	0	0.26
Mandore	-3.35	0	-0.2	-2.89	0	-0.2	-2.09	0.04	-0.2	-3.04	0	-0.3	-3.52	0	0.26

Raron Ki Dhani	-0.79	0.43	-0	-1.12	0.26	-0.1	1.83	0.07	0.05	0	1	0	-0.2	0.84	-0
Devatra	1.27	0.21	0.07	-2.01	0.04	-0.2	-0.99	0.32	-0.1	-1.33	0.18	-0.1	-0.62	0.53	-0
Jodhpur	-5.43	0	-0.5	-3.98	0	-0.5	-4.35	0	-0.4	-4.39	0	-0.4	-4.15	0	-0.3
Bhawi	-1.18	0.24	-0.1	1.3	0.19	0.07	-0.61	0.54	-0.1	-1.87	0.06	-0.1	-0.34	0.73	-0
Chopasni Nath	-11.19	0	-0.2	-9.85	0	-0.2	-4.73	0	-0.2	-7.03	0	-0.2	-9.41	0	-0.2
Cazri	-12.07	0	-1.1	-12.29	0	-1	-13.92	0	-1	-10.13	0	-1	-13.47	0	-1
Bhimkam Kaur	-2.78	0.01	-0.1	-2.29	0.02	-0.1	-5.35	0	-0.1	-5.25	0	-0.1	-2.34	0.02	-0.1
Benan	1.85	0.06	0.17	0.05	0.96	0	0.24	0.81	0.06	-0.21	0.83	-0.1	0.24	0.81	0.01
Naran Ki Dhani	8.97	0	0.42	6.7	0	0.39	12.12	0	0.44	11.25	0	0.59	7.63	0	0.44
Dangiwas	2.94	0	0.12	5.47	0	0.15	6.02	0	0.19	2.92	0	0.13	5.04	0	0.16
Bap	-3.54	0	-0.1	-1.93	0.05	-0.1	-1.04	0.29	-0	-4.31	0	-0.1	-0.95	0.34	-0
Bari Dhani	-2.34	0.02	-0	-1.71	0.09	-0.1	-5.3	0	-0.1	-4.71	0	-0.1	-1.71	0.09	-0.1
Dhawa	-5.69	0	-0.8	-5.15	0	-0.7	-4.06	0	-0.7	-4.54	0	-0.8	-5.19	0	-0.8
Ramrawas	-1.86	0.06	-0	-0.79	0.43	-0	1.14	0.25	0.01	0.45	0.66	0	-0.85	0.39	-0
Sajjara	-3.53	0	-0.1	-2.09	0.04	-0	-3.44	0	-0.1	-5.06	0	-0.1	-3.28	0	-0.1
Kalpan	1.29	0.19	0.66	1.51	0.13	0.26	1.19	0.05	0.26	-0.98	0.32	-0.2	3.2	0	1.15
Kapuria	4.36	0	0.28	4.71	0	0.36	4.28	0	0.29	4.38	0	0.33	4.44	0	0.3
Lordi	2.41	0.02	0.14	4.98	0	0.19	2.78	0.01	0.26	6.34	0	0.46	4.86	0	0.26
Kolu	4.34	0	0.66	5.62	0	1.29	5.32	0	1.84	5.69	0	1.46	5.93	0	1.7
Kangik Sirdi	7.19	0	0.39	6.29	0	0.15	0.92	0.36	0.08	6.51	0	0.59	3.93	0	0.21

Jatyansani	0.96	0.34	0.05	-0.77	0.44	-0	1.11	0.27	0.26	0.66	0.51	0.05	0	1	0
Ajmer															
Ajagara	-2.24	0.02	-0.1	-0.12	0.9	-0	-0.34	0.73	-0	-1.88	0.06	-0.1	-1.48	0.14	-0.1
Arian	-0.5	0.61	-0	-2.4	0.02	-0.1	0.59	0.54	0.05	-0.48	0.63	-0	-2.31	0.02	-0.1
Baglias	-0.09	0.34	-0.1	0.16	0.87	0.02	2.13	0.03	0.11	1.23	0.22	0.07	0.12	0.91	0.02
Jawaja	-1.09	0.27	-0.1	-0.41	0.68	-0	1.69	0.09	0.08	-1.13	0.26	-0.1	-1.34	0.18	-0.1
Jhopadiyan	-2.91	0	-0.2	-0.53	0.59	-0	0	1	0	-0.98	0.32	-0.1	-2.21	0.03	-0.2
Kanpur	-0.16	0.87	-0	-0.68	0.49	-0.1	0.41	0.68	0.05	-0.73	0.46	-0	-1.45	0.15	-0.2
Ludiyana	0.51	0.61	0.03	1.71	0.09	0.1	2.54	0.01	0.14	0.36	0.72	0.03	0.86	0.39	0.05
Masuda	-0.66	0.51	-0.1	-1.27	0.2	-0.1	0.04	0.96	0.02	0.8	0.42	0.06	-2.31	0.02	-0.3
Narbadkhera	-1.84	0.06	-0.2	-1.02	0.31	-0	-0.05	0.95	-0	-1.32	0.19	-0.1	-1.26	0.21	-0.1
Nasirabad	-4.09	0	-0.1	-3.46	0	-0.2	-0.04	0.96	0	-3.23	0	-0.1	-2.13	0.03	-0.2
Sanpla	-3.07	0	-0.1	-3.66	0	-0.1	-2.34	0.02	-0.1	-3.63	0	-0.2	-6.31	0	-0.2
Taragarh	-3.59	0	-0.1	-3.89	0	-0.2	-1.23	0.22	-0	-3.04	0	-0.1	-3.75	0	-0.2
Pakhriawas	0.55	0.28	0.08	-1.11	0.26	-0.1	1.41	0.16	0.12	0.64	0.52	0.04	-0.92	0.36	-0.1
Ramsar	-4.82	0	-0.3	-7.08	0	-0.3	-3.26	0	-0.3	-4.19	0	-0.3	-7.26	0	-0.3
Bogla	-0.42	0.68	-0	0.56	0.57	0.03	1.21	0.23	0.07	0.37	0.71	0.02	0.49	0.62	0.03
Kalyanpura	0.69	0.49	0.06	1.46	0.14	0.16	1.47	0.14	0.15	0.77	0.44	0.08	0.57	0.57	0.07
Ghugra	0.33	0.74	0.09	-0.82	0.41	-0.1	-0.18	0.86	-0	0	1	-0	-1.32	0.19	-0.5

•

Dausa															
Bapi	0.94	0.35	0.04	2.84	0	0.13	2.03	0.04	0.11	1.22	0.22	0.09	2.23	0.03	0.12
Lawan	5.83	0	0.94	7.17	0	1.1	7.74	0	1.01	8.13	0	1.12	11.12	0	1.01
Mahuwa	2.74	0.01	1.59	4.56	0	1.57	5.29	0	1.67	4.69	0	1.7	5.42	0	1.71
Sikandara	5.76	0	1.59	5.78	0	1.58	9.22	0	1.1	6.55	0	1.52	10.28	0	1.27
Prahladpura	6.65	0	1.71	6.22	0	1.46	4.81	0	1.58	7.09	0	1.43	8.56	0	1.58
Bhandarej	5.32	0	0.49	7.83	0	0.59	6.89	0	0.87	9.24	0	0.59	9.85	0	0.54
Garh Ranoli	14.17	0	1.03	6.57	0	1.21	6.87	0	1.39	5.04	0	1.52	10.68	0	1.04
Dausa	7.42	0	0.62	6.36	0	0.64	3.51	0	0.63	3.63	0	0.97	4.93	0	0.64
Gijgarh	5.33	0	2.11	7.9	0	1.48	14.67	0	1.96	17.51	0	1.97	11.61	0	1.72
Barmer															
Bachhbar	6.38	0	0.34	2.75	0.01	0.27	3.5	0	0.37	3.85	0	0.32	10.42	0	0.3
Balewa	-5.92	0	-0.5	-5.12	0	-0.5	-5.41	0	-0.5	-5.13	0	-0.5	-4.38	0	-0.5
Barmer	-2.16	0.03	-0.3	-1.29	0.19	-0.3	-2.52	0.01	-0.5	-1.83	0.07	-0.4	-1.96	0.05	-0.4
Bisala	-7.35	0	-0.3	-6.67	0	-0.3	-5.25	0	-0.4	-6.67	0	-0.3	-6.7	0	-0.4
Bisukalan	4.56	0	0.04	3.83	0	0.03	4.68	0	0.06	4.42	0	0.03	3.51	0	0.03
Chohtan	1.37	0.17	0.14	2.65	0.01	0.12	-0.84	0.39	-0.1	-0.46	0.64	-0	2.86	0	0.15
Derasar	-2.13	0.03	-0.2	-3.13	0	-0.2	0.88	0.37	0.17	-4.97	0	-0.5	-4.15	0	-0.2
Devra	0.84	0.4	0.19	4.62	0	0.31	4.82	0	0.36	0.57	0.57	0.04	3.17	0	0.19
Doli	-2.72	0	-0.7	-1.27	0.21	-0.5	-2.87	0	-0.7	-2.21	0.03	-0.6	-1.61	0.11	-0.5

Hathitala	-4.02	0	-0	-6.93	0	-0.1	-0.48	-0.63	-0	-6.34	0	-0.1	-5.83	0	-0.1
Jasai	0.68	0.49	0.04	-1.04	0.29	-0.1	-1.51	0.13	-0.1	-1.95	0.05	-0.2	-1.76	0.08	-0.2
Jawansingh Ki Ber	-3.69	0	-0.5	-4.4	0	-0.5	-5.07	0	-0.6	-3.53	0	-0.5	-3.56	0	-0.5
Kateria	0	1	0	-0.84	0.4	0	1.02	0.31	0.02	-1.73	0.08	-0	-0.25	0.8	0
Matasar	-8.74	0	-0.2	-6.35	0	-0.1	-5.15	0	-0.1	-5.67	0	-0.1	-6.02	0	-0.1
Nand	-3.51	0	-0.2	-1.34	0.18	-0.1	-3.84	0	-0.4	-3.41	0	-0.4	-1.57	0.12	-0.2
Nimri	-2.95	0	-0.1	-0.97	0.33	-0	-5.36	0	-0.2	-4.15	0	-0.2	-0.86	0.39	-0
Padmaniyon	2.36	0.02	0.04	-1.02	0.31	-0.1	-2.41	0.02	-0.1	0.26	0.79	0	-0.6	0.55	-0
Panavada	-4.45	0	-0.1	-8.07	0	-0.1	-3.03	0	-0.1	-5.97	0	-0.1	-8.8	0	-0.1
Panchla	-8.18	0	-0.3	-8.25	0	-0.3	-8.33	0	-0.3	-6.62	0	-0.3	-8.17	0	-0.3
Patrasar	5.28	0	0.22	4.09	0	0.22	5.26	0	0.15	5.31	0	0.19	4.25	0	0.25
Redana	-1.88	0.06	-0.3	-1.46	0.14	-0.2	-5.96	0	-0.4	-2.45	0.01	-0.2	-1.78	0.08	-0.2
Sanawara	-3.41	0	-0.1	-5.02	0	-0.1	-3.61	0	-0.2	-3.72	0	-0.2	-3.44	0	-0.1
Sanlor	-2.77	0.01	-0.1	-5.72	0	-0.1	-1.17	0.24	-0.1	-9.95	0	-0.3	-8.03	0	-0.1
Sasion Ka Kua	3.28	0	0.14	2.65	0.01	0.19	3.17	0	0.19	1.48	0.14	0.05	2.09	0.04	0.13
Saupadamsingh	-10.99	0	-0.4	-8.47	0	-0.3	-8.99	0	-0.4	-11.39	0	-0.4	-6.18	0	-0.3
Sihani	8.43	0	0.56	2.11	0.03	0.24	-1.45	0.15	-0.2	-1.24	0.22	-0.2	1.43	0.15	0.15
Siyaga Tala	0.74	0.46	0.02	-1.06	0.29	-0.1	-2.66	0	-0.1	-0.89	0.37	-0.1	-3.38	0	-0.1
Sutharon ki dha	-1.07	0.29	-0.1	-1	0.32	-0.1	-0.21	0.84	-0	-0.45	0.65	-0	-1.61	0.11	-0.1
Thob	-0.76	0.45	-0.1	-1.1	0.27	-0.1	1.74	0.08	0.09	3.38	0	0.09	-2.28	0.02	-0.2

Gujro ka Bera	5.95	0	1.16	6.64	0	1.08	6.23	0	1.09	6.39	0	1.13	7.04	0	1.19
Kashmir	6.46	0	0.89	6.91	0	0.82	8.75	0	0.77	5.94	0	0.81	7.18	0	0.95
Sindari	-3.26	0	-0	-3.75	0	-0	-0.26	0.79	0	-1.55	0.12	-0	-1.61	0.11	-0
Piparli Gaon	-8.42	0	-0.1	-5.97	0	-0.1	-9.49	0	-0.1	-12.01	0	-0.1	-7.07	0	-0.1
Adel	0.87	0.38	0.01	1.99	0.05	0.07	3.34	0	0.07	1.47	0.14	0.07	2.46	0.01	0.08

Source: Authors' calculation

•

Table 4.5: Statistical summary of groundwater quality parameters from 2000 to 2018

Ajmer

Total Alkalinity (mg/L)	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Median	550.00	369.70	459.85	380.30	259.80	409.80	419.70	359.75	369.70	359.80	400.00	375.00	429.70	248.77	575.00	355.08	350.00	359.84
SD	297.29	279.58	283.40	294.07	230.68	263.34	199.18	244.33	279.83	102.92	227.75	205.21	258.73	219.99	429.34	322.33	349.14	211.80
Maximum	1119.70	1440.20	1060.30	1119.70	919.70	1219.70	1040.20	1050.00	1440.20	557.40	900.00	1050.00	1064.80	1030.33	1519.67	1519.00	1519.67	550.00
Minimum	300.00	130.30	109.80	80.30	109.80	190.00	209.80	130.30	130.30	159.80	110.30	150.00	159.80	69.18	369.67	136.07	80.33	129.51
Calcium (mg/L)																		
Median	78.00	72.00	52.00	48.00	30.00	52.00	48.00	61.00	56.00	48.00	96.00	54.50	60.50	56.00	134.00	64.00	56.00	61.00
SD	57.38	58.70	55.67	46.45	28.57	38.49	245.06	23.91	59.89	198.04	85.39	77.56	89.13	55.87	78.67	684.84	75.53	95.17
Maximum	208.00	264.00	248.00	216.00	116.00	144.00	160.00	91.00	264.00	810.00	296.00	320.00	325.00	280.00	256.00	2800.00	325.00	368.00

-

Minimum	24.00	20.00	20.00	12.00	8.00	12.00	24.00	19.00	20.00	22.00	16.00	19.00	29.00	40.00	40.00	8.00	20.00	0.00
Chloride (mg/L)																		
Median	770.00	213.00	337.50	202.00	198.50	241.00	376.00	188.50	213.00	133.00	362.00	206.00	371.00	212.50	465.00	177.50	296.00	425.00
SD	1242.68	771.81	706.96	596.67	259.65	420.74	1715.61	748.14	771.11	1078.31	920.27	775.31	775.35	451.69	1195.69	2254.14	903.07	824.23
Maximum	5254.00	2907.00	2102.00	1773.00	936.00	1588.00	5566.00	2723.00	2907.00	4330.00	2591.00	2698.00	2264.00	1520.00	3337.00	9230.00	3337.00	2127.00
Minimum	78.00	14.00	28.00	21.00	21.00	28.00	43.00	36.00	14.00	42.00	36.00	29.00	54.00	35.00	213.00	43.00	43.00	46.00
Electrical Conductivity (mumhos/cm) at 25 C)																		
Median	3680.00	1700.00	2240.00	1560.00	1612.50	1910.00	2250.00	1270.00	1700.00	1265.00	2000.00	1699.50	2840.00	1225.00	2750.00	1185.00	2530.00	2800.00
SD	3671.78	2381.78	2668.05	2353.60	1332.18	1529.98	5384.25	3089.68	2381.78	3141.24	3424.30	3116.77	2909.46	1600.56	5393.07	6443.31	3688.62	2732.51

Maximum	15415.00	9380.00	9120.00	7490.00	5660.00	5700.00	20500.00	11780.00	9380.00	13400.00	10450.00	12520.00	9180.00	6170.00	14540.00	26900.00	14540.00	7100.00
Minimum	1030.00	310.00	560.00	240.00	435.00	490.00	600.00	660.00	310.00	710.00	438.00	488.00	488.00	390.00	1800.00	370.00	370.00	695.00
Fluoride (mg/L)																		
Median	2.18	1.48	2.48	2.31	1.95	2.84	2.38	0.98	1.48	1.71	0.94	1.00	1.10	0.85	2.50	1.90	0.80	0.65
SD	1.70	1.40	1.10	2.68	2.62	2.87	1.93	0.78	1.40	3.79	0.56	0.78	0.87	0.76	3.04	1.96	1.98	0.36
Maximum	5.93	4.93	4.52	11.47	10.22	10.60	8.75	2.63	4.93	4.60	2.60	3.32	3.20	3.32	9.00	8.70	9.00	1.20
Minimum	1.05	0.21	0.80	0.56	0.62	0.63	0.32	0.13	0.21	0.33	0.17	0.25	0.40	0.25	1.80	0.20	0.13	0.07
Iron (mg/L)																		
Median	0.33	0.21	0.04	0.44	0.20	0.72	0.15	0.61	0.21	0.84	0.27	0.91	0.60	0.91	4.35	0.40	0.60	0.29
SD	1.65	0.53	0.03	2.10	1.17	4.54	1.12	1.11	0.53	2.27	3.39	2.69	1.31	1.18	4.74	0.78	1.27	0.54
Maximum	7.00	1.65	0.14	9.48	4.40	16.50	4.44	3.50	1.65	7.01	14.40	12.00	4.30	4.90	10.00	2.50	4.90	1.95
Minimum	0.09	0.03	0.02	0.03	0.01	0.12	0.02	0.03	0.03	0.08	0.04	0.18	0.10	0.18	0.12	0.13	0.00	0.00

Total Hardness (mg/L)																		
Median	460.00	420.00	300.00	235.00	215.00	270.00	450.00	300.00	420.00	270.00	460.00	277.50	395.00	310.00	550.00	290.00	340.00	360.00
SD	365.33	411.02	236.40	247.90	123.98	259.73	843.40	189.85	411.02	607.40	371.82	356.34	409.45	349.99	366.78	1805.23	411.57	487.71
Maximum	1440.00	1550.00	1060.00	1000.00	500.00	1040.00	1800.00	870.00	1550.00	2602.00	1250.00	1340.00	1350.00	1620.00	1200.00	7500.00	1350.00	2020.00
Minimum	120.00	110.00	100.00	40.00	60.00	50.00	110.00	193.00	110.00	142.00	110.00	147.00	120.00	150.00	300.00	110.00	110.00	90.00
Bicarbonate (mg/L)																		
Median	671.00	451.00	561.00	464.00	317.00	464.00	512.00	433.00	451.00	427.00	488.00	457.50	503.00	291.50	805.00	335.50	396.00	439.00
SD	362.68	341.38	331.96	358.76	281.42	319.18	242.99	299.34	341.38	125.28	277.85	243.92	319.90	221.12	418.67	263.17	361.72	252.52
Maximum	1366.00	1757.00	1196.00	1366.00	1122.00	1488.00	1269.00	1281.00	1757.00	680.00	1098.00	1281.00	1299.00	1013.00	1488.00	1159.00	1488.00	671.00
Minimum	366.00	159.00	134.00	98.00	134.00	183.00	256.00	159.00	159.00	195.00	37.00	183.00	171.00	60.00	451.00	98.00	98.00	158.00

Potassium (mg/L)																		
Median	17.50	11.00	8.60	7.45	8.80	7.50	13.00	2.00	11.00	13.50	9.30	11.90	6.50	1.25	9.00	4.10	3.70	6.40
SD	79.43	78.37	58.43	11.12	15.85	20.15	19.91	15.08	78.37	16.09	42.82	9.58	34.36	1.84	59.93	7.66	43.62	30.89
Maximum	320.00	283.00	242.00	47.00	64.00	77.00	76.00	53.00	283.00	66.00	187.00	37.00	140.00	7.80	144.00	32.00	144.00	121.00
Minimum	3.00	1.90	2.70	2.20	1.90	2.10	2.40	1.00	1.90	0.40	2.90	1.40	1.00	1.00	4.00	0.80	1.10	1.00
Magnesium (mg/L)																		
Median	76.50	46.00	38.50	28.00	29.50	41.00	63.00	35.00	46.00	38.95	43.80	46.61	45.65	36.34	61.00	32.00	43.17	48.69
SD	77.94	73.03	26.44	38.08	20.38	50.19	101.59	43.41	73.03	31.68	55.07	52.11	56.06	57.13	73.45	38.43	65.07	114.62
Maximum	270.00	224.00	107.00	146.00	80.00	197.00	389.00	180.00	224.00	141.27	182.59	177.54	149.22	224.02	218.96	122.00	218.88	439.00
Minimum	7.00	4.90	12.00	2.40	9.70	4.90	12.00	21.00	4.90	19.53	1.00	19.53	11.58	0.07	44.00	5.00	11.55	12.18
Sodium (mg/L)																		

Median	653.00	281.00	402.50	271.00	257.50	325.00	409.00	196.50	281.00	172.00	277.00	223.50	310.00	125.00	484.00	179.00	240.00	303.00
SD	790.47	610.19	623.66	498.30	316.59	321.94	1217.74	766.82	610.19	453.44	790.45	641.41	648.83	295.95	1079.51	1022.24	734.37	531.20
Maximum	3050.00	2473.00	1978.00	1580.00	1288.00	1124.00	4840.00	2775.00	2473.00	1878.00	2144.00	2419.00	2060.00	1060.00	2750.00	4200.00	2750.00	1155.00
Minimum	193.00	18.00	58.00	12.00	41.00	55.00	73.00	48.00	18.00	82.00	22.00	29.00	30.00	28.00	162.00	33.00	33.00	43.00
Nitrate (mg/L)																		
Median	26.00	22.00	16.00	28.00	43.00	38.00	50.00	21.00	22.00	30.00	23.00	15.00	43.50	20.00	154.00	21.00	20.00	28.00
SD	76.19	30.47	57.83	53.52	145.10	108.27	169.29	93.18	30.47	27.67	99.25	86.98	103.08	47.46	175.91	38.31	107.38	86.39
Maximum	310.00	129.00	173.00	247.00	488.00	327.00	588.00	333.00	129.00	100.00	303.00	374.00	300.00	145.00	400.00	120.00	400.00	302.00
Minimum	0.20	0.20	0.60	0.20	1.00	1.00	0.03	3.00	0.20	1.07	0.17	0.20	2.00	0.20	0.00	0.00	1.00	0.00
pH																		
Median	7.98	7.75	8.19	7.68	7.83	8.20	7.93	8.10	7.75	7.87	7.81	8.01	8.05	8.22	7.97	7.63	8.13	7.93
SD	0.19	0.20	0.36	0.18	0.33	0.29	0.25	0.23	0.20	0.25	0.40	0.21	0.34	0.28	0.35	0.32	0.35	0.29

Maximum	8.30	7.96	8.45	7.96	8.28	8.72	8.25	8.60	7.96	8.12	8.72	8.45	8.50	8.84	8.52	8.27	8.52	8.44
Minimum	7.79	7.14	7.35	7.37	7.00	7.60	7.73	7.70	7.14	7.37	7.17	7.53	7.17	7.75	7.70	7.26	7.50	7.28
Sulphate (mg/L)																		
Median	368.00	155.00	195.00	34.50	111.00	150.00	190.00	61.50	155.00	63.00	88.00	112.50	120.00	33.00	215.00	60.00	86.00	182.00
SD	394.78	392.33	195.64	177.02	160.67	154.69	706.30	471.28	392.33	189.21	594.74	425.41	445.84	110.58	245.98	833.96	427.55	128.47
Maximum	1680.00	1620.00	720.00	610.00	510.00	580.00	2885.00	1690.00	1620.00	763.00	1788.00	958.00	700.00	440.00	755.00	3420.00	742.00	571.00
Minimum	64.00	0.00	45.00	0.00	17.00	22.00	30.00	7.00	0.00	9.00	15.00	10.00	10.00	5.00	175.00	15.00	5.00	43.00
Carbonate (mg/L)																		
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD	0.00	0.00	19.26	0.00	0.00	26.66	0.00	9.34	0.00	12.39	19.68	8.26	19.60	31.43	73.48	0.00	43.14	21.69
Max	0.00	0.00	48.00	0.00	0.00	84.00	0.00	24.00	0.00	48.00	72.00	36.00	72.00	120.00	180.00	0.00	180.00	84.00

Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barmer																		
Total Alkalinity (mg/L)																		
Median	280.30	284.80	229.95	266.63	305.00	316.68	321.72	359.85	302.45	265.00	282.93	287.57	292.15	398.78	300.00	332.38	349.67	311.88
SD	114.27	138.68	137.28	120.68	108.69	120.24	149.13	146.10	125.11	134.64	130.18	133.47	118.81	140.71	167.57	162.44	236.88	233.78
Max	590.30	630.30	630.30	650.00	625.40	632.80	669.70	635.25	630.30	600.00	602.45	604.90	534.40	650.00	800.00	805.41	1100.00	983.61
Min	190.20	140.20	109.80	130.30	140.20	195.10	150.00	150.00	140.20	130.30	135.05	139.80	168.90	160.33	80.33	169.95	159.84	169.67
Calcium (mg/L)																		
Median	52.00	60.00	82.00	56.67	68.00	78.50	70.50	81.50	68.75	90.50	97.96	92.67	74.00	98.00	80.00	76.00	70.00	52.00
SD	82.85	54.70	71.34	78.63	90.86	56.53	48.23	66.25	87.05	89.79	64.69	49.33	74.81	62.14	42.63	110.23	51.52	32.57
Max	272.00	212.00	328.00	317.33	360.00	213.67	220.00	296.00	328.00	334.00	280.50	227.00	340.00	240.00	160.00	482.00	232.00	151.00

Min	16.00	32.00	24.00	32.00	28.00	35.50	28.00	17.00	23.20	23.00	22.00	21.00	20.00	47.50	40.00	24.00	24.00	16.00
Chloride (mg/L)																		
Median	696.00	575.00	617.75	697.17	877.00	733.50	671.00	841.50	564.50	713.00	666.81	610.13	621.50	533.00	461.00	448.75	411.00	278.00
SD	1140.45	868.70	1274.47	1727.83	2001.65	1272.40	1075.77	1056.20	1175.07	953.02	791.89	847.66	1471.08	575.83	859.50	1222.23	1217.10	739.17
Max	4296.00	2638.00	5645.00	6390.00	8130.00	4205.00	4473.00	4403.00	5041.00	3480.67	2857.00	3657.00	6745.00	2075.00	2942.00	4146.00	4500.00	2320.00
Min	64.00	81.50	64.00	50.00	50.00	135.00	115.00	99.00	78.00	30.00	137.00	114.00	64.00	99.00	43.00	43.00	71.00	79.00
Electrical Conductivity (mumhos/cm) at 25 C)																		
Median	3640.00	3130.00	3400.00	3485.00	3760.00	3797.50	3180.00	3240.00	2652.50	3510.00	3130.00	2995.00	2964.38	3230.00	2600.00	2650.00	2785.00	1875.00
SD	3397.39	2511.81	3283.82	4424.84	4352.53	2971.21	2983.04	3080.76	3281.76	3015.92	2861.70	3377.20	5251.40	2462.00	2924.62	4700.88	4124.82	2596.03

Max	13830.00	8615.00	14940.00	17500.00	17520.00	9940.00	13100.00	12600.00	14670.00	10330.00	11145.00	15000.00	24930.00	9210.00	10115.00	18580.00	15550.00	9250.00
Min	820.00	525.00	500.00	720.00	835.00	1202.50	1351.67	720.00	525.00	500.00	860.00	800.00	664.00	970.00	350.00	610.00	950.00	1040.00
Fluoride (mg/L)																		
Median	1.72	1.75	1.55	1.38	1.32	1.37	1.38	1.15	1.49	1.17	1.16	1.11	1.00	1.06	1.01	1.07	1.35	1.36
SD	0.66	0.92	1.06	0.90	0.78	0.78	0.92	0.73	0.97	0.74	0.67	0.66	0.62	0.67	0.58	0.43	1.77	0.85
Max	3.50	3.40	4.47	4.40	3.88	3.40	3.50	3.45	3.40	2.88	2.38	2.30	2.35	2.50	2.45	1.77	7.50	2.95
Min	1.02	0.19	0.45	0.35	0.39	0.50	0.15	0.22	0.19	0.27	0.21	0.10	0.10	0.10	0.35	0.18	0.04	0.25
Iron (mg/L)																		
Median	0.07	0.03	0.08	0.10	0.17	0.14	0.07	0.06	0.06	0.14	0.14	0.09	0.15	0.09	0.21	0.25	0.05	0.23
SD	0.18	0.62	0.49	1.00	0.72	0.36	0.13	0.36	0.54	2.08	1.08	0.35	1.58	1.85	1.35	1.16	0.40	1.18
Max	0.56	2.37	1.91	4.20	3.18	1.63	0.52	1.22	2.37	9.21	4.64	1.15	7.20	7.20	4.65	4.50	1.50	4.51
Min	0.01	0.01	0.03	0.03	0.01	0.04	0.03	0.01	0.01	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.15
Total Hardness (mg/L)																		

Median	400.00	400.00	446.67	320.00	415.00	471.00	482.00	367.00	317.25	442.50	540.50	470.00	443.68	513.33	520.00	469.25	458.38	360.00
SD	339.23	248.85	681.08	763.93	771.29	471.66	366.06	329.68	392.70	455.57	340.93	297.64	429.50	397.82	245.84	562.07	478.81	209.59
Max	1280.00	865.00	3250.00	3123.33	3060.00	2067.67	1360.00	1290.00	1540.00	1800.00	1321.25	1247.50	1900.00	1550.00	1070.00	2100.00	2095.00	935.00
Min	80.00	90.00	80.00	160.00	170.00	178.67	187.33	83.00	90.00	157.80	195.20	200.00	80.00	230.00	150.00	160.00	160.00	240.00
Bicarbonate (mg/L)																		
Median	317.00	347.50	277.25	317.17	354.00	373.17	380.33	439.00	369.00	292.50	323.80	306.30	337.20	418.00	366.00	389.00	390.00	380.50
SD	110.69	171.42	167.94	148.79	136.50	148.04	182.28	178.23	154.83	166.99	158.25	169.26	146.66	155.20	205.69	284.10	236.50	249.74
Max	561.00	769.00	769.00	793.00	763.00	772.00	817.00	775.00	769.00	732.00	735.00	738.00	652.00	671.00	976.00	1281.00	976.00	956.00
Min	232.00	171.00	134.00	159.00	171.00	238.00	183.00	183.00	171.00	159.00	116.00	73.00	142.33	98.00	98.00	61.00	177.00	175.00
Potassium (mg/L)																		

Median	36.00	16.50	10.13	18.50	12.25	13.48	14.17	15.00	15.40	13.17	11.80	10.40	5.62	9.35	4.70	10.13	9.40	2.50
SD	107.60	84.91	62.16	29.95	30.62	46.25	63.88	74.53	86.43	111.55	94.86	80.94	78.33	69.74	36.75	39.21	39.38	37.10
Max	440.00	362.50	285.00	130.00	125.00	205.00	285.00	336.00	399.00	462.00	414.00	366.00	318.00	270.00	165.00	145.00	141.00	141.00
Min	4.00	2.15	0.30	1.47	1.10	0.90	0.10	1.00	1.63	1.00	1.00	1.00	0.80	0.90	1.00	1.00	1.30	1.00
Magnesium (mg/L)																		
Median	66.00	53.50	51.50	56.00	57.00	85.50	85.00	57.50	43.50	63.00	67.24	63.20	65.74	73.05	68.27	67.54	69.31	58.41
SD	38.55	43.50	126.38	140.40	136.34	84.72	70.26	47.88	52.46	65.42	52.42	50.51	64.29	62.91	41.94	78.86	86.58	37.38
Max	151.00	175.00	591.00	566.33	554.00	371.00	287.00	178.00	175.00	252.62	182.20	176.93	255.70	231.00	168.01	311.00	368.45	148.41
Min	10.00	15.00	15.00	10.00	7.00	13.33	19.67	5.00	10.00	17.61	23.92	24.32	7.32	25.02	12.21	15.00	19.46	21.98
Sodium (mg/L)																		
Median	658.00	592.00	553.50	708.67	742.00	674.25	527.00	631.50	472.75	628.83	599.42	528.83	503.75	484.00	390.00	408.75	392.50	234.50

SD	796.77	552.97	579.12	933.61	1110.16	709.97	656.21	677.74	682.45	639.16	628.28	749.75	1043.11	463.04	591.46	876.89	867.55	559.57
Max	3175.00	1878.00	2355.00	3795.00	4750.00	2487.50	2760.00	2700.00	3005.00	2087.33	2297.50	3182.00	4800.00	1820.00	1930.00	3340.00	3250.00	1826.00
Min	111.00	42.00	78.00	87.00	105.00	161.00	160.67	8.00	42.00	28.00	39.50	51.00	30.00	99.00	14.00	42.00	114.00	69.00
Nitrate (mg/L)																		
Median	82.00	151.00	125.50	97.00	136.50	149.33	142.50	123.00	182.50	96.00	93.12	101.45	48.50	68.00	33.66	77.50	78.00	43.00
SD	168.72	150.28	137.55	94.82	122.30	147.02	202.06	184.12	182.44	213.58	189.33	179.06	180.84	195.25	60.13	82.00	98.80	122.97
Max	490.00	479.50	527.00	377.00	508.00	509.00	800.00	766.00	777.00	788.00	802.60	817.20	831.80	846.40	203.00	332.00	360.00	397.00
Min	2.30	1.15	0.00	5.00	0.00	1.87	3.00	2.00	2.85	0.00	7.71	1.11	0.00	1.10	4.00	2.43	2.00	8.80
pH2																		
Median	8.08	7.97	8.08	8.10	7.99	7.82	7.86	7.86	7.97	8.09	8.12	8.12	8.15	8.07	8.08	8.18	8.28	8.14
SD	0.43	0.35	0.27	0.26	0.30	0.23	0.37	0.22	0.39	0.38	0.30	0.25	0.26	0.26	0.23	0.16	0.21	0.39
Max	8.97	8.33	8.30	8.46	8.45	8.50	8.75	8.23	8.52	8.95	8.87	8.79	8.71	8.75	8.56	8.48	8.46	8.85
Min	7.54	7.11	7.43	7.45	7.45	7.58	7.15	7.40	7.11	7.43	7.64	7.80	7.75	7.75	7.78	7.92	7.65	7.12

Sulphate (mg/L)																		
Median	464.00	311.00	168.00	281.17	289.67	273.50	229.00	214.50	167.25	262.60	247.71	239.50	390.00	256.75	135.00	153.00	187.00	120.00
SD	401.92	237.89	217.45	323.39	380.65	253.44	204.84	264.81	241.47	426.09	443.45	520.97	552.46	473.69	332.27	741.93	616.57	215.35
Max	1687.00	925.50	800.00	1219.00	1323.00	1093.50	864.00	905.00	976.50	1515.00	1511.75	2004.00	2350.00	1608.00	1346.50	2680.00	2400.00	870.00
Min	134.00	0.03	24.00	32.00	35.00	32.50	30.00	15.00	0.03	24.00	48.50	13.00	30.00	13.00	20.00	10.00	54.00	25.00
Carbonate (mg/L)																		
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD	29.62	0.00	0.00	13.07	11.94	0.00	0.00	0.00	0.00	15.94	0.00	38.29	23.15	35.99	12.30	30.73	49.41	37.64
Max	96.00	0.00	0.00	36.00	36.00	0.00	0.00	0.00	0.00	48.00	0.00	120.00	72.00	120.00	36.00	90.00	180.00	120.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dausa																		
Total Alkalini																		

ty (mg/L)																		
Median	280.00	689.75	495.05	660.00	572.30	464.75	690.15	737.30	689.75	570.10	350.00	325.00	222.95	358.95	500.00	472.54	471.86	520.16
SD	-	226.00	203.97	373.96	289.09	329.13	332.70	236.87	226.00	123.71	85.93	79.68	47.60	126.86	238.84	175.63	154.52	85.41
Max	280.00	918.00	759.87	959.80	910.25	880.30	1019.70	844.70	918.00	639.80	490.20	400.20	300.10	509.84	659.84	626.56	593.28	590.16
Min	280.00	369.70	309.80	240.20	349.75	130.30	230.30	330.30	369.70	359.85	286.90	213.30	194.80	200.00	100.00	226.78	300.00	400.00
Calcium (mg/L)																		
Median	20.00	36.00	29.33	34.00	32.00	30.00	68.00	39.00	36.00	51.00	54.00	58.00	108.00	103.50	70.00	96.00	56.50	80.00
SD	-	76.28	88.51	69.82	17.92	37.95	53.36	93.88	76.28	88.02	104.03	37.43	93.69	61.60	37.67	55.99	70.84	37.52
Max	20.00	184.00	204.00	168.00	60.00	100.00	159.50	219.00	184.00	216.00	248.00	120.00	260.00	190.00	120.00	122.00	192.00	88.00
Min	20.00	24.00	22.67	20.00	18.00	16.00	36.00	20.00	24.00	24.00	20.00	32.00	38.00	44.00	28.00	4.00	42.00	8.00
Chloride (mg/L)																		

Median	320.00	440.00	340.67	354.50	294.25	234.00	245.00	348.50	440.00	425.50	262.50	191.50	367.50	454.50	408.50	451.00	735.50	514.00
SD	-	734.98	740.79	757.36	148.75	644.82	724.28	755.37	734.98	672.63	677.91	652.17	642.41	631.38	583.15	612.64	578.31	851.24
Max	320.00	1874.00	1789.00	1801.00	518.00	1490.00	1659.50	1829.00	1874.00	1718.00	1562.00	1456.00	1506.00	1476.00	1446.00	1450.00	1560.00	1992.00
Min	320.00	341.00	249.00	184.00	163.00	142.00	156.00	270.00	341.00	287.50	135.00	85.00	96.00	107.00	170.00	144.00	348.00	78.00
Electrical Conductivity (mumhos/cm) at 25 C)																		
Median	1730.00	3275.00	2708.33	3200.00	2557.50	2245.00	2500.00	2802.50	3275.00	2805.00	1890.00	2299.00	2350.00	3152.50	2415.00	3295.00	3702.50	2450.00
SD	-	1676.99	1801.82	1872.01	698.55	1636.22	1646.36	1702.21	1676.99	1616.51	1628.38	1735.82	1746.23	2079.75	1379.88	2145.71	1233.97	2815.56
Max	1730.00	6470.00	5985.00	5890.00	2800.00	4950.00	5500.00	6050.00	6470.00	5690.00	4910.00	4740.00	4790.00	4900.00	4780.00	5230.00	5300.00	7510.00
Min	1730.00	2930.00	1990.00	1360.00	1267.50	1175.00	1840.00	2425.00	2930.00	2170.00	1330.00	970.00	985.00	1000.00	1590.00	1150.00	2570.00	1200.00

Fluoride (mg/L)																		
Median	1.10	1.63	1.99	1.36	1.61	1.55	1.12	1.23	1.63	1.43	1.93	2.21	2.10	2.07	1.65	1.75	1.67	1.81
SD	-	0.70	0.80	1.45	1.33	1.43	0.55	0.50	0.70	0.38	1.09	0.90	1.05	1.01	1.16	0.83	1.03	1.88
Max	1.10	2.95	3.35	4.16	4.18	4.21	1.60	1.68	2.95	1.95	3.60	3.40	3.60	3.70	3.80	3.10	3.35	5.40
Min	1.10	1.45	1.51	1.09	1.43	1.05	0.41	0.61	1.45	1.03	1.25	1.38	1.20	1.39	1.25	1.30	1.09	1.40
Iron (mg/L)																		
Median	0.60	0.72	0.52	0.93	0.59	0.33	1.06	1.10	0.67	0.29	0.12	0.44	0.30	0.39	0.20	0.22	0.20	0.17
SD	-	0.63	0.69	0.52	0.40	0.21	1.98	4.29	0.53	0.32	0.76	0.06	0.16	0.90	0.12	0.96	0.48	0.06
Max	0.60	1.56	1.64	1.80	1.10	0.69	4.84	9.40	1.56	0.87	1.60	0.47	0.49	2.11	0.40	2.11	1.13	0.21
Min	0.60	0.33	0.10	0.60	0.18	0.20	0.62	0.35	0.33	0.20	0.03	0.34	0.10	0.19	0.11	0.11	0.12	0.07
Total Hardness (mg/L)																		
Median	300.00	410.00	311.67	310.00	275.00	240.00	415.00	369.00	410.00	445.00	300.00	355.00	405.00	545.00	395.00	555.00	555.00	570.00
SD	-	582.14	562.51	534.31	132.92	393.39	452.21	616.77	582.14	461.11	399.33	464.21	462.93	414.97	410.41	455.88	400.43	556.08

Max	300.00	1520.00	1390.00	1340.00	500.00	1000.00	1287.50	1575.00	1520.00	1270.00	1020.00	1200.00	1250.00	1200.00	1150.00	1170.00	1140.00	1340.00
Min	300.00	270.00	200.00	210.00	190.00	170.00	330.00	300.00	270.00	230.00	140.00	160.00	215.00	270.00	240.00	110.00	240.00	50.00
Bicarbonate (mg/L)																		
Median	244.00	841.50	563.33	744.00	667.75	567.00	842.00	899.50	841.50	671.00	427.00	152.50	189.75	383.00	610.00	630.00	498.00	598.00
SD	-	275.75	264.62	428.67	344.40	401.55	405.88	288.95	275.75	129.77	104.82	97.56	47.29	204.33	291.38	240.07	180.23	95.28
Max	244.00	1120.00	927.00	1147.00	1110.50	1074.00	1244.00	1030.50	1120.00	732.00	598.00	293.00	250.00	622.00	805.00	642.00	720.00	720.00
Min	244.00	451.00	378.00	293.00	414.50	159.00	281.00	403.00	451.00	439.00	350.00	65.00	140.00	122.00	122.00	154.00	366.00	488.00
Potassium (mg/L)																		
Median	2.60	2.10	3.68	6.50	4.70	2.90	4.65	2.23	2.10	2.85	2.50	4.20	1.85	3.47	4.15	3.65	3.17	3.40
SD	-	8.00	6.12	6.73	2.74	6.95	3.60	1.28	8.00	6.10	4.72	4.72	2.27	2.20	3.63	4.10	4.15	2.48
Max	2.60	18.00	15.00	16.00	7.80	16.00	10.00	4.00	18.00	14.50	11.00	11.00	6.00	6.00	10.00	11.00	11.30	6.84

Min	2.60	1.80	1.67	1.40	1.40	1.40	1.80	1.00	1.80	1.50	1.00	1.00	0.95	0.90	2.00	1.70	2.70	1.80
Magnesium (mg/L)																		
Median	61.00	78.00	52.17	54.50	47.25	40.00	60.50	69.00	78.00	77.33	48.65	51.07	32.50	69.43	53.57	76.61	102.45	87.63
SD	-	104.00	87.95	87.69	21.58	72.60	78.56	96.83	104.00	59.07	38.32	90.43	57.36	64.37	78.96	81.95	66.72	120.69
Max	61.00	258.00	214.00	224.00	85.00	182.00	216.00	250.00	258.00	177.78	97.55	218.88	146.00	176.41	206.81	210.37	160.51	277.27
Min	61.00	18.00	25.00	39.00	35.50	32.00	56.00	38.00	18.00	41.36	4.92	19.46	29.20	38.95	41.37	24.32	29.18	7.30
Sodium (mg/L)																		
Median	281.00	664.50	561.67	687.00	442.25	455.00	490.00	585.25	664.50	555.00	265.50	377.50	371.75	430.00	401.00	507.00	625.75	312.50
SD	-	173.31	203.02	272.80	190.72	230.90	191.24	151.17	173.31	258.46	304.79	217.93	248.55	353.82	248.41	341.36	105.68	446.97
Max	281.00	985.00	851.00	838.00	602.50	700.00	756.00	812.00	985.00	902.50	820.00	589.00	589.00	804.00	790.00	808.00	710.00	1200.00
Min	281.00	610.00	391.00	211.00	183.50	156.00	290.00	450.00	610.00	364.00	165.00	164.00	145.00	111.00	196.00	200.00	500.00	295.00

Nitrate (mg/L)																		
Median	0.00	102.50	92.17	58.00	36.75	58.00	48.00	78.25	102.50	38.00	22.00	11.11	13.50	22.75	14.50	12.50	12.04	10.00
SD	-	53.84	51.52	29.23	25.54	34.53	32.68	49.01	53.84	136.56	8.65	5.34	17.16	317.21	1.71	320.20	158.86	15.35
Max	0.00	131.00	129.00	74.00	61.00	89.00	75.00	116.00	131.00	297.00	29.00	17.09	46.00	654.10	16.00	650.00	327.00	36.00
Min	0.00	7.80	8.87	11.00	12.50	14.00	0.09	3.95	7.80	8.45	9.10	4.04	9.07	14.10	12.00	4.00	4.07	3.00
pH2																		
Median	8.90	7.94	8.14	8.40	8.21	8.03	8.08	8.07	7.94	7.93	8.00	8.33	8.37	8.14	7.98	8.11	7.86	7.85
SD	-	0.38	0.30	0.28	0.16	0.13	0.18	0.21	0.38	0.35	0.08	0.07	0.12	0.27	0.38	0.44	0.20	0.31
Max	8.90	8.10	8.58	8.63	8.37	8.10	8.15	8.20	8.10	8.46	8.10	8.42	8.40	8.45	8.16	8.35	7.99	8.33
Min	8.90	7.25	7.85	7.98	8.00	7.80	7.76	7.71	7.25	7.63	7.90	8.24	8.15	7.85	7.34	7.39	7.52	7.62
Sulphate (mg/L)																		
Median	174.00	381.50	312.83	252.00	143.25	70.00	226.00	258.75	381.50	247.00	57.50	166.50	170.00	177.00	200.00	220.00	208.25	14.00

SD	-	116.60	66.11	97.40	37.92	82.90	102.11	95.18	116.60	102.16	101.91	280.07	252.14	113.93	148.96	156.20	93.95	303.79
Max	174.00	561.00	345.00	323.00	163.00	220.00	293.50	367.00	561.00	398.00	235.00	642.00	650.00	368.00	345.00	380.00	371.50	618.00
Min	174.00	282.00	199.00	93.00	76.50	35.00	55.00	153.00	282.00	151.00	14.00	12.00	113.00	120.00	40.00	48.00	158.00	4.00
Carbonate (mg/L)																		
Median	48.00	0.00	18.00	12.00	0.00	0.00	0.00	0.00	0.00	24.00	0.00	108.00	48.00	30.00	0.00	0.00	0.00	0.00
SD		0.00	25.46	31.75		0.00	0.00	0.00	0.00	33.94	0.00	13.86	31.75	42.43	0.00	36.00	0.00	18.00
Max	48.00	0.00	36.00	60.00	0.00	0.00	0.00	0.00	0.00	48.00	0.00	120.00	60.00	60.00	0.00	72.00	0.00	36.00
Min	48.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	96.00	0.00	0.00	0.00	0.00	0.00	0.00
Jaipur																		
Total Alkalinity (mg/L)																		
Median	425.40	420.20	400.00	351.16	356.89	430.30	430.30	398.40	480.30	470.10	450.00	450.00	459.80	544.93	540.16	495.08	392.42	300.00

SD	185.43	183.90	214.95	252.56	254.07	287.11	221.00	188.85	191.43	183.07	264.10	259.96	136.37	245.86	270.04	268.03	279.61	205.41
Max	780.30	919.70	983.13	1110.00	940.20	1180.30	930.30	834.85	919.70	860.88	900.00	990.20	675.00	1150.00	1229.51	1174.59	1119.67	719.67
Min	180.30	260.25	159.80	239.80	140.20	170.30	279.93	300.00	330.30	340.20	7.00	204.90	280.00	230.33	310.00	189.84	69.67	114.75
Calcium (mg/L)																		
Median	80.00	36.00	33.33	52.00	56.00	64.00	52.00	48.00	40.00	52.00	120.00	48.00	55.00	22.67	44.00	24.00	48.00	44.00
SD	51.81	108.04	49.07	78.71	111.25	84.05	87.30	103.56	126.25	109.94	124.12	33.96	90.17	43.97	45.02	36.86	37.34	54.61
Max	160.00	400.00	180.00	220.00	388.00	260.00	280.00	314.00	400.00	340.00	408.00	130.00	352.00	150.00	160.00	144.00	128.00	200.00
Min	4.00	4.00	11.00	4.00	6.00	8.00	6.00	4.00	4.00	12.00	12.00	16.00	2.00	7.00	12.00	8.00	20.00	20.00
Chloride (mg/L)																		
Median	383.00	142.00	277.00	291.00	323.60	303.80	220.00	419.00	142.00	553.00	121.00	468.00	511.00	312.50	422.00	291.00	390.25	340.00
SD	383.42	1165.68	693.39	1318.08	1281.63	1044.72	837.70	986.98	1154.62	897.93	1072.70	282.65	996.34	403.75	892.06	837.82	773.64	819.89

Max	1207.00	4260.00	2343.00	4544.00	4260.00	2982.00	2726.50	3493.25	4260.00	2801.00	3976.00	1065.00	3777.00	1384.50	3018.00	2707.00	2396.00	2836.00
Min	53.00	21.00	92.00	21.00	42.50	50.00	28.00	64.00	21.00	43.00	28.00	71.00	61.67	52.33	43.00	38.00	33.00	28.00
Electrical Conductivity (mumhos/cm) at 25 C)																		
Median	1900.00	1300.00	2290.00	1730.00	2562.00	2526.00	1465.00	2415.00	1410.00	3155.00	2100.00	2310.00	2700.00	2450.00	2761.25	2270.00	2483.75	2950.00
SD	1506.46	3888.04	2347.03	4359.87	3830.18	3226.31	3079.23	3385.81	3862.87	2782.59	3183.20	1932.98	3930.68	1446.91	2933.82	2826.51	2457.75	2936.14
Max	5670.00	14760.00	8310.00	15700.00	13750.00	9870.00	9945.00	12352.50	14760.00	9700.00	12310.00	7410.00	15600.00	6400.00	11000.00	9525.00	8250.00	11090.00
Min	850.00	160.00	512.50	700.00	800.00	730.00	675.00	622.50	160.00	830.00	570.00	1160.00	1000.00	1035.00	1160.00	660.00	1120.00	780.00
Fluoride (mg/L)																		
Median	2.68	1.87	2.02	1.97	2.67	1.84	1.52	1.88	1.87	3.14	0.85	1.10	1.29	1.19	2.01	1.71	1.16	0.78
SD	3.70	1.96	2.14	2.65	2.21	3.69	4.05	2.67	2.07	4.73	1.41	1.21	0.87	1.52	3.68	2.54	1.20	0.83

Max	11.30	6.13	7.53	10.32	8.19	13.80	15.32	10.73	6.13	18.30	4.81	4.20	2.98	4.80	14.00	8.40	4.97	2.40
Min	0.17	0.14	0.48	0.54	0.39	0.10	0.28	0.54	0.14	0.40	0.16	0.20	0.06	0.40	0.12	0.47	0.30	0.01
Iron (mg/L)																		
Median	0.81	0.39	0.99	1.00	0.75	1.10	0.38	0.29	0.34	0.58	0.25	1.26	0.20	0.37	0.42	0.23	0.04	0.01
SD	2.23	2.64	2.92	3.25	1.45	1.62	0.92	0.98	0.79	1.46	1.53	2.37	0.57	0.58	0.94	1.60	0.96	0.72
Max	7.02	10.00	10.00	10.00	5.20	5.69	2.71	2.76	2.91	5.06	4.81	7.98	2.03	2.00	3.03	5.93	3.28	2.23
Min	0.08	0.16	0.08	0.15	0.08	0.15	0.01	0.07	0.10	0.04	0.11	0.04	0.03	0.02	0.01	0.00	0.00	0.00
Total Hardness (mg/L)																		
Median	320.00	300.00	290.00	380.00	340.00	460.00	440.00	380.00	300.00	400.00	440.00	380.00	280.00	230.00	485.00	300.00	387.50	290.00
SD	520.91	720.65	252.89	554.47	385.15	441.59	459.85	587.24	759.86	556.28	510.30	179.06	475.07	256.56	275.53	241.10	347.78	314.61
Max	1850.00	2780.00	860.00	1700.00	1240.00	1270.00	1720.00	2250.00	2780.00	1950.00	1700.00	850.00	1880.00	860.00	800.00	770.00	1350.00	1050.00
Min	120.00	30.00	122.50	60.00	55.00	50.00	80.00	105.00	30.00	120.00	100.00	180.00	100.00	60.00	50.00	100.00	130.00	100.00

Bicarbonate (mg/L)																		
Median	519.00	439.00	378.00	415.00	411.00	525.00	525.00	476.00	586.00	573.50	549.00	549.00	435.00	549.00	714.00	586.00	518.50	366.00
SD	222.62	227.62	253.31	279.49	311.07	353.47	272.96	232.07	234.88	223.35	322.20	318.29	169.16	240.95	303.58	325.97	314.30	256.61
Max	952.00	1122.00	1134.33	1159.00	1147.00	1440.00	1135.00	1018.50	1122.00	1050.27	1098.00	1208.00	857.00	1159.00	1500.00	1433.00	1366.00	878.00
Min	220.00	317.00	195.00	195.00	171.00	159.00	309.00	362.00	403.00	415.00	8.54	250.00	244.00	281.00	305.00	220.00	85.00	140.00
Potassium (mg/L)																		
Median	5.00	2.10	5.00	6.20	4.10	6.70	4.00	4.00	2.00	4.00	1.80	7.00	9.07	7.00	6.30	5.00	6.19	8.76
SD	25.12	146.77	13.87	107.63	27.84	41.00	75.27	110.66	146.50	9.34	7.12	7.15	167.29	105.43	57.58	55.47	55.73	36.53
Max	80.00	535.00	43.00	400.00	98.00	148.75	277.50	406.25	535.00	36.00	23.00	29.00	595.00	360.00	213.50	206.25	199.00	129.00
Min	1.00	0.20	1.55	1.00	0.90	0.80	0.55	0.30	0.20	1.27	0.80	1.60	1.00	2.00	1.50	1.00	2.56	2.24
Magnesium (mg/L)																		

Median	35.00	24.00	38.33	39.00	49.00	61.00	39.00	49.00	45.01	56.02	48.77	60.80	36.00	49.00	81.00	53.38	60.28	43.82
SD	107.63	113.56	47.28	97.18	77.49	66.42	70.42	88.67	113.24	79.65	56.94	30.56	61.59	37.64	45.56	44.63	66.77	45.43
Max	353.00	433.00	163.00	292.00	260.00	206.72	279.50	356.25	433.00	277.56	165.83	127.51	243.00	136.00	145.98	141.00	255.36	141.16
Min	10.00	5.00	19.00	12.00	9.50	7.00	12.00	18.00	5.00	2.00	9.80	12.16	19.00	7.00	4.88	16.23	17.86	12.18
Sodium (mg/L)																		
Median	278.00	284.09	368.00	302.36	323.00	378.00	307.50	326.73	322.00	568.00	345.00	327.00	481.50	464.00	460.00	458.00	565.75	416.00
SD	243.27	710.44	502.17	858.02	711.94	720.67	644.35	663.00	700.90	668.43	610.53	412.89	651.54	288.60	587.12	608.62	549.83	556.73
Max	736.00	2615.00	1656.00	3040.00	2438.00	2140.00	1804.00	2209.50	2615.00	2255.00	2300.00	1550.00	2385.00	1118.00	2210.00	1984.00	1758.00	2001.00
Min	64.00	62.00	60.00	82.00	81.00	80.00	86.00	82.00	98.00	134.00	39.80	96.00	103.00	22.00	172.00	51.00	114.00	80.00
Nitrate (mg/L)																		
Median	17.00	30.00	59.00	26.00	44.00	39.00	29.00	39.10	34.00	87.00	67.00	26.00	28.67	21.00	28.00	37.00	24.50	18.00

SD	49.43	217.19	90.84	194.70	125.89	140.58	165.33	190.60	216.74	78.23	112.94	111.94	147.80	19.68	226.27	53.29	71.27	92.53
Max	159.00	810.00	295.00	667.00	446.00	537.00	628.00	719.00	810.00	252.00	395.00	420.00	525.00	78.00	820.00	145.00	225.00	253.00
Min	2.00	4.20	12.00	0.00	4.70	8.90	13.00	1.60	4.20	16.00	10.00	5.00	4.00	3.50	2.00	5.50	8.00	0.00
pH2																		
Median	7.85	8.27	8.35	8.31	8.08	8.12	7.76	8.20	8.12	8.05	7.91	8.11	8.25	8.12	8.12	8.17	8.05	8.21
SD	0.32	0.41	0.36	0.39	0.42	0.29	0.40	0.33	0.41	0.26	0.41	0.17	0.16	0.31	0.28	0.29	0.28	0.41
Max	8.40	9.00	9.00	8.92	8.93	8.39	8.43	8.56	9.00	8.21	8.30	8.40	8.40	8.76	8.70	8.54	8.27	8.50
Min	7.42	7.70	7.77	7.69	7.50	7.60	7.05	7.52	7.48	7.44	7.00	7.84	7.84	7.84	7.80	7.54	7.21	7.02
Sulphate (mg/L)																		
Median	141.00	35.00	144.00	94.25	104.00	91.00	65.00	102.00	35.00	190.00	55.00	142.00	148.00	116.67	162.50	148.00	206.75	291.00
SD	276.90	558.58	254.95	446.71	348.72	343.25	379.94	451.58	560.11	567.64	258.06	505.35	429.67	148.27	164.48	225.05	426.29	194.84
Max	900.00	2060.00	963.00	1610.00	1217.00	1080.00	1291.50	1675.75	2060.00	2142.00	854.00	1945.00	1592.00	595.50	545.00	830.00	1644.00	692.00
Min	12.00	15.00	24.33	13.00	42.50	45.00	12.00	16.00	7.00	45.00	23.00	50.00	48.00	60.00	66.50	28.00	74.00	90.00

Carbonate (mg/L)																		
Median	0.00	0.00	36.00	24.00	0.00	0.00	0.00	24.00	0.00	0.00	0.00	0.00	72.00	30.00	0.00	12.00	0.00	0.00
SD	16.00	30.01	32.50	38.35	20.78	9.80	0.00	24.00	27.27	0.00	0.00	0.00	33.11	53.89	11.38	18.14	0.00	9.05
Max	48.00	84.00	72.00	96.00	48.00	24.00	0.00	48.00	84.00	0.00	0.00	0.00	120.00	120.00	36.00	48.00	0.00	30.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.00	0.00	0.00	0.00	0.00	0.00
Jodhpur																		
Total Alkalinity (mg/L)																		
Median	400.00	282.52	240.15	257.13	303.84	339.80	378.88	344.21	340.15	299.95	334.78	318.10	383.20	340.16	323.22	319.67	319.67	275.00
SD	176.61	186.21	119.99	196.51	205.39	316.28	226.09	179.00	150.68	164.77	145.81	153.65	159.95	158.46	184.72	199.16	225.30	227.10
Max	830.30	730.30	450.00	789.70	754.85	1303.30	930.30	793.28	669.80	730.30	600.30	675.20	719.70	675.25	700.00	775.00	850.00	830.00
Min	180.30	59.80	69.70	93.43	100.00	100.00	190.20	119.70	119.70	139.70	13.10	124.60	145.10	138.74	132.39	126.03	100.00	65.57

Calcium (mg/L)																		
Median	106.00	72.60	70.00	81.40	80.00	77.60	81.45	78.50	84.07	86.00	87.25	83.70	80.00	72.00	82.00	62.00	80.00	84.00
SD	97.72	63.12	22.80	41.42	67.10	101.45	136.79	175.12	67.56	64.16	53.40	63.24	104.63	85.35	55.04	41.31	47.74	40.28
Max	344.00	266.00	116.00	164.00	290.50	417.00	564.50	712.00	266.00	272.00	212.67	283.00	360.00	364.00	242.00	136.00	184.00	140.00
Min	16.00	16.00	32.00	20.00	16.00	12.00	24.00	18.00	16.00	28.00	24.00	33.00	32.00	33.00	24.00	20.00	20.00	22.00
Chloride (mg/L)																		
Median	809.50	571.50	373.17	650.22	530.93	497.25	602.56	601.17	642.28	713.39	534.33	603.92	487.67	454.50	421.33	388.17	468.00	372.50
SD	910.01	703.56	316.98	592.70	458.45	419.80	538.02	846.56	679.10	826.68	389.32	376.09	1183.92	345.75	790.81	1570.32	720.92	1001.30
Max	2450.00	2556.00	859.00	2130.00	1476.50	1448.00	1875.00	3305.00	2556.00	2801.00	1448.00	1454.00	4680.00	1240.00	3085.00	6010.00	2836.00	3200.00
Min	57.00	42.50	14.00	28.00	35.00	89.67	131.00	154.60	155.30	149.00	159.00	28.00	181.80	28.00	35.00	28.00	28.00	60.00
Electrical																		

Conductivity (mumhos/cm) at 25 C)																		
Median	3130.00	2855.00	2145.00	3008.89	2680.83	2690.28	3017.22	3039.00	3153.00	3341.25	2951.00	2905.00	2940.00	2430.00	2706.00	2850.00	3000.00	2530.00
SD	2816.96	2262.40	1199.96	1763.88	1775.94	1810.65	2071.09	2286.62	2049.77	2738.89	1147.70	1512.42	3367.11	1536.63	2367.35	5920.61	3692.19	4051.07
Max	9080.00	9150.00	3770.00	7060.00	7605.00	8150.00	9100.00	10050.00	9150.00	10500.00	5500.00	5540.00	14500.00	6050.00	10060.00	23420.00	15200.00	13800.00
Min	930.00	677.50	260.00	273.33	280.00	843.33	1320.00	1440.00	1140.00	1575.00	1600.00	500.00	1500.00	500.00	650.00	800.00	350.00	350.00
Fluoride (mg/L)																		
Median	1.17	1.38	1.84	0.91	1.00	0.97	1.16	1.04	1.38	1.07	0.98	0.98	0.82	0.91	0.83	0.78	0.79	1.04
SD	1.05	1.86	2.38	1.58	1.31	1.20	1.19	1.10	1.80	1.02	0.74	0.95	0.67	0.88	1.30	1.02	0.54	0.70
Max	4.04	7.50	7.89	4.62	4.29	4.35	4.94	4.10	7.50	4.00	3.02	3.60	2.44	3.60	4.44	3.40	1.93	2.60
Min	0.24	0.51	0.54	0.43	0.46	0.48	0.61	0.41	0.71	0.50	0.15	0.15	0.05	0.15	0.35	0.10	0.05	0.23
Iron (mg/L)																		
Median	0.06	0.12	0.12	0.12	0.10	0.10	0.07	0.07	0.09	0.13	0.11	0.11	0.14	0.15	0.17	0.18	0.02	0.30

SD	0.24	0.20	0.33	0.60	0.25	0.26	0.25	0.69	0.36	0.38	0.43	0.49	0.52	0.54	0.57	0.28	0.22	0.35
Max	0.87	0.77	1.02	2.30	0.79	0.88	1.01	2.52	1.28	1.42	1.56	1.69	1.83	1.96	2.10	0.90	0.72	1.31
Min	0.04	0.01	0.03	0.03	0.03	0.03	0.03	0.04	0.01	0.02	0.00	0.01	0.01	0.01	0.04	0.03	0.00	0.16
Total Hardness (mg/L)																		
Median	420.00	425.00	391.67	434.20	416.67	414.58	473.33	469.00	485.00	557.50	410.00	427.50	520.00	385.00	387.50	370.00	450.00	340.00
SD	498.70	377.44	169.01	220.32	338.05	531.23	672.41	821.29	371.21	286.77	207.86	285.21	572.52	374.19	291.28	584.18	234.63	154.62
Max	1650.00	1660.00	800.00	920.00	1520.00	2300.00	2887.50	3475.00	1660.00	1290.00	981.33	1322.00	2210.00	1660.00	1140.00	2400.00	820.00	550.00
Min	190.00	110.00	130.00	143.33	150.00	140.00	165.00	232.00	110.00	250.00	180.00	240.00	180.00	240.00	160.00	130.00	160.00	100.00
Bicarbonate (mg/L)																		
Median	476.00	363.25	311.00	338.20	367.50	382.61	407.10	409.00	378.50	330.81	301.96	346.75	419.60	332.63	351.20	427.00	390.00	335.50
SD	220.01	198.28	141.69	231.26	237.87	379.56	281.10	219.45	172.71	199.82	181.78	194.92	219.50	212.18	228.02	203.09	246.83	252.82

Max	1013.00	891.00	549.00	939.00	856.00	1590.00	1135.00	953.20	771.40	769.00	634.00	775.00	878.00	781.00	854.00	915.00	854.00	915.00
Min	220.00	146.00	85.00	114.00	122.00	122.00	232.00	146.00	146.00	24.00	16.00	152.00	177.00	146.00	161.50	153.75	122.00	80.00
Potassium (mg/L)																		
Median	12.50	8.50	6.60	8.00	8.70	9.52	9.78	10.00	10.50	8.28	10.30	8.00	6.40	8.50	8.80	9.10	9.40	6.65
SD	89.44	92.28	26.66	20.68	19.42	19.68	22.00	25.38	92.67	22.43	31.59	24.42	25.94	25.20	21.16	27.28	41.65	7.26
Max	320.00	344.00	104.67	78.00	64.67	63.20	78.00	82.00	344.00	90.00	96.00	98.00	98.00	98.00	64.50	102.00	157.00	20.30
Min	2.00	2.20	2.48	1.80	2.40	3.00	1.20	2.00	2.20	2.40	1.70	2.88	0.90	2.44	1.00	2.00	1.90	1.00
Magnesium (mg/L)																		
Median	77.00	56.00	41.80	55.86	52.67	55.83	61.90	66.78	65.55	73.83	58.44	56.86	57.88	51.08	40.50	40.13	53.50	28.07
SD	72.54	61.18	36.75	44.31	47.21	71.80	85.29	97.17	58.71	42.34	24.31	39.27	79.76	42.12	44.83	128.49	38.60	13.92
Max	231.00	236.00	151.00	161.00	193.00	306.00	360.50	415.00	236.00	151.00	109.30	149.45	319.00	182.00	165.46	501.00	150.78	48.80

Min	11.00	14.50	5.00	9.67	12.00	27.00	26.00	37.98	15.00	24.43	29.20	19.00	24.00	19.00	17.11	17.00	19.46	10.97
Sodium (mg/L)																		
Median	500.50	497.00	327.30	485.83	428.70	408.17	404.83	453.50	474.67	571.50	416.33	475.00	405.00	399.25	348.00	390.00	351.00	395.00
SD	517.90	413.57	237.96	366.79	339.61	307.74	330.56	359.43	377.32	616.71	275.55	313.58	598.58	283.33	589.22	1141.43	805.65	904.58
Max	1528.00	1410.00	656.00	1360.00	1220.00	1080.00	1154.00	1284.00	1410.00	2290.00	1154.50	1195.00	2500.00	1195.00	2360.00	4420.00	3144.00	3050.00
Min	67.00	46.00	11.00	10.33	10.00	100.00	137.00	162.00	140.00	182.00	202.00	19.00	188.00	19.00	25.00	7.00	10.00	40.00
Nitrate (mg/L)																		
Median	37.50	66.25	100.08	116.15	84.94	53.75	44.67	80.00	129.70	96.50	78.88	83.83	122.00	80.00	94.50	75.13	41.00	207.50
SD	158.40	234.88	94.34	171.04	149.82	185.12	146.38	266.23	229.58	107.50	115.14	139.05	203.96	262.64	176.74	632.78	154.73	205.50
Max	576.00	800.00	302.00	481.00	593.40	710.00	466.50	904.00	800.00	320.50	409.00	550.00	780.00	1010.00	706.00	2353.00	502.00	605.00
Min	6.00	1.50	1.00	5.33	7.00	0.50	20.00	19.00	1.50	4.60	6.59	8.58	12.00	9.00	16.00	22.09	6.12	2.00
pH2																		

Median	8.02	8.11	8.05	8.08	8.19	7.94	7.85	7.82	8.14	8.02	8.08	7.83	7.76	7.98	7.96	8.00	7.87	7.97
SD	0.23	0.39	0.30	0.25	0.31	0.42	0.38	0.32	0.38	0.30	0.43	0.44	0.39	0.41	0.32	0.37	0.42	0.31
Max	8.25	8.95	8.73	8.60	8.75	8.90	8.85	8.34	8.95	8.50	8.82	8.70	8.58	8.46	8.37	8.64	8.43	8.40
Min	7.42	7.86	7.60	7.55	7.50	7.45	7.40	7.30	7.76	7.54	7.29	7.29	7.35	7.35	7.35	7.20	6.94	7.42
Sulphate (mg/L)																		
Median	103.00	160.00	155.75	162.03	145.50	127.50	201.10	243.17	216.70	366.97	283.00	248.83	223.00	212.00	134.00	94.00	176.00	295.00
SD	295.28	174.72	81.38	65.47	63.59	74.93	142.04	177.94	159.34	460.67	181.79	277.50	144.83	249.91	229.94	240.86	611.47	345.45
Max	931.00	688.00	288.00	278.00	282.50	287.00	622.00	680.00	688.00	1383.00	701.00	994.00	469.00	994.00	908.00	880.00	2328.00	1250.00
Min	14.00	52.00	48.00	28.67	17.00	30.00	39.00	103.00	68.00	166.22	98.00	54.00	21.00	23.75	26.50	14.00	24.00	30.00
Carbonate (mg/L)																		
Median	0.00	0.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00	0.00	48.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD	0.00	12.43	16.97	5.37	25.46	28.32	16.00	0.00	13.42	32.39	61.44	12.96	0.00	61.12	10.73	34.78	27.14	15.18

Max	0.00	36.00	48.00	12.00	36.00	72.00	48.00	0.00	36.00	72.00	144.00	36.00	0.00	144.00	24.00	108.00	90.00	48.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tonk																		
Total Alkalinity (mg/L)																		
Median	184.90	229.95	279.95	253.15	385.08	420.10	331.83	324.98	250.00	370.05	379.90	369.80	410.30	200.00	400.00	437.66	445.00	389.76
SD	195.71	176.82	179.56	251.84	219.10	207.75	198.27	201.01	219.20	196.59	184.27	139.59	179.76	156.33	226.11	145.51	108.13	151.28
Max	569.70	710.00	639.70	900.00	869.95	839.90	809.85	779.80	749.75	840.20	850.00	737.70	698.19	658.68	1060.33	775.24	609.84	750.00
Min	90.20	85.20	119.70	119.70	112.80	105.90	99.00	92.10	85.20	222.55	149.20	230.30	140.20	109.84	280.33	275.00	250.00	259.84
Calcium (mg/L)																		
Median	52.00	36.00	58.00	30.00	38.00	46.00	40.33	38.00	31.00	40.00	48.00	60.00	66.00	55.00	63.50	52.00	80.00	50.50
SD	22.25	19.86	50.25	26.63	28.79	26.57	29.40	32.90	21.70	92.31	68.21	75.68	48.60	68.77	53.37	27.73	34.64	63.74

Max	80.00	76.00	180.00	96.00	104.00	104.00	95.00	112.00	76.00	352.00	280.00	248.00	216.00	252.00	216.00	120.00	140.00	213.00
Min	16.00	16.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	32.00	24.00	32.00	16.00	20.00	12.00	20.00	21.00
Chloride (mg/L)																		
Median	146.00	135.00	142.00	96.83	81.50	84.30	88.00	100.00	124.50	153.00	211.50	220.00	202.50	248.50	301.50	222.00	277.00	278.00
SD	289.34	314.17	852.05	295.96	290.81	291.44	239.66	244.82	303.46	688.01	529.25	504.42	198.06	544.73	264.46	295.11	299.28	355.59
Max	834.00	923.00	3089.00	978.00	865.00	893.00	809.00	866.00	923.00	2499.00	1882.00	1732.00	625.00	1794.00	1065.00	1136.00	1205.00	1260.00
Min	25.00	14.00	50.00	14.00	19.60	18.20	16.80	15.40	14.00	21.00	36.00	28.00	43.00	28.00	36.00	36.00	35.00	186.00
Electrical Conductivity (mumhos/cm) at 25 C)																		
Median	900.00	1175.00	1287.50	1130.00	1482.50	1375.00	1093.75	1010.00	945.00	1470.00	1843.00	1820.00	2230.00	1285.00	2075.00	1755.00	2110.00	1970.00

SD	1316.50	1092.46	2290.07	1049.44	1065.00	1054.83	861.11	849.49	1054.93	2497.37	2373.25	2193.28	1350.77	1882.30	1564.20	1237.91	929.85	1827.28
Max	3800.00	3520.00	9056.00	3940.00	3740.00	3930.00	3426.67	3473.33	3520.00	9320.00	8250.00	7560.00	5000.00	7110.00	6880.00	4900.00	4680.00	6950.00
Min	460.00	390.00	520.00	450.00	500.00	500.00	500.00	500.00	390.00	200.00	447.00	620.00	640.00	410.00	920.00	370.00	1050.00	1410.00
Fluoride (mg/L)																		
Median	0.54	1.55	1.42	2.10	2.08	1.91	1.79	1.08	1.59	1.36	1.28	0.88	0.82	0.83	0.69	0.54	0.61	0.66
SD	3.44	2.27	2.13	2.26	2.04	2.06	1.41	1.16	2.25	3.59	5.57	1.17	1.10	0.77	0.65	0.58	0.80	0.59
Max	9.72	6.99	8.03	7.76	7.63	7.50	4.35	4.53	6.99	13.49	20.30	4.20	3.30	2.46	2.24	2.14	2.25	1.97
Min	0.18	0.82	0.64	0.35	0.48	0.61	0.50	0.38	0.82	0.50	0.19	0.09	0.24	0.34	0.10	0.21	0.01	0.25
Iron (mg/L)																		
Median	0.20	0.18	0.16	0.33	0.34	0.20	0.19	0.17	0.24	0.34	0.09	0.46	0.23	0.20	0.01	0.07	0.30	0.22
SD	1.45	0.46	0.14	0.34	0.34	0.66	0.58	0.69	0.73	0.67	1.03	0.62	0.23	0.22	0.13	0.29	0.63	0.95
Max	3.02	1.49	0.50	1.12	1.16	1.95	1.56	2.01	2.45	2.52	3.63	1.85	0.95	0.89	0.46	1.03	2.05	2.26
Min	0.01	0.04	0.01	0.05	0.05	0.06	0.02	0.05	0.07	0.07	0.01	0.03	0.10	0.05	0.00	0.00	0.04	0.00

Total Hardness (mg/L)																		
Median	190.00	235.00	280.00	160.00	192.00	207.67	224.08	211.00	210.00	286.25	305.00	285.00	390.00	252.50	285.00	302.50	395.00	380.00
SD	120.58	85.90	337.57	162.74	148.71	129.50	116.16	124.51	100.38	676.65	578.95	400.50	294.30	467.09	318.52	235.82	155.39	347.15
Max	460.00	375.00	1380.00	680.00	605.00	530.00	476.67	471.00	375.00	2580.00	2250.00	1400.00	1320.00	1820.00	1240.00	1020.00	670.00	1250.00
Min	100.00	135.00	120.00	90.00	98.33	106.67	115.00	100.00	100.00	140.00	130.00	130.00	167.50	70.00	100.00	120.00	120.00	150.00
Bicarbonate (mg/L)																		
Median	189.00	280.50	315.00	302.83	454.38	512.50	404.83	391.60	305.00	432.75	463.50	421.00	415.00	244.00	476.00	427.00	524.50	475.50
SD	256.45	171.47	196.48	309.47	261.38	235.64	206.18	191.03	199.43	214.64	214.23	179.75	184.22	125.18	228.80	258.54	138.93	184.56
Max	695.00	671.00	699.33	1098.00	1020.67	943.33	866.00	788.67	711.33	1025.00	1037.00	900.00	723.75	547.50	1074.00	927.00	744.00	915.00
Min	85.00	104.00	146.00	146.00	137.60	129.20	120.80	112.40	104.00	271.50	182.00	281.00	171.00	134.00	342.00	134.00	305.00	317.00

Potassium (mg/L)																		
Median	6.00	5.00	6.60	4.00	3.53	5.28	3.79	2.53	4.25	5.23	3.40	6.35	4.83	3.00	5.10	2.98	3.90	5.91
SD	25.32	13.60	8.57	5.33	4.40	4.88	4.73	9.92	13.80	4.23	3.87	41.51	11.64	11.99	20.38	16.04	20.00	104.91
Max	73.00	45.00	29.00	21.00	17.00	19.00	14.80	27.50	45.00	12.90	14.10	148.00	31.00	39.00	75.00	57.50	72.30	304.00
Min	2.00	1.00	2.70	1.00	1.57	1.40	1.20	1.00	1.00	1.00	0.80	1.20	1.00	1.00	1.40	0.50	0.05	1.10
Magnesium (mg/L)																		
Median	15.00	31.00	30.83	27.33	26.27	23.25	28.00	25.50	28.50	33.02	40.35	31.38	55.95	35.00	30.45	42.08	48.64	54.15
SD	21.82	16.92	57.60	27.23	28.49	31.79	24.08	19.54	18.48	107.67	101.54	53.18	43.09	80.40	48.65	43.59	21.37	47.08
Max	71.00	71.00	226.00	107.00	92.50	115.00	96.50	78.00	71.00	408.00	377.00	189.70	190.00	289.00	170.45	175.00	77.82	174.71
Min	11.00	12.00	15.00	15.00	16.00	15.00	14.00	13.00	9.70	20.00	7.00	12.16	15.87	5.00	12.00	19.00	14.59	21.30
Sodium (mg/L)																		

Median	78.00	231.00	186.33	222.00	258.00	220.25	189.35	244.00	215.00	354.25	349.50	307.50	347.50	246.00	318.00	263.50	295.00	252.00
SD	266.08	276.12	511.04	221.81	226.54	227.55	213.56	205.86	267.80	386.91	460.70	374.31	232.59	268.03	254.41	212.42	199.47	266.08
Max	682.00	773.00	1886.00	636.00	713.00	758.00	638.00	689.00	773.00	1421.00	1690.00	1152.33	685.00	1002.00	1013.00	638.00	807.00	910.00
Min	24.00	33.00	41.00	31.00	40.20	38.40	36.60	34.80	33.00	84.00	30.00	59.00	35.00	36.00	74.00	43.00	65.00	80.00
Nitrate (mg/L)																		
Median	24.00	27.00	19.50	19.00	19.10	21.50	22.00	20.63	21.00	16.50	16.00	30.50	28.00	63.00	40.95	15.40	20.57	25.75
SD	40.72	26.49	22.91	27.66	40.34	28.35	16.58	23.82	27.65	155.01	290.42	208.03	138.72	32.33	48.21	37.24	35.58	39.79
Max	100.00	78.00	85.00	91.00	144.00	102.00	55.50	91.00	78.00	543.50	1021.00	713.00	405.00	102.00	145.00	124.00	118.00	110.00
Min	0.00	2.00	6.00	4.60	3.80	3.00	5.00	4.00	2.00	0.00	6.30	5.40	0.00	3.00	4.68	0.74	0.00	6.50
pH																		
Median	8.47	8.20	8.33	8.07	8.01	8.04	8.06	8.05	8.11	8.19	7.97	7.64	8.18	8.04	7.99	8.02	7.97	7.96
SD	0.88	0.29	0.27	0.22	0.22	0.30	0.38	0.32	0.31	0.25	0.26	0.31	0.21	0.40	0.29	0.29	0.31	0.21
Max	9.84	8.83	8.77	8.47	8.34	8.32	8.49	8.66	8.83	8.58	8.38	8.30	8.37	8.89	8.66	8.56	8.38	8.10

Min	7.01	7.80	7.94	7.80	7.63	7.30	7.00	7.47	7.80	7.75	7.56	7.15	7.73	7.85	7.41	7.63	7.37	7.50
Sulphate (mg/L)																		
Median	70.00	164.00	142.00	68.00	65.13	51.50	56.25	71.50	121.00	224.75	202.50	171.00	166.50	132.50	98.00	158.00	102.00	125.00
SD	80.80	159.57	240.77	141.17	105.23	97.90	105.50	119.71	162.91	425.66	652.07	449.47	362.97	322.10	406.14	124.19	87.03	326.05
Max	226.00	545.00	918.00	450.00	297.50	285.00	340.67	396.33	545.00	1258.50	2410.00	1609.33	1090.00	1210.00	1489.00	392.00	302.00	1020.00
Min	8.00	60.00	25.00	10.00	2.00	13.33	24.67	30.00	60.00	11.00	16.00	80.00	92.00	8.00	37.00	14.00	27.00	47.00
Carbonate (mg/L)	2000.00	2001.00	2002.00	2004.00	2005.00	2006.00	2007.00	2008.00	2009.00	2010.00	2011.00	2012.00	2013.00	2014.00	2015.00	2016.00	2017.00	2018.00
Median	9.00	0.00	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00
SD	13.68	33.96	33.08	10.12	0.00	0.00	0.00	14.53	35.55	48.00	14.92	22.77	32.00	21.10	32.56	33.96	24.25	0.00
Max	30.00	96.00	84.00	24.00	0.00	0.00	0.00	36.00	96.00	120.00	48.00	72.00	96.00	60.00	108.00	96.00	84.00	0.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Authors' calculation

Table 4.6: Trends in groundwater quality parameters

Chloride (mg/L)			Calcium (mg/L)			Total Alkalinity (mg/L)
Z	Sen	p-value	Z	Sen	p-value	Z
2.35	0.92	0.78	0.27	3.31	0.12	1.53
-2.22	0.33	0.76	0.29	-43.4	0.05	-1.92
-1.36	0.11	0.8	0.24	-12.4	0.17	-1.37
0.32	0	0.46	-0.73	-12.8	0.58	-0.54
0.35	5.53	0.02	2.26	0	0.91	-0.11
-0.1	10.6	0.19	1.28	-50	0.13	-1.51
1.07	0.65	0.73	0.34	-10	0.64	-0.47
-0.42	-3.16	0.59	-0.53	-4.74	0.32	-0.99
1.22	-7.31	0.16	-1.37	-54.9	0	-3.35
1.76	4.28	0.16	1.38	28.46	0.19	1.3
3.07	-1	0.27	-1.09	6.56	0.35	0.93
-9.96	0	0.82	0.22	-54.4	0.07	-1.83
-3.99	-3.55	0.21	-1.25	-79.8	0.05	-1.95
3.24	1.31	0.83	0.21	1.02	0.59	0.53
-0.55	0	0.86	0.16	0	1	0
1.8	-0.58	0.78	-0.27	-8.9	0.42	-0.79
1.15	4.57	0.43	0.78	13.73	0.13	1.48
2.05	2.25	0.19	1.28	4.92	0.3	1.03
-1.47	2.4	0.13	1.49	-1.22	0.8	-0.25
-1.8	-1.53	0.04	-1.99	3.94	0.21	1.23
-0.93	0	0.88	-0.13	-5.89	0.27	-1.09

Fluoride (mg/L)			Electrical Conductivity (mumhos/cm) at 25 C)		
Z	Sen	p-value	Z	Sen	p-value
-4.59	64	0.28	1.06	18	0.01
-1.89	-365.4	0	-3.66	-94.75	0.02
-5.5	0	1	0	-8.16	0.17
-7.43	-24.16	0.21	-1.25	0.43	0.74
-1.33	40	0.44	0.76	4	0.72
-4.73	-48.35	0.76	-0.3	-0.66	0.92
-2.95	46.78	0.78	0.26	8	0.28
-2.93	13.75	0.46	0.73	-4.5	0.67
-3.1	-57.33	0	-3.38	3.8	0.22
-0.41	367.14	0.02	2.31	95.02	0.08
-0.144	56	0	3.11	10.14	0
-6.95	-610	0	-8.78	-165.4	0
-7.08	-563.3	0	-4.96	-134.1	0
-3.29	80.71	0	4.17	12.48	0
0.98	-19.5	0.55	-0.58	-2.8	0.57
-2.5	16.27	0.06	1.87	5.4	0.07
-4.42	-25	0.54	-0.59	5	0.24
-1.75	214.16	0	2.84	32.43	0.04
-44.6	-90.27	0.19	-1.29	-19.77	0.14
-0.44	-80	0	-3.3	-15.72	0.07
-3.47	-7.16	0.05	-1.94	-0.67	0.35

•

		Total Hardness (mg/L)			Iron (mg/L)		
Sen	p-value	Z	Sen	p-value	Z	Sen	p-value
10	0.04	2.02	0.11	0	2.82	-0.1	0
-6	0.28	-1.07	0.07	0.12	1.52	-0.1	0.05
-2.3	0.45	-0.75	0.01	0.42	0.79	-0.2	0
-1.11	0.33	-0.95	0.02	0.17	1.36	-0.4	0
14	0	3.2	0.03	0	3.24	-0.3	0.18
16.42	0.19	1.29	0.15	0	2.95	-0.1	0
4.5	0.51	0.64	0	1	0	-0.3	0
-6.83	0.45	-0.75	0.07	0.02	2.35	-0.1	0
-36.42	0	-2.71	-0	0.07	-1.76	-0.1	0
54	0.03	2.15				-0.1	0.68
8.57	0	3.26	0.01	0.11	1.58	0	0.88
-16.67	0.05	-1.95				-0.3	0
-34.12	0	-3.51	0.02	0.14	1.47	-0.4	0
11.45	0.01	2.46	0.03	0.19	1.29	-0	0
0	1	0	0.02	0	2.63	0.02	0.32
-0.29	0.69	-0.39	0	0.28	1.07	-0	0.01
16	0	3.74	0.02	0.13	1.5	-0.3	0
39.64	0	3.4	0.08	0	7.48	-0	0.07
1.29	0.75	0.31	0.01	0.53	0.61	-0.1	0
-0.93	0.82	-0.21	0.05	0	3.25	-0	0.65
6.18	0	3.87				-0.1	0

	Magnesium (mg/L)			Potassium (mg/L)			Bicarbonate (mg/L)
p-value	Z	Sen	p-value	Z	Sen	p-value	Z
0.14	1.46	-0.39	0	-3.21	12	0.01	2.56
0.03	-2.05	-1	0	-4.96	-56	0	-5.57
0.36	-0.91	-0.42	0	-6.68	-16.2	0	-5.26
0.55	-0.58	-0.12	0	-2.57	-21.6	0	-3.23
0.09	1.65	0	1	0	0	1	0
0.05	-1.88	-8.12	0	-3.16	-52.1	0	-3.88
0.72	-0.35	-0.04	0.41	-0.82	-1.45	0.43	-0.78
0.27	-1.09	0.01	0.61	0.51	-3.54	0.14	-1.44
0.01	-2.4	-1.91	0	-3.01	-59	0	-6.28
0.05	1.9	2.45	0.09	1.65	18.75	0	3.25
0.04	2.01	-1.45	0.06	-1.83	6.37	0.02	2.28
0.03	-2.13	-0.35	0.04	-1.97	-77.2	0	-8.35
0	-5.35	-15.5	0	-5.85	-101	0	-6.03
0	2.84	0.25	0.11	1.55	1.25	0.21	1.23
0.73	-0.34	-0.13	0.22	-1.2	-4.16	0.21	-1.24
0.24	1.16	-0.31	0	-3.43	-16.9	0	-4.39
0	3.48	2.6	0.07	1.76	9	0.06	1.86
0	3.07				4.89	0.21	1.24
0.61	-0.5	-0.41	0	-2.65	0	0.88	0.13
0.91	-0.1	-0.32	0.02	-2.17	2.74	0.05	1.89
0	9.16	0.02	0.73	0.33	-7.2	0	-3.36

•

		pH			Nitrate (mg/L)			Sodium (mg/L)	
Sen	p-value	Z	Sen	p-value	Z	Sen	p-value	Z	Sen
0.01	0.13	1.48	1	0	5.53	40	0.02	2.39	3.37
-0	0.11	-1.56	-16.9	0	-6.02	-109.3	0	-4.9	-2.44
0.01	0.19	1.3	0	0.9	-0.12	-10	0.01	-2.46	-0.31
-0	0.51	-0.65	-0.63	0.1	-1.62	-15.05	0	-3.28	-0.25
0.01	0.12	1.54	-1.75	0	-3.21	5.33	0.08	1.74	2.33
0.01	0.55	0.58	0	0.19	1.28	-12.87	0.11	-1.57	-3.88
0.02	0.08	1.7	-7.01	0	-3.66	4.31	0.85	0.18	-0.82
0.02	0	3.25	-0.42	0.36	-0.91	-1.75	0.63	-0.47	-0.35
-0	0.83	-0.2	-3.86	0	-3.86	-0.46	0.79	-0.26	-1.25
0.04	0.07	1.76	23.05	0	3.07	76.03	0.27	1.09	11.21
-0	0.32	-0.99	1.14	0.06	1.89	7.55	0.11	1.57	2.12
-0	0.47	-0.71	-0.72	0.58	-0.55	-146.8	0	-8.59	-3.62
0.01	0.32	0.99	-0.58	0	-2.71	-115.6	0	-5.17	-5.38
0.02	0	4.11	9.23	0	7.14	9.14	0	3.11	0.55
0.01	0.36	0.89	-2.6	0.22	-1.21	-1	0.86	-0.16	-0.03
0.01	0.6	0.52	0.09	0.89	0.12	-0.07	0.89	-0.13	0.36
0.07	0	4.09	-0.16	0.41	-0.82	0	1	0	4.54
0.01	0.58	0.54	1.45	0.25	1.13	34	0	2.59	7.06
-0	0.71	-0.37	-2.65	0	-2.94	-20	0.3	-1.02	-0.57
0.03	0	4.42	1	0.03	2.07	-10.62	0	-2.78	-0.1
0	1	0	1.12	0	4.9	-5.75	0	-4.69	1.51

•

		Station			Sulphate (mg/L)
Longitute	Latitute	Ajmer	Sen	p-value	Z
75.1	26.0333333	Ajagara	6	0.25	1.13
75.0666667	26.45	Arian	-41.8	0	-5.07
74.2	25.9083333	Baglias	-17.2	0	-6.96
75.0361111	26.2125	Barora	-1.81	0.06	-1.82
75.2333333	25.8333333	Bogla	0	1	0
75.1333333	26.4166667	Dasuk	0.09	0.91	0.1
74.9277778	26.1291667	Goelo	0	1	0
74.2	25.9333333	Jawaja1	0	1	0
74.6583333	26.025	Jhopadiyan	0.83	0.75	0.31
74.8666667	26.4	Kanpur1	0	1	0
75.15	25.9833333	Kekri1	0.67	0.49	0.67
74.4916667	26.2333333	Lamana	-32.8	0	-3.62
74.5833333	25.9972222	Ludiyana	-48	0	-4.53
74.5125	26.0916667	Masuda1	-0.06	0.95	-0.05
74.7402778	26.2866667	Nasirabad	-0.75	0.32	-0.98
74.4166667	26.1	Pakhriawas	5.82	0	4.2
74.8333333	26.2666667	Ramgarh2	-16	0	-5.62
75.0416667	25.9111111	Sanpla	25	0	3.32
75	26.05	Sarwad	-14.5	0.13	-1.48
74.6166667	26.4	Tabiji	-14.7	0	-6.44
74.15	25.8833333	Taragarh	-2.58	0	-2.82

•

	Chloride (mg/L)			Calcium (mg/L)			Total Alkalinity
p-value	Z	Sen	p-value	Z	Sen	p-value	Z
0	4.07	-1.5	0	-3.21	1.25	0.75	0.31
0.03	-2.12	-0.5	0.5	-0.66	1.44	0.75	0.31
0	5.99	7.66	0	5.38	10.53	0	2.8
0.1	1.63	0.21	0.46	0.73	5.72	0	5.05
0	4.6	0.61	0	3.29	20.9	0	3.9
0.11	1.56	0.25	0.05	1.88	-28.6	0	-5.85
0.02	-2.23	-4.5	0.02	-2.26	5.01	0.06	1.83
0.03	-2.14	0	1	0	23.97	0	3.45
0	4.76	2.53	0	4.56	-21.6	0	-5.88
0.01	2.64	-0.5	0.05	-1.99	-1.33	0.24	-1.15
0	4.06	-5.7	0.69	-0.38	39.11	0.21	1.24
0.21	1.23	0.5	0	2.98	1.46	0.78	0.27
0	-5.72	-0.5	0.19	-1.28	1.63	0.02	2.32
0.52	0.63	1.33	0.04	2.02	6.1	0	11.94
0	-3.26	-7.6	0.18	-1.31	28.33	0	2.99
0	-3.36	4.31	0.02	2.41	-13.8	0	-2.89
0	-4.311	-3.5	0	-4.03	2.47	0	5.38
0.52	-0.64	-3.5	0.77	-0.28	-0.87	0.7	-0.38
0	2.68	1.91	0.01	2.69	13.28	0	4.22
0.77	0.28	-1.1	0.16	-1.38	2.69	0.04	2.02
0	3.31	5	0	4.66	5.73	0	4.01
0.57	0.56	6.09	0	6.27	-5.08	0	-3.04
0.01	2.47	0	1	0	6.25	0	3.04
0.45	-0.73	-0.3	0.46	-0.73	2.51	0.02	2.38
0	-4.87	-2.6	0.02	-2.3	-3.55	0.03	-2.12
0.82	0.21	-1.3	0.34	-0.95	13.72	0	4.01
0	4.33	3.3	0	2.94	16.75	0	4.37
0.05	1.94	-1	0.74	-0.32	4.43	0.09	1.7
0	-4.62	-0.7	0.46	-0.72	2.78	0	5.69
0	4	0	1	0	-3.7	0.01	-2.58
0.1	1.62	-1	0.34	-0.93	0.83	0.52	0.63
0	-3.77	1	0.06	1.84	13.44	0	6.05

•

	Fluoride (mg/L)			Electrical Conductivity (mumhos/cm) at 25 C)	
p-value	Z	Sen	p-value	Z	Sen
0	3.27	45.5	0	2.83	7.14
0	-3.45	-131.7	0	-7.56	-29.67
0.04	2.01	219.28	0	6.59	71
0	-3.76	110.84	0	3.99	15.25
0	-3.09	106.47	0	4.19	10.63
0	-7.95	40.63	0	3.73	2.2
0.94	0.06	-313.5	0	-2.99	-91.25
0.07	-1.76	-138.6	0.05	-1.97	-44.2
0	-3.22	190	0	6.12	74
0.48	-0.69	47.7	0	5.9	5.25
0.38	0.86	240	0.01	2.56	36.81
0	-3.74	-16.72	0.29	-1.03	3.3
0	4.89	6	0.25	1.13	-3.95
0	-3.3	75	0.01	2.56	2.7
0.59	-0.53	-350	0.38	-0.87	-212
0	2.89	-203.7	0	-3.62	-45.91
0	-6.9	-81.42	0.12	-1.52	-127.9
0	-5.48	77.7	0.42	0.8	-14.43
0	-4.02	128.88	0	4.4	13.88
0	4.21	12.38	0.33	0.96	1.05
0.03	2.13	165.76	0	5.56	30.92
0	7.17	56.92	0.3	1.02	17.72
0	-5.32	35	0	5.06	4.26
0	-7.62	1.53	0.72	0.34	-0.7
0.67	-0.41	-135.5	0	-2.77	-49.67
0.58	-0.54	14.37	0.71	0.36	1.88
0.11	1.59	90.67	0	3.93	16.71
0.87	0.15	24.37	0.25	1.12	10.5
0	-4.46	-32.5	0.04	-2.04	-18.4
0	-2.88	41	0	3.39	8.41
0.33	-0.95	16	0.41	0.82	3.53
0	-6.11	-84.54	0	-4.25	-26.3

•

Bicarbonate (mg/L)			Total Hardness (mg/L)			Iron (mg/L)	
Z	Sen	p-value	Z	Sen	p-value	Z	Sen
-0.4	4.28	0.06	1.87	-0	0	-3.11	0.02
1.44	-3.33	0.36	-0.91	-0.4	0	-3.9	-0
2.47	33.34	0	5.7	-0.1	0	-4.25	0.03
5.41	5.71	0.03	2.16	0.03	0	6.02	-0
6.13	4	0	3.87	-0	0.01	-2.6	-0.1
-9.25	-0.62	0.44	-0.77	0.03	0.09	1.65	-0.1
5.38	-25.17	0.02	-2.41	-0.1	0	-4.73	0.01
5.15	-18.57	0.3	-1.02	0.03	0.53	0.62	-0.1
-4.93	20	0	4.12	0	0.92	-0.09	-0.4
1.03	6.6	0	3.43	0.04	0.24	1.16	0
0.57	-4.45	0.93	-0.07	-0	0.71	-0.37	0.09
1.14	3.4	0.01	2.57	-0	0	-4.19	-0.1
2.39	-6.25	0	-3.54	-0.1	0	-8.13	0.04
3.09	5	0.03	2.15	0.1	0.19	1.3	-0
-2.95	-107.8	0.15	-1.42	-0	0	-3	-0
5.11	-0.95	0.94	-0.06	0.02	0	4.64	0.05
-0.83	-15.33	0.11	-1.57	0.01	0.11	1.55	-0.1
3.06	24.13	0.34	0.93	-0	0.04	-2.03	-0
0.58	8.67	0.06	1.81	-0	0.17	-1.35	-0.1
2.75	3	0.42	0.8	-0	0.17	-1.34	0.03
-4.05	40	0	8.93	0.01	0	2.63	0.01
1.29	18.18	0	3.14	0.01	0.55	0.58	-0.2
1.73	2.5	0.03	2.15	0.01	0	3.57	-0.1
-1.93	3.75	0	3.06	0.05	0	9.11	-0.1
4.01	-15.83	0	-5.38	0.06	0	2.84	-0
5.58	-19.04	0.09	-1.68	0.01	0	9.79	-0
1.56	21.12	0	2.91	0	0.89	-0.13	0.03
3.15	-2.04	0.79	-0.25	-0.1	0	-4.85	0
-3.26	-4.89	0	-3.72	0.01	0.02	2.38	-0.1
0.19	9.5	0	3.02	0	0.72	0.35	-0
3.67	-1.33	0.58	-0.54	0	0.75	-0.31	-0
0.68	2.23	0.26	1.12	0.09	0	5.74	-0.1

•

Sodium (mg/L)			Magnesium (mg/L)			Potassium (mg/L)		
Z	Sen	p-value	Z	Sen	p-value	Z	Sen	p-value
3.37	2.2	0	3.64	1.1	0	2.88	-1.78	0.68
-7.82	-1.67	0.23	-1.17	0.1	0.53	0.62	21.8	0.14
6.15	4.5	0	5.02	-0.1	0.45	-0.74	9.13	0.01
0.94	1.03	0.22	1.21	2.23	0.1	1.63	7.41	0
4.28	0.23	0.67	0.41	0.23	0	3.45	35.64	0
-6.76	-0.65	0.01	-2.44	0.18	0	4.33	-27.2	0
-2.74	-2.41	0.1	-1.62	-1.5	0	-3.16	14.7	0
-1.41	-4.5	0.17	-1.36	-1.3	0	-3.35	23.16	0
3.62	3.74	0.05	1.97	-1	0.17	-1.36	-23.6	0
4.31	1.99	0	4.37	-1.1	0	-5.33	1.33	0.29
4	5.11	0.15	1.44	0.18	0.49	0.68	47.72	0.56
0.94	0.71	0	3.3	0	1	0	7.3	0.25
5.45	-0.82	0	-5.05	0.07	0.01	2.45	4.08	0.02
1.51	-0.48	0.5	-0.67	-1.4	0	-11.88	28.87	0
-0.68	-25.9	0.12	-1.51	-2.1	0	-2.66	-16.3	0
-3.66	-2.62	0	-2.94	-4.9	0	-6.12	9.39	0
-3.22	-4.03	0.11	-1.58	-1.1	0	-3.7	-9.25	0.41
0.85	8.37	0	2.89	-1.7	0.76	-0.29	9.06	0
4.22	0.92	0.13	1.49	0.2	0.72	0.34	1.61	0.55
0.58	1.21	0.02	2.26	-0.6	0	-5.32	7	0
2.79	6.78	0	9.05	0	0.93	-0.07	-5.23	0
-0.18	2	0.31	1.01	1.15	0.04	2.04	6.77	0.19
3.93	0.32	0.02	2.22	-0	0.65	-0.48	2.72	0.08
-4.09	0.91	0	2.76	-0.1	0	-3.18	-4.55	0.05
-1.15	-2.22	0	-3.88	-0.4	0.05	-2.22	16.75	0
0.55	-3.21	0.11	-1.58	-1.4	0.03	-2.14	13.09	0
4.19	0.36	0.48	0.69	0.14	0	4.99	5.33	0.11
1.8	0.36	0.35	0.92	-0.2	0.06	-1.89	1.5	0
-3.54	-0.19	0.79	-0.25	-1.7	0	-3.32	-6.1	0
2.02	2.39	0	3.97	3.2	0	3.38	0.67	0.84
0.59	1.38	0	8.08	-0.3	0.11	-1.61	7.43	0
-4.3	0.12	0.49	0.68	-0.8	0	-3.11	0.54	0.49

•

	Sulphate (mg/L)			pH			Nitrate (mg/L)		
p-value	Z	Sen	p-value	Z	Sen	p-value	Z	Sen	p-value
0	3.99	0.04	0	5.21	0.66	0.5	0.65	4.75	0
0.46	0.73	0	0.23	-1.12	-2.75	0.05	-1.91	-19.5	0
0	3.89	-0	0	-3.55	-0.36	0.01	-2.58	39.23	0
0	3.22	-0	0.01	-2.52	1.41	0	9.36	7.35	0.35
0	4.31	-0	0	-2.68	-1.33	0.08	-1.75	25.83	0
0.16	1.38	-0	0.16	-1.38	-1.2	0	-8.6	-9.1	0
0.04	-2.03	0.01	0.46	0.73	1.12	0.04	2.02	-58.1	0
1	0	-0	0.28	-1.07	-15.8	0	-2.64	-19.2	0.15
0.02	2.3	-0	0.02	-2.42	8.91	0	5.33	29.53	0
0	6.24	-0	0.67	-0.42	1.41	0.14	1.46	9	0
0.35	-0.93	-0	0.9	-0.12	0	0.03	2.12	6.09	0
0.94	0.06	-0	0.06	-1.88	0.07	0.59	0.52	1.6	0.34
0	4.81	0	0.96	0.04	-2	0	-3.35	5.07	0
0	4.37	0.04	0	8.37	0.95	0	8.21	10.75	0.12
0.62	-0.49	0.08	0	6.21	-2.42	0.89	-0.13	-34	0.49
0	-3.84	-0	0	-2.95	-36.2	0	-4.66	-50.5	0
0.41	-0.81	0.03	0	2.95	0.85	0	4.12	-58.3	0
0.94	0.06	0.02	0.02	2.28	25.87	0	4.41	4.44	0.39
0	4.5	0.01	0.68	0.41	1.11	0.09	1.67	16.23	0
0.45	0.74	0.01	0	3.41	-4.73	0	-4.05	0.6	0.55
0	5.28	-0	0	-3.89	-3.71	0	-3.09	21.43	0.01
0.58	0.55	-0	0.36	-0.91	-6.77	0.03	-2.19	-0.8	0.85
0.06	1.87	0	0.9	0.11	0.09	0.18	1.31	6.1	0
0.52	-0.63	0.01	0	2.81	-1.92	0	-4.16	-3	0
0.22	-1.2	0.01	0.04	2.02	-0.44	0.05	-1.94	-20	0.24
0.46	-0.73	0.01	0.4	0.83	-9.87	0	-3.26	5.37	0.58
0	4.49	0.01	0.11	1.61	-2.58	0	-4.17	12.84	0
1	0	-0	0.03	-2.11	-7.89	0.04	-2.06	3.89	0.07
0.17	-1.34	0.03	0	3.02	-4.17	0	-3.22	-17.7	0
0.02	2.27	0.01	0.19	1.28	-0.05	0.84	-0.19	5.8	0.04
0.4	-0.83	0.01	0.04	2.01	-4.57	0.04	-1.97	2.31	0.55
0	-9.77	0.02	0.08	1.73	-11.6	0	-9.14	-24.4	0

		Station	
Longitute	Latitute	Jaipur	Sen
75.8666667	26.9833333	Amber	
76.0666667	26.8333333	Bassi2	3.75
75.95	26.6	Chaksu	6.25
75.7541667	26.5672222	Dawach	13.33
75.9083333	26.6791667	Goner	10.23
75.6	26.975	Kalwad	9.44
75.2777778	26.61	Mangarwara	0.61
75.3625	26.6833333	Mozmabad	-27.9
75.4333333	26.8	Nasnota	0
76.205	27.1166667	Rasala	6.68
75.9005556	26.7136111	Shivdaspura	4.89
75.8861111	26.6125	Thalli	-4.09
75.7733333	27.2917444	Tigaria	0.21
		Barmer	8.69
70.1666667	25.9916667	Panchla	
70.9583333	25.7416667	Bachhbar	35
70.875	25.9152778	Balewa	-1.09
72.2583333	25.8291667	Balotra1	-21.9
71.3972222	25.7361111	Barmer1	-19.4
71.2416667	25.9083333	Bisala	4.14
71.0666667	25.475	Chohtan	11.55
72.5166667	25.7333333	Devra	2.11
72.6666667	26.0666667	Doli	63.57
70.6388889	25.7402778	Gadra Road	3.28
71.2555556	25.7166667	Jasai	7
72.3686111	25.9416667	Kuri2	-0.43
71.1166667	25.9833333	Nand	-4.94
71.2236111	25.6777778	Patrasar	-2.21
70.9388889	25.8458333	Redana	7.61
71.4	25.4833333	Sanawara	0
71.2333333	25.5958333	Sanlor	-12.4
71.0833333	25.775	Sihani	5.89
71.15	24.9222222	Sihaniya	-1.5
71.2166667	24.8833333	Tarla	-22.1

		Total Alkalinity (mg/L)
Sen	p-value	Z
1.06	0.03	2.11
0.51	0.47	0.71
6.39	0.19	1.28
14.81	0	3.53
-9.62	0	-4.96
14.78	0	4.43
-10.7	0	-8.08
24.21	0	3.41
-12.4	0.25	-1.14
14.18	0	6.67
-6.95	0.22	-1.21
2.56	0	4.05
8.91	0	6.49
17.14	0	4.11
-13	0.07	-1.77
14.77	0	7.16
9.98	0	8.67
13.11	0	5.73
-30	0	-3.95
10.66	0	3.36
2.94	0	2.81
4.92	0	3.03
-12.9	0	-3.05
5.57	0.03	2.24
17.25	0	3.55
6.39	0	3.58
0.75	0.95	0.06
-44.3	0	-4.81
-18.4	0	-4.27

		Chloride (mg/L)			Calcium (mg/L)
Sen	p-value	Z	Sen	p-value	Z
2.33	0	3.02	2.75	0	8.35
1.75	0.15	1.41	1.43	0.18	1.31
-3.75	0	-2.82	-1.2	0.12	-1.51
0.99	0	7.79	1.2	0	2.94
25.22	0	11.51	3.21	0	6.25
-25	0	-8.08	0	1	0
-6	0	-3.02	0.95	0.05	1.93
93.28	0	3.09	-0.1	0.57	-0.55
20.6	0.01	2.63	-1.7	0.39	-0.84
24.25	0	4.24	8.09	0	4.95
4.33	0.13	1.51	0	0.62	0.48
0.18	0.97	0.04	2.05	0	3.06
3.35	0.18	1.31	-2	0	-3.41
-20.6	0	-3.16	-0.4	0.28	-1.06
-3.5	0.79	-0.27	1.69	0.69	0.39
-0.13	0.82	-0.23	-0.1	0.4	-0.83
4	0.06	1.87	0.33	0.27	1.09
71.33	0	6.05	6	0	5.49
5.83	0.03	2.15	2.67	0	2.95
-21.7	0.22	-1.21	-0.1	0.92	-0.09
3.6	0.06	1.84	1.14	0.13	1.48
3	0	2.99	0.4	0.11	1.57
1.17	0.18	1.32	0.36	0.02	2.24
11.32	0	5.61	0.2	0.8	0.25
6.64	0.02	2.31	1.2	0.04	2.03
0	1	0	1.33	0	6.26
-21.5	0	-3.92	0.36	0.51	0.64
-7.25	0.79	-0.25	1.73	0	6.94
5.8	0.09	1.68	1.92	0.01	2.73

•

		Fluoride (mg/L)			Electrical Conductivity (mumhos/cm) at 25 C)
Sen	p-value	Z	Sen	p-value	Z
-0	0	-8.59	8.82	0.02	2.42
-0	0.01	-2.66	24	0.09	1.68
-0	0.19	-1.28	-4.67	0.63	-0.47
0.02	0	9.13	69.67	0	5.07
-0.3	0	-4.95	56.32	0	11.08
-0.1	0	-8.95	-19.23	0.34	-0.93
-0.2	0	-3.37	-107.4	0	-5.02
-0	0.08	-1.72	492	0.01	2.73
0.02	0.65	0.45	0	0.97	-0.04
-0	0.01	-2.79	187.45	0	4.25
-0.1	0	-4.07	72.5	0	4.42
-0.3	0	-3.69	-41.67	0	-5.44
-0	0	-3.19	37.5	0	4.5
-0.1	0	-4.26	71.43	0.18	1.31
-0	0.48	-0.69	22.18	0.47	0.71
-0	0.37	-0.88	31.32	0.02	2.22
-0	0.02	-2.37	40	0.1	1.64
-0	0	-2.68	320.91	0	6.55
-0.1	0	-11.14	-13	0.86	-0.17
-0.1	0	-11.55	14.61	0.96	0.05
-0.1	0	-4.01	13.03	0.47	0.72
-0	0	-3.15	13.34	0	3.81
-0.2	0	-4.24	23.34	0.44	0.75
-0.2	0.02	-2.23	37.21	0	5.73
0.03	0	4.33	90	0	4.18
-0.5	0	-12.07	0	1	0
-0.6	0	-7.89	-51.11	0.03	-2.13
-0.1	0	-5.66	-65	0.09	-1.69
0.03	0.05	1.92	23.08	0.42	0.79

•

•

	Bicarbonate (mg/L)			Total Hardness (mg/L)			Iron (mg/L)
p-value	Z	Sen	p-value	Z	Sen	p-value	Z
0	2.69	11.53	0	6.18	0.01	0.74	0.33
0.02	2.41	2.5	0.74	0.31	0.01	0.19	1.31
0.25	1.13	-10.8	0	-4.78	0.01	0	7.45
0	3.35	7.25	0	5.76	0.14	0.01	2.56
0	-3.93	21.94	0	3.61	-0	0.04	-2.07
0	3.95	-11.2	0	-3.11	-0	0.02	-2.3
0	-4.08	-10.4	0	-4.63	-0	0	-3.61
0.04	2.08	1.11	0.78	0.27	0	0.12	1.54
0.15	-1.42	-5.95	0.63	-0.48	0	0.41	0.82
0	5.29	53.56	0	3.38	0.02	0.03	2.14
0.61	-0.51	-5.36	0	-3.56	-0	0.24	-1.16
0	4.05	3	0.17	1.35	0.01	0	3.14
0.29	1.04	-1.28	0.39	-0.86	0.01	0	3.55
0	3.77	-1.67	0.81	-0.24	0.01	0.36	0.91
0.08	-1.77	10	0.69	0.39	-0	0.08	-1.77
0	4.59	-5.75	0.13	-1.5	-0.6	0.02	-2.26
0	6.95	6.36	0.01	2.53	-0	0.04	-2.09
0	6.12	28.34	0	4.29	0	0.83	0.21
0	-4.67	16.87	0	3.11	0.01	0.44	0.78
0	3.08	0.19	0.96	0.05	0.01	0.59	0.54
0	4.62	10	0	4.41	0.02	0	3.32
0	3.01	5	0	6.01	-0	0.57	-0.57
0	-3.56	1.39	0.01	2.5	0	0.02	2.44
0.09	1.64	2.92	0.46	0.73	-0	0	-5.93
0	3.72	14	0	3.27	0.01	0	2.97
0.33	0.97	6.25	0	5.61	-0	0	-3.07
68	0.41	-5	0.07	-1.85	0.04	0.02	2.41
0	-4.48	6.67	0.29	1.03	-0.1	0	-11.2
0	-3.97	3.46	0.14	1.46	0.01	0.51	0.66

	Sodium (mg/L)			Magnesium (mg/L)			Potassium (mg/L)	
p-value	Z	Sen	p-value	Z	Sen	p-value	Z	Sen
0	-4.82	1.11	0	6.63	-0.7	0.25	-1.13	7.38
0.34	0.95	0.09	0.89	0.12	-0.1	0.54	-0.61	5.06
0	5.46	-2	0	-4.04	-0	0.11	-1.61	5.44
0	4.41	0.99	0	12.88	1	0	2.94	18.07
0.48	-0.69	3.69	0.01	2.49	0.32	0.18	1.31	-33.1
0.25	-1.14	-2.3	0	-6.36	-0.1	0.29	-1.05	14.17
0	-3.44	-2.5	0	-6.54	0.32	0.01	2.45	-7.75
0	3.1	1	0.63	0.47	0.23	0.42	0.79	21.09
0.04	2.03	0.12	0.83	0.21	4	0.08	1.77	-13.9
0	4.46	4.46	0	2.91	0.03	0.88	0.15	13.71
0	2.72	-1	0	-4.74	0	0.71	0.37	-4.17
0	-4.09	-1.3	0	-6.22	0.12	0.2	1.27	3.13
0	4.46	0.69	0	3.6	-2.2	0.1	-1.65	1
0	4.21	-2.4	0	-3.57	-0.9	0	-7.06	19.35
0.19	-1.31	1.59	0.55	0.59	-1.1	0.71	-0.37	-15.8
0	3.83	-0.4	0.64	-0.45	-0.1	0.21	-1.24	9.8
0.15	1.41	1.45	0	3.49	0.36	0.02	2.18	11
0	7.36	7.02	0	6.92	2	0	3.09	15.25
0	-6.61	2.59	0	4.06	-0.1	0.14	-1.45	-44.4
0.47	-0.71	-0.1	0.92	-0.09	0.08	0.38	0.87	15.71
0.79	-0.26	1.17	0.07	1.79	-0	0.15	-1.44	4.78
0	3.15	1.4	0	5.02	-0.8	0.01	-2.78	7.2
0.11	1.59	0	0.83	-0.21	0.16	0.01	2.56	-26.3
0	4.94	0.31	0.15	1.42	-0.1	0	-3.21	9.32
0	3.82	2.5	0	3.04	-0.1	0	-3.27	21
0.16	-1.39	0.21	0.73	0.35	0.1	0.16	1.41	1.75
0	-3.91	-0.9	0.03	-2.14	-0.2	0	-3.22	2
0.04	-1.99	2.2	0.01	2.46	0.02	0.51	0.65	-57
0.89	0.12	-0.2	0.9	-0.11	0.03	0.46	0.72	-22

•

		Sulphate (mg/L)			pH			Nitrate (mg/L)	
Sen	p-value	Z	Sen	p-value	Z	Sen	p-value	Z	Sen
2.41	0.23	1.18	0.01	0.02	2.31	-3.5	0.08	-1.72	-2.8
0.17	0.71	0.37	0.01	0.16	1.4	0.9	0	5.86	1
-6.32	0.27	-1.08	-0	0	-6.3	-1.15	0.47	-0.72	2.27
15.36	0.01	2.56	-0	0	-4.5	7.51	0	11.8	12.92
1.78	0	6.6	0.02	0.19	1.28	-1.83	0.42	-0.81	-1.62
3.95	0.21	1.26	-0	0	-3.6	1.5	0.09	1.69	-7
-20.6	0	-4.07	-0	0	-3.2	-0.49	0.83	-0.21	-29
34.14	0.01	2.67	0.01	0.28	1.06	9.08	0.01	2.58	107.5
29.86	0.14	1.46	0.01	0.45	0.75	-3.49	0.59	-0.53	5.2
8.11	0	2.8	-0	0	-4.2	18.34	0	3.76	16.43
17.5	0	4.75	-0	0.04	-2.1	-1.86	0	-2.93	16.19
-9.22	0	-3.86	-0.1	0	-5	-8.03	0.12	-1.55	-13.4
3.54	0.04	2.09	-0	0	-4	3.96	0.03	2.24	5.28
18.06	0	4.68	0.03	0.01	2.49	-13.3	0	-6.58	14.33
14.1	0.84	0.19	-0	0	-4	-26.5	0.01	-2.73	-14.9
-8.06	0	-2.71	-0	0.28	-1.1	0	0.61	0.5	8.75
3	0.32	0.97	-0	0.15	-1.4	-0.04	0.88	-0.14	2.4
18.18	0	4.01	-0.3	0	-4.4	4.11	0	3.31	49.61
2.43	0.18	1.32	-0	0.01	-2.6	-0.24	0.15	-1.43	-26.1
-1.5	0.85	-0.17	0	0.41	-0.8	1.05	0.27	1.08	-4.42
0.18	0.95	0.05	-0	0	-3.3	0.14	0.77	0.29	-0.34
1.42	0.07	1.81	-0	0	-2.8	-1	0	-4.87	4
0.35	0.57	0.55	-0	0	-4.8	-0.17	0.77	-0.27	2
-1.34	0.75	-0.31	-0	0	-4.6	-0.61	0	-3.5	9.58
7.2	0	5.37	-0	0.07	-1.8	3.68	0	4.13	15.54
-3.84	0.11	-1.56	-0	0	-3.1	1.65	0.01	2.82	-6.43
-8.34	0.05	-1.92	-0	0.54	-0.6	-3.42	0	-6.29	-12.7
0	1	0	-0	0.07	-1.8	-5.35	0	-5.86	-24.8
0	1	0	-0	0	-4.9	-3	0.26	-1.12	0.46

Station		
Jodhpur	Latitute	Longitude
Bap1	27.3666667	72.35
Cazri	26.2666667	73
Chopasni Nath	26.275	72.9333333
Dangiwas	26.2666667	73.2833333
Devatra	26.5102778	73.3777778
Dharmi	26.7375	73.6416667
Dhawa	26.0583333	72.7416667
Jatyasani	26.0916667	72.8333333
Jodhpur	26.3	73.0333333
Karani	26.2722222	72.825
Kumbhariya	26.7375	73.5375
Mandawar1	26.35	73.0416667
Osian1	26.725	72.9166667
Piparcity	26.388	73.53
Tonk		
Aligarh	25.9666667	76.0833333
Arniyalmal	26.0583333	75.8083333
Bantholi	25.8833333	75.5666667
Dikoliya	25.975	75.9661111
Hamirpur	26.1833333	75.575
Jainagar	25.8166667	76.2327778
Mahuva	25.9986111	75.6833333
Malpura1	26.2833333	75.3833333
Nayagaon	26.0408333	75.8888889
Niwai1	26.3666667	75.9333333
Ramthala	25.8638889	75.2805556
Sohela	26.2416667	75.85
Dausa		
Mahuwa	27.075	76.95
Dausa1	26.8958333	76.325
Bhandarej	26.9166667	76.4
Bapi	26.975	76.2916667

Source: Authors' calculation

Table 4.7: Percentage of wells/piezometers violating the BIS (2012) and WHO (2011) guidelines

Ajmer	Calcium (Beyond Acceptable limit)	Calcium (Beyond Permissible limit)	Chloride (Beyond Acceptable limit)	Chloride (Beyond Permissible limit)	Fluoride (Beyond Acceptable limit)	Flouride (Beyond Permissible limit)	Potassium (Beyond Acceptable limit)	Magnesium (Beyond Acceptable limit)	Sodium (Beyond Acceptable limit)	Nitrate (Beyond Acceptable limit)	Sulphate (Beyond Acceptable limit)	Sulphate (Beyond Permissible limit)	pH (Beyond Acceptable limit)
2000	42.86	9.52	57.14	38.10	85.71	61.90	52.38	23.81	80.95	23.81	61.90	38.10	0.00
2001	42.86	4.76	42.86	23.81	57.14	38.10	33.33	23.81	47.62	19.05	38.10	23.81	0.00
2002	23.81	4.76	52.38	19.05	71.43	71.43	14.29	4.76	57.14	23.81	33.33	19.05	4.76
2004	14.29	4.76	33.33	23.81	76.19	71.43	19.05	9.52	61.90	19.05	33.33	9.52	0.00

2005	9.52	0.00	33.33	0.00	66.67	52.38	19.05	0.00	42.86	38.10	23.81	9.52	0.00
2006	14.29	0.00	23.81	4.76	52.38	52.38	14.29	4.76	57.14	28.57	19.05	4.76	9.52
2007	28.57	4.76	47.62	19.05	66.67	47.62	38.10	28.57	57.14	38.10	33.33	33.33	0.00
2008	9.52	0.00	23.81	4.76	28.57	14.29	14.29	4.76	28.57	14.29	14.29	9.52	4.76
2009	38.10	4.76	42.86	23.81	57.14	38.10	33.33	23.81	47.62	19.05	38.10	23.81	0.00
2010	19.05	4.76	28.57	4.76	47.62	47.62	42.86	4.76	23.81	9.52	9.52	4.76	0.00
2011	57.14	14.29	52.38	28.57	33.33	9.52	33.33	33.33	52.38	33.33	33.33	28.57	4.76
2012	28.57	9.52	42.86	14.29	47.62	23.81	47.62	23.81	66.67	38.10	33.33	19.05	0.00
2013	28.57	14.29	47.62	19.05	42.86	19.05	19.05	28.57	57.14	38.10	28.57	19.05	0.00
2014	23.81	4.76	33.33	9.52	38.10	14.29	0.00	14.29	38.10	23.81	4.76	4.76	23.81
2015	19.05	4.76	23.81	4.76	23.81	23.81	9.52	4.76	19.05	14.29	14.29	4.76	4.76
2016	28.57	4.76	28.57	9.52	57.14	52.38	9.52	14.29	33.33	23.81	28.57	23.81	0.00
2017	38.10	9.52	47.62	14.29	38.10	14.29	14.29	28.57	57.14	33.33	28.57	23.81	4.76
2018	28.57	4.76	42.86	23.81	9.52	0.00	23.81	23.81	52.38	28.57	23.81	4.76	0.00
Barmer													
2000	25.00	10.00	55.00	25.00	75.00	55.00	55.00	15.00	65.00	55.00	60.00	45.00	45.00
2001	35.00	5.00	70.00	25.00	75.00	55.00	45.00	10.00	70.00	70.00	45.00	30.00	15.00

2002	55.00	5.00	70.00	25.00	85.00	60.00	40.00	20.00	80.00	70.00	35.00	20.00	0.00
2004	35.00	10.00	75.00	40.00	80.00	40.00	65.00	30.00	80.00	70.00	55.00	30.00	0.00
2005	45.00	10.00	75.00	50.00	85.00	35.00	50.00	35.00	85.00	75.00	55.00	25.00	0.00
2006	55.00	10.00	80.00	45.00	75.00	35.00	55.00	35.00	85.00	80.00	65.00	25.00	0.00
2007	45.00	5.00	80.00	35.00	55.00	40.00	60.00	35.00	95.00	80.00	60.00	20.00	5.00
2008	60.00	5.00	75.00	35.00	55.00	30.00	55.00	20.00	80.00	70.00	55.00	25.00	0.00
2009	40.00	10.00	85.00	25.00	75.00	45.00	50.00	20.00	85.00	85.00	40.00	25.00	5.00
2010	60.00	15.00	85.00	35.00	70.00	40.00	50.00	40.00	75.00	75.00	55.00	35.00	10.00
2011	65.00	10.00	85.00	30.00	65.00	40.00	50.00	25.00	80.00	70.00	65.00	35.00	10.00
2012	60.00	5.00	95.00	30.00	60.00	35.00	45.00	30.00	85.00	60.00	70.00	45.00	5.00
2013	50.00	5.00	85.00	25.00	45.00	20.00	30.00	30.00	85.00	50.00	70.00	50.00	5.00
2014	60.00	15.00	80.00	20.00	60.00	30.00	45.00	30.00	85.00	55.00	60.00	35.00	10.00
2015	60.00	0.00	65.00	35.00	50.00	25.00	30.00	10.00	70.00	30.00	35.00	25.00	10.00
2016	45.00	10.00	55.00	15.00	50.00	15.00	35.00	15.00	60.00	50.00	30.00	20.00	20.00
2017	35.00	5.00	65.00	25.00	45.00	35.00	25.00	20.00	60.00	45.00	35.00	15.00	20.00
2018	25.00	0.00	40.00	15.00	55.00	30.00	15.00	10.00	40.00	35.00	20.00	5.00	40.00
Tonk													

-

2000	8.33	0.00	25.00	0.00	25.00	25.00	16.67	0.00	25.00	16.67	8.33	0.00	16.67
2001	8.33	0.00	33.33	0.00	66.67	50.00	25.00	0.00	50.00	33.33	50.00	16.67	16.67
2002	41.67	0.00	25.00	8.33	66.67	50.00	25.00	8.33	41.67	16.67	33.33	8.33	41.67
2004	16.67	0.00	16.67	0.00	66.67	58.33	8.33	8.33	58.33	16.67	25.00	8.33	0.00
2005	16.67	0.00	16.67	0.00	66.67	66.67	8.33	0.00	66.67	16.67	33.33	0.00	0.00
2006	16.67	0.00	16.67	0.00	66.67	66.67	8.33	8.33	58.33	16.67	16.67	0.00	0.00
2007	33.33	0.00	16.67	0.00	58.33	58.33	16.67	0.00	50.00	8.33	16.67	0.00	0.00
2008	25.00	0.00	16.67	0.00	50.00	41.67	25.00	0.00	50.00	8.33	16.67	0.00	8.33
2009	8.33	0.00	25.00	0.00	75.00	58.33	33.33	0.00	50.00	25.00	41.67	16.67	16.67
2010	16.67	8.33	41.67	8.33	58.33	33.33	8.33	8.33	75.00	25.00	50.00	16.67	8.33
2011	8.33	8.33	41.67	8.33	75.00	33.33	8.33	16.67	83.33	33.33	50.00	16.67	0.00
2012	16.67	16.67	33.33	8.33	41.67	25.00	33.33	16.67	75.00	41.67	50.00	16.67	0.00
2013	25.00	8.33	41.67	0.00	41.67	41.67	25.00	8.33	58.33	41.67	33.33	33.33	0.00
2014	33.33	8.33	50.00	16.67	33.33	25.00	25.00	16.67	58.33	75.00	41.67	8.33	33.33
2015	33.33	8.33	58.33	8.33	33.33	8.33	25.00	16.67	83.33	50.00	33.33	16.67	8.33
2016	8.33	0.00	33.33	8.33	25.00	8.33	16.67	8.33	66.67	25.00	41.67	0.00	8.33
2017	58.33	0.00	66.67	8.33	41.67	33.33	8.33	0.00	75.00	25.00	25.00	0.00	0.00

2018	16.67	8.33	41.67	8.33	16.67	8.33	25.00	8.33	41.67	25.00	16.67	8.33	0.00
Jodhpur													
2000	50.00	21.43	57.14	42.86	50.00	28.57	42.86	28.57	64.29	28.57	28.57	21.43	0.00
2001	42.86	7.14	71.43	21.43	64.29	35.71	28.57	14.29	71.43	78.57	28.57	14.29	21.43
2002	35.71	0.00	64.29	0.00	71.43	57.14	28.57	7.14	64.29	64.29	28.57	0.00	7.14
2004	64.29	0.00	64.29	21.43	42.86	28.57	35.71	21.43	64.29	78.57	28.57	0.00	7.14
2005	57.14	7.14	64.29	21.43	50.00	28.57	35.71	28.57	64.29	71.43	14.29	0.00	7.14
2006	57.14	7.14	64.29	14.29	50.00	28.57	28.57	21.43	71.43	57.14	21.43	0.00	14.29
2007	57.14	14.29	64.29	21.43	57.14	35.71	35.71	21.43	78.57	42.86	50.00	7.14	7.14
2008	57.14	14.29	64.29	14.29	50.00	35.71	42.86	21.43	92.86	78.57	64.29	21.43	0.00
2009	64.29	7.14	78.57	21.43	64.29	28.57	35.71	14.29	92.86	78.57	50.00	14.29	21.43
2010	64.29	7.14	78.57	21.43	50.00	21.43	35.71	28.57	92.86	78.57	85.71	35.71	0.00
2011	57.14	7.14	85.71	14.29	50.00	21.43	50.00	14.29	100.00	57.14	78.57	35.71	14.29
2012	57.14	7.14	71.43	7.14	50.00	14.29	35.71	21.43	85.71	78.57	64.29	35.71	7.14
2013	50.00	14.29	71.43	7.14	35.71	14.29	28.57	21.43	85.71	78.57	50.00	14.29	7.14
2014	42.86	7.14	57.14	7.14	35.71	14.29	35.71	14.29	78.57	71.43	50.00	14.29	0.00
2015	50.00	7.14	50.00	7.14	21.43	21.43	28.57	14.29	78.57	71.43	35.71	7.14	0.00

2016	42.86	0.00	64.29	7.14	21.43	21.43	42.86	14.29	78.57	57.14	21.43	14.29	7.14
2017	50.00	0.00	71.43	14.29	42.86	7.14	35.71	14.29	71.43	42.86	42.86	14.29	0.00
2018	42.86	0.00	42.86	21.43	35.71	14.29	21.43	0.00	57.14	50.00	50.00	14.29	0.00
Jaipur													
2000	38.46	0.00	38.46	7.69	61.54	53.85	15.38	7.69	46.15	15.38	15.38	7.69	7.69
2001	23.08	7.69	38.46	15.38	69.23	61.54	23.08	7.69	69.23	23.08	15.38	15.38	23.08
2002	30.77	0.00	53.85	23.08	69.23	53.85	38.46	15.38	69.23	53.85	38.46	15.38	23.08
2004	46.15	15.38	53.85	30.77	69.23	61.54	46.15	23.08	69.23	30.77	30.77	15.38	23.08
2005	30.77	15.38	53.85	30.77	76.92	76.92	30.77	30.77	69.23	46.15	38.46	38.46	15.38
2006	46.15	15.38	53.85	38.46	76.92	61.54	38.46	23.08	69.23	38.46	38.46	23.08	0.00
2007	30.77	15.38	38.46	15.38	76.92	53.85	30.77	7.69	61.54	38.46	23.08	23.08	0.00
2008	38.46	15.38	53.85	23.08	84.62	69.23	38.46	23.08	69.23	38.46	38.46	30.77	15.38
2009	23.08	15.38	46.15	15.38	61.54	61.54	30.77	15.38	76.92	23.08	15.38	15.38	15.38
2010	38.46	15.38	69.23	15.38	61.54	53.85	7.69	30.77	84.62	61.54	46.15	30.77	0.00
2011	53.85	15.38	46.15	23.08	46.15	23.08	15.38	23.08	76.92	53.85	23.08	15.38	0.00
2012	23.08	0.00	61.54	7.69	53.85	23.08	7.69	7.69	84.62	30.77	38.46	30.77	0.00
2013	15.38	7.69	69.23	23.08	61.54	30.77	38.46	15.38	76.92	38.46	30.77	23.08	0.00

2014	15.38	0.00	53.85	15.38	69.23	38.46	30.77	7.69	76.92	15.38	30.77	7.69	23.08
2015	38.46	0.00	53.85	30.77	84.62	69.23	15.38	15.38	92.31	30.77	46.15	15.38	15.38
2016	15.38	0.00	53.85	23.08	76.92	76.92	30.77	23.08	76.92	38.46	38.46	15.38	7.69
2017	30.77	0.00	69.23	23.08	69.23	30.77	23.08	23.08	76.92	38.46	46.15	23.08	7.69
2018	23.08	0.00	46.15	15.38	38.46	30.77	30.77	15.38	61.54	30.77	53.85	38.46	15.38
Dausa													
2000	0.00	0.00	25.00	0.00	25.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	25.00
2001	25.00	0.00	100.00	25.00	100.00	75.00	25.00	25.00	100.00	75.00	100.00	25.00	0.00
2002	25.00	25.00	75.00	25.00	100.00	100.00	25.00	25.00	100.00	75.00	75.00	0.00	25.00
2004	25.00	0.00	75.00	25.00	100.00	25.00	25.00	25.00	100.00	50.00	75.00	0.00	25.00
2005	0.00	0.00	75.00	0.00	100.00	50.00	0.00	0.00	75.00	50.00	0.00	0.00	0.00
2006	25.00	0.00	25.00	25.00	100.00	75.00	25.00	25.00	75.00	50.00	25.00	0.00	0.00
2007	25.00	0.00	50.00	25.00	50.00	25.00	0.00	25.00	100.00	50.00	75.00	0.00	0.00
2008	25.00	25.00	100.00	25.00	50.00	50.00	0.00	25.00	100.00	75.00	75.00	0.00	0.00
2009	25.00	0.00	100.00	25.00	100.00	75.00	25.00	25.00	100.00	75.00	100.00	25.00	0.00
2010	25.00	25.00	100.00	25.00	100.00	25.00	25.00	25.00	100.00	50.00	75.00	0.00	0.00
2011	25.00	25.00	50.00	25.00	100.00	50.00	0.00	0.00	50.00	0.00	25.00	0.00	0.00

2012	25.00	0.00	25.00	25.00	100.00	75.00	0.00	25.00	75.00	0.00	50.00	25.00	0.00
2013	75.00	25.00	50.00	25.00	100.00	75.00	0.00	25.00	50.00	25.00	25.00	25.00	0.00
2014	75.00	0.00	50.00	25.00	100.00	75.00	0.00	25.00	50.00	25.00	50.00	0.00	0.00
2015	25.00	0.00	75.00	25.00	100.00	75.00	0.00	25.00	75.00	0.00	50.00	0.00	0.00
2016	50.00	0.00	50.00	25.00	100.00	50.00	0.00	50.00	75.00	25.00	50.00	0.00	0.00
2017	25.00	0.00	100.00	50.00	100.00	50.00	0.00	50.00	100.00	25.00	50.00	0.00	0.00
2018	75.00	0.00	75.00	25.00	100.00	75.00	0.00	50.00	100.00	0.00	25.00	25.00	0.00
Total													
2000	32.14	8.33	47.62	23.81	61.90	45.24	38.10	15.48	58.33	28.57	38.10	25.00	15.48
2001	32.14	4.76	54.76	19.05	67.86	48.81	32.14	13.10	63.10	46.43	39.29	21.43	13.10
2002	36.90	3.57	55.95	16.67	75.00	61.90	28.57	11.90	65.48	47.62	35.71	13.10	13.10
2004	33.33	5.95	51.19	25.00	70.24	51.19	35.71	19.05	69.05	44.05	38.10	13.10	5.95
2005	29.76	5.95	51.19	20.24	71.43	50.00	28.57	17.86	65.48	51.19	32.14	14.29	3.57
2006	36.90	5.95	47.62	21.43	65.48	48.81	29.76	19.05	69.05	46.43	33.33	10.71	4.76
2007	38.10	7.14	52.38	20.24	61.90	45.24	36.90	21.43	71.43	45.24	40.48	17.86	2.38
2008	36.90	7.14	50.00	16.67	51.19	35.71	33.33	14.29	64.29	44.05	39.29	16.67	4.76
2009	35.71	7.14	59.52	19.05	67.86	46.43	36.90	16.67	71.43	48.81	40.48	20.24	9.52

2010	39.29	10.71	61.90	17.86	59.52	39.29	32.14	22.62	67.86	48.81	47.62	22.62	3.57
2011	50.00	11.90	63.10	22.62	54.76	26.19	32.14	22.62	75.00	47.62	48.81	26.19	5.95
2012	38.10	7.14	60.71	15.48	53.57	27.38	34.52	21.43	78.57	47.62	51.19	29.76	2.38
2013	36.90	10.71	63.10	16.67	47.62	26.19	26.19	22.62	71.43	47.62	42.86	28.57	2.38
2014	38.10	7.14	54.76	14.29	50.00	26.19	25.00	17.86	65.48	45.24	36.90	14.29	16.67
2015	39.29	3.57	50.00	17.86	44.05	30.95	20.24	11.90	64.29	34.52	32.14	13.10	7.14
2016	30.95	3.57	46.43	13.10	50.00	35.71	25.00	16.67	60.71	38.10	32.14	15.48	8.33
2017	40.48	3.57	64.29	19.05	48.81	25.00	20.24	20.24	67.86	36.90	35.71	15.48	7.14
2018	29.76	2.38	44.05	17.86	34.52	19.05	21.43	14.29	52.38	32.14	30.95	13.10	11.90

Source: Authors' calculation

Table 4.8: Classification of wells/piezometers based of EC and SAR (in Percentage)

	EC (µS/cm)					SAR			
Dausa	Excellent	Good	Permissible	Doubtful	Unsuitable	Excellent	Good	Doubtful	Unsuitable
2000	0	0	25	0	0	25.00	0.00	0.00	0.00
2001	0	0	0	25	75	0.00	75.00	25.00	0.00
2002	0	0	25	50	25	25.00	25.00	0.00	0.00

2004	0	0	25	0	75	50.00	25.00	25.00	0.00
2005	0	0	25	75	0	25.00	0.00	0.00	0.00
2006	0	0	50	25	25	50.00	50.00	0.00	0.00
2007	0	0	25	50	25	25.00	50.00	0.00	0.00
2008	0	0	0	75	25	25.00	25.00	0.00	0.00
2009	0	0	0	25	75	0.00	75.00	25.00	0.00
2010	0	0	0	50	50	25.00	0.00	25.00	0.00
2011	0	0	50	25	25	50.00	50.00	0.00	0.00
2012	0	0	50	0	50	75.00	25.00	0.00	0.00
2013	0	0	50	0	50	50.00	25.00	0.00	0.00
2014	0	0	50	0	50	25.00	25.00	0.00	0.00
2015	0	0	25	50	25	50.00	50.00	0.00	0.00
2016	0	0	50	0	50	0.00	0.00	0.00	0.00
2017	0	0	0	25	75	0.00	0.00	0.00	0.00
2018	0.00	0.00	25.00	50.00	25.00	50.00	25.00	25.00	0.00
Barmer									
2000	0.00	0.00	20.00	10.00	45.00	23.81	9.52	28.57	9.52

2001	0.00	5.00	25.00	10.00	45.00	19.05	4.76	19.05	4.76
2002	0.00	5.00	25.00	10.00	60.00	33.33	33.33	9.52	9.52
2004	0.00	5.00	20.00	20.00	55.00	23.81	19.05	4.76	19.05
2005	0.00	0.00	30.00	15.00	55.00	33.33	19.05	28.57	9.52
2006	0.00	0.00	20.00	20.00	60.00	0.00	0.00	0.00	0.00
2007	0.00	0.00	30.00	20.00	50.00	33.33	19.05	9.52	9.52
2008	0.00	5.00	25.00	20.00	50.00	42.86	19.05	4.76	14.29
2009	0.00	5.00	25.00	30.00	40.00	23.81	4.76	23.81	9.52
2010	0.00	5.00	20.00	20.00	55.00	33.33	19.05	19.05	4.76
2011	0.00	0.00	20.00	25.00	55.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	15.00	35.00	50.00	28.57	9.52	9.52	4.76
2013	0.00	5.00	10.00	35.00	50.00	19.05	14.29	23.81	9.52
2014	0.00	0.00	25.00	20.00	55.00	42.86	19.05	9.52	0.00
2015	0.00	10.00	20.00	25.00	40.00	42.86	9.52	14.29	4.76
2016	0.00	5.00	20.00	25.00	30.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	20.00	25.00	35.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	40.00	15.00	15.00	47.62	4.76	4.76	9.52

Ajmer									
2000	0.00	0.00	23.81	9.52	52.38	45.00	10.00	10.00	25.00
2001	0.00	9.52	42.86	4.76	33.33	70.00	10.00	10.00	5.00
2002	0.00	4.76	23.81	14.29	33.33	40.00	15.00	5.00	20.00
2004	4.76	9.52	47.62	9.52	23.81	60.00	20.00	0.00	20.00
2005	0.00	14.29	33.33	14.29	14.29	45.00	25.00	0.00	10.00
2006	0.00	4.76	28.57	14.29	14.29	40.00	15.00	0.00	10.00
2007	0.00	9.52	19.05	14.29	28.57	40.00	25.00	5.00	5.00
2008	0.00	4.76	33.33	4.76	14.29	50.00	0.00	0.00	10.00
2009	0.00	9.52	42.86	4.76	33.33	70.00	10.00	10.00	5.00
2010	0.00	4.76	47.62	9.52	9.52	60.00	10.00	5.00	0.00
2011	0.00	9.52	33.33	4.76	42.86	65.00	10.00	0.00	20.00
2012	0.00	4.76	47.62	19.05	23.81	80.00	5.00	5.00	10.00
2013	0.00	9.52	23.81	4.76	38.10	50.00	15.00	0.00	15.00
2014	0.00	19.05	33.33	9.52	23.81	65.00	20.00	5.00	0.00
2015	0.00	0.00	4.76	9.52	9.52	10.00	10.00	0.00	5.00
2016	0.00	14.29	33.33	4.76	23.81	0.00	0.00	0.00	0.00

2017	0.00	23.81	19.05	4.76	42.86	0.00	0.00	0.00	0.00
2018	0.00	9.52	23.81	4.76	33.33	45.00	15.00	5.00	10.00
Jaipur									
2000	0.00	0.00	38.46	23.08	7.69	46.15	23.08	0.00	0.00
2001	7.69	0.00	53.85	15.38	23.08	23.08	30.77	23.08	7.69
2002	0.00	7.69	38.46	30.77	23.08	23.08	15.38	15.38	0.00
2004	0.00	7.69	46.15	15.38	30.77	38.46	15.38	0.00	15.38
2005	0.00	0.00	46.15	7.69	46.15	15.38	30.77	15.38	0.00
2006	0.00	7.69	38.46	7.69	46.15	30.77	7.69	7.69	15.38
2007	0.00	7.69	46.15	15.38	30.77	23.08	23.08	0.00	7.69
2008	0.00	7.69	38.46	7.69	46.15	23.08	0.00	15.38	0.00
2009	7.69	0.00	53.85	15.38	23.08	30.77	23.08	23.08	7.69
2010	0.00	0.00	30.77	0.00	69.23	30.77	15.38	23.08	7.69
2011	0.00	7.69	38.46	7.69	46.15	53.85	30.77	15.38	0.00
2012	0.00	0.00	38.46	23.08	38.46	53.85	23.08	7.69	7.69
2013	0.00	0.00	30.77	30.77	38.46	15.38	23.08	7.69	23.08
2014	0.00	0.00	38.46	38.46	23.08	30.77	7.69	0.00	7.69

2015	0.00	0.00	30.77	23.08	46.15	15.38	38.46	7.69	15.38
2016	0.00	7.69	30.77	30.77	30.77	0.00	0.00	0.00	0.00
2017	0.00	0.00	23.08	38.46	30.77	0.00	0.00	0.00	0.00
2018	0.00	0.00	30.77	23.08	30.77	46.15	7.69	15.38	15.38
Jodhpur									
2000	0.00	0.00	28.57	14.29	42.86	50.00	28.57	7.14	0.00
2001	0.00	7.14	28.57	14.29	50.00	35.71	28.57	7.14	7.14
2002	0.00	14.29	35.71	14.29	35.71	35.71	35.71	0.00	0.00
2004	0.00	7.14	28.57	14.29	50.00	14.29	7.14	14.29	0.00
2005	0.00	7.14	21.43	35.71	35.71	14.29	0.00	0.00	0.00
2006	0.00	0.00	28.57	21.43	50.00	21.43	21.43	0.00	7.14
2007	0.00	0.00	28.57	14.29	57.14	35.71	14.29	7.14	7.14
2008	0.00	0.00	28.57	21.43	50.00	50.00	0.00	21.43	0.00
2009	0.00	0.00	28.57	14.29	57.14	28.57	21.43	7.14	7.14
2010	0.00	0.00	21.43	21.43	57.14	21.43	14.29	7.14	14.29
2011	0.00	0.00	14.29	35.71	50.00	28.57	21.43	0.00	7.14
2012	0.00	7.14	21.43	21.43	50.00	42.86	14.29	7.14	7.14

2013	0.00	0.00	14.29	35.71	42.86	28.57	7.14	7.14	7.14
2014	0.00	7.14	21.43	35.71	28.57	50.00	7.14	0.00	7.14
2015	0.00	7.14	35.71	7.14	42.86	21.43	0.00	0.00	14.29
2016	0.00	0.00	35.71	14.29	42.86	0.00	0.00	0.00	0.00
2017	0.00	14.29	14.29	14.29	50.00	0.00	0.00	0.00	0.00
2018	0.00	14.29	14.29	21.43	21.43	42.86	7.14	7.14	14.29
Tonk									
2000	0.00	25.00	16.67	8.33	8.33	41.67	16.67	0.00	0.00
2001	0.00	16.67	58.33	8.33	16.67	58.33	33.33	8.33	0.00
2002	0.00	16.67	58.33	16.67	8.33	58.33	8.33	16.67	0.00
2004	0.00	16.67	66.67	0.00	16.67	50.00	25.00	8.33	0.00
2005	0.00	25.00	58.33	0.00	16.67	33.33	25.00	0.00	0.00
2006	0.00	25.00	58.33	0.00	16.67	33.33	16.67	0.00	0.00
2007	0.00	16.67	66.67	8.33	8.33	16.67	0.00	0.00	0.00
2008	0.00	16.67	66.67	8.33	8.33	41.67	8.33	0.00	0.00
2009	0.00	25.00	58.33	0.00	16.67	58.33	33.33	0.00	0.00
2010	8.33	0.00	58.33	8.33	25.00	33.33	16.67	8.33	0.00

2011	0.00	8.33	58.33	8.33	25.00	66.67	16.67	8.33	8.33
2012	0.00	8.33	50.00	8.33	33.33	50.00	25.00	0.00	8.33
2013	0.00	8.33	41.67	16.67	33.33	58.33	25.00	0.00	0.00
2014	0.00	8.33	58.33	16.67	16.67	75.00	16.67	0.00	0.00
2015	0.00	0.00	33.33	41.67	25.00	50.00	33.33	8.33	0.00
2016	0.00	16.67	41.67	33.33	8.33	0.00	0.00	0.00	0.00
2017	0.00	0.00	41.67	50.00	8.33	0.00	0.00	0.00	0.00
2018	0.00	0.00	33.33	25.00	8.33	41.67	25.00	0.00	0.00
Total									
2000	0.00	3.57	25.00	11.90	33.33	39.29	15.48	10.71	8.33
2001	1.19	7.14	38.10	10.71	36.90	39.29	21.43	14.29	4.76
2002	0.00	8.33	33.33	17.86	34.52	36.90	22.62	8.33	7.14
2004	1.19	8.33	39.29	11.90	38.10	38.10	17.86	5.95	11.90
2005	0.00	8.33	35.71	17.86	32.14	29.76	19.05	9.52	4.76
2006	0.00	5.95	33.33	14.29	36.90	25.00	13.10	1.19	5.95
2007	0.00	5.95	34.52	16.67	35.71	30.95	19.05	4.76	5.95
2008	0.00	5.95	34.52	15.48	33.33	41.67	7.14	7.14	5.95

2009	1.19	7.14	38.10	14.29	36.90	40.48	19.05	14.29	5.95
2010	1.19	2.38	33.33	14.29	41.67	36.90	14.29	13.10	4.76
2011	0.00	4.76	32.14	16.67	44.05	40.48	15.48	3.57	7.14
2012	0.00	3.57	34.52	21.43	39.29	52.38	14.29	5.95	7.14
2013	0.00	4.76	23.81	22.62	41.67	34.52	16.67	8.33	10.71
2014	0.00	7.14	34.52	21.43	32.14	51.19	15.48	3.57	2.38
2015	0.00	3.57	22.62	21.43	30.95	28.57	17.86	5.95	7.14
2016	0.00	8.33	32.14	19.05	28.57	0.00	0.00	0.00	0.00
2017	0.00	8.33	21.43	23.81	36.90	0.00	0.00	0.00	0.00
2018	0.00	4.76	28.57	17.86	22.62	45.24	11.90	7.14	9.52
Source: Authors' calculation									

Table 4.9: Trends in climatic variables						
Tmin		latitute	Longitute	Z	Sen	p-value
bogla	Ajmer	25.8333	75.2333	1.99	0.04	0.01
taragarh	Ajmer	25.8833	74.15	0.54	0	0.03
baglias	Ajmer	25.9083	74.2	0.54	0	0.03
sanpla	Ajmer	25.9111	75.0417	1.99	0.04	0.01
jawaja	Ajmer	25.9333	74.2	0.54	0	0.03
ludiyana	Ajmer	25.9972	74.5833	0.54	0	0.03
jhopadiyan	Ajmer	26.025	74.6583	7.3	0	0.03
ajagara	Ajmer	26.0333	75.1	2.51	0.01	0.02
narbadkhera	Ajmer	26.05	74.2833	7.3	0	0.03
masuda	Ajmer	26.0917	74.5125	7.3	0	0.03
pakhriawas	Ajmer	26.1	74.4167	7.3	0	0.03
kalyanpura	Ajmer	26.1411	74.8022	7.3	0	0.03
ramsar	Ajmer	26.2667	74.8333	7.3	0	0.03
nasirabad	Ajmer	26.2867	74.7403	7.3	0	0.03
kanpur	Ajmer	26.4	74.8667	7.3	0	0.03
arian	Ajmer	26.45	75.0667	2.51	0.01	0.02
ghugra	Ajmer	26.5042	74.6917	7.3	0	0.03
	Ajmer					
piparli gaon	Barmer	25.1222	71.5889	8.28	0	0.04
kateria	Barmer	25.1583	71.4542	8.28	0	0.04
siyaga tala	Barmer	25.3375	70.8653	8.28	0	0.04
padmaniyon	Barmer	25.3458	71.4	8.28	0	0.04
adel	Barmer	25.425	71.7083	8.28	0	0.04
chohtan	Barmer	25.475	71.0667	8.28	0	0.04
sanawara	Barmer	25.4833	71.4	8.28	0	0.04

hathitala	Barmer	25.5744	71.3986	8.28	0	0.04
sindari	Barmer	25.5667	71.9	8.28	0	0.04
sanlor	Barmer	25.5958	71.2333	8.28	0	0.04
nimri	Barmer	25.6083	71.2833	8.28	0	0.04
patrasar	Barmer	25.6778	71.2236	8.28	0	0.04
sasion ka kua	Barmer	25.7042	71.4125	8.28	0	0.04
jasai	Barmer	25.7167	71.2556	8.28	0	0.04
devra	Barmer	25.7333	72.5167	7.19	0	0.04
bachhbar	Barmer	25.7417	70.9583	8.09	0	0.04
barmer	barmer	25.7361	71.3972	8.28	0	0.04
sihani	Barmer	25.775	71.0833	8.28	0	0.04
matasar	Barmer	25.7917	71.6	8.28	0	0.04
sutharon ki dha	Barmer	25.8083	71.0389	8.28	0	0.04
redana	Barmer	25.8458	70.9389	8.09	0	0.04
bisala	Barmer	25.9083	71.2417	8.28	0	0.04
derasar	Barmer	25.9181	70.1583	8.09	0	0.04
balewa	Barmer	25.9153	70.875	8.09	0	0.04
nand	Barmer	25.9833	71.1167	8.28	0	0.04
panchla	Barmer	25.9917	70.1667	8.09	0	0.04
panavada	Barmer	26.0292	71.7792	8.17	0	0.04
thob	Barmer	26.05	72.3583	8.31	0	0.04
jawansingh ki ber	Barmer	26.0667	70.9833	7.79	0	0.04
doli	Barmer	26.0667	72.6667	8.31	0	0.04
saupadamsingh	Barmer	26.2	71.825	8.17	0	0.04
kashmir	Barmer	26.2597	71.6056	8.17	0	0.04
bisukalan	Barmer	26.275	71.3056	8.17	0	0.04
gujro ka bera	Barmer	26.3383	71.5556	8.17	0	0.04

	Barmer					
prahladpura	Dausa	26.6833	76.2	2.22	0.02	0.01
lawan	Dausa	26.7833	76.2167	2.22	0.02	0.01
garh ranoli	Dausa	26.8125	76.5097	2.22	0.02	0.01
gijgarh	Dausa	26.8847	76.6431	2.22	0.02	0.01
dausa	dausa	26.8958	76.325	2.22	0.02	0.01
bhandarej	Dausa	26.9167	76.4	2.22	0.02	0.01
sikandara	Dausa	26.9667	76.5792	2.22	0.02	0.01
bapi	Dausa	26.975	76.2917	2.22	0.02	0.01
mahuwa	Dausa	27.075	76.95	0.38	0.69	0
	Dausa					
dawach	Jaipur	26.5672	75.7542	2.51	0.01	0.02
chaksu	Jaipur	26.6	75.95	2.51	0.01	0.02
mangarwara	Jaipur	26.61	75.2778	2.51	0.01	0.02
thalli	Jaipur	26.6125	75.8861	2.51	0.01	0.02
mozmabad	Jaipur	26.6833	75.3625	2.51	0.01	0.02
goner	Jaipur	26.6792	75.9083	2.51	0.01	0.02
shivdaspura	Jaipur	26.7136	75.9006	2.51	0.01	0.02
pallukhurd	Jaipur	26.7361	75.3	2.51	0.01	0.02
sirohikhurd	Jaipur	26.7917	75.15	2.51	0.01	0.02
nasnota	Jaipur	26.8	75.4333	2.51	0.01	0.02
durgapura	Jaipur	26.8417	75.7889	2.51	0.01	0.02
mes jaipur	Jaipur	26.9333	75.7792	2.51	0.01	0.02
jhotwara	Jaipur	26.9433	75.7444	2.51	0.01	0.02
kalwad	Jaipur	26.975	75.6	2.51	0.01	0.02
amber	Jaipur	26.9833	75.8667	2.51	0.01	0.02
rasala	Jaipur	27.1167	76.205	0.38	0.69	0

tigaria	Jaipur	27.2919	75.7733	0.5	0.61	0.01
	Jaipur					
dhawa	Jodhpur	26.0583	72.7417	8.31	0	0.04
jatyansani	Jodhpur	26.0917	72.8333	8.31	0	0.04
bhawi	Jodhpur	26.1078	73.1792	8.11	0	0.04
sajjara	Jodhpur	26.1139	73.2472	8.11	0	0.04
raron ki dhani	Jodhpur	26.1944	72.775	8.31	0	0.04
bujawar	Jodhpur	26.225	72.9083	8.31	0	0.04
naran ki dhani	Jodhpur	26.2444	72.9083	8.31	0	0.04
karani	Jodhpur	26.2722	72.825	8.31	0	0.04
chopasni nath	Jodhpur	26.275	72.9333	8.31	0	0.04
cazri	Jodhpur	26.2667	73	8.31	0	0.04
dangiwas	Jodhpur	26.2667	73.2833	8.11	0	0.04
jodhpur	jodhpur	26.3	73.0333	8.11	0	0.04
lordi	Jodhpur	26.3111	72.8333	8.31	0	0.04
benan	Jodhpur	26.3167	73.4208	8.11	0	0.04
mandore	Jodhpur	26.35	73.0417	8.11	0	0.04
ramrawas	Jodhpur	26.3694	73.3458	8.11	0	0.04
devatra	Jodhpur	26.5103	73.3778	8.11	0	0.04
bhimkam kaur	Jodhpur	26.8	72.7936	8.31	0	0.04
kolu	Jodhpur	26.9167	72.3	8.31	0	0.04
kapuria	Jodhpur	26.9367	73.0589	8.11	0	0.04
kalpan	Jodhpur	27.0667	72.2458	8.08	0	0.04
bari dhani	Jodhpur	27.3417	72.3194	8.08	0	0.04
bap	Jodhpur	27.3667	72.35	8.08	0	0.04
kangik sirdi	Jodhpur	27.4875	72.475	8.08	0	0.04
	Jodhpur					

ramthala	Tonk	25.8639	75.2806	1.99	0.04	0.01
bantholi	Tonk	25.8833	75.5667	1.99	0.04	0.01
dikoliya	Tonk	25.975	75.9661	1.99	0.04	0.01
mahuva	Tonk	25.9986	75.6833	1.99	0.04	0.01
todarsingh	Tonk	26.0139	75.4889	2.51	0.01	0.02
nayagaon	Tonk	26.0408	75.8889	2.51	0.01	0.02
arniyalmal	Tonk	26.0583	75.8083	2.51	0.01	0.02
hamirpur	Tonk	26.1833	75.575	2.51	0.01	0.02
dewal1	Tonk	26.2383	75.1875	2.51	0.01	0.02
sohela	Tonk	26.2417	75.85	2.51	0.01	0.02
malpura	Tonk	26.2833	75.3833	2.51	0.01	0.02
jaisinghpur	Tonk	26.3917	75.4875	2.51	0.01	0.02
Tmax		Longitute	latitute	Z	p-value	Sen
bogla	Ajmer	75.2333	25.8333	1.94	0.05	0.02
taragarh	Ajmer	74.15	25.8833	1.76	0.07	0.02
baglias	Ajmer	74.2	25.9083	1.76	0.07	0.02
sanpla	Ajmer	75.0417	25.9111	1.94	0.05	0.02
jawaja	Ajmer	74.2	25.9333	1.76	0.07	0.02
ludiyana	Ajmer	74.5833	25.9972	1.76	0.07	0.02
jhopadiyan	Ajmer	74.6583	26.025	0.82	0.41	0.01
ajagara	Ajmer	75.1	26.0333	1.1	0.27	0.01
narbadkhera	Ajmer	74.2833	26.05	0.82	0.41	0.01
masuda	Ajmer	74.5125	26.0917	0.82	0.41	0.01
pakhriawas	Ajmer	74.4167	26.1	0.82	0.41	0.01
kalyanpura	Ajmer	74.8022	26.1411	0.82	0.41	0.01
ramsar	Ajmer	74.8333	26.2667	0.82	0.41	0.01
nasirabad	Ajmer	74.7403	26.2867	0.82	0.41	0.01

kanpur	Ajmer	74.8667	26.4	0.82	0.41	0.01
arian	Ajmer	75.0667	26.45	1.1	0.27	0.01
ghugra	Ajmer	74.6917	26.5042	0.82	0.41	0.01
	Ajmer					
piparli gaon	Barmer	71.5889	25.1222	1.93	0.05	0.01
kateria	Barmer	71.4542	25.1583	1.93	0.05	0.01
Siyaga Tala	Barmer	70.8653	25.3375	3.66	0	0.02
padmaniyon	Barmer	71.4	25.3458	1.93	0.05	0.01
adel	Barmer	71.7083	25.425	1.93	0.05	0.01
chohtan	Barmer	71.0667	25.475	1.93	0.05	0.01
sanawara	Barmer	71.4	25.4833	1.93	0.05	0.01
hathitala	Barmer	71.3986	25.5744	1.93	0.05	0.01
sindari	Barmer	71.9	25.5667	1.93	0.05	0.01
sanlor	Barmer	71.2333	25.5958	1.93	0.05	0.01
nimri	Barmer	71.2833	25.6083	1.93	0.05	0.01
patrasar	Barmer	71.2236	25.6778	1.93	0.05	0.01
sasion ka kua	Barmer	71.4125	25.7042	1.93	0.05	0.01
jasai	Barmer	71.2556	25.7167	1.93	0.05	0.01
devra	Barmer	72.5167	25.7333	0.35	0.72	0
bachhbar	Barmer	70.9583	25.7417	3.66	0	0.02
barmer	barmer	71.3972	25.7361	1.93	0.05	0.01
sihani	Barmer	71.0833	25.775	1.93	0.05	0.01
matasar	Barmer	71.6	25.7917	1.93	0.05	0.01
sutharon ki dha	Barmer	71.0389	25.8083	1.93	0.05	0.01
redana	Barmer	70.9389	25.8458	3.66	0	0.01
bisala	Barmer	71.2417	25.9083	1.93	0.05	0.01
derasar	Barmer	70.1583	25.9181	3.66	0	0.02

balewa	Barmer	70.875	25.9153	3.66	0	0.02
nand	Barmer	71.1167	25.9833	1.93	0.05	0.01
panchla	Barmer	70.1667	25.9917	3.66	0	0.02
panavada	Barmer	71.7792	26.0292	0.79	0.42	0
thob	Barmer	72.3583	26.05	0.79	0.42	0.01
jawansingh ki ber	Barmer	70.9833	26.0667	2.89	0	0.01
doli	Barmer	72.6667	26.0667	0.79	0.42	0
saupadamsingh	Barmer	71.825	26.2	0.79	0.42	0
kashmir	Barmer	71.6056	26.2597	0.79	0.42	0
bisukalan	Barmer	71.3056	26.275	0.79	0.42	0
gujro ka bera	Barmer	71.5556	26.3383	0.79	0.42	0
	Barmer					
prahladpura	Dausa	76.2	26.6833	1.05	0.29	0.01
lawan	Dausa	76.2167	26.7833	1.05	0.29	0.01
garh ranoli	Dausa	76.5097	26.8125	1.05	0.29	0.01
gijgarh	Dausa	76.6431	26.8847	1.05	0.29	0.01
dausa	dausa	76.325	26.8958	1.05	0.29	0.01
bhandarej	Dausa	76.4	26.9167	1.05	0.29	0.01
sikandara	Dausa	76.5792	26.9667	1.05	0.29	0.01
bapi	Dausa	76.2917	26.975	1.05	0.29	0.01
mahuwa	Dausa	76.95	27.075	0.54	0.58	0.01
	Dausa					
dawach	Jaipur	75.7542	26.5672	1.1	0.27	0.01
chaksu	Jaipur	75.95	26.6	1.1	0.27	0.01
mangarwara	Jaipur	75.2778	26.61	1.1	0.27	0.01
thalli	Jaipur	75.8861	26.6125	1.1	0.27	0.01

mozmabad	Jaipur	75.3625	26.6833	1.1	0.27	0.01
goner	Jaipur	75.9083	26.6792	1.1	0.27	0.01
shivdaspura	Jaipur	75.9006	26.7136	1.1	0.27	0.01
pallukhurd	Jaipur	75.3	26.7361	1.1	0.27	0.01
sirohikhurd	Jaipur	75.15	26.7917	1.1	0.27	0.01
nasnota	Jaipur	75.4333	26.8	1.1	0.27	0.01
durgapura	Jaipur	75.7889	26.8417	1.1	0.27	0.01
mes jaipur	Jaipur	75.7792	26.9333	1.1	0.27	0.01
jhotwara	Jaipur	75.7444	26.9433	1.1	0.27	0.01
kalwad	Jaipur	75.6	26.975	1.1	0.27	0.01
amber	Jaipur	75.8667	26.9833	1.1	0.27	0.01
rasala	Jaipur	76.205	27.1167	0.54	0.58	0.01
tigaria	Jaipur	75.7733	27.2919	0.18	0.85	0
	Jaipur					
dhawa	Jodhpur	72.7417	26.0583	0.79	0.42	0.01
jatyansani	Jodhpur	72.8333	26.0917	0.79	0.42	0.01
bhawi	Jodhpur	73.1792	26.1078	0.92	0.35	0.01
sajjara	Jodhpur	73.2472	26.1139	0.92	0.35	0.01
raron ki dhani	Jodhpur	72.775	26.1944	0.79	0.42	0.01
bujawar	Jodhpur	72.9083	26.225	0.79	0.42	0.01
naran ki dhani	Jodhpur	72.9083	26.2444	0.79	0.42	0.01
karani	Jodhpur	72.825	26.2722	0.79	0.42	0.01
chopasni nath	Jodhpur	72.9333	26.275	0.79	0.42	0.01
cazri	Jodhpur	73	26.2667	0.79	0.42	0.01
dangiwas	Jodhpur	73.2833	26.2667	0.92	0.35	0.01
jodhpur	jodhpur	73.0333	26.3	0.92	0.35	0.01
lordi	Jodhpur	72.8333	26.3111	0.79	0.42	0.01

benan	Jodhpur	73.4208	26.3167	0.92	0.35	0.01
mandore	Jodhpur	73.0417	26.35	0.92	0.35	0.01
ramrawas	Jodhpur	73.3458	26.3694	0.92	0.35	0.01
devatra	Jodhpur	73.3778	26.5103	0.92	0.35	0.01
bhimkam kaur	Jodhpur	72.7936	26.8	0.79	0.42	0.01
kolu	Jodhpur	72.3	26.9167	0.79	0.42	0.01
kapuria	Jodhpur	73.0589	26.9367	0.92	0.35	0.01
kalpan	Jodhpur	72.2458	27.0667	1.39	0.16	0.01
bari dhani	Jodhpur	72.3194	27.3417	1.39	0.16	0.01
bap	Jodhpur	72.35	27.3667	1.39	0.16	0.01
kangik sirdi	Jodhpur	72.475	27.4875	1.39	0.16	0.01
	Jodhpur					
ramthala	Tonk	75.2806	25.8639	1.94	0.05	0.02
bantholi	Tonk	75.5667	25.8833	1.94	0.05	0.02
dikoliya	Tonk	75.9661	25.975	1.94	0.05	0.02
mahuva	Tonk	75.6833	25.9986	1.94	0.05	0.02
todarsingh	Tonk	75.4889	26.0139	1.1	0.27	0.01
nayagaon	Tonk	75.8889	26.0408	1.1	0.27	0.01
arniyalmal	Tonk	75.8083	26.0583	1.1	0.27	0.01
hamirpur	Tonk	75.575	26.1833	1.1	0.27	0.01
dewal1	Tonk	75.1875	26.2383	1.1	0.27	0.01
sohela	Tonk	75.85	26.2417	1.1	0.27	0.01
malpura	Tonk	75.3833	26.2833	1.1	0.27	0.01
jaisinghpur	Tonk	75.4875	26.3917	1.1	0.27	0.01
Rain		Longitute	latitute	Z	Sen	p-value
jawaja	Ajmer	74.2	25.9333	0	1	0
bogla	Ajmer	75.2333	25.8333	0.58	0.56	0

taragarh	Ajmer	74.15	25.8833	0	1	0
baglias	Ajmer	74.2	25.9083	0	1	0
sanpla	Ajmer	75.0417	25.9111	0.69	0.48	0.01
ludiyana	Ajmer	74.5833	25.9972	0.69	0.48	0.01
jhopadiyan	Ajmer	74.6583	26.025	3.5	0	0.02
ajagara	Ajmer	75.1	26.0333	0.69	0.48	0.01
masuda	Ajmer	74.5125	26.0917	6.09	0	0.03
narbadkhera	Ajmer	74.2833	26.05	0	1	0
pakhriawas	Ajmer	74.4167	26.1	6.09	0	0.03
kalyanpura	Ajmer	74.8022	26.1411	1.78	0.07	0.01
ramsar	Ajmer	74.8333	26.2667	1.78	0.07	0.01
nasirabad	Ajmer	74.7403	26.2867	1.78	0.07	0.01
kanpur	Ajmer	74.8667	26.4	-2.83	0	-0.01
arian	Ajmer	75.0667	26.45	2.14	0.03	0.02
ghugra	Ajmer	74.6917	26.5042	-2.83	0	-0.01
	Ajmer					
piparli gaon	Barmer	71.5889	25.1222	1.25	0.2	0
kateria	Barmer	71.4542	25.1583	0.65	0.51	0
Siyaga Tala	Barmer	70.8653	25.3375	-2.15	0.03	-0.01
padmaniyon	Barmer	71.4	25.3458	0.65	0.51	0
adel	Barmer	71.7083	25.425	4.4	0	0.01
chohtan	Barmer	71.0667	25.475	-1.75	0.07	-0.01
sanawara	Barmer	71.4	25.4833	2.96	0	0.01
hathitala	Barmer	71.3986	25.5744	2.96	0	0.01
sindari	Barmer	71.9	25.5667	2.47	0.01	0.01
sanlor	Barmer	71.2333	25.5958	1.85	0.06	0.01
nimri	Barmer	71.2833	25.6083	1.85	0.06	0

patrasar	Barmer	71.2236	25.6778	3.6	0	0.01
jasai	Barmer	71.2556	25.7167	3.6	0	0.14
bachhbar	Barmer	70.9583	25.7417	-1.05	0.28	0
Barmer	Barmer	71.3972	25.7361	-1.05	0.28	0
sihani	Barmer	71.0833	25.775	-1.05	0.28	0
matasar	Barmer	71.6	25.7917	3.31	0	0.01
derasar	Barmer	70.1583	25.9181	-2.68	0	-0.01
sasion ka kua	Barmer	71.4125	25.7042	3.31	0	0.1
devra	Barmer	72.5167	25.7333	2.46	0.01	0.01
Sutharon ki dha	Barmer	71.0389	25.8083	-2.68	0	-0.01
redana	Barmer	70.9389	25.8458	-1.05	0.28	0
bisala	Barmer	71.2417	25.9083	2.87	0	0.01
balewa	Barmer	70.875	25.9153	-1.69	0.08	-0.01
nand	Barmer	71.1167	25.9833	0.54	0.58	0
panchla	Barmer	70.1667	25.9917	-2.68	0	-0.01
panavada	Barmer	71.7792	26.0292	-2.74	0.01	-0.01
thob	Barmer	72.3583	26.05	2.3	0.02	0.01
doli	Barmer	72.6667	26.0667	2.36	0.01	0.01
Jawansingh Ki Ber	Barmer	70.9833	26.0667	0	1	0
saupadamsingh	Barmer	71.825	26.2	-0.39	0.69	0
kashmir	Barmer	71.6056	26.2597	0	1	0
bisukalan	Barmer	71.3056	26.275	0	1	0
gujro ka bera	Barmer	71.5556	26.3383	0	1	0
	Barmer					
prahladpura	Dausa	76.2	26.6833	-0.62	0.53	-0.01
lawan	Dausa	76.2167	26.7833	-0.62	0.53	-0.01

garh ranoli	Dausa	76.5097	26.8125	-1.96	0.04	-0.02
gijgarh	Dausa	76.6431	26.8847	2.44	0.01	0.02
dausa	dausa	76.325	26.8958	-1.14	0.25	-0.01
bhandarej	Dausa	76.4	26.9167	-2.56	0.01	-0.01
sikandara	Dausa	76.5792	26.9667	-2.56	0.01	-0.01
bapi	Dausa	76.2917	26.975	-1.14	0.25	-0.01
mahuwa	Dausa	76.95	27.075	-2.42	0.01	-0.01
	Dausa					
dawach	Jaipur	75.7542	26.5672	1.37	0.16	0.01
chaksu	Jaipur	75.95	26.6	0.43	0.65	0
mangarwara	Jaipur	75.2778	26.61	-0.91	0.35	-0.01
thalli	Jaipur	75.8861	26.6125	0.43	0.65	0
mozmabad	Jaipur	75.3625	26.6833	-2.02	0.04	-0.01
goner	Jaipur	75.9083	26.6792	0.71	0.47	-0.01
shivdaspura	Jaipur	75.9006	26.7136	-0.71	0.47	-0.01
pallukhurd	Jaipur	75.3	26.7361	-2.02	0.04	-0.01
sirohikhurd	Jaipur	75.15	26.7917	-2.02	0.04	-0.01
nasnota	Jaipur	75.4333	26.8	0.34	0.72	0
durgapura	Jaipur	75.7889	26.8417	1.24	0.21	0.01
jhotwara	Jaipur	75.7444	26.9433	-1.34	0.17	-0.01
kalwad	Jaipur	75.6	26.975	0.67	0.49	0.01
amber	Jaipur	75.8667	26.9833	-1.34	0.17	-0.01
rasala	Jaipur	76.205	27.1167	-1.14	0.25	-0.01
mes jaipur	Jaipur	75.7792	26.9333	-1.34	0.17	-0.01
tigaria	Jaipur	75.7733	27.2919	0	1	0
	Jaipur					
dhawa	Jodhpur	72.7417	26.0583	2.36	0.17	0.01

jatyansani	Jodhpur	72.8333	26.0917	0.36	0.17	0.01
bhawi	Jodhpur	73.1792	26.1078	4.81	0	0.03
sajjara	Jodhpur	73.2472	26.1139	4.81	0	0.03
bujawar	Jodhpur	72.9083	26.225	1.54	0	0.01
dangiwas	Jodhpur	73.2833	26.2667	4.95	0	0.03
raron ki dhani	Jodhpur	72.775	26.1944	1.6	0.1	0
naran ki dhani	Jodhpur	72.9083	26.2444	1.54	0.1	0.01
karani	Jodhpur	72.825	26.2722	1.6	0.1	0
chopasni nath	Jodhpur	72.9333	26.275	1.54	0.1	0.01
cazri	Jodhpur	73	26.2667	1.54	0.1	0.01
jodhpur	jodhpur	73.0333	26.3	1.54	0.1	0.01
lordi	Jodhpur	72.8333	26.3111	1.6	0.1	0.01
benan	Jodhpur	73.4208	26.3167	2.9	0	0.02
mandore	Jodhpur	73.0417	26.35	1.54	0.1	0.01
ramrawas	Jodhpur	73.3458	26.3694	4.95	0	0.02
devatra	Jodhpur	73.3778	26.5103	6.5	0	0.02
Bhimkam Kaur	Jodhpur	72.7936	26.8	6.5	0	0.02
kolu	Jodhpur	72.3	26.9167	2.01	0.04	0.01
kapuria	Jodhpur	73.0589	26.9367	-0.01	0.94	0
kalpan	Jodhpur	72.2458	27.0667	2.01	0.04	0.01
bari dhani	Jodhpur	72.3194	27.3417	2.07	0.03	0.01
bap	Jodhpur	72.35	27.3667	2.07	0.03	0.01
kangik sirdi	Jodhpur	72.475	27.4875	1.29	0.19	0.01
	Jodhpur					
ramthala	Tonk	75.2806	25.8639	0.58	0.56	0
bantholi	Tonk	75.5667	25.8833	3.59	0	0.02
dikoliya	Tonk	75.9661	25.975	1.03	0.29	0

mahuva	Tonk	75.6833	25.9986	3.14	0	0.02
todarsingh	Tonk	75.4889	26.0139	3.59	0	0.02
nayagaon	Tonk	75.8889	26.0408	1.03	0.29	0
arniyalmal	Tonk	75.8083	26.0583	3.14	0	0.02
hamirpur	Tonk	75.575	26.1833	2.88	0	0.02
dewal1	Tonk	75.1875	26.2383	1.33	0.18	0.01
sohela	Tonk	75.85	26.2417	1.86	0.06	0.17
malpura	Tonk	75.3833	26.2833	2.84	0	0.02
jaisinghpur	Tonk	75.4875	26.3917	-0.65	0.51	0
Source: Authors' calculation						

Table 4.10: Trends in temperature and precipitation								
Station			Temperature			Precipitation		
Ajmer	Latitute	Longitute	Z	p-value	Sen	Z	p-value	Sen
Ajagara	26.03333	75.1	1.85	0.06	0.03	-1.99	0.05	0
Arian	26.45	75.06667	1.4	0.16	0.02	-2.79	0	-0.41
Baglias	25.90833	74.2	0.84	0.39	0.02	-1.8	0.07	0
Barora	26.2125	75.03611	1.85	0.06	0.03	-1.99	0.05	0
Bogla	25.83333	75.23333	1.85	0.06	0.03	-1.99	0.05	0
Dasuk	26.41667	75.13333	1.4	0.16	0.02	-2.79	0	-0.41
Goelo	26.12917	74.92778	1.85	0.06	0.03	-1.99	0.04	0
Jawaja1	25.93333	74.2	0.84	0.39	0.02	-1.8	0.07	0
Jhopadiyan	26.025	74.65833	0.84	0.39	0.02	-1.8	0.07	0
Kanpur1	26.4	74.86667	1.4	0.16	0.02	-2.79	0	-0.41
Kekri1	25.98333	75.15	1.85	0.06	0.03	-1.99	0.05	0
Lamana	26.23333	74.49167	0.84	0.39	0.02	-1.8	0.07	0
Ludiyana	25.99722	74.58333	0.85	0.39	0.02	-1.8	0.07	0
Masuda1	26.09167	74.5125	0.85	0.39	0.02	-1.8	0.07	0

Nasirabad	26.28667	74.74028	1.4	0.16	0.02	-2.79	0	-0.41
Pakhriawas	26.1	74.41667	0.85	0.39	0.02	-1.8	0.07	0
Ramgarh2	26.26667	74.83333	1.4	0.16	0.02	-2.79	0	-0.41
Sanpla	25.91111	75.04167	1.85	0.06	0.03	-1.99	0.04	0
Sarwad	26.05	75	1.85	0.06	0.03	-1.99	0.04	0
Tabiji	26.4	74.61667	0.11	0.91	0.01	-1.83	0.06	0
Taragarh	25.88333	74.15	0.85	0.39	0.02	-1.8	0.07	0
Jaipur								
Amber	26.98333	75.86667	0.57	0.56	0.01	-3.05	0	-0.59
Bassi2	26.83333	76.06667	0.93	0.35	0.02	-2.34	0.02	-0.48
Chaksu	26.6	75.95	2.27	0.02	0.03	-3.08	0	-0.59
Dawach	26.56722	75.75417	1.65	0.09	0.02	-4.09	0	-0.59
Goner	26.67917	75.90833	1.65	0.09	0.02	-4.09	0	-0.59
Kalwad	26.975	75.6	0.57	0.56	0.01	-3.05	0	-0.59
Mangarwara	26.61	75.27778	1.4	0.16	0.02	-2.79	0	-0.41
Mozmabad	26.68333	75.3625	1.65	0.09	0.02	-4.09	0	-0.59
Nasnota	26.8	75.43333	0.57	0.56	0.01	-3.05	0	-0.59

Rasala	27.11667	76.205	0.93	0.35	0.02	-2.34	0.02	-0.48
Shivdaspura	26.71361	75.90056	1.65	0.09	0.02	-4.09	0	-0.59
Thalli	26.6125	75.88611	1.65	0.09	0.02	-4.09	0	-0.59
Tigaria	27.29174	75.77333	0.31	0.75	0.01	-3.18	0	-0.65
Barmer								
Panchla	25.99167	70.16667	3.01	0	0.03	1.57	0.11	0
Bachhbar	25.74167	70.95833	2.22	0.03	0.03	1.48	0.13	0
Balewa	25.91528	70.875	2.85	0	0.02	0.32	0.75	0
Balotra1	25.82917	72.25833	0.52	0.59	0.01	-0.53	0.59	0
Barmer1	25.73611	71.39722	2.29	0.03	0.03	1.48	0.13	0
Bisala	25.90833	71.24167	1.67	0.09	0.02	0.33	0.74	0
Chohtan	25.475	71.06667	2.22	0.03	0.03	1.48	0.13	0
Devra	25.73333	72.51667	1.79	0.07	0.01	0.07	0.94	0
Doli	26.06667	72.66667	0.52	0.59	0.01	-0.53	0.59	0
Gadra Road	25.74028	70.63889	2.95	0	0.04	0.21	0.83	0
Jasai	25.71667	71.25556	2.23	0.03	0.03	1.48	0.13	0
Kuri2	25.94167	72.36861	0.52	0.59	0.01	-0.53	0.59	0

Nand	25.98333	71.11667	1.68	0.09	0.02	0.33	0.74	0
Patrasar	25.67778	71.22361	2.23	0.03	0.03	1.48	0.13	0
Redana	25.84583	70.93889	1.677	0.09	0.02	0.33	0.74	0
Sanawara	25.48333	71.4	2.23	0.03	0.03	1.48	0.13	0
Sanlor	25.59583	71.23333	2.23	0.03	0.03	1.48	0.13	0
Sihani	25.775	71.08333	1.68	0.09	0.02	0.33	0.74	0
Sihaniya	24.92222	71.15	2.88	0	0.03	-0.23	0.81	0
Tarla	24.88333	71.21667	2.88	0	0.03	-0.23	0.81	0
Jodhpur								
Bap1	27.36667	72.35	-1.31	0.19	-0.02	2.51	0.01	0.52
Cazri	26.26667	73	0	1	0	0	1	0
Chopasni Nath	26.275	72.93333	0	1	0	0	1	0
Dangiwas	26.26667	73.28333	0	1	0	0	1	0
Devatra	26.51028	73.37778	0	1	0	0	1	0
Dharmi	26.7375	73.64167	0	1	0	0.2	0.83	0
Dhawa	26.05833	72.74167	0.52	0.59	0.01	-0.53	0.59	0
Jatyasani	26.09167	72.83333	0.58	0.59	0.01	-0.76	0.44	0

Jodhpur	26.3	73.03333	0	1	0	0	1	0
Karani	26.27222	72.825	0	1	0	0	1	0
Kumbhariya	26.7375	73.5375	0	1	0	0.2	0.83	0
Mandawar1	26.35	73.04167	0	1	0	0	1	0
Osian1	26.725	72.91667	0	1	0	0	1	0
Piparcity	26.388	73.53	0	1	0	0.2	0.83	0
Tonk								
Aligarh	25.96667	76.08333	2.79	0.01	0.05	-2.91	0	-0.66
Arniyalmal	26.05833	75.80833	2.36	0.02	0.03	-3.21	0	-0.47
Bantholi	25.88333	75.56667	2.36	0.02	0.03	-3.21	0	-0.47
Dikoliya	25.975	75.96611	2.79	0.01	0.05	-2.91	0	-0.66
Hamirpur	26.18333	75.575	2.36	0.02	0.03	-3.21	0	-0.47
Jainagar	25.81667	76.23278	2.79	0.01	0.05	-2.91	0	-0.66
Mahuva	25.99861	75.68333	2.36	0.02	0.03	-3.21	0	-0.48
Malpura1	26.28333	75.38333	1.65	0.09	0.02	-4.09	0	-0.59
Nayagaon	26.04083	75.88889	2.36	0.02	0.03	-3.21	0	-0.47
Niwai1	26.36667	75.93333	1.65	0.09	0.02	-4.09	0	-0.59

Ramthala	25.86389	75.28056	1.85	0.06	0.03	-1.99	0.05	0
Sohela	26.24167	75.85	2.36	0.02	0.03	-3.21	0	-0.48
Dausa								
Mahuwa	27.075	76.95	0	1	0	-1.24	0.21	0
Dausa1	26.89583	76.325	0.93	0.35	0.02	-2.34	0.02	-0.48
Bhandarej	26.91667	76.4	0.93	0.35	0.02	-2.34	0.02	-0.48
Bapi	26.975	76.29167	0.93	0.35	0.02	-2.34	0.02	-0.48
Source: Authors' calculation								

Table 4.11: District-wise correlation analysis						
Barmer						
Variables	NIA	Population	Fertilizer	Industry	Temperature	Rainfall
PC1	-0.884*	-0.836*	-0.805*	-0.361	-0.278	-0.074
PC2	-0.719*	-0.633*	-0.696*	-0.309	-0.304	-0.047
PC3	0.339	0.483*	0.402*	0.483*	-0.234	0.32
PC4	0.408*	0.414*	0.357	0.321	-0.25	0.534*
Ajmer						
PC1	-0.151	-0.27	0.295	0.4814*	0.272	0.081
PC2	0.255	0.244	0.218	0.3637	0.097	-0.155
PC3	-0.379	-0.2143	0.008	0.6189*	0.238	-0.185
PC4	0.016	0.192	-0.012	-0.312	-0.17	0.248
Jodhpur						
PC1	-0.428*	-0.373	-0.147	-0.2775	0.034	0.025
PC2	0.529*	0.520*	0.537*	0.4304*	0.147	-0.355
PC3	-0.430*	-0.421*	-0.151	0.355	0.219	-0.179
PC4	-0.055	0.091	0.336	-0.1807	-0.022	-0.033
Jaipur						
PC1	-0.263	0.609*	0.221	0.1744	0.055	-0.349
PC2	0.032	0.366	-0.02	0.4516*	0.182	-0.185
PC3	-0.053	-0.012	-0.09	0.4348*	0.09	-0.01
PC4	0.183	-0.332	0.025	0.8193*	0.254	-0.092
PC5	0.475*	-0.652*	-0.156	-0.54	-0.218	0.017
Tonk						
PC1	0.698*	0.801*	0.398	-0.164	0.253	-0.471*

PC2	0.632*	0.587*	0.294	0.094	-0.073	-0.167
PC3	0.388	0.457*	0.575*	-0.493	0.302	-0.427*
PC4	-0.042	-0.116	0.134	0.073	-0.36	-0.173
PC5	-0.169	-0.099	-0.193	-0.05	0.356	0.088
Dausa						
PC1	-0.157	-0.434*	0.106	0.086	-0.076	0.533*
PC2	-0.076	0.677*	0.061	0.496*	0.188	-0.065
PC3	0.278	0.616*	-0.198	0.6701*	0.175	-0.487*
PC4	-0.139	0.164	0.12	0.545*	0.13	0.266
PC5	0.278	0.004	-0.479*	-0.25	-0.439*	-0.424*
*p<0.05						
Source: Authors’ calculation						

Table 4.12: Parameters of the univariate GAM						
Response variable	Explaining variables	edf	p-value	R-sq. (adj)	AIC	DE (%)
Arid Districts						
Barmer						
PC1	NIA	3.6	2.02e-05***	0.8	-18.9	87.1
	Population	2.8	<2e-16***	0.8	-27	91
	Fertilizer usage	2.2	0.0***	0.6	-7.9	72.4
PC2	NIA	3.8	0.0***	0.6	-18.3	75.4
	Population	7.6	0.0***	0.7	-22.8	87.6
	Fertilizer usage	3.8	0.0***	0.6	-14.4	69.8
PC3	Population	8.3	0.0***	0.8	-10.2	89.7
	Fertilizer usage	2.6	0.0**	0.3	7.4	48.2
	Industrialization	4.6	0.0***	0.7	-5	79.2
PC4	NIA	2.9	0.0**	0.4	1.5	55
	Population	8.3	0.0***	0.8	-14.1	89.7

	Rainfall	1	0.0*	0.1	5.9	25
Jodhpur						
PC1	NIA	1.1	0.1*	0.1	-1.3	20.4
PC2	NIA	1	0.0**	0.2	-4.9	28
	Population	1	0.0*	0.2	-4.6	27
	Fertilizer usage	4.6	0.0***	0.6	-15.4	73.3
	Industrialization	1	0.0*	0.1	-2.6	18.5
PC3	NIA	1	0.0*	0.1	1.8	18.5
	Population	1	0.0*	0.1	2	17.7
Semi-Arid Districts						
Ajmer						
PC1	Industrialization	3.3	0.0*	0.3	-1.5	48.5
PC3	Industrialization	1.8	0.0**	0.4	6.3	48.9
Jaipur						
PC1	Population	1	0.0***	0.3	4	37.1
PC2	Industrialization	4.3	0.0***	0.4	1.9	70.8
PC3	Industrialization	4.1	0.0**	0.6	-6.6	73.5

PC4	Industrialization	1	0.0***	0.6	-1.1	67.1
PC5	NIA	1	0.0**	0.1	12.6	22.6
	Population	1	0.0***	0.3	7.3	42.5
Tonk						
PC1	NIA	7.4	0.0***	0.7	-12.7	86.2
	Population	1	6.41e-05***	0.6	-8.5	64.2
	Rainfall	4.8	0.0***	0.5	-3.8	69.6
PC2	NIA	4.8	0.0***	0.6	-10.4	77.6
	Population	4.2	0.0***	0.7	-12.4	78.6
PC3	Population	4.8	0.1*	0.3	7.6	54.7
	Fertilizer usage	6.2	0.0***	0.6	-1.9	77.2
	Rainfall	1.8	0.1*	0.2	8.8	31.7
Dausa						
PC1	Population	7.6	0.0***	0.7	-5.7	83.6
	Rainfall	1	0.0**	0.2	7.4	28.4
PC2	Population	2.3	0.0***	0.5	-6.9	63
	Industrialization	8.6	0.0***	0.7	-14.1	87.6

PC3	Population	5.1	0.0***	0.7	-10.2	80.6
	Industrialization	4.3	0.0***	0.6	-5.4	72.1
	Rainfall	1	0.0**	0.1	5.9	23.7
PC4	Industrialization	7.2	0.0*	0.4	-2.4	70.2
PC5	Fertilizer usage	1	0.0**	0.1	4.8	22.9
	Temperature	2.8	0.1*	0.2	4.3	38.6
	Rainfall	3	0.1*	0.3	3.4	43.2
Note: *** = p< 0.01; ** = p< 0.05; * = p< 0.1						
Source: Authors' calculation						

Table 4.13: Parameters of multivariate GAM

No.	Model Formula	R-sq. (adj)	AIC	DE (%)	edf	F	p-value	VIF
Arid Districts								
Barmer								
PC1								
Model1	NIA	0.8	-18	88.1	3.3	4.1	0.0**	9.3
	Fertilizer usage				1.5	0.2	0.6	

PC2								
Model1	NIA	0.6	-16.3	72.7	2.8	3.4	0.0**	9.3
	Fertilizer usage				1	0.2	0.6	
PC3								
Model1	Population	0.7	-3.9	77	1.6	1.9	0.2	9.3
	Industrialization				2.6	3.2	0.0**	
Model2	Fertilizer usage	0.7	-3.4	79.2	1	0.2	0.7	5.4
	Industrialization				4.4	6.4	0.0***	
PC4								
Model1	NIA	0.9	-24.8	97	7.1	15.1	0.0***	1
	Rainfall				1	1.4	0.3	
Model2	Population	0.8	-8.6	86	4.4	6.3	0.0**	1
	Rainfall				1	1.2	0.3	
Jodhpur								
PC2								
Model1	NIA	0.5	-12.4	64.7	1	2.1	0.1	2.5
	Fertilizer usage				2.7	3.7	0.0**	

Model2	NIA	0.2	-3.1	29	1	2.2	0.1	5.1
	Industrialization				1	0.2	0.7	
Model3	Population	0.6	-12.8	66.4	1	2	0.9	3.2
	Fertilizer usage				2.9	3.8	0.0**	
Model4	Population	0.2	-2.9	30.8	1.3	1.2	0.2	3.3
	Industrialization				1	0.1	0.8	
Model5	Industrialization	0.5	-13.8	68	1	3	0.1*	1.6
	Fertilizer usage				2.8	5.4	0.0**	
Semi-Arid Districts								
Jaipur								
PC5								
Model1	NIA	0.4	8	48.1	1	1	0.3	1.3
	Population				1.2	5.2	0.0**	
Tonk								
PC1								
Model1	NIA	0.7	-14.1	86.9	6.21	1.9	0.17	2.93
	Population				1	4.89	0.05*	

Model2	NIA	0.9	-30.82	96.6	5.52	5.47	0.02**	1.27
	Rainfall				5.46	4.36	0.04**	
Model3	Population	0.72	-11.15	81.6	1	9.66	0.01**	1.39
	Rainfall				4.67	2.45	0.26	
PC2								
Model1	NIA	0.69	-10.62	78.3	1	0.28	0.6	2.93
	Population				4.03	3.62	0.03**	
PC3								
Model1	Population	0.78	-10.27	87.5	6.34	4.84	0.01***	1.23
	Fertilizer usage				1.17	15.61	0***	
Model2	Population	0.55	2.37	74	5.26	1.96	0.17	1.39
	Rainfall				2	1.8	0.18	
Model3	Fertilizer usage	0.62	-0.61	77.6	6.08	3.23	0.04**	1.21
	Rainfall				1	0.06	0.81	
Dausa								
PC1								
Model1	Population	0.24	8.28	33.3	1.05	1	0.36	1.27

	Rainfall				1	3.14	0.09*	
PC2								
Model1	Population	0.58	-6.75	66.5	2.33	4.98	0.01**	2.06
	Industrialization				1	0.96	0.34	
PC3								
Model1	Population	0.77	-13.33	86.4	5.05	3.7	0.03**	2.06
	Industrialization				1.86	2.04	0.2	
Model2	Population	0.84	-20.08	93.6	4.7	6.83	0.02**	1.27
	Rainfall				5.55	2.12	0.2	
Model3	Industrialization	0.81	-16.85	89.9	1	28	0.00***	1.1
	Rainfall				6.83	4.95	0.02**	
PC5								
Model1	Fertilizer usage	0.33	3.31	47.4	1	2.86	0.11	1.07
	Temperature				2.67	1.56	0.26	
Model2	Fertilizer usage	0.3	2.86	38.2	1	4.89	0.04**	1.01
	Rainfall				1	3.71	0.07*	
Model3	Temperature	0.77	-14.39	88.7	2.59	5.98	0.02**	1.01

	Rainfall				6.08	5	0.02**	
Note: *** = p< 0.01; ** = p< 0.05; * = p< 0.1								
Source: Authors' calculation								

Table 4.14: Multivariate GAM model test

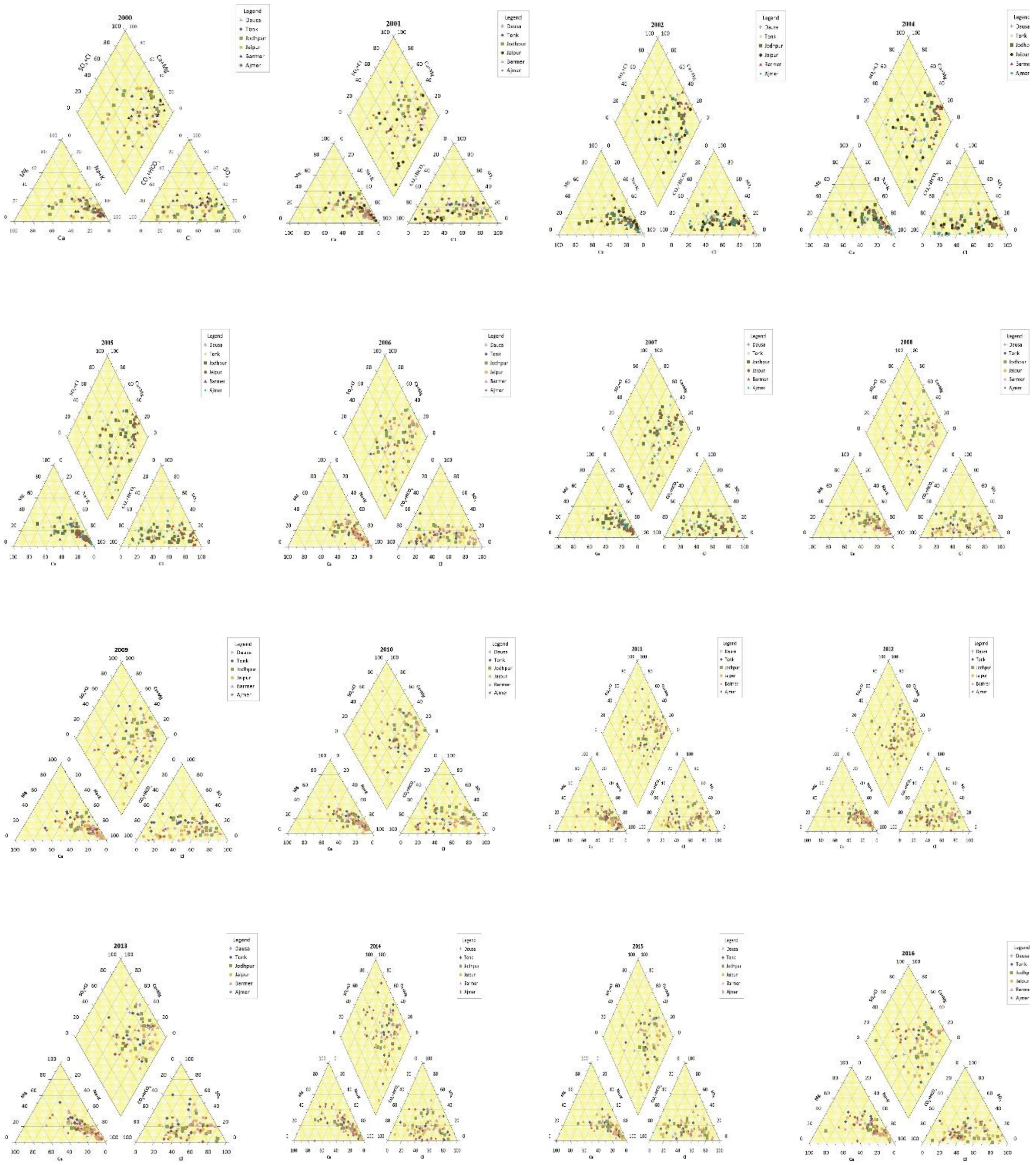
Model	Variables	Basis checking results				Shapiro-wilk normality test of GAM residuals
No.		k	edf	k-index	p-value	p-value
Barmer						
PC1						
Model_1	NIA	8	3.3	1.2	0.7	0.2
	Fertilizer usage	8	1.5	1.2	0.6	
PC2						
Model_1	NIA	3	2.9	1.4	0.9	0.8
	Fertilizer usage	3	1.0	0.9	0.2	
PC3						
Model_1	Population	8	1.6	1.1	0.6	0.4

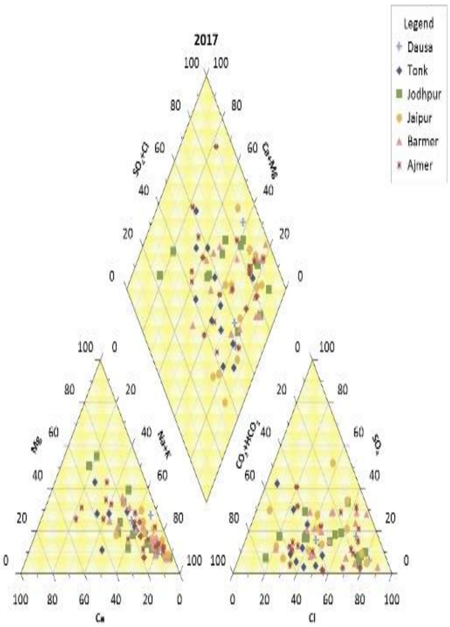
	Industrialization	8	2.6	1.3	0.8	
PC4						
Model_1	NIA	8	7.1	1.8	1.0	1.0
	Rainfall	4	1.0	1.3	0.8	
Jodhpur						
PC2						
Model_5	Industrialization	8	1.0	0.9	0.3	0.2
	Fertilizer usage	8	2.8	1.3	0.8	
Jaipur						
PC5						
Model_1	NIA	8	1.0	1.0	0.4	0.5
	Population	8	1.3	1.4	1.0	
Tonk						
PC1						
Model_2	NIA	8	5.5	1.6	1.0	0.6
	Rainfall	8	5.5	1.7	1.0	

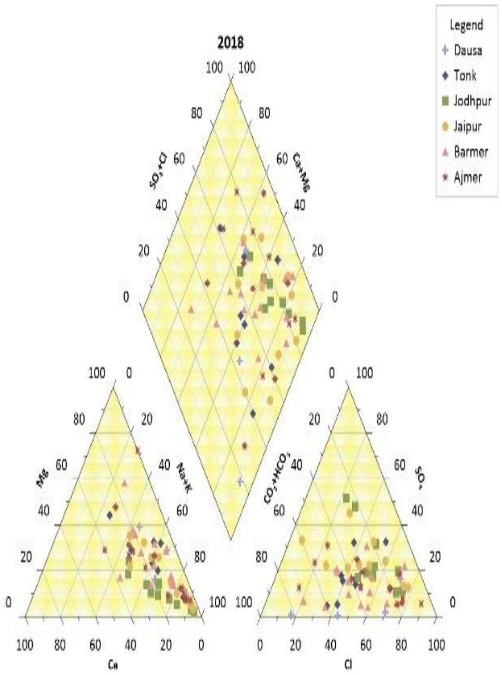
PC2						
Model_1	NIA	8	1.0	1.4	0.9	0.9
	Population	8	4.0	1.3	0.9	
PC3						
Model_1	Population	8	6.3	1.6	1.0	1.0
	Fertilizer usage	8	1.2	1.6	1.0	
Dausa						
PC1						
Model_1	Population	8	1.1	1.0	0.4	0.5
	Rainfall	8	1.0	1.1	0.6	
PC2						
Model_1	Population	8	2.3	1.1	0.6	0.9
	Industrializatio n	8	1.0	0.9	0.2	
PC3						
Model_2	Population	8	4.7	1.5	1.0	0.9
	Rainfall	8	5.6	1.5	1.0	

PC5						
Model_3	Temperature	8	2.6	1.5	0.9	0.6
	Rainfall	8	6.1	1.3	0.8	
Note : *** = p< 0.01; ** = p< 0.05; * = p< 0.1						
Source: Authors' calculation						

Figure 4.1 Piper plot of the examined region

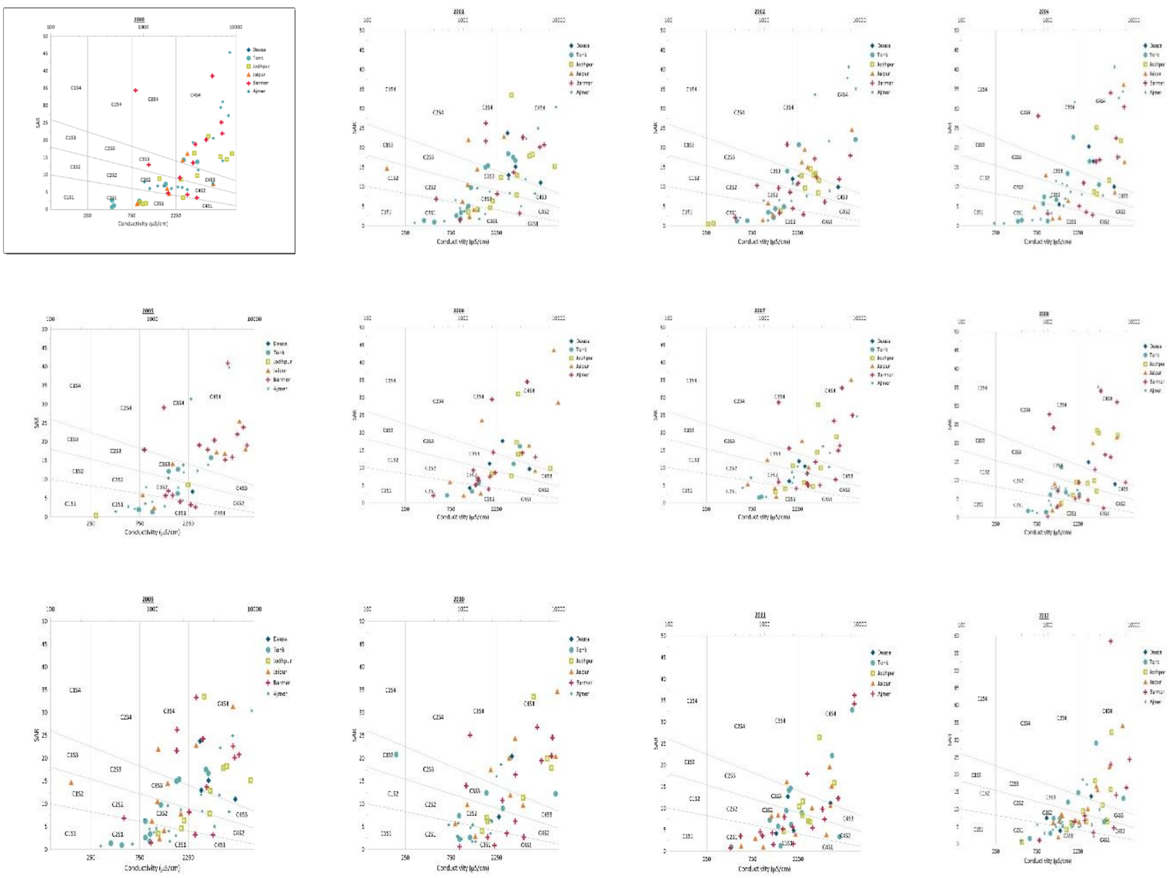


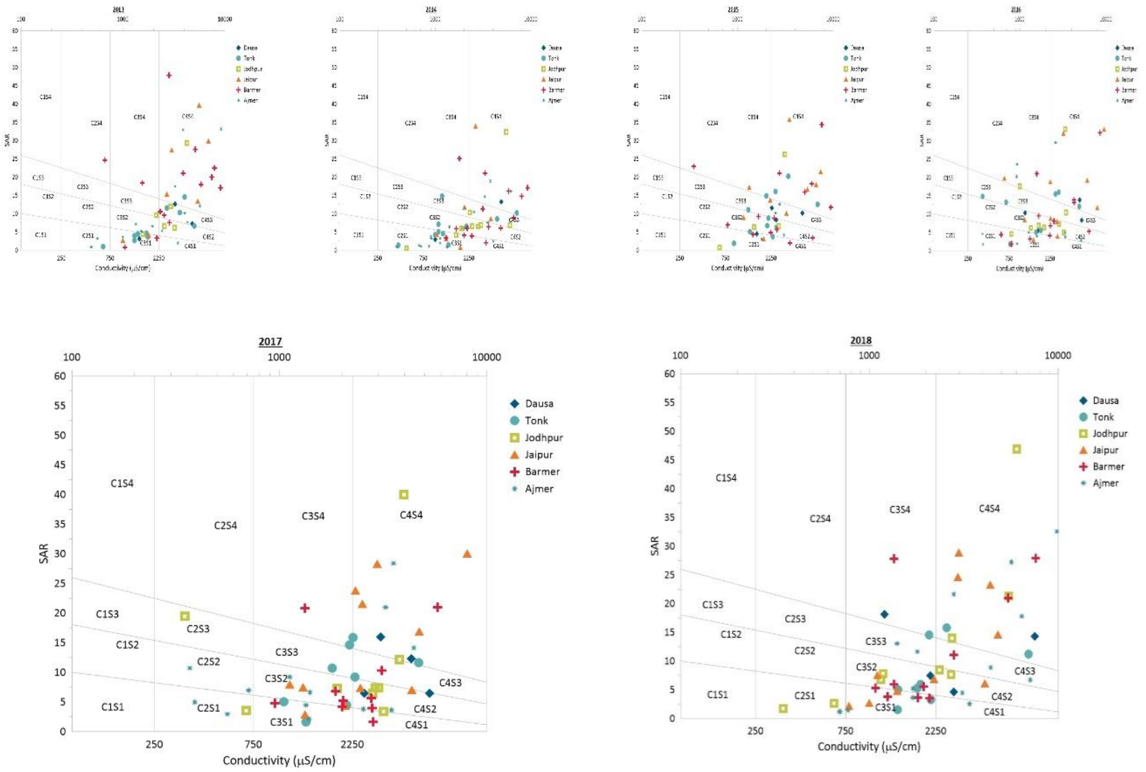




Source: Author's construction

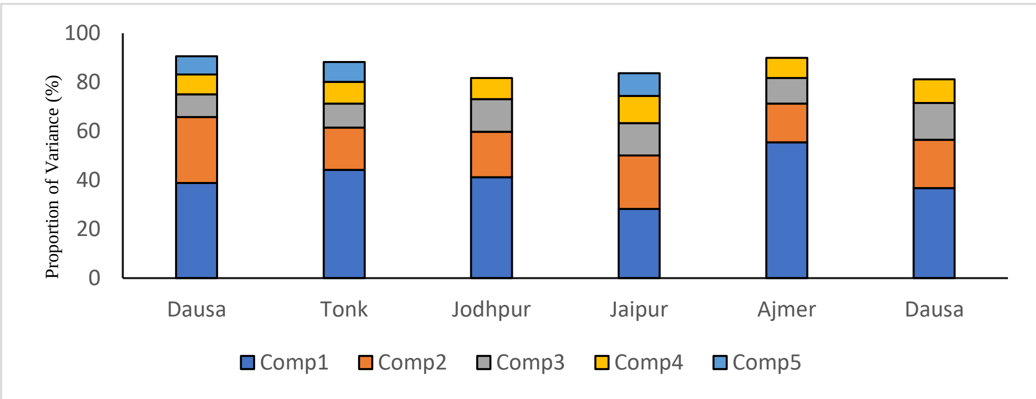
Figure 4.2 USSL Plot





Source: Author's construction

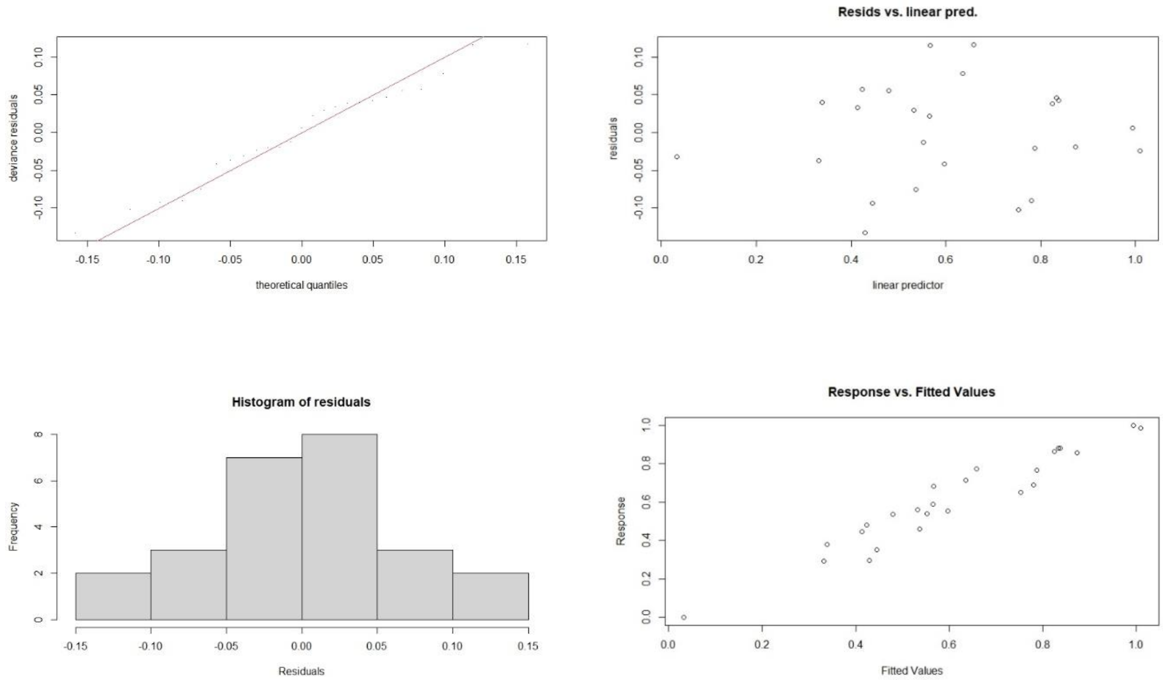
Figure 4.3: Proportion of variance explained by components



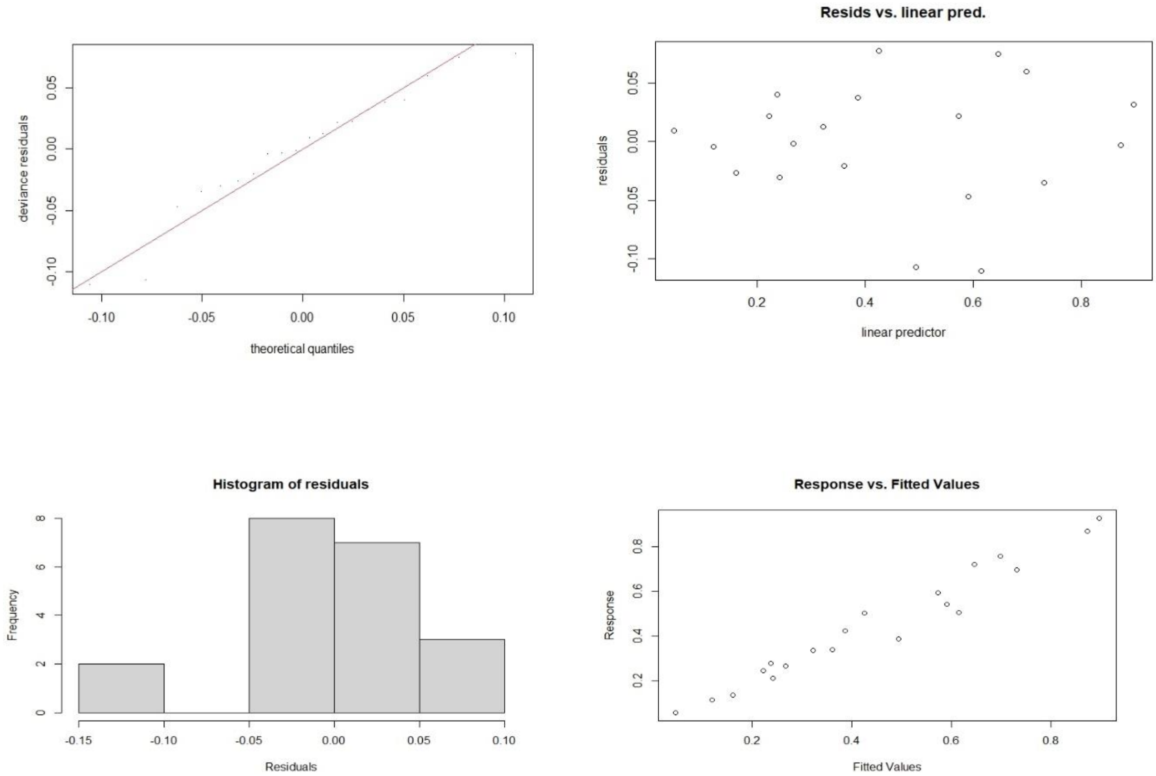
Source: Authors' construction

Figure 4.4: Model fit test for GAM: DGWL

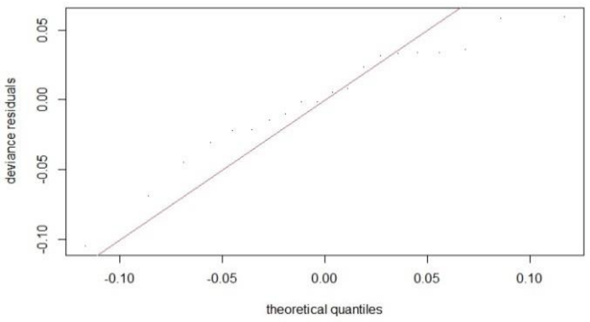
Ajmer: Model6

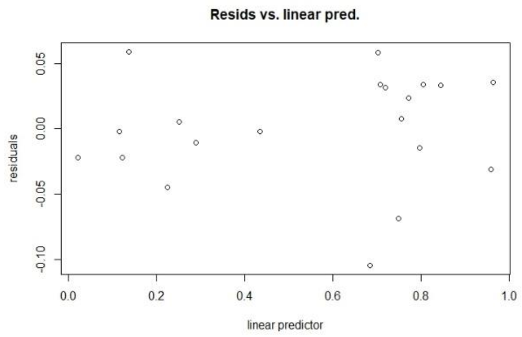


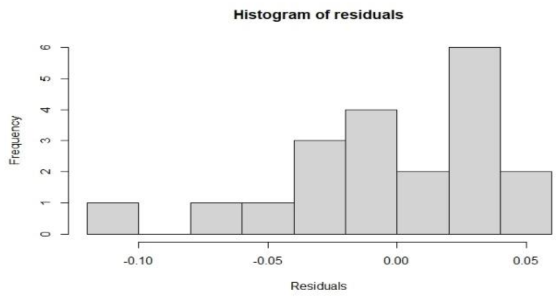
Dausa: Model2

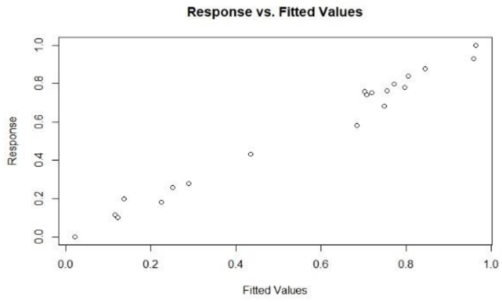


Tonk: Model3

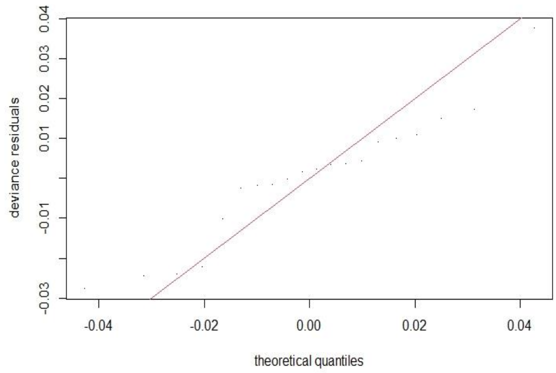


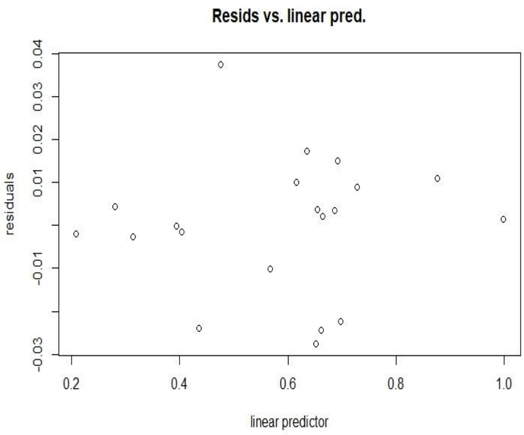


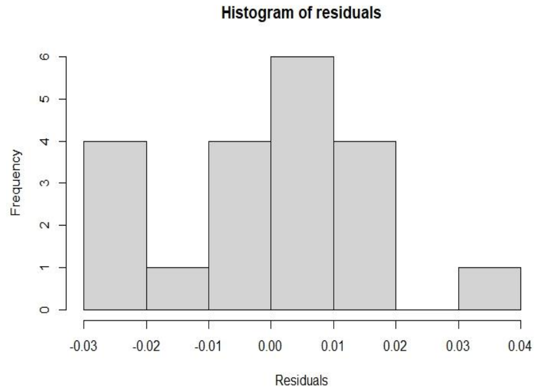


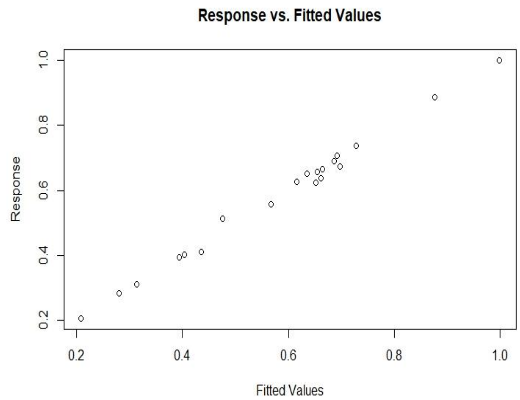


Jaipur: Model2







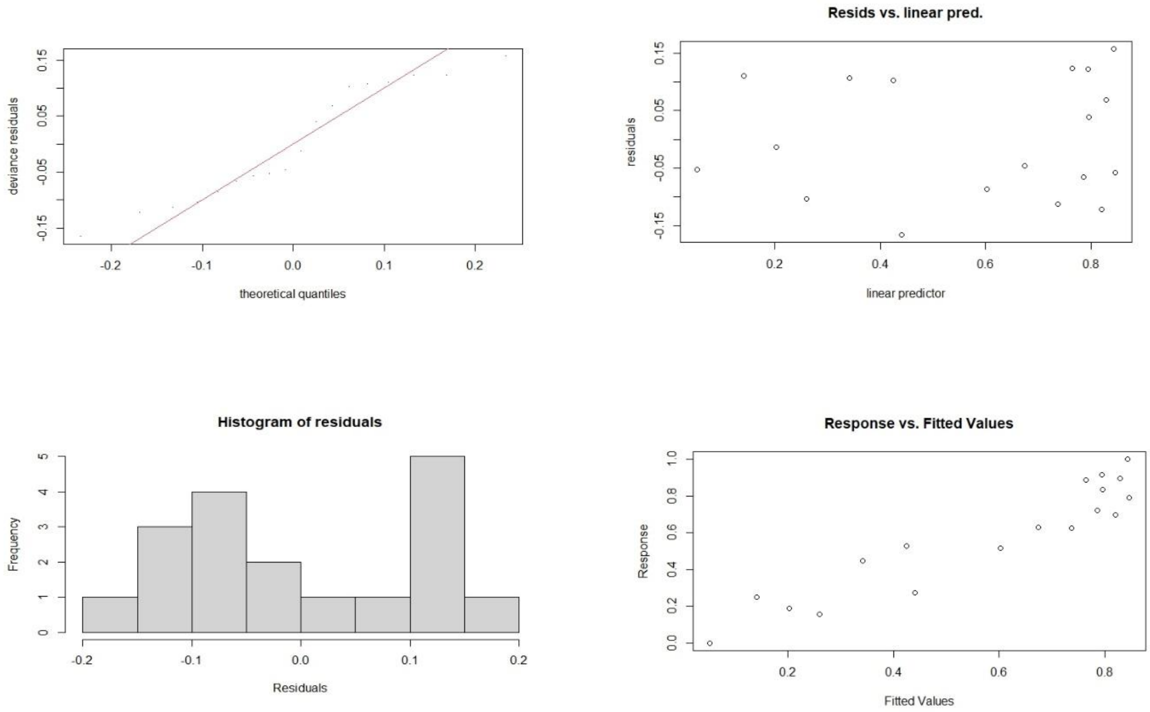


Source: Authors' construction

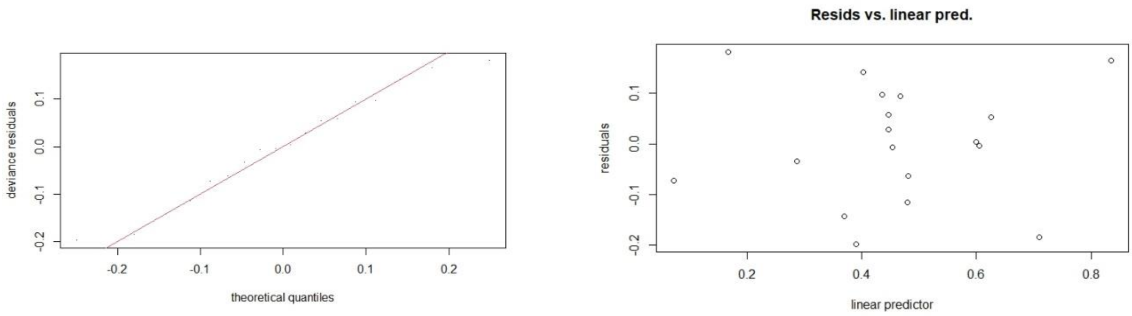
Figure 4.5: Model fit test for GAM: water qualtiy

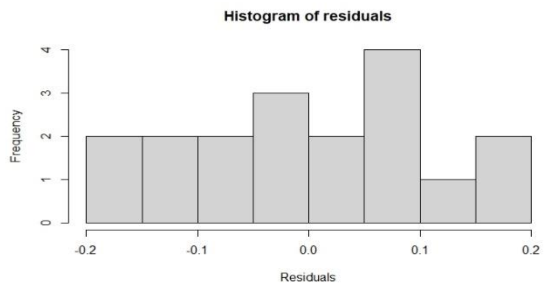
Barmer

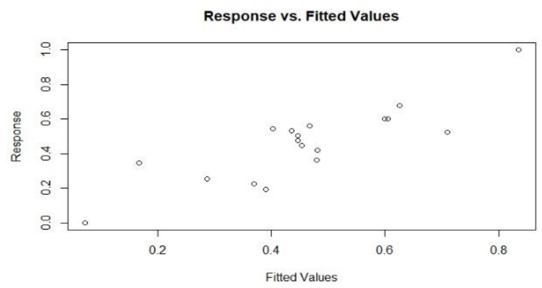
PC1- Model_1



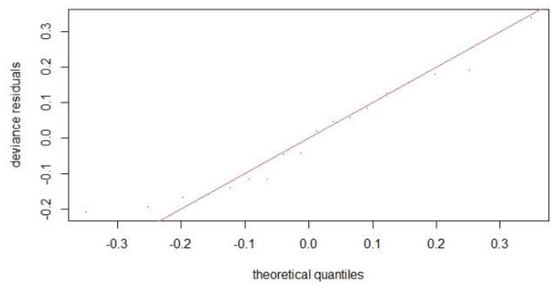
PC2- Model_1

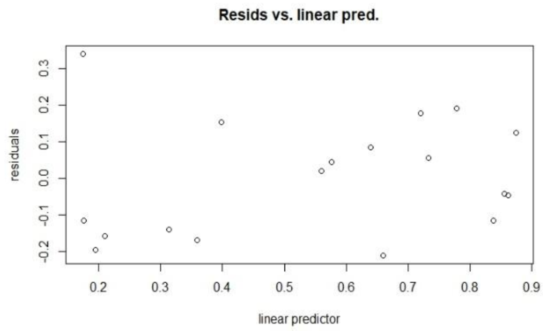


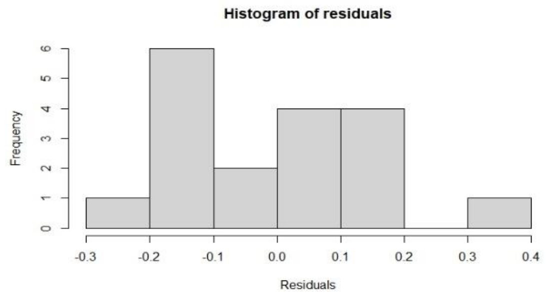


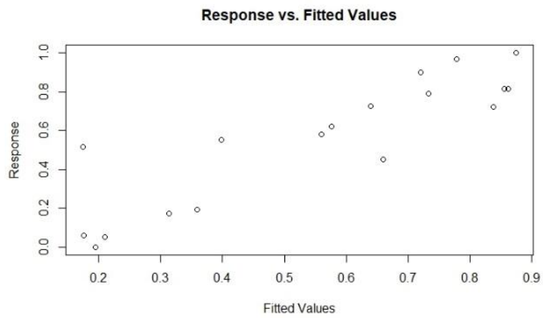


PC3- Model_1

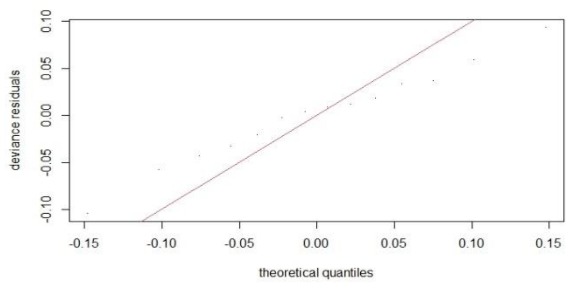


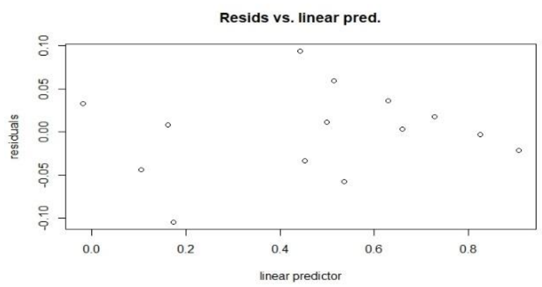


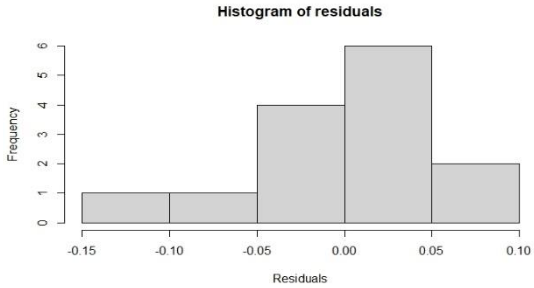


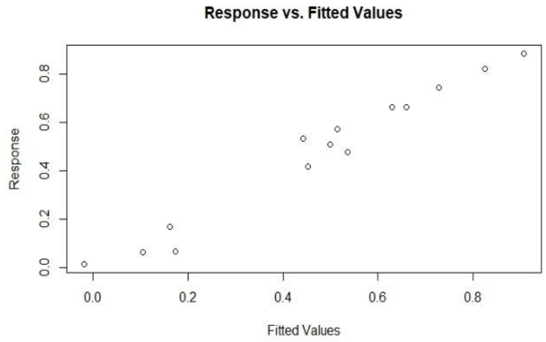


PC4 -Model_1



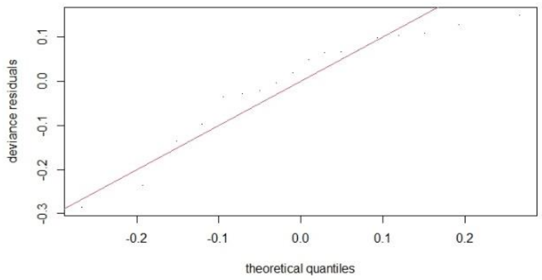


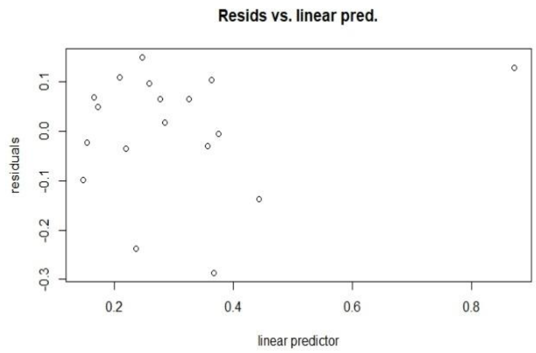


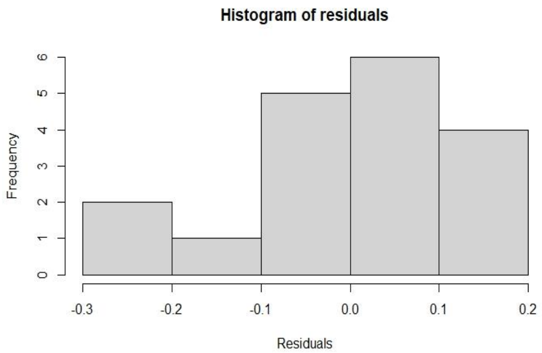


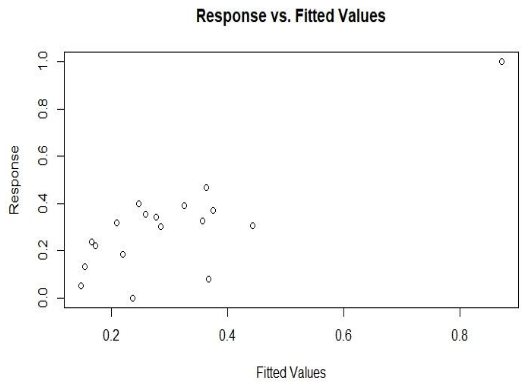
Jodhpur

PC2- Model_5



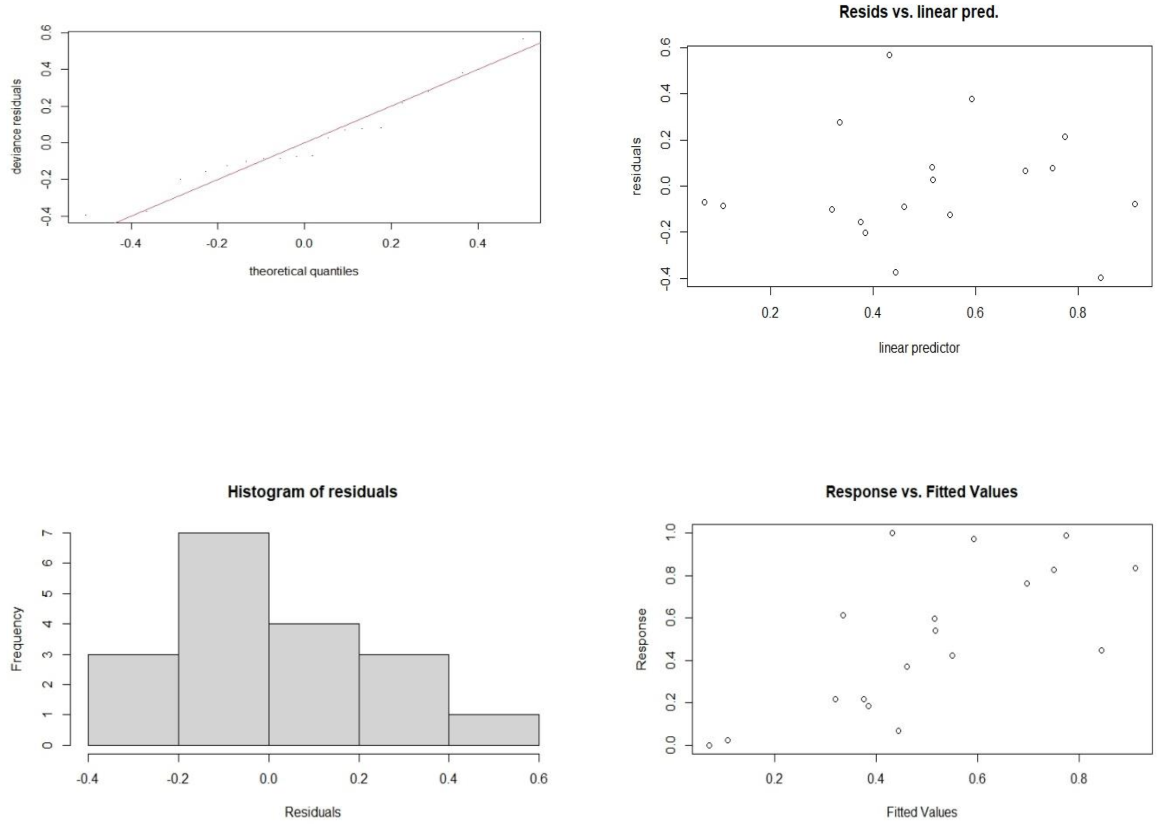






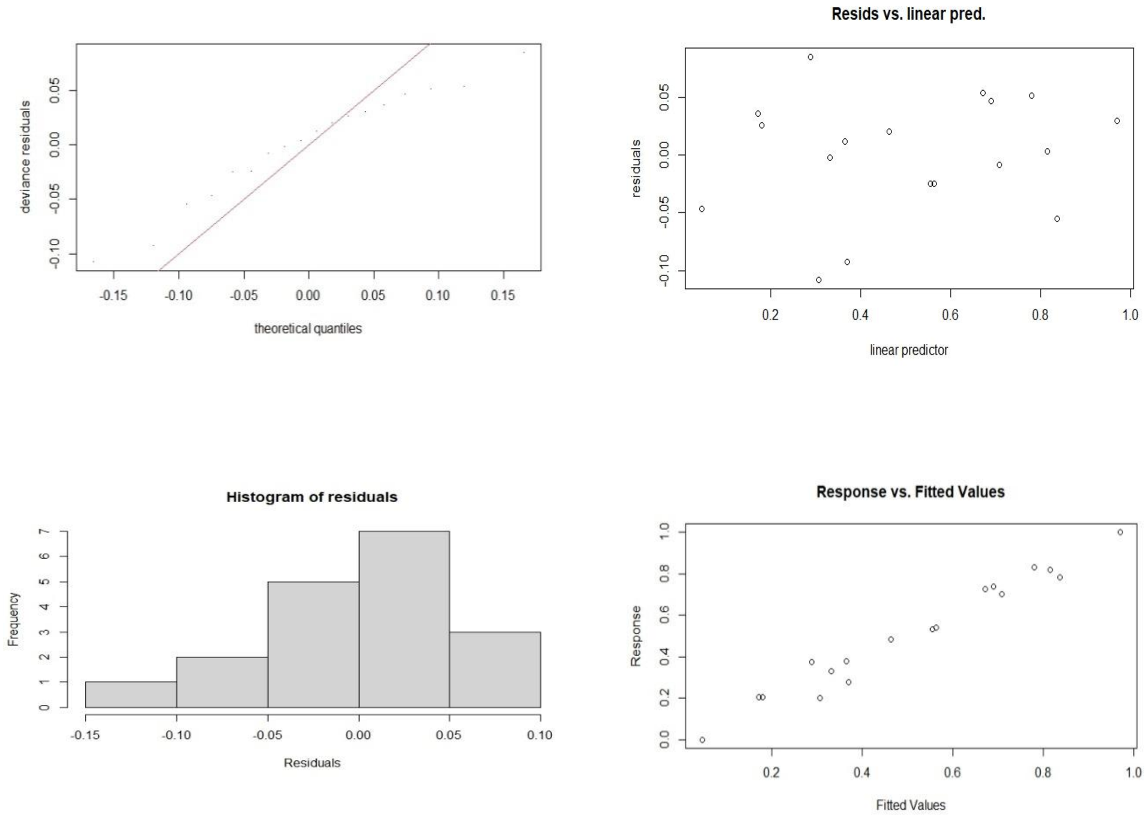
Jaipur

PC5- Model_1

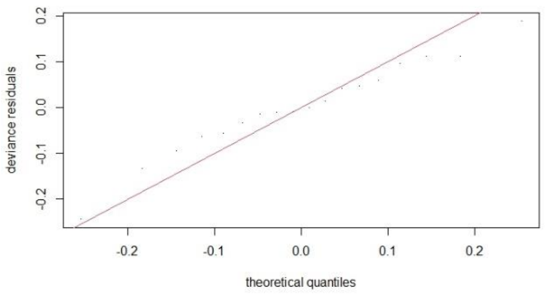


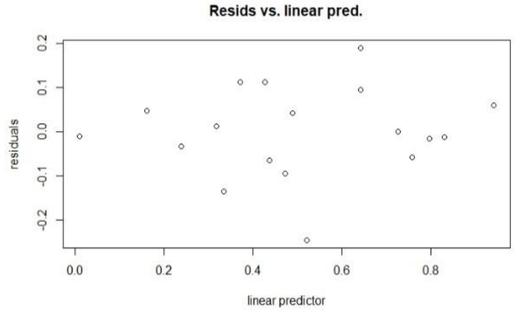
Tonk

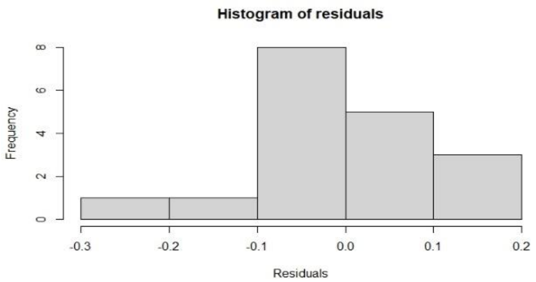
PC1- Model_2

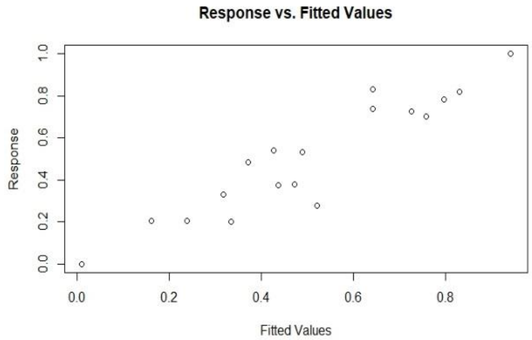


PC2- Model_1

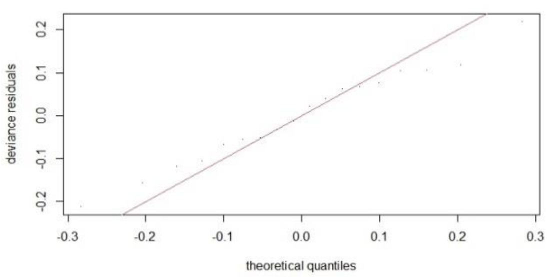


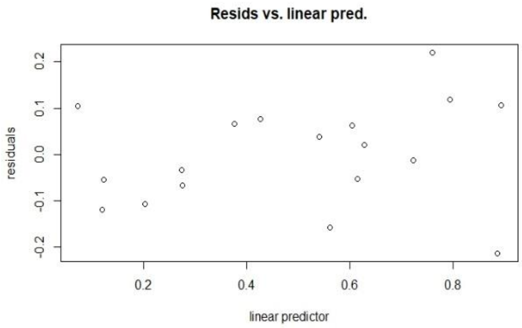


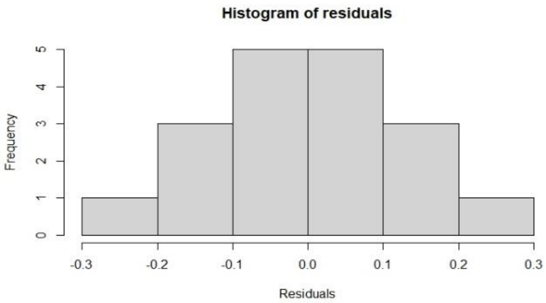


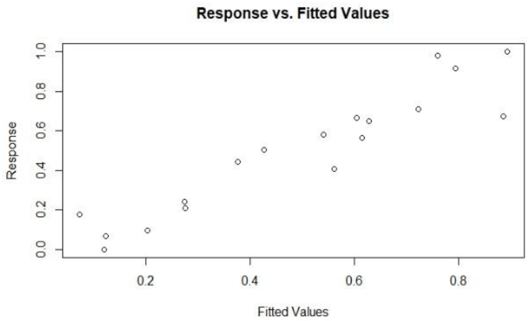


PC3- Model_1



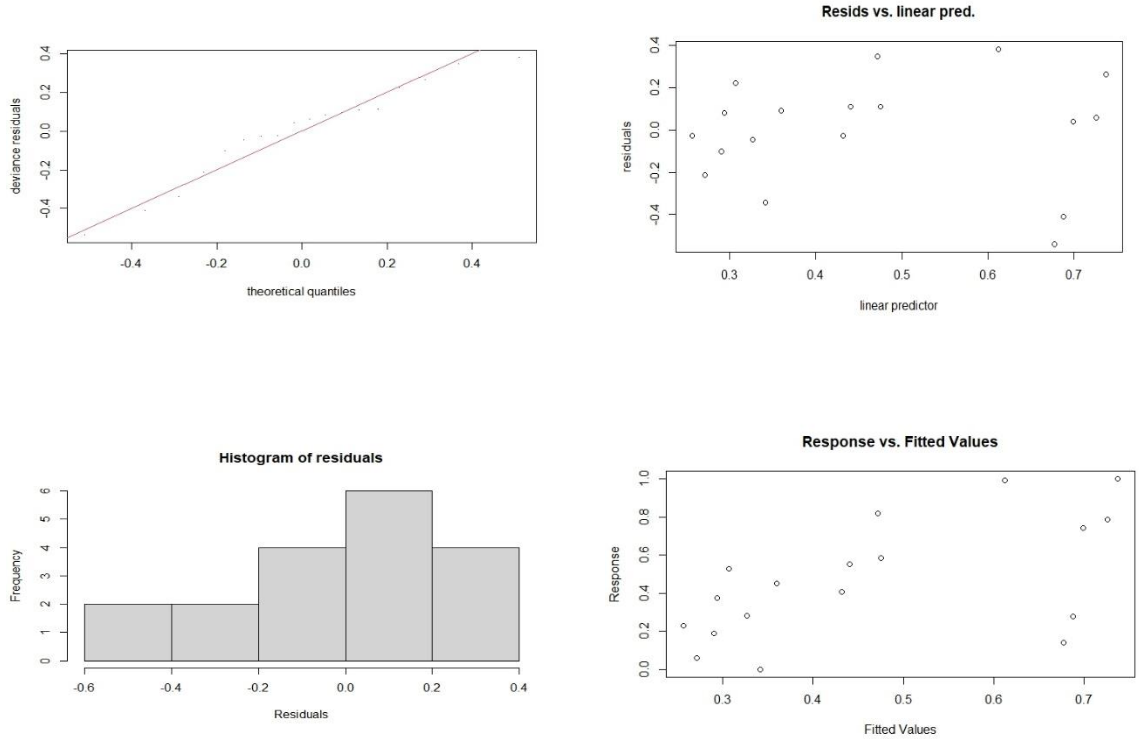




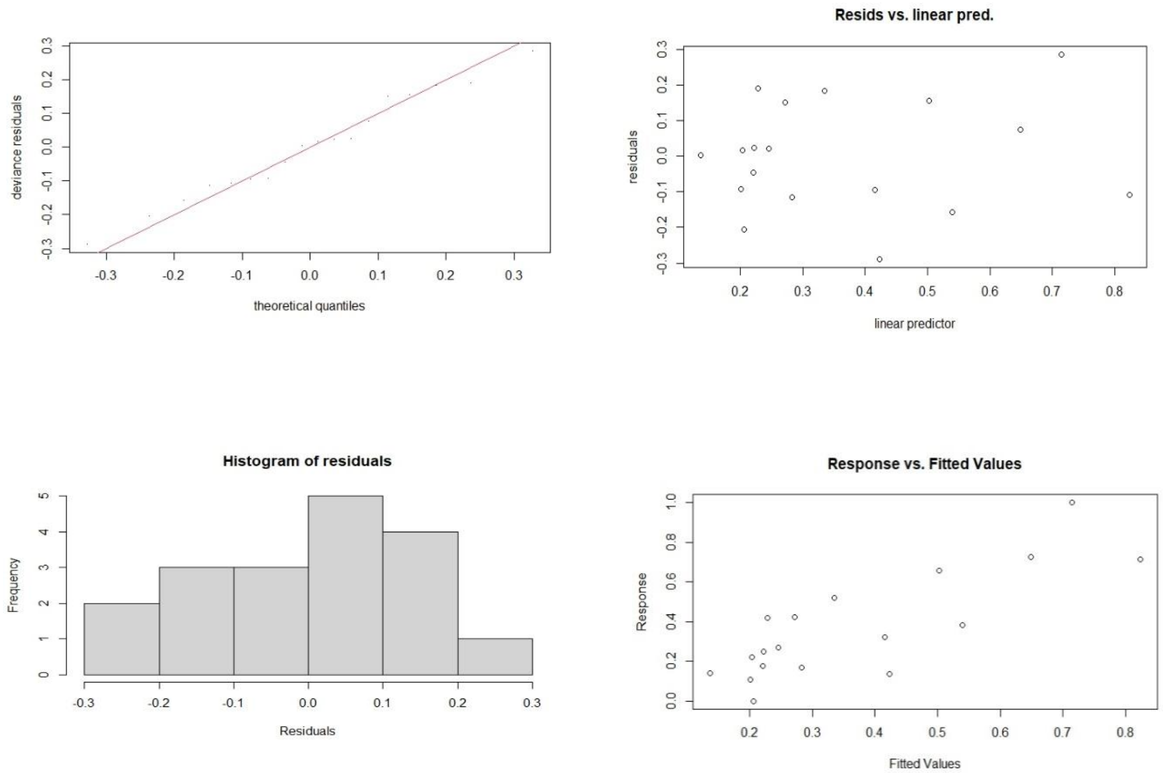


Dausa

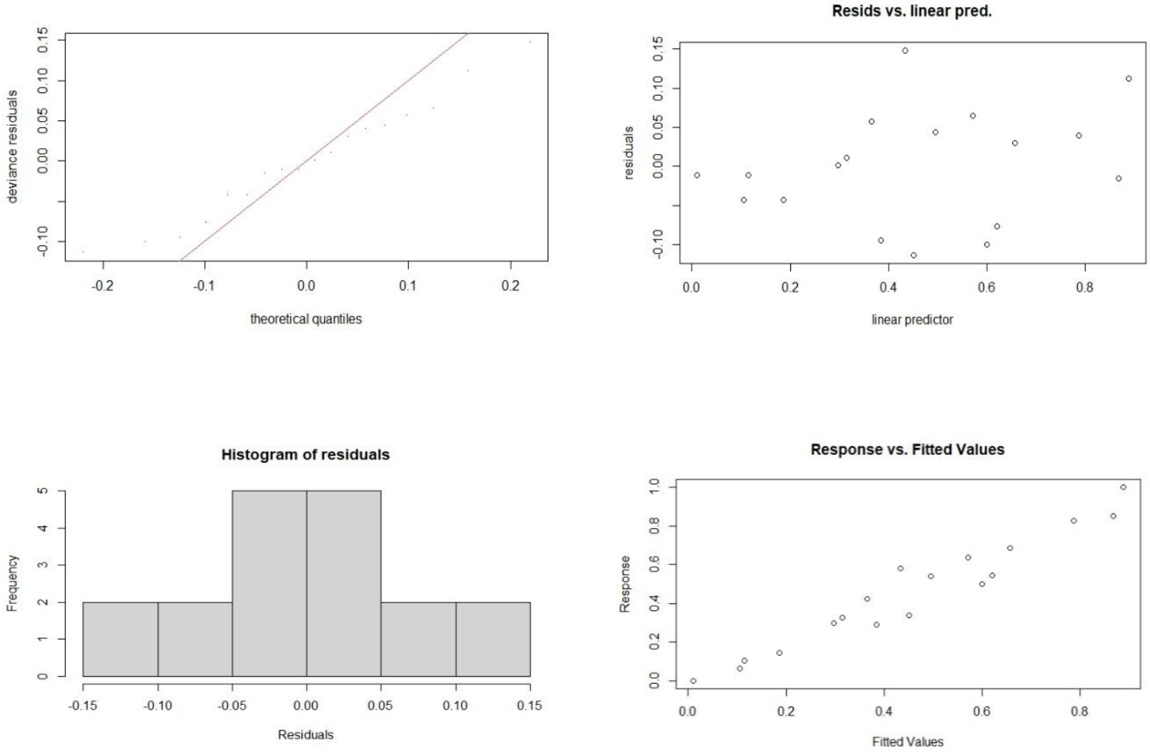
PC1- Model_1



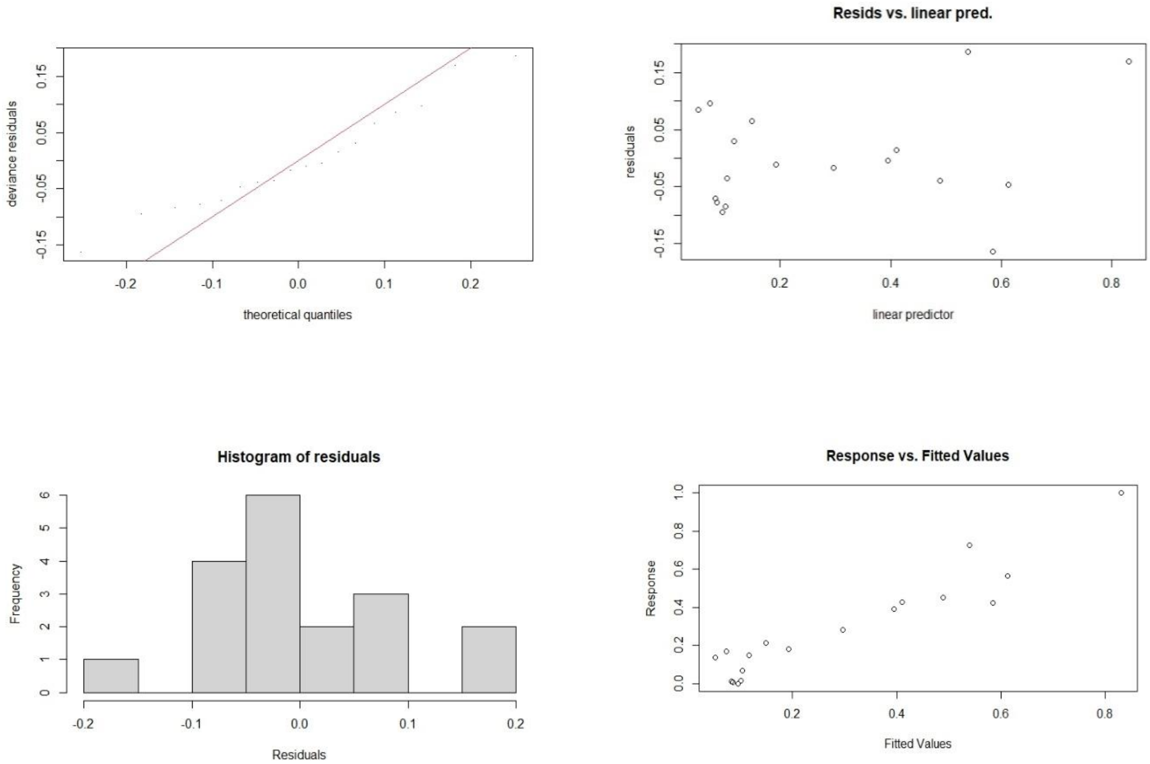
PC2- Model_1



PC3- Model_2

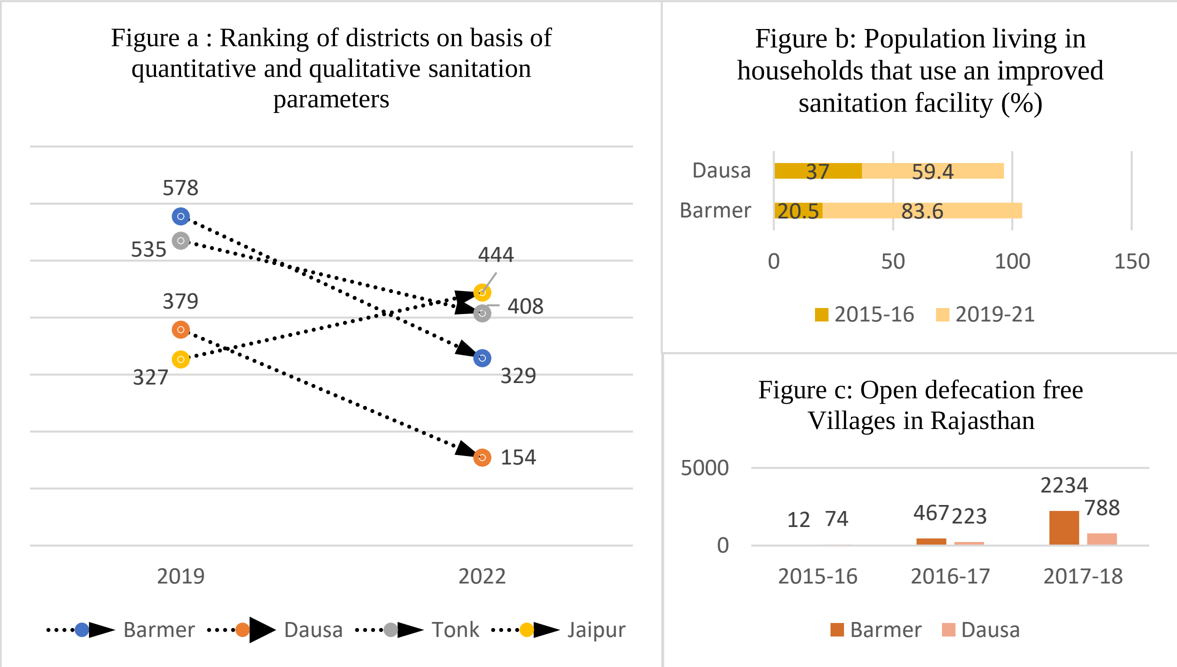


PC5- Model_3



Source: Authors' construction

Figure 4.6: Status of sanitation parameters



Source: Authors' construction from (a) Swachh Survekshan Grameen (2022); (b) National Family Health Survey-5 (2021); (c) Bairwa (2018)

* The Figure indicate improvement in ranking of Barmer, Dausa and Tonk.

Chapter 5

Serial No.______

Thank you for agreeing to provide the required information. This information will be kept in the strictest confidentiality.

Household Survey

Details of Investigators

a.	Name of Investigator	
b.	Place of Survey	
c.	Date of Survey	

Details of Respondent

a.	Full Name	
b.	Gender	☐ Male ☐ Female ☐ Other
c.	Age	☐ 15 - 35 ☐ 35 - 55 ☐ 55 – 75 ☐ above 75
d.	Name of Village	
e.	Name of Tehsil / Sub-District	
f.	Name of District	
g.	Relationship of Respondent to the household head	☐ Head ☐Wife/Husband ☐Son/ Daughter ☐Daughter in law/Son in law ☐Grandchild ☐Father/Mother ☐Brother/Sister ☐Father in law/Mother in law ☐Nephew/Niece ☐Brother in law/Sister in law ☐Other relatives ☐ Servant/Others
h.	Contact Details (Optional)	
i.	Educational status of Respondent	☐ No formal schooling ☐ Primary schooling (1st – 5th Std.) ☐ Upper primary schooling (6th - 8th std.) ☐ Secondary schooling (9th – 10th Std.) ☐ Senior Secondary schooling (11th-12th std.) ☐ Vocational training ☐ College ☐ University
j.	Marital Status of Respondent	☐Married ☐Unmarried ☐Widowed ☐Separated/Divorced

Section A. Information of the Household Head		
A1.	Name	
A2.	Gender	☐ Male ☐ Female ☐ Other
A3.	Age	☐ 15 - 35 ☐ 35 - 55 ☐ 55 – 75 ☐ above 75
A4.	Originality	☐ Native / Born and raised in the community ☐ Migrant
A5.	Caste	
A6	Religion	
A7.	Marital Status	☐ Married ☐ Unmarried ☐ Widowed ☐ Separated/ Divorced
A8.	Number of years stayed in the community	☐ 20-29 ☐ 30-49 ☐ Above 50 years
A9.	Household size	☐ < 3 ☐ 4 - 6 ☐ 7 – 10 ☐ >10
A10.	Does the household head have any social responsibility (social position) in the community?	☐ Yes ☐ No

A11.	Health Status of household head	☐ 100 % fit ☐ Bedridden ☐ Sickly ☐ Others
A12.	Literacy status of household head	☐ Neither read nor write ☐ Read only ☐ Write only ☐ Read and Write both
A13.	Educational/Training status of household head	☐ No formal schooling ☐ Primary schooling (1^{st} – 5^{th} Std.) ☐ Upper primary schooling (6^{th} - 8^{th} std.) ☐ Secondary schooling (9^{th} – 10^{th} Std.) ☐ Senior Secondary schooling (11^{th}-12^{th} std.) ☐ Vocational training ☐ College ☐ University
A14.	Annual household income (in Lakhs INR)	☐ < 3 ☐ 3 – 5 ☐ 5 - 10 ☐ > 10

	Section B: Water Source for the Household	
	Availability and Access	
B1.	What is the situation of water availability in your locality? (Rate: Very high=5; High=4; Medium=3; Less=2; Very less=1)	Inadequate water supply _______ Rationing of water supply _______ Fair water distribution _______ Low water pressure _______ No potable water _______
B1.1	What is the main source of water for drinking and cooking for your household?	Bottled water ☐ Rainwater collection ☐ Piped water into dwelling ☐ Piped water to yard/plot ☐ Public tap/standpipe ☐ Tube well/Borehole ☐ Well: Protected ☐ Well: Unprotected ☐ Surface water: Tank/pond ☐ Other surface water (Dam, canal etc.) ☐ Others (Tanker-truck, cart with small tank or drum, etc) ☐
B1.1.1	If Tube well/Borehole, what is the total depth of the borewell?	
B1.1.2	Is it allowed to dug at [mentioned depth] level?	Yes ☐ No ☐ Don't Know ☐
B1.1.3	What are the total hours of pumping on a daily basis?	
B1.2	Why do you prefer this main source of water for drinking and cooking?	Distance ☐ No better alternative ☐ Time ☐ Financial ☐ Water quality ☐ Others (Specify) ☐
B1.3	Does your household use other sources of water for drinking and other purposes?	Yes ☐ No ☐ Don't Know ☐
B1.3.1	If yes, Please state the main source and other sources for each use of water.	(see table below)

	Dry Season		Wet Season	
Activities	MainSource	Other Source	Main Source	Other Source
Drinking				
Cooking				
Washing clothes				
House cleaning				
Bathing				
Livestock				
Others				

	Ask if water is not in dwelling, or in yard.	
B1.4.	How far is the water source from the dwelling or yard?	(see table below)

	Dry Season	Wet Season
Less than 200 meters		
201-500 meters		
501meters-1kilometre		
More than 1 kilometer		
Don't know		

B1.4.1	What time does your household normally fetch water?	(see table below)

	Dry Season	Wet Season		Dry Season	Wet Season
Before 6:00	☐	☐	12:00-15:00	☐	☐
6:00-9:00	☐	☐	15:00-18:00	☐	☐
9:00-12:00	☐	☐	After 18:00	☐	☐

B1.4.2	How much time does it take, daily, to fetch and collect water from this source during dry season, including the time spent waiting in line and coming back home?	_________________Minutes _________Don't know
B1.4.3	And in wet season?	________________Minutes ____________Don't know
B1.4.4	How long do you have to queue up before you get your turn to fetch water?	Dry season / Wet season Less than 15 minutes ☐ ☐ 15-30 min ☐ ☐ 30-60 min ☐ ☐ More than 60 min ☐ ☐
B1.4.5	What means of transport does your household primarily use for fetching water?	Foot ☐ Motor Vehicle ☐ Animal or drawn cart ☐ Pay others to do it ☐ Bicycle ☐ Other (Specify) ☐
B1.4.6	Who usually go to the source to collect water for your household?	Adult men ☐ Boys under 15 ☐ Adult women ☐ Other (specify) ☐ Girls under 15 ☐ Don't Know ☐
B1.4.7	How many trips does each person normally make to the water source? ASK FOR EACH GROUP IDENTIFIED IN (c)	Summer ____________ Winter __________
B1.4.8	Is it safe to go to the water source?	Yes ☐ No ☐
B1.4.9	If No, do you face harassment?	Yes ☐ No ☐
B1.5	Are you satisfied with the quantity of water in your household?	Yes ☐ No ☐
B1.5.1	If No, Does the household get sufficient water throughout the year for all household activities? (Collective from primary and secondary sources)	Yes / No / Yes / No Drinking ☐ ☐ Livestock ☐ ☐ Cooking ☐ ☐ Gardening ☐ ☐ Washing ☐ ☐ Bathing ☐ ☐ Others ☐ ☐
B1.5.2	If No, during which season availability of water is not sufficient?	Dry season ☐ Wet season ☐
B1.6	What is the frequency of supply of water?	see table below
B1.7	Did your household experience any interruptions/breakdowns in water supply?	Yes ☐ No ☐
B1.7.1	If Yes, how many times were there major interruptions or breakdowns?	Dry season_____________ Wet season_______________
B1.7.2	What was the main reason for the interruption or breakdown of water supply?	see table below
B1.7.3	Compared to past, have major interruptions or breakdowns in the water supply become more common, less common or remained the same?	More Common ☐ About the same ☐ Less common ☐ Don't Know ☐

B1.6 table:

	Dry Season		Wet Season	
	MainSource	Other Source	Main Source	Other Source
Daily				
Once in two days				
Once in three days				
Once in a week				
Others				

B1.7.2 table:

	Dry Season	Wet Season
Service Disruption		
Water Unavailable from source		
Pump or pipe broken		
Too expensive/Couldn't pay		
Scarcity		
Don't Know		
Other (Specify)		

B1.8	Does your household have water storage container?	Yes ☐ No ☐
B1.8.1	If Yes, what kind of vessel does your household use to store water?	Container with a lid ☐ Bucket without a lid ☐ Container without a lid ☐ Others ☐ Bucket with a lid ☐
B1.8.3	What is the size of the container(s) you are using? Interviewer: Ask to see the containers and note the size.	_____________________ Liter
B 1.8.4	Compare to the past has the water storage facility changed?	Yes ☐ No ☐
B 1.8.5	If Yes, please specify (Increase in size of containers, increase in number of containers used)	
B1.8.6	How does your household remove water from the container(s)?	Tap ☐ Cup/dipper/ladle ☐ Pitcher ☐ Pour from the container ☐ With hands ☐ With bottle Others ☐
B1.8.7	Is the water storage facility clean?	Very Clean ☐ Clean ☐ Not Clean ☐
B1.8.8	How often does your household usually clean these container(s)?	Daily ☐ Several times per week ☐ Once a week ☐ Once a month ☐ Once every half year ☐ Less often than half yearly ☐ Don't know ☐
B1.8.9	Do you use disinfectant to clean water storage facility?	Yes ☐ No ☐
B1.8.10	Where do you use the stored water for?	Drinking ☐ Cooking ☐ Washing ☐ Bathing ☐ Livestock ☐ Gardening ☐

	Quality Of Water	
B2.	Are you satisfied with the quality of water in your household?	Yes ☐ No ☐
B2.1.	How would you rate the quality of water? (Good=1, Acceptable=2, Poor=3)	(see table below)
B2.1.1	Compared to the past, have there been any changes in the quality of water from the **SAME** source?	(see table below)
B2.2	Is the water source protected against contamination?	Yes ☐ No ☐
B2.2.1	If No, is the water visibly contaminated with excrement or waste?	Yes ☐ No ☐
B2.2.2	Is the water source also used by animals? Is there protection against animals accessing the water source?	Yes ☐ No ☐
B2.2.3	Is household, agriculture or industrial waste water discharge in the water source?	Yes ☐ No ☐

B2.1.:

	Dry Season		Wet Season	
	MainSource	Other Source	Main Source	Other Source
Clarity				
Colour				
Smell				
Taste				

B2.1.1:

	Dry Season		Wet Season	
	MainSource	Other Source	Main Source	Other Source
Improved to a great extent				
Improved to some extent				
Stayed the same				
Worsened to some extent				
Worsened to great extent				
Didn't use the source before				

B2.2.4	Is there regular maintenance of water supply system?	Yes ☐ No ☐
B2.3	Does your household treat water?	Yes ☐ No ☐
B2.3.1	If Yes, whose responsibility it is?	Adult men ☐ Boys under 15 ☐ Adult women ☐ Other (specify) ☐ Girls under 15 ☐ Don't Know ☐
B2.3.2	If no, why do you not treat water?	Water is safe to drink ☐ Water is unsafe to drink but I don't think it's necessary to treat ☐ Too expensive ☐ No knowledge of treatment options ☐ Not enough time ☐ Unavailability of treatment technologies ☐ Others (specify) ☐

	Water Insecurity		
		Gender	Frequency
B3.1	How frequently did you or anyone in your household worry you would not have enough water for all of your household needs?		
B3.2	How frequently have problems with water meant that clothes could not be washed?		
B3.3	How frequently have you or anyone in your household had to change schedules or plans due to problems with your water situation? (Activities that may have been interrupted include caring for others, doing household chores, agricultural work, income-generating activities, etc.)		
B3.4	How frequently have you or anyone in your household had to change what was being eaten because there were problems with water (eg, for washing foods, cooking, etc.)		
B3.5	How frequently have you or anyone in your household had to go without washing hands after dirty activities (eg, defecating or changing diapers, cleaning animal dung) because of problems with water?		
B3.6	How frequently have you or anyone in your household had to go without washing their body because of problems with water (eg, not enough water, dirty, unsafe)?		
B3.7	How frequently has there not been as much water to drink as you would like for you or anyone in your household?		
B3.8	How frequently did you or anyone in your household feel angry about your water situation?		
B3.9	How frequently have you or anyone in your household gone to sleep thirsty because there wasn't any water to drink?		
B3.10	How frequently have problems with water caused you or anyone in your household to feel ashamed/excluded/stigmatized?		

	Section C: Sanitation	
C1	Does the household have access to toilet?	Exclusive use of household ☐ No latrine ☐ Public/community latrine without payment ☐ Others ☐ Public/community latrine with payment ☐
C1.2	What kind of toilet facility does the household have?	Flush to piped sewer system ☐ Pit latrine without slab/open pit ☐ Flush to septic tank ☐ Composting toilet ☐ Flush/pour flush to pit ☐ Ventilated improved pit latrine ☐ Flush/pour flush to elsewhere ☐ Others ☐ Not used ☐
C1.2.1	If Not used, reason?	Not clean/Insufficient water ☐ Malfunctioning of the latrine ☐ Personal preference ☐ Cannot afford charges for paid latrine ☐ Others ☐
C1.3	Where is this toilet located?	In own dwelling ☐ In own yard/plot ☐ Elsewhere ☐
C1.3.1	If elsewhere, how long does it take to go to the toilet?	____________________________
C1.4	How often is the sanitation facility cleaned?	___________________________
C1.5	What is your perception of the sanitation facility? (On a scale of 1 to 5, with 1 being least satisfied and 5 being most satisfied.)	Effective operation (No leakage, No overflow, No blockage) ☐ Cleanliness ☐ Smell ☐ Distance ☐ Safety ☐

	Section D: Willingness to pay	
D1	Do you pay for water?	Yes ☐ No ☐

D1.1	If yes, what is the most and least amount of money you pay for water?	Most ___________________ Least ___________________
D1.2	Are these prices set by the public authorities?	Yes ☐ No ☐
D1.2.1	Is there a free basic water supply for those who cannot pay?	Yes ☐ No ☐
D1.3	Your household currently does not receive water service/ pays[amount] in water tariff. [However] The water availability is not satisfactory. If you were to receive 'SATISFACTORY WATER SERVICES' would you pay for that? Note: This would be in addition to your current monthly household expenditures.	Yes ☐ No ☐
D1.3.1	If Yes, how much price you would be willing to pay for the same?	**<100** ☐ **100-200** ☐ **200-300** ☐ **300-400** ☐ **400-500** ☐ **>500** ☐
D1.4	Your household is not connected to the sanitation facility/ the sanitation facilities are not satisfactory for example there is problem of overflow, smell etc. If you were to receive 'SATISFACTORY SANITATION FACILITY' would you pay for that? Note: This would be in addition to your current monthly household expenditures.	**Yes** ☐ **No** ☐
D1.4.1	If Yes, how much price you would be willing to pay for the same?	

	Section E: Perception	
E1	Do you think there is any problem in your locality related to water?	Yes ☐ No ☐
E1.1	If Yes, what kind of problem?	Water scarcity ☐ Water quality ☐
E2	What are the reasons for water scarcity? Rate 1 (not important) to 5 (very important)	Dry season ☐ Governance issue ☐ Increase in water use ☐ Inadequate water supply ☐ Increase in population ☐ Decrease in precipitation ☐ Increase in temperature ☐ Power cuts for using pumps ☐ Aging infrastructure (Old and degraded) ☐ Disruptions in seasons (seasonal cycle) ☐ Quality of water communal borewell is poor ☐ More extreme in summers ☐ Excessive exploration of water resources is greater than the past ☐
E3	What changes have you noticed with regard to sources of water over the past years?	Variations in water flows in the stream/river/spring ☐ Lowering of water table ☐ Increased/decreased sediment in surface water ☐ If any other (Specify) ☐
E4	Do you think water scarcity situation are becoming more or less frequent?	More ☐ No difference ☐ Less ☐ Don't know ☐
E5	Do you think water scarcity situation will intensify in coming future?	Yes ☐ No ☐
E6	Please rate following impacts of water scarcity. (Very high=5; High=4; Medium=3; Less=2; Very less=1)	(see table below)
E7	Do you think access to water will improve your standard of living?	Yes ☐ No ☐

E6:

	Male	Female
Household food security		
Health		
Unemployment		
Household income		
Migration		
Schooling of children		
Hopelessness and sense of loss		
Conflict in society		

E8	Have you heard about recycled water?	Yes ☐ No ☐
E9	How acceptable do you think the following uses of reclaimed/recycled water would be in your community?	Using reclaimed water to. a. Irrigate food crops ☐ b. Flush toilets in households ☐ c. Washing vehicles ☐ d. Clean streets ☐

	Section F: Awareness	
F1	Please indicate whether you strongly disagree, disagree, neither disagree nor agree, agree or agree strongly	
F1.1	There is enough water in my region to meet current needs	
F1.2	There is enough water in my region to meet future needs	
F1.3	Water conservation is essential to prevent water scarcity	
F2	Where do you get most of your information on water resources? (Please indicate how often you use each of the following sources for information using 0(never) to 10(very often) scale.	Mass media ☐ Friends ☐ Non-profit organizations ☐ Government agencies ☐ Environmental interest groups ☐
F3	Is anyone in your household member of institutions related to water management?	Yes ☐ No ☐
F3.1	If yes, how active you are?	Attended drought meeting ☐ Received drought information ☐ Contacted agriculture advisory service ☐
F3.2	Do you have a voice when decisions are made related to access to water?	Yes ☐ No ☐

	Section G: Adaptation	
G1	How prepared do you consider yourself to deal with situation of water scarcity?	Very high ☐ High ☐ Medium ☐ Less ☐ Very less ☐
G2	What adaptive measure your household use to deal with or adjust to water scarcity? Rate 1 (not important) to 5 (very important)	Rainwater harvesting ☐ Changes in agricultural measures ☐ Storage ☐ Alternation in water supply source ☐ Buying water ☐ Water treatment ☐ Livelihood diversification ☐ Migration (Temporary /seasonal or permanent) ☐ Water conservation ☐
G3	If agricultural measures are employed, what changes are made by the household?	Change cropping pattern ☐ / Reduction in livestock numbers ☐ Switch to modern methods of irrigation (like drip sprinklers etc) ☐ / Change from fertilizers and pesticides to green manure ☐ Less water intensive crops ☐ / Change in livestock types ☐ Altering date for agricultural operations ☐ / Relocation of livestock ☐ Short duration crops ☐
G4	If migration is used as adaptive measure, who moves?	Male ☐ Females ☐ Whole family ☐
G5	How many members of the household have migrated?	Gender | Age | Position in the household
G6	How has migration affected the economic situation of the household?	Income increased/decreased expenses increased/decreased Savings increased/decreased Living conditions (such as housing conditions and sanitation) improve/deteriorated Any other changes? Please specify
G7	Compared to past, is there an increase in the number of F/M members of the community migrating?	Yes ☐ No ☐
G8	Any conflict in the household due to water scarcity or stress?	Yes ☐ No ☐
G9	If yes, who gets affected?	

G10	If you do change your livelihood options due to water scarcity, kindly indicate from which to which	
G11	How has the change affected the economic situation of the household?	Income increased/decreased expenses increased/decreased Savings increased/decreased Living conditions (such as housing conditions and sanitation) improve/deteriorated Any other changes? Please specify
G12	In adapting to water scarcity, did you receive any assistance?	Yes ☐ No ☐
G13	If yes, indicate the source of assistance	Community association ☐ Local government ☐ State government ☐ Federal government ☐ Self-family ☐ Cooperative societies ☐ Others, specify ☐
G14	Do you know of any government policy specifically dealing with water scarcity for this community?	Yes ☐ No ☐
G15	If yes, are they to specifically help you adapt to water scarcity?	Yes ☐ No ☐
G16	If yes, what are the polices of government?	Subsidy for: adopting new agricultural machines ☐ adopting drip irrigation ☐ adopting sprinklers ☐ adopting rainwater harvesting technique ☐ adopting solar power plants ☐ adopting water-resilient crops ☐ Educating programs on water issues ☐
G17	Which among the following do you consider as an important factor affecting adaptation to water scarcity in your community? (Tick the most appropriate)	Inadequate income level to make use of alternative water source ☐ Educational level ☐ Lack of information of adaptive measures ☐ Labor shortage ☐ Health ☐ The formal institutions for water supply are too weak to function effectively ☐ Modern water resources exploration and exploitation technology too costly and complex ☐ No access to credit ☐
G18	What additional measures would you consider in the future?	Use water saving irrigation methods in future ☐ Migration ☐ Planning for water conservation ☐ Off-farm employment ☐ Alteration in livestock ☐

	Section H: Sustainable Development Goals						
H1	**Health**						
H1.1	Child Mortality in last 5 years						
H1.2	Malnutrition						
H2	Has anyone in your household suffered the following health problems during last year?						
	Diseases	Gender	***Age***	During last year, has anyone in this household visited any health facility due to this disease? No. of members	How many school days did children (ages 5 and above) and adults in school, miss due to this disease? No. of days	How many working days have household members 15 years or above missed due to this disease? No. of days.	How many working days have household members missed due to caring for a household member with this disease? No. of days
H2.1	Gastrointestinal disorders						
H2.2	Typhoid						
H2.3	Diarrhea						
H2.4	Cholera						
H2.5	Dysentery						
H2.6	Hepatitis						
H2.7	Blood disease or anemia						
H2.8	Diseases related to iodine deficiency						

H2.9	Diseases related to musculoskeletal system (bones, joints)						
H2.10	Back pain						
H2.11	Respiratory diseases						
H2.12	Others (specify)						

H3	**Education**	
H3.1	Is your child enrolled in formal schooling?	Gender / Yes/No
H3.2	If No, what is the reason for not enrollment	Fetching water ☐ Illness ☐ Distant of school ☐ Financial ☐ Absent of school ☐ Traditional barriers ☐
H3.3	How would you rate your class participation?	Gender / Very poor / Poor / Good / Very good
H3.4	How would you rate the quality of your test scores?	Gender / Very poor / Poor / Good / Very good

	Section I: Human Rights	
I1	Do you receive information about water issues?	Yes ☐ No ☐
I2	Is it difficult to access this information? (language barrier)	Yes ☐ No ☐
I3	Are you satisfied with the information provided? Give reasons.	Yes ☐ No ☐
I4	Have you ever made a complaint regarding the water supply?	Yes ☐ No ☐
I5	Are you satisfied with the mechanism for making the complaint?	Yes ☐ No ☐
I6	Have you ever felt that there is discrimination in water supply to certain localities or communities? If yes, In what way?	Yes ☐ No ☐
I7	If yes, does the state pay special attention to these vulnerable groups?	Yes ☐ No ☐

	Section J: Household Characteristics	
J1	Household size	Male__________ Female___________ Total____________
J2	Highest level of education of male member of the household	
J3	Highest level of education of female member of household	
J4	What is the principal source of income for the household?	☐ Agriculture ☐ Allied agriculture ☐ Agricultural wage labour ☐ Non-agricultural wage labour ☐ Artisan/Independent work ☐ Petty shop/Small business ☐ Organized trade/business (if more than 5 employees) ☐ Salaried employed ☐ Pension/Rent/Dividend, etc. ☐ Others

	Section K: Assets, Housing & Amenities	
K1	Type of House (Kutcha-1; Semi-pucca-2; Pucca-3; Other, (please specify) -97) (OBSERVE & RECORD)	
K2	If Pucca House, then number of rooms in the house	
K3	Ownership Status of House (Owned-1; Rented-2; Provided by employer-3; Any other (please specify)-97)	
K4	Do you have electricity connection in your house? (Yes-1; No-2)	
K5	Consumer Durables (Number of Consumer Durables) (If No consumer durables, record '99')	Television ☐ Two-Wheeler ☐

		Air Conditioner ☐ Computer or laptop ☐ Mobile Phone ☐ Telephone Landline ☐ Radio/Transistor ☐ Car ☐
K6	If engaged in Farm.	Tractor ☐ Harvester ☐ Power Tiller ☐ Drip Irrigation System ☐ Sprinkler ☐

BRIEF BIOGRAPHY OF THE CANDIDATE

Suchitra Pandey is a Research Scholar in the Department of Economics & Finance at BITS Pilani, Pilani Campus. Her research interests lie in Environmental Economics and Development Economics. She has presented her work at prestigious conferences, including the Singapore Economic Review Conference (2022) and the 57th Annual Conference of the Indian Econometric Society. Her research has been published in reputable journals such as the Journal of Cleaner Production, Natural Resources Forum, and the International Journal of Social Economics. She completed her master's degree at Banaras Hindu University and her undergraduate studies at Delhi University. With experience handling national-level survey data, she is proficient in software including STATA, SPSS, and R.

PUBLICATIONS

1. Published Papers

- Pandey, S., Mohapatra, G. and Arora, R. (2024). Spatio-temporal variation of depth to groundwater level and its driving factors in arid and semi-arid regions of India. Regional Sustainability, indexed in Scopus, Q1(0.82). https://doi.org/10.1016/j.regsus.2024.100143
- Pandey, S., Mohapatra, G., and Arora, R. (2024). A temporal and spatial assessment of water stress with water poverty index: A case study of Rajasthan. Natural Resources Forum, indexed in Scopus, H-index: 59, Q1(0.85). https://doi.org/10.1111/1477-8947.12453
- Pandey, S., Mohapatra, G., and Arora, R. (2023). Groundwater quality, human health risks and major driving factors in arid and semi-arid regions of Rajasthan, India. Journal of Cleaner Production, indexed in ABDC-A, Scopus, H-index: 309, Q1(2.06). https://doi.org/10.1016/j.jclepro.2023.139149
- Pandey, S., Mohapatra, G. and Arora, R. (2022). Examining the interstate variations and interlinkage between water poverty and multidimensional poverty in India: evidence from household-level data. International Journal of Social Economics, indexed in ABDC-B, Scopus, H-index: 48, Q2(0.48). https://doi.org/10.1108/IJSE-12-2021-0731
- Pandey, S., Mohapatra, G. and Arora, R. (2022). Water Poverty Index and its changing trend in India. Journal of Economic and Administrative Sciences, indexed in ABDC-C, Scopus. https://doi.org/10.1108/JEAS-12-2021-0268
- Pandey, S., Mohapatra, G. and Arora, R. (2022). Mapping and situation analysis of water poverty at household level in Rajasthan: Evidence from a nationally

representative survey. Empirical Economics Letters, indexed in ABDC-C. https://doi.org/10.5281/zenodo.8087885.

2. **Accepted Papers**

   - Pandey, S., Mohapatra, G. and Arora, R. Implications of adopting water policy and caste on Multidimensional poverty: Evidence from household-level data in India.

3. **Working Papers**

   - Pandey, S., Mohapatra, G. and Arora, R. Perception, Adaptation, and Vulnerability to Water Scarcity among Rural Households in Arid and Semi-Arid Districts of Rajasthan.

CONFERENCES

- March 23-25, 2023 presented paper entitled “Examining the groundwater level in arid and semi-arid districts of Rajasthan: spatiotemporal trend and determinants”, at International Conference on Sustainable Business Management (SBM 2023), organized by IIT Roorkee.
- February 4-5, 2023 presented paper entitled “Examining the Impact of Water Poverty Index on Human Capital Index: A Case Study of India”, at 6th SANEM Annual Economists’ Conference (SAEC), organized by The South Asian Network on Economic Modelling (SANEM).
- January 4-6,2023 presented paper entitled “Interlinkages between Water Poverty and Multidimensional Poverty: Does Water Policy Improves the well-being of households?”, at 57th Annual Conference of the Indian Econometric Society (TIES), organized by The University of Hyderabad, Hyderabad.
- August 19-20, 2022 presented paper entitled “A temporal and spatial assessment of water stress with Water Poverty Index: a case study of Rajasthan”, at 11th Congress of the Asian Association of Environmental and Resource Economics (AAERE), organized by University of Economics Ho Chi Minh City, Vietnam.
- August 1-3, 2022 presented paper entitled “Implications of adopting water policy and caste on Multidimensional poverty: Evidence from household-level data in India”, at Singapore Economic Review Conference (SERC).
- February 4-7, 2022 presented paper entitled “Determinants of Gender-Difference in Water Access and Management Practices: A Case Study of Indian Households”, at International Conference on Contemporary Issues in Economics, conducted by XIM University Odisha.

BRIEF BIOGRAPHY OF SUPERVISOR

Prof. Geetilaxmi Mohapatra is currently serving as an Associate Professor in the Department of Economics and Finance at Birla Institute of Technology and Science, Pilani, Pilani Campus, India. She holds a first-class Master's degree in Economics from the Central University of Hyderabad and a doctorate in Environmental Economics from Utkal University, Bhubaneswar. Her research interests include Environmental Economics, Development Economics, and International Economics. With over fifteen years of experience in research and teaching at the postgraduate level, she is actively involved in research and consultancy. Prof. Mohapatra has authored numerous research papers in national and international journals and conference proceedings.

BRIEF BIOGRAPHY OF CO-SUPERVISOR

Prof. Rahul Arora is an Assistant Professor in the Department of Economics and Finance at Birla Institute of Technology and Science, Pilani, Pilani Campus, India. He obtained his master’s degree in Economics from Punjab School of Economics, G.N.D.U. and a Ph.D. in Economics with specialization in International Trade from IIT Kanpur, Kanpur. He is a recipient of Junior and Senior Research Fellowship from UGC and Internation travel grants from CESifo, Germany. He has published several research papers in the journals of national and international repute. He also acts as a reviewer for various high-quality journals. His research area is applied econometrics and economic sustainability. He has more than five years of experience in teaching post graduate level in Economics at BITS Pilani. Prior to it, he has two years of experience as a policy analyst with CUTS International at Jaipur.