WATER INSECURITY IN THE ERA OF URBANIZATION AND CLIMATE CHANGE: INSIGHTS FROM DHARAN AND DHULIKHEL, NEPAL

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ABSTRACT

Water insecurity poses a global challenge, with rapidly urbanizing cities bearing the brunt of its impacts. The cities are grappling with the severe impacts of climate change. Previous studies have firmly established the connection between urbanization and water, as well as, between climate change and water, outlining the impacts of these factors on water resources. However, scholars have highlighted a notable lack of focus and scholarly examination on urban water security in Himalayan towns, considering the tripartite and interconnected challenges of climate change, water insecurity and rapid urbanization, along with associated governance challenges. Ensuring water security in such a context is challenging owing to the specificities of urban areas, high water demand and sectoral water needs as well as complexity in water governance. Literature on water security and urban water security in particular, notes that 'water security' covers diverse elements and has expanded its focus from quantity and quality to other dimensions such as accessibility, affordability, risk and sustainability.

In regard to different dimensions of water security, 'governance' is considered to be key component for securing water. An array of institutional and policy issues has been identified in recent studies, and strengthening governance has been recommended to achieve water security, which is highly complex in the urban context. However, 'governance' has received very limited focus in water security literature.

Nepal is committed to provide universal access to water to all of its citizens, as enshrined in its 2015 Constitution as well as its commitment to Sustainable Development Goal 6 and recent water policies. In the federal context, local governments are empowered in managing the water resources and formulate water related policies. Policies and institutional responses addressing this issue are apparent, yet numerous challenges persist. In this context, this study aimed to identify and analyze the key drivers, responses and challenges to address growing water insecurity in two- rapidly urbanizing cities of Nepal: Dharan, a mid-sized foothill town and Dhulikhel, a small mid-hill town of Nepal.

The research adopted a pragmatic approach considering its applicability and has applied qualitative-led mixed methods approach combining both qualitative and quantitative methods. In-depth interviews, focused group discussions and participatory observations formed the qualitative methods while surveys (211 households in Dhulikhel and 273 households in Dharan) were conducted as part of quantitative methods during 2018-2021. The research

followed embedded mixed method design in which quantitative data played a secondary role to interpret the findings from the qualitative data. Both primary data from above methods were collected and secondary data consisted of conceptual and empirical literature review and review of relevant policies. The qualitative data were analyzed by thematic coding and content analysis while the simple descriptive analysis and a few statistical analyses was carried out for the quantitative data.

This study has adopted 'urban water security' theory for understanding and addressing the multifaceted water security related challenges. It combines DECS (Drinking water and human beings, Ecosystem, Climate change and water related hazards and Socio-economic factors) framework with urban water security theory and considers the cities as 'complex adaptive system'.

The research and analysis had two specific research objectives: the first one was to analyze the key drivers affecting water security in the context of rapid urbanization and climate change impacts. The findings of the first research question under the first research objective, regarding the nature and drivers of water insecurity identified various socio-economic, technological, environmental, management and governance drivers. The findings additionally uncovered that these various factors, either independently or in combination, impacted different dimensions of water security. Moreover, the analysis underscored 'governance' as the key driver shaping urban water security. The identification of the drivers has offered valuable insights to the water institutions and local governments to confront the challenges and integrate them into actionable strategies of ensuring water security.

The second objective of the research was to analyze the institutional and policy responses and challenges and constraints in securing water. This objective consisted of three research questions. The first question examined how institutions and policy responses were made in addressing water insecurity in the study sites. The findings revealed sectoral policy formulation, infrastructure-based supply augmentation, and collaboration with NGOs, universities, and research organizations, organizing water forums and integrating solutions such as recharge pits and recharge ponds into municipal policies formed the key responses. Furthermore, the private sector has played a significant role in optimizing water usage.

The second research question examined the challenges and constraints in securing water for the future. The study has identified ambiguities in the roles and responsibilities for water management among the three tiers of government in the federal context. These included

conflict and coordination issues among water management institutions, limited capacity of the local governments and gaps in women's representation and effective participation as the main institutional constraints. Further, incoherent sectoral policies were identified as hindering the development of resilient water systems in cities amidst urbanization and climate change impacts. Efforts to organize water forums and implement watershed conservation initiatives encountered obstacles due to inadequate prioritization by the water institutions and shifting leadership.

The third research question explored the key elements of 'governance' dimension of the urban water security theory. The identified elements include: a) coherent policies and efficient institutions, b) equitable distribution and meaningful participation and c) risk-sensitive evidence informed planning. The gaps in the water security literature have also been discussed to establish why these elements are integral to governance dimension. To enhance water security, the study urges the need to incorporate improved version of water governance which allows flexible, adaptive and innovative planning approaches, tailoring context-specific responses and interventions.

This thesis contributes to the urban water security literature by exploring the intersection of urbanization, water security and climate change for the academic community. The study also contributes to social change or practice change by offering actionable insights from Dharan and Dhulikhel to the practitioners, various water stakeholders and policy makers to address water security related challenges in the emerging cities. The identification of drivers affecting water security, responses of water institutions and constraints the water institutions are facing in the study sites offer useful lessons to manage the drivers and plan actions towards addressing them. The research highlights institutional and policy gaps, emphasizing the need for equitable and socially just approaches in large-scale water supply schemes, particularly in the context of climate impacts on urban water systems. Specifically, this research expands the scope of water justice by emphasizing the need towards inclusive, adaptive, and risk-sensitive governance to ensure socially just urban water systems in Nepal. The insights and findings bear relevance to the rapidly urbanizing small to mid-sized Himalayan cities, in and beyond Nepal, that are experiencing the water insecurity challenge.

APPROVAL OF THE THESIS

Thesis of Gyanu Maskey presented to the School of Arts Public Defense on April 27, 2025.

Title: Water Insecurity in the Era of Urbanization and Climate Change: Insights from Dharan and Dhulikhel, Nepal

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DEDICATION

This thesis is dedicated to my late father who always prioritized my education and envisioned me pursuing this degree.

DECLARATION

I hereby declare that this thesis has not been submitted for candidature for any other degree.

I understand that my thesis will become part of the permanent collection of Kathmandu University Library. My signature below authorizes the release of my thesis to any reader upon request.

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Gyanu Maskey

April, 2025

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Gyanu Maskey
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ACRONYMS

UN DESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
GLOFs	Glacial Lake Outburst Floods (GLOFs)
IPCC	Intergovernmental Panel on Climate Change (IPCC)
WWDR	World Water Development Report
HKH	Hindu Kush Himalayas
SDG	Sustainable Development Goals
ILO	International Labor Organization
IWRM	Integrated Water Resource Management
WECS	Water and Energy Commission Secretariat
N-WASH Policy	National Water Supply and Sanitation Policy
MWSP	Melamchi Water Supply Project
GWP	Global Water Partnership
FAO	Food and Agriculture Organization
IWRM	Integrated Water Resource Management
IRBM	Integrated River Basin Management
OECD	Organization for Economic Co-operation and Development
CAS	Complex Adaptive Systems
IoT	Internet of Things
CBS	Central Bureau of Statistics
VDC	Village Development Committee
ADB	Asian Development Bank
DDWSUC	Dhulikhel Drinking Water and Sanitation Users Committee
KVIWSP	Kavre Valley Integrated Water Supply Project
KVIWSB	Kavre Valley Integrated Water Supply Board
NWSC	Nepal Water Supply Corporation
WHO	World Health Organization
LGOA	Local Government Operation Act

STUEIP Project	Secondary Towns Integrated Urban Environmental Improvement
IUDP	Integrated Urban Development Project
DWSS	Department of Water Supply and Sewerage
NGO	Non-Governmental Organizations
INGO	International Non-Governmental Organizations
FEDWASUN	Federation of Drinking Water and Sanitation Users Nepal
FECOFUN	Federation of Community Forests users Nepal
FNCCI	Federation of the Chamber of Commerce
WATSAT	Water Security Assessment Tool

Units

Km^2	Square kilometers
MLD	Million of liters per day
LPCD	Liters per person (capita) per day

CHAPTER ONE: WATER INSECURITY AMID URBANIZATION & CLIMATE CHANGE

I start the introduction chapter by laying out the context of the study. This chapter presents a brief background of the research and an introduction to the water related challenges in the context of increasing water demand and impacts of climate change. In the following section, I have identified the gaps in research in the existing literature discussing the global research and the studies in Nepal to fit into the need of the research in water security in the urban context amid burgeoning population growth and climate impacts. Having discussed this, I explain the research objectives and the research questions. Following the research questions, I highlight the major proposition of the thesis and, lastly, I present briefly how the chapters in the thesis are organized.

1.1 Background

Water insecurity is global (Ojha et al., 2020; Singh et al., 2020) and is increasing over time as a 'wicked problem' (Grafton, 2017). The impending water crisis is one of the most critical challenges facing the urbanizing Global South which makes a long-term water management planning approach indispensable for the sustenance of the newly emerging towns and cities. Asian Water Development Outlook 2020 emphasizes effective water management as critical to Asia-Pacific region's (a home to 60% of the global population) economic growth and social well-being post COVID-19 pandemic. The report further notes that despite impressive progress in the last decades, 1.5 billion individuals in rural areas and 0.6 billion in urban areas in Asia continue to grapple with inadequate access to water supply and sanitation and the challenges amid overexploited groundwater, rising water demand and climate variability (Asian Water Development Outlook 2020).

Urban water systems are increasingly experiencing stress primarily owing to the tripartite challenges of urbanization, population pressure and impacts of climate along with resource limitations, governance issues and inappropriate urban planning failing to account the floating population (Ballarin et al., 2023; Ferguson et al., 2013; Hoekstra et al., 2018; Pandey, 2020; Singh et al., 2020). While the demand for water is rising from range of sectors as agriculture, energy and industry, the impacts of climate change is decreasing the renewable water and limiting the water availability and quality (Alamanos et al., 2020), thus compounding water scarcity. Population increase, observed mostly in developing countries, with Asia as second after Africa, is a key factor causing these regions to be already grappling with the lack of clean

water (Boretti & Rosa, 2019). With burgeoning population and the climate change impacts leading to decrease in rainfall, water quantity and quality are at risk, and this is affecting segments of the population unequally (Islam & Winkel, 2017). Particularly, the lower Himalayan region in Asia faces intensified challenges of water insecurity due to profound impacts of climate change (Chaudhary & Bawa, 2011; Scott et al., 2019a). The water insecurity challenge in this region is further exacerbated by the rapid pace of urbanization and its status as a hotspot for social marginalization, fragility and higher vulnerability to the impact of climate change, exposing the communities and ecosystem to higher stress (Kovacs et al., 2019; Prakash & Molden, 2020).

Urban water systems depict a prime example of a situation of scarcity arising from population density and climatic impacts, combining highly interwoven social, ecological, and technical systems (Brown et al., 2009; Duran-Encalada et al., 2017). The greater water demand for household and commercial sectors and changing lifestyles, floating population, drying springs and limited groundwater recharge are some of the challenges cities have to deal with. While cities are facing both a rising demand for water in a time of scarcity and threats to the quality of the water supply, they are often too slow to respond to the water crisis (Shrestha et al., 2014). Studies indicate that cities have not been able to prioritize urban water resilience (Aylett, 2015), and South Asian cities remain particularly underprepared (Shrestha et al., 2014; Subhadra, 2015).

The water problems are deeply rooted in the new types of societal structures' and interwoven institutions, characterized by significant complexity and uncertainty with wider diversity of stakeholders involved (Van der Brugge & Rotmans, 2007). This leads the cities to manage complex governance systems. To address this issue, an understanding of water problems as placed in complex hydrologic, socio-economic environment, plays an important role in determining the institutions required in water management, and in developing enabling environments for equitable, climate adaptive and sustainable water management. Moreover, water being a finite common-pool resource flows beyond administrative borders, frequently triggering disputes. The present scenario hence requires water institutions[1] for successfully

[1] Institutions are characterized by both the formal and informal practices that structure human interactions, including established rules, laws, organizational entities, norms and codes of conduct (Armitage et al., 2007).

managing water resources as the institutions are the link that governs social-natural systems' relationship (Dolsak & Ostrom, 2003; Kramer et al., 2013).

Given the complexities of water use within society, sustainable water management has been a major challenge, especially in the context of Nepal. Cities in Nepal are experiencing the critical water issues owing to the specific characteristics of urban areas as concentrated population density and haphazard urbanization, land use and water use changes, changing precipitation patterns and extreme weather events, surface sealing as well as complex governance structure. The residents are forced to depend on multiple water sources, mostly as municipal water supply is not guaranteed, private water tankers supply water to the individual households. Water demand has outstripped the supply and introduced the cities with complex water management challenges of which ensuring safe and adequate potable water services to growing populations are of major concern (Joshi et al., 2020; Shrestha et al., 2019). The uncertainties surrounding the key drivers like climate change, population growth and urbanization make urban water management a complex issue (Mittal et al., 2022).

Research on urban water security is integral to development studies as it addresses key aspects of human well-being, sustainable urban development, environmental conservation, economic growth, social equity, climate resilience, and effective governance amidst rapid urbanization. Urban water security in Nepal is not just an environmental issue but a deeply interconnected problem with economic, social, and political dimensions. Water insecurity is also a social justice issue. Addressing water insecurity in the context of climate change is inherently aligned with the concept of sustainable development, which seeks to balance environmental, social, and economic goals. The challenges of ensuring equitable access to clean water and integrating climate change adaptation into urban water management is central to achieve SDGs (particularly SDG 6 on clean water and sanitation). Urban water insecurity in Nepal impacts people's health, education, and livelihoods, and addressing these issues lies at the heart of the human development agenda.

Urban water security research in Nepal, particularly in the context of climate change, is important for understanding the broader dynamics of development. It explores how cities can manage and secure water resources, ensuring access for all, while minimizing environmental impact and adapting to the challenges of urbanization and climate change. It also informs policies and practices for ensuring access to clean water, promoting sustainable urban development, and enhancing the overall quality of life in growing urban areas.

1.2 Research Gaps

As explained in the background section, water insecurity is a growing concern that Himalayan cities are experiencing in the present context and it is urgent to ensure urban water security for saving humanity's food, economic, ecological and national security (Aboelnga et al., 2019). This research on water security in the context of urbanization and climate change are aimed to address major three gaps.

Firstly, the past studies have well established the linkage of urbanization-water and climate-water in terms of the impacts of urbanization and climate change on water (Hoekstra et al., 2018, Pandey, 2020; He at al., 2021; Link et al., 2016; Turral et al., 2011). But the earlier researches in urbanization, climate and water focus have been separate or linking only any two of the sectors. The contemporary literature shows that there is a dearth of research focused on urban water insecurity in Himalayan towns considering the interconnected challenges of climate change, rapid urbanization and associated governance challenges on water security (Aihara et al., 2015; Hoekstra et al., 2018; Ojha et al., 2020; Pandey, 2020).

While studies globally have captured the nexus between changing climate, urbanization, and water security in developed countries, there is limited attention and scholarly analysis directed towards urban water security in lesser developed countries and small and mid-sized cities like Nepal (Bakker & Morinville, 2013; Hoekstra et al., 2018; Pandey, 2020; Pandey & Bajracharya, 2017; Rogers & Hall, 2003). Studies have pointed out that large scale availability analyses have missed urban water management (Aihara et al., 2015). Hence, this study aims to contribute to the literature of urban water security, operating in the nexus of urbanization, water security and climate change, using insights of rapidly urbanizing cities of Nepal. Further, past studies have also indicated that 'urban water security' or water security in the urban context has been of limited interest (Cook and Bakker, 2013). Only three definitions are related to urban water security out of 25 definitions on water security and often, water security definitions are recommended to use in the urban context (Allan et al., 2018). However, considering the complexity of urban context, urban water security requires specific attention. This study has considered cities as complex adaptive system (explained in conceptual framework of chapter 2: Literature Review) and analyzes the responses and constraints faced in addressing the issue of water insecurity.

Secondly, literature in water security has discussed different dimensions and have expanded its focus from quantity and quality to include access, affordability, sustainability, and risk

components (Cook and Bakker, 2012). Another key dimension of water security is 'water governance'. In other words, ineffective water governance has been identified as a key constraint to water insecurity and in achieving sustainable development, particularly in developing countries (Mishra et al., 2020b). But the water security framework generally discusses other dimensions such as availability, quality, access, affordability, and risks and less attention has been received in the 'governance' dimension. More recent definitions have discussed governance aspects such as 'capacity' of institutions (Allan et al., 2018) but what that means in terms of water security in the context of urbanization and climate change has not been clear. The analysis from this study will add a new contribution to governance dimension (policy and institutional aspects of governance) by adding a new perspective to the existing literature. It also explores the key dimensions of 'governance' in urban water literature and insights from the study sites.

Few studies have dealt with the issue holistically or identified current water related policies in Nepal, which are ineffective in responding to climate change as the policies have not captured the changing context (Regmi & Shrestha, 2018). A mix of political, institutional and capacity barriers prevents effective implementation of the existing strong water laws and strategies on paper (Grumbine et al., 2015). Gaps in knowledge and capacity of city governments in urban water management were highlighted by Jha and Shrestha (2013). But there have been limited studies focusing on the institutional response or the city level responses of the institutions (Ojha et al., 2020).

Thirdly, the existent gap in the water security related research is that the traditional assessments of water scarcity receive poor attention to human dimensions like social and institutional capacities (Bakker & Morinville, 2013) which this research will address. Particularly, the in-depth analysis of the governance aspect, chiefly the institutional and policy aspects have not received attention in the past studies; hence, are poorly integrated with the needs of policy makers and practitioners (Bakker, 2012). Most studies have focused on empirical, modelling and lab-based analysis with limited focus on conceptual issues (Pahl-Wostl et al., 2016). Global literature is found to focus on use of climate models, on assessing urban water security under changing climate (Jaramillo & Nazemi, 2018); developing model for assessing urban water security using evaluation method (Yang et al., 2012); and adaptive water management (Allan et al., 2013). Some studies on water security have focused on water related risks (Grey et al., 2013; Scott et al., 2013; Hall and Borgomeo, 2013) while others have developed frameworks for assessing urban water security (Tjandraatmadjaa et al., 2013; Paton et al., 2014). These

reflect most of the studies on water security are quantitative and modelling based research and assessments of water security situations as very high to low risks. Cook and Bakker (2012) also discuss that the academic literature in the theme of water security include mostly the modelling studies. In the review-based study, the authors (ibid) classified the 95 web of science articles into 4 main categories and found that about fifty percent of the studies were empirical (44) and about one third were modelling (30), and few were conceptual (15) and lab-based studies (4). Such assessments using indicators are useful for comparing the status of cities. However, actions to address the key issues require in-depth understanding of the challenges prevalent in the cities. Moreover, understanding the social-natural relationships with water, amid the different measures adopted to secure water is crucial. This research hence adopts the mixed-method approach to adequately bring out the critical insights useful to the water managers including the policy makers as well as water users.

Marttunen et al. (2019) noted that the integration of both the physical and human pressures on water resources is a precursor for developing a broad understanding of human-water systems. In the context of Nepal, studies have focused on water quality including physico-chemical parameters & microbial analysis (Koju et al., 2014; Pant, 2013; Prasai et al., 2007; Warner et al., 2008, Kannel et al., 2007; Koju et al., 2022), climate change adaptation in water supply (Jha, 2012); Integrated Water Resource Management (IWRM) (Suhardiman et al., 2015), water-energy-agriculture nexus (Nepal et al., 2021), household and domestic water demand (Udmale et al., 2016; Thapa et al., 2018); peri-urban water security (Shrestha et al, 2013; Narain et al., 2013; Shrestha et al., 2018); conflicts and cooperation (Roth et al., 2018), equity in water distribution (Ayadi et al., 2020), and adaptive capacity of local government in urban water supply in the context of climate change (Jha and Shrestha, 2013). Further, Shrestha (2019, 2020) examined peri-urban Kathmandu with a focus on community resilience and groundwater exploitation in the context of urbanization.

This reveals limited research being done in the nexus of climate change, urbanization and water security at city scale and most of the researches on urban water are focused in Kathmandu. Hence, the rapidly urbanizing cities representing the hill-top and foothill towns in Nepal bearing the burgeoning water need and facing climate impacts will provide insightful evidence in responses and constraints in securing water.

As highlighted by Aboelnga et al. (2019), in order to better understand urban water security, it is important to determine the factors that influences its insecurity, on ways of water management, constraints and strategies required to the infrastructure to achieve urban water security. At the same time, aligning with the needs of policy makers and practitioners identified as the gap in academic literature (Bakker, 2012), this study, aims to investigate the challenges of urban water security in the context of climate change and rapid urbanization in two Nepalese cities, the institutional and policy responses and the challenges or constraints in achieving water security.

1.3 Research Objective and Questions

Based on the discussion above, in the context of increasing water scarcity to meet the demands of burgeoning populations, expansion of cities, and the impacts of climate change, water resource constraints will continue in the future and potentially escalate into conflicts for accessing water. Developing climate adaptive water management strategies and sustainable solutions are of utmost need in the present context. The research hence, broadly intends to investigate water security issues in two rapidly emerging Himalayan cities of Nepal in the context of rapid urbanization and climate change.

In doing so, the research examines the nature and drivers of urban water insecurity. Analyzing the drivers and determinants of water insecurity, or the factors that are contributing to the problem of water scarcity, would help in devising the solutions to secure water in cities. These can also be termed as stressors or drivers affecting water security which are challenging in urban context. As mentioned, the study considers urbanization and climate change as the context that literature (Hoekstra et al., 2018, Pandey, 2020) have identified having implications on the water need and supply. Beyond these prominent factors, the study also discusses an array of determinants affecting the components of water security. The research will thus contribute to the body of water security knowledge and literature in the nexus of urbanization, water security and climate change.

Furthermore, the role of water institutions in managing water services is identified to lie at the heart of securing water. Studies have found that institutional capacity to provide the necessary water services is among the three main dimensions characterizing water scarcity[2] (FAO, 2012).

[2] Main dimensions that characterize water scarcity are a physical lack of water availability to satisfy demand; the level of infrastructure development that controls storage, distribution and access; and the institutional capacity to provide the necessary water services (FAO, 2012).

Poor management of water is noted as one of the causes for water scarcity along with overuse of water and natural factors as droughts (Rijsberman, 2006, Padowski et al., 2016). Therefore, recognizing importance of water resilient and robust institutions for successfully adapting to water insecurity situation and the uncertainty, the research analyzes how responses to growing water insecurity are organized. The responses can range from the technical inputs, infrastructural development to policy changes. Further, it will document the initiatives and challenges the water institutions are experiencing which can be a learning to other cities to upscale innovative approaches and also to learn from the challenges and barriers for effective implementation of reforms in water sector. Therefore, the empirical findings and lessons on institutional and policy constraints will assist the water managers and water policy makers from federal to local levels in effectively devising the water management legislations towards developing water secure system.

The study analyses the limits or constraints in the journey of securing water. Identifying the barriers would help in devising the effective responses to deal with the existent water insecurity issues. By doing so, the study aims to contribute to the governance dimension of 'urban water security theory', on what dimensions the urban water governance needs to integrate. This will be the analytical contribution of the study that proposes the need of rethinking water security, particularly the elements of governance dimension that has been missing in the 'urban water security theory'. Governance here represents both institutional and policy aspects.

Hence, the broad research objective of the study can be stated as:

> *The research broadly aims to identify and analyze the key drivers, responses, challenges and ways to address growing water insecurity in the rapidly emerging cities amid climate impacts.*

Specific research objectives:

Research Objective 1: To analyze the key drivers and nature of water insecurity in the context of rapid urbanization and climate change impacts.

The research question to address this objective is

1 What are the key drivers and nature of water insecurity in emerging cities of Nepal?

Research Objective 2: To analyze the institutional and policy responses to growing urban water insecurity in the rapidly urbanizing cities, and the challenges and constraints in securing water.

The research questions to address this objective can be summarized as:

2 How are the responses to growing urban water insecurity organized in the study sites?
3 What challenges and limits are being faced in securing water in the study sites?
4 What elements of governance dimension are imperative in the urban water security theory and why?

1.4 Thesis Proposition

The proposition of the thesis engages with 'urban water security' and discusses literature on evolution of the meaning of water security in the urban context and its different dimensions. Although sustainable cities have urban water security as one of its goals, increasing population and urbanization have placed water resources under threat (Pradhanang & Jahan, 2021). Achieving water security is considered primarily as increasing the quantity of water and ensuring good water quality focusing mainly on infrastructural development and techno-engineering investments, while the socio-ecological aspects have not gained much attention. Ensuring equitable access to water, affordability, sustainability aspects and taking into consideration the dynamic context of urban expansion, climate and socio-economic features are precursors to achieve urban water security. In rapidly urbanizing cities, water distribution often reflects existing socio-economic inequalities, where marginalized and low-income communities face persistent challenges in accessing safe, reliable, and affordable water. Ensuring equity involves not only physical access but also affordability, quality, and reliable water supply—factors that are often unevenly distributed across urban populations due to geographic, institutional, and political factors. In the context of climate change and growing urban populations, addressing equity becomes even more urgent.

The literature also indicates that rather than the availability of water, water insecurity is due to the crisis of governance (poor governance) or the mismanagement of the available water resources (OECD, 2011; Rogers & Hall, 2003). OECD (2011) report highlights improving water governance as a prerequisite for sustainable and innovative water policies that are able to 'do better with less'. Whether water is scarce or plentiful, developed or developing countries, efficient management comes with the effective water governance (Mishra et al., 2020b). According to Rogers and Hall (2003) and Mishra et al. (2020b), the effectiveness of water governance is weakened by poor management, corruption, lack of appropriate water institutions that are non-responsive, bureaucratic inertia, insufficient capacity, along with collaboration, communication and coordination issues. These issues are more prevalent in developing countries such as Nepal. Nepal, in the federal context, has three tiers of government:

Federal, Provincial and Local level. Despite the devolution of authority by the Constitution of Nepal 2015 and Local Government Operation Act 2017 to the local level for local water management, the provisions of multiple institutions and lack of robust water planning and governance have limited the effectiveness of responses by the local government. Further, a significant gap in the policies in paper and practice is common.

The thesis presents evidence from two study sites by analyzing the changing contexts, challenges, and responses to shortages in the water management sector at different time periods. Sharing the struggle cities have gone through in their efforts to secure water, the thesis presents the limits and constraints being dealt with. In doing so, the study aims to contribute to the 'urban water security theory' drawing attention to and highlighting on governance dimension, on what key dimensions the urban water governance needs to integrate.

1.5 Overview of Dissertation

The thesis is organized into 9 chapters. In the first chapter, I introduced the context of water security not only as a global challenge but also as a topic of concern in the Nepalese context and briefly, I also introduced the importance of water institutions in managing supply and distribution of water. I further discussed the key research gaps based on the existing literature on water security to establish the value of the study. I then presented the broad research objective and research questions the study aims to focus on. Finally, I highlighted the thesis proposition and provided the dissertation overview.

It is followed by the second chapter on Literature Review. In this chapter, I presented the review of water security and urban water security literature and how the meaning of water security evolved and broadened to include different dimension. Then, I referred to wide range of literatures that encompass the impact of climate change and urbanization on water. I presented the detailed discussion covering climate, urban and water themes. I also discussed the water crisis situation and the responses in securing water at the global and national levels. Further, I referred the scholarly works to establish role of water institutions in urban water management. Then I discussed the conceptual and theoretical framework of the study.

The third chapter includes the research approach of the study and methods. I started the chapter highlighting the philosophical standpoint of the research. Then, I discussed the mixed-method research approach and further explained how it best fits to represent the cases of urban water issues. It highlights the methods of qualitative and quantitative data collection, sampling procedures, data analysis, data management and ethical considerations. This section also

provides overview of the study sites and methodological reflections gained through the research. Lastly, I highlighted the limitations of this research.

In Chapter 4, I discussed the research findings of my first research question on nature and drivers of water security in the study sites. The drivers identified are categorized and explained under different categories as socio-economic, environmental, technological, management and governance. The contribution of these drivers to the various components of water security are also discussed in this chapter.

In Chapter 5, I discussed about the institutional and policy responses undertaken in the study sites to address the issues of water insecurity. In this chapter, situating the historical context of development of institutions in the study sites, how the institutions are responding to the issue of water insecurity is detailed out. In doing so, the review of sectoral policies in urban, water and climate themes is presented to explain the context of these policies as a response. Next institutional responses include the water projects implementation and municipal responses towards securing water.

In Chapter 6, I highlighted the key challenges or constraints in securing water in the study sites. This chapter illustrated how the different initiatives towards addressing the issue of water insecurity, have been ineffective and unsustainable. In the chapter, at first, the incoherent policy responses are highlighted as constraint followed by the inadequate institutional responses amid complex governance challenges.

In Chapter 7, I discussed the key elements of 'governance' dimension of urban water security theory as an analytical contribution of the study. Referring to the literature on the water security/ urban water security and governance dimension, and the empirical evidences, this chapter has presented the key elements of governance and discussed why these elements are important in urban water security theory.

I presented the discussion of the findings in Chapter 8 in relation to the research questions. Referring to the relevant literature, the chapter first discussed the findings on identifying the key drivers of water insecurity. It further discussed the institutional responses as infrastructure focused implementation of large-scale water schemes, and sectoral policies formulation as policy responses and the associated challenges faced by the urban water systems. Further, the chapter discussed the urban water security theory detailing out the concept of city as a complex adaptive system, 'governance' dimension in urban water security theory, components of DECS framework and contribution to the 'governance' dimension of urban water security theory.

I concluded the dissertation with Chapter 9, summarizing the study. The last chapter has summarized the research findings in line with the research questions and suggested regarding managing urban water. Lastly, it has highlighted the implications of study and future direction for further research.

CHAPTER TWO: LITERATURE REVIEW

In this chapter, I present a detailed review of the existing literature on the interconnection of urbanization and climate change with water which are the key themes of the study. The chapter also discusses the themes that build upon the concept of the study on water security. The literature review formed a constant iterative part of the research and writing through review of international and national literature on water security, trends of global and national urbanization, and climate change and its impact on water resources. The chapter begins with discussing the impact of rapid urbanization on water and the impacts of climate change on water taking into account global to local impacts. As water insecurity is a growing concern worldwide, the chapter further provides a glimpse of global to national scenario of water crisis and connects the global issues to local issues of urban water. It then presents global and national responses made in water management sector. Highlighting the importance and role of institutions in managing water resources, the discussion further deals with institutional role in urban water management. Having discussed the relevant themes in sections above, the chapter discusses the conceptual and theoretical framework of the study. This section begins with clarifying the meaning of water security and what differentiates it from the general water scarcity occasionally experienced by city dwellers. It further discusses the debate on evolution of water security.

2.1 Understanding the impact of rapid urbanization on water

Water is ranked as the global risk with the single greatest potential impact on economies over the next ten years. The Global Risk Report 2023 identified ‘water shortages’ along with food, metals and mineral shortages, as severe risks over the next decade that could ignite humanitarian and ecological crisis. This is due to the risk from water wars and famines, resulting from over-exploitation of natural resources on the one hand while limited action on climate adaptation and mitigation, on the other.

A number of factors - population growth, increased urbanization, rising income levels, and climate change - all point towards the likelihood of water scarcity concerns magnifying over time. Among these, urbanization is the major factor leading to increase in population and industrial expansion. Thus, with a growing demand from urban areas and the irrigation sector, it is likely to result in increased competition for water in the future. Moreover, urbanization brings about changes in land use, increase in population and human activities demanding more water and impacting the hydrology and water quality (Heidari et al., 2021).

In many parts of the world, water systems have been unable to keep up with the rapid urbanization and the trend of urbanization will continue to increase. A study of 140 countries by Hutton and Varughese (2016)[3] found that only 68% of urban residents have access to safely managed water and another 2 billion urban residents still need access to safely managed water. Likewise, another 3.2 billion urban residents still need access to safely managed sanitation (only 26 percent have it). The issue of access to water are challenging in cities in particular as the cities are complex systems due to the dynamic interacting components the cities contain. Cities inherently concentrate high water demand within confined spaces, which pose significant strain on limitedavailable water resources near cities (McDonald et al., 2014). Cities in rapidly urbanizing and industrializing countries experience some of the world's most acute problems with flooding, access to potable water and sanitation, and pollution of waterways (McFarlance, 2010). Accelerating urbanization means that demand often outstrips the ability of local bodies and governments to provide reliable access to drinking water, sewerage and wastewater treatment (Foster, 2005).

Predictions about the growing population and rapid urbanization has hinted that majority of cities will confront challenges related to water scarcity. United Nation's World Population Prospects 2022 report indicated that the world population will grow to around 8.5 billion in 2030, and further to 9.7 billion in 2050 and 10.4 billion in 2100 (United Nations, 2022). The UN DESA (2019) report mentioned that an estimated 2.5 billion more people (two out of every three people) will be living in the cities by 2050 and highlights the need for more sustainable urban planning and public services (UN, 2019). In line with the global trend of urbanization, South Asia is also facing rapid urbanization in the last decade. It hosts over 10 million people with most populous cities of the world. UN (2018) estimated that 90% of urbanization will happen in Africa and Asia alone and the causes for this are attributed as population growth and rural to urban migration. Further, linking to water scarcity, a study by He et al. (2021) predicted the urban population of the world facing water scarcity shall double from 933 million (33%) in 2016 to 1.693–2.373 billion (35–51%) in 2050. Further, the number of large cities bearing water scarcity under at least one scenario will increase from 193 (37%) to 292 (56%).

The urbanization rate in the Hindu Kush Himalayas (HKH) region is markedly higher than the total population growth rate. Therefore, water insecurity is more pronounced in cities resulting in water crisis situation. It is very challenging for the cities in the dynamic context to maintain

[3] Most of those still without water supply and sanitation services live in informal and overcrowded parts of large cities or on the outskirts of cities—areas that are difficult to reach with a traditional piped network.

its water services in urbanizing context which is also prone to the impacts of climate change (Heidari et al., 2021). Many cities have showcased such examples of facing threat of running out of drinking water and water security has been a challenge for both developing as well as developed countries.

The water crisis of 2017-18 in Cape Town of South Africa is one of them in which the city was within days of reaching ground zero and the storage levels dropped to less than 17% (Western Cape Government, 2018). A similar ordeal was faced by Sao-Paulo, Brazil's financial capital and one of the 10 most populated cities in the world in 2015. During the water crisis in 2015 in the city, the city of over 21.7 million inhabitants had less than 20 days of water supply and police had to escort water trucks to stop looting. Likewise, other water stressed cities, to name a few are Mexico-city with water stress, pollution and leakage; water shortage and pollution issues in Cairo in Egypt, water shortage once in every decade since 1960s in Tokyo, Japan; water pollution and groundwater depletion issue in Jakarta, Indonesia, depleting access to groundwater and pollution in Beijing in China. Further, drying of borewells in Bangalore in India, devastating Millennium Drought in Melbourne, Australia for over a decade from 1997 to 2009; water shortage issues in London due to various factors, including thousands of pipe bursts as a result of climate change weakening their infrastructure, pollution in the city's water sources are additional cases. Most recently (as of 2021, July 2), China (regional capital of Zhengzhou) and Germany are suffering from deadly floods due to climate change impacts. A recent study by Kahraman et al. (2021) reveals that climate change is likely to increase in numbers of large, slow-moving storms in Europe that can linger longer in one area and deliver deluges of the kind seen in Germany and Belgium.

The above discussion clarifies that water issues are a concern worldwide and are more challenging in an urbanizing context where the water demand outstrips the supply. Hence, the rapidly urbanizing cities need to carefully devise the responses before it is too late and close to face the worse scenarios as observed in other cities of the world. As the literature shows a clear connect of urbanization and growing population to maximum water demand or has established urbanization as an important driver of growing water insecurity (Hoekstra et al., 2018; Pandey, 2020), this study has considered urbanization as an important driver of water insecurity and explores other drivers responsible for the issue, as the first research question of the study. This empirical study exploring the water issues in rapidly urbanizing cities of Nepal will add insights in devising effective solutions to address the problem of growing water insecurity.

Urbanization and its impact on water in Nepal

The highest rate of urbanization is experienced in the least developed countries. For instance, Nepal is one of the least developed countries but is one of the top ten fastest urbanizing countries in the world with the growth rate of 18.2% per year. Furthermore, Nepal is witnessing unplanned urbanization in the recent decades (Devkota et al., 2023; Raut et al., 2020), particularly the recent years (Chapagain, 2018). This sharp rise of urban population of Nepal is due to the government's political decision of annexation of rural areas into urban (Ishtiaque et al., 2017). Besides, a number of factors such as socio-economic, geographical, political, demographic factors have accelerated urbanization in the recent decades and this rate of urbanization is likely to continue in the future (Sapkota, 2022).

Such rapid urbanization has induced land use and land cover changes converting the natural ecosystem and arable lands to the built-up areas (Liu et al., 2019). A study by Rimal et al. (2018) on urbanization of Morang and Sunsari districts of Eastern Nepal that includes three large cities: Biratnagar metropolitan, Itahari sub metropolitan, and Dharan sub-metropolitan shows rapid urbanization resulting in decline of cultivated land in the future, increasing environmental degradation. The study found increase of built-up area in the region from 29.20 km^2 in 1989 to 140.10 km^2 in 2016 and is expected to cover 318 km^2 by 2036. It predicts the continuation of the trend to expand to 229.05 km^2 (8.95%) and 318.51 km^2 (12.45%) by 2026 and 2036, respectively. The study revealed the expansion of the region with annual growth rate of 9.36% during 1996-2016 with prediction of increase to 11.96% during 2016–2036. The region had population of 1.1 million in 1991 that increased to 1.5 million, in 2001 and 1.7 million in 2011 (CBS, 2014). Further, a recent analysis by Devkota et al. (2023) of 12 rapidly urbanizing Nepalese cities from 1990 to 2020 found continuous increase in built-up areas and reduced agricultural lands. The authors have highlighted the factors such as multiparty democracy, civil war, federal system, government policies change, increase in remittance economy and abandonment of agriculture as key reasons of land use and land cover changes (ibid).

Urban areas are defined dynamically with changing criteria across the countries. In Nepal, with a varied definition of urban centers during different census years 1952, 1962, 1992, it was only in l999 with the promulgation of Local Self-Governance Act, a consensus was achieved,[4] and

[4] Nepal provided a specific definition of a sahar or urban centre for the first time in 1961. The 1962 Nagar Panchayat Act provided municipal status to urban centres with a minimum population of 10,000, which was

the municipalities were divided as metropolitan city, sub-metropolitan and municipality having varying criteria for Terai and hill municipalities. These have further been updated in the Constitution of Nepal 2015 and the federal restructuring annexed the Village Development Committees (VDCs) to form urban areas as municipalities (*Nagarpalikas)* and rural as rural municipalities *(Gaupalikas)*. The restructuring of the local government with extension of municipal boundaries and addition of new urban areas or reclassification of rural into urban areas has caused growth of urban settlements (Muzzini & Aparicio, 2013). Data shows increase in municipalities from 58 in 2013 (with 17% urban population) to 217 in 2014/15 (with 40% urban population) and 293 in 2016/17 (with 66%) urban population. The recent national statistics report has compared CBS data of 2011 to 2021 that notes following the state restructuring, the population residing in urban municipalities increased from 62.93% to 66.02% while the rural municipalities population has decreased from 37.07% to 33.98% as shown in the Table 1

Table 1. Changes in demography in urban and rural areas

Units	**Administrative Units**	**Number**	**2011 2068 B.S.**			**2021 2078 B.S.**		
			Total population	**Population (%)**	**Total (%)**	**Total population**	**Population (%)**	**Total (%)**
Urban municipalities	Metropolitan city	6	23,99,457	9.12%	62.93 %	25,55,579	8.84%	66.02 %
	Sub-metropolitan city	11	15,56,513	5.93%		19,53,289	6.75%	
	Municipality	276	1,25,64,541	47.86%		1,45,88,998	50.44%	
Rural municipalities	Rural municipality	460	97,31,079	37.07%	37.07 %	98,27,614	33.98%	33.98 %
Total		**753**	**2,62,51,590**	**100%**		**2,89,25,480**	**100%**	

Source: Degree of Urbanization in Nepal, Central Bureau of Statistics, Government of Nepal Kathmandu, Nepal, January 2024, (CBS 2011, 2021)

again reduced to 9,000 in 1976, since several urban centres were excluded when the Village Development Committee (VDC) became the main unit of enumeration in the 1971 census (Singh et al., 2020).

In such a situation, the municipal water demands rise as the water users are additional due to integration as well as through rural-urban migration and natural population growth in the area. In order to meet the growing pressure on limited water resources, infrastructure development or the drinking water project implementation are the responses cities adopt. Therefore, in the rapidly urbanizing small towns of Nepal which are transforming from rural to urban, there exists mixed water management system: community managed rural supply system with intervention by large urban schemes. With the integration of nearby rural areas, water user numbers increase and the water schemes face stress to extend their water services to increasing water users. But most of the drinking water supply interventions fail to take into account the future water demand and needs. Such infrastructural responses try to bring more people under formal water supply systems and tend to opt for alternative water sources, even from distant sources when there is no possibility of sources at proximity (Singh et al., 2020). Tapping water from distant sources are challenging for cities as this immediate response in dealing with water stress are costly. The sources nearby may face terrain difficulty in the hilly region. Water is extracted from the sources more than its capacity to meet the water demand and in many urban areas of Nepal, poor management of wastewater is also a concern. Overall, such large-scale water schemes in developing countries are highly vulnerable to uncertainties owing to the economic constraints, political uncertainty, weak institutional settings and social unrest leading to social movements (Domènech et al., 2013).

In this context, it will be interesting to explore water management in rapidly urbanizing cities and their responses for achieving sustainable water management, which is the second research question of the study, as indicated in the introduction chapter.

2.2 Unravelling climate change impact on water

Water scarcity is being intensified not only by the impacts of urbanization, but also due to climate change impacts jointly in the cities of the world (He et al., 2021). Climate change is widely recognized as one of the key environmental challenges of the 21st century, and it is emerging as one of the major determinants of water security (Link et al., 2016; Turral et al., 2011). Globally, water resource availability will be altered by changed rainfall patterns and increased rates of evaporation. Changing climate patterns globally are affecting rainfall distribution, increasing water demand and challenging the ability to capture, store and manage water resources. The future impacts of climate change lead to high spring runoff, water related disasters as GLOFs and flood risks, followed by extremely low summer runoff (Diffenbaugh

et al., 2013). As response to combat climate change impacts, countries around the world have made efforts since early 1990s and the negotiations have produced important agreements, as Montreal Protocol in 1987, UN Framework Convention on Climate Change (UNFCCC) 1992, the Kyoto Protocol 2005, and the Paris Agreement 2015. However, there is a growing concern from the scientists and activist that the commitments made under global agreements are not ambitious and Paris Agreement is not enough (Maizland, 2023).

Data from Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report from 1880 to 2012 show a linear trend of warning of 0.85°C (± 0.20) global average combined surface temperature (Stocker, 2014). Further, Pachauri et al. (2014) predicted the increase of global mean surface temperature to range from 1.5 to 4°C by 2020 with greater occurrence of heatwaves, droughts, floods, hail, storms, cyclones and wildfires, intensified melting of glaciers and other ice, sea level increases and soil erosion. Further, the recent IPCC report 2023 noted the global surface temperature was 1.09°C higher in 2011-2020 than 1850-1900, with higher increase over land (1.59°C) than over the ocean (0.88°C) (IPCC, 2023).

Water availability impact due to reductions in river runoff and aquifer recharge was predicted in the Mediterranean basin and the semi-arid areas of the Americas, Australia and southern Africa. While in Asia, snowmelt and high mountain glaciers impact was noted (Turral et al., 2011). Climate change is expected to intensify water stress in South Asia by increasing variability in rainfall, river flows and groundwater recharge rates. According to the IPCC, more than one billion people in Asia alone are projected to experience negative impacts of water resources by 2050 as a result of climate change. One of the most significant effects of climate change in South Asia is likely to be the increased frequency of extreme weather events. The region constantly experiences flood, but climate change is expected to alter the variability of rainfall and river flows that lead to them.

The Himalayan region is facing high climate variability, with annual average precipitation and temperatures increasing in many areas, and hence the region is facing acute water insecurity (Scott et al., 2019b). Studies suggest the maximum temperature in Nepal increased at a rate of 0.1 °C /decade on average between 1975 and 2010 (Shrestha et al., 2017) and the precipitation was found increasing and heavy during 1961-2006 (Baidya et al., 2008). Both the average annual mean temperature and precipitation are projected to increase by 11–23% and 1.7–3.6 °C by 2100 respectively, and are expected to affect different developmental sectors, such as

water, disaster management, energy, biodiversity, agriculture, health, urban planning and livelihoods (MoFE, 2019).

While population changes and economic development are lexpected to be the primary drivers affecting on water supply-demand balance in the early 21st century (Vörösmarty et al., 2000), additional impacts of climate change are predicted to undermine the ability of many existing urban water supply systems to meet the present and future water needs (Gosling & Arnell, 2016). Climate change impacts on water level, weather patterns and their severity, ground water, and agricultural production, are all predicted to create negative consequences, as the world adapts and faces human-induced global climate impacts (Turra et al., 2011; Link et al., 2016; Hendrix and Salehyan, 2012).

The impact of climate change will compound water problems as it is likely to lead to increased variability in water supplies, as well as more frequent severe weather events causing floods and droughts in many countries. Climate change impacts on water demand, water resource management as well as water supply. It has biophysical as well as socio-economic impacts. Changes in evapo-transpiration and precipitation due to change in climate parameters will affect the amount and distribution, spatially or temporarily or surface runoff. Climate change can affect the water quality aspect (Delpla et al., 2009) of the water management in three ways. First, reduced hydrologic resources may leave less dilution flow in the stream, leading to degraded water quality or increased investments in wastewater treatment. Second, higher temperatures reduce the dissolved oxygen content in water bodies. Third, in response to climate change, water uses, especially those for agriculture, may increase the concentration of pollution being released to the streams. Together, these pose a threat to the water quality and the integrity of the aquatic ecosystem.

Climate variability can affect the surface water resources that are already bearing significant challenges of depletion due to increasing water demand coupled with inadequate conservation and unsustainable land management practices (Bhaga et al., 2020). Further, climate change will increase the demand for clean drinking water, while adversely affecting supply and creating additional water stress. The groundwater supply will be affected by increased or decreased percolation of water due to changes in the amount and distribution of precipitation and stream-flow. This can lead to increased pumping costs if percolation decreases because of decreased precipitation or losses of soil moisture from increased evapo-transpiration. Increasing climate variability and change is already intensifying water-related threats and will continue to do so

in the future as water availability becomes less predictable, and as extreme weather events become more common (Schiermeier, 2014).

Himalayan cities are particularly at risk from climate change and delaying action to adapt will be much more costly in the long term than immediate action (EEA, 2012). The high impacts of changing climate are observed in several sectors of Nepal, among which water resources is one of the most strongly influenced sectors (WECS, 2011). The situation is more complex in the developing countries as rapid urbanization faces lack of resources, insufficient infrastructure, and often changes in social and political structures (Freire, 2006). The impact of climate change is set to escalate the water insecurity in many parts of Nepal (Dahal et al., 2019). Climate change issues that impact on the quotidian existence of many poorer people until recently have been overlooked (Mac Manus et. al., 2021). Further, poor water quality led to 270 preventable deaths attributed to waterborne diseases in Nepal, as per the 2017 report of Department of Health Service of Nepal.

Given the impacts of climate change on water resources, this study has taken climate change as the context, or one of the drivers affecting water security. Particularly in the context of Himalayas bearing high impacts of climate, this study explores how climate has affected water security of the cities and whether the responses have considered the risk of climate impacts. This links to the first research question on identifying the drivers of water security.

2.3 Overview of water crisis at the global and national levels

Water crises are among the greatest challenges the world is facing (WEF, 2017). It has been reported that 80% of the world's population is exposed to high level of water security risk, with consumptive water use being one of the strongest stressors (Vorosmarty et al., 2010). More recent data shows that over 2 billion people are living in highly water stressed areas which is expected to increase in the future (Tzanakakis et al., 2020). About 47 percent of the global population (about 3.6 billion) experience severe water stress for at least 1 month each year, likely to worsen in next few decades, according to United Nations (UN) World Water Development Report (WWDR) (UN, 2018). Additionally, recent predictions from Boretti & Rosa (2019) claim that this data is underestimated and that the estimation made by Mekonnen & Hoekstra (2016) could be even larger, reaching 52 percent of the global population (4 billion), especially in developing countries.

HKH are the freshwater towers of South Asia and parts of Southeast Asia. Water originating from their snow, glaciers and rainfall feed the ten largest river systems in Asia. Together these

rivers support the drinking water, irrigation, energy, industry and sanitation needs of 1.3 billion people living in the mountains and downstream (HEMS, 2015). With increasing population and dependence on water for various needs including energy and food demands, the stress on Asia's water resources is rapidly intensifying. Large-scale urbanization, an increasing demand for agricultural products due to a rising population, poor water management and the insufficient maintenance of water conveyance infrastructure are largely responsible for increasing water insecurity in South Asia (Walsh, 2017). With a three-fold increase in human population since 1950, South Asia's per capita water availability has reduced to one fifth of what it was 60 years ago. One out of five people (700 million) are deprived of access to safe drinking water and half of the region's population (1.8 billion people) lack access to basic sanitation.

The water and sanitation crisis in South Asia demonstrates deeply rooted issues of inequity and unequal power relationships in this part of the world, with marginalized people being affected with the water crisis the most. In South Asia, as much as 43 percent of the population live in absolute poverty, compared to 14 percent in East Asia (excluding China), 24 percent in Latin America and 39 percent in sub-Saharan Africa. Depleting ground water, pollution of surface water, and source sustainability and security are the major future challenges in fulfilling the right to water in this region (Gupta, 2015). Changing rainfall patterns due to climate change impact the groundwater stores that is already overstressed due to its heavy extraction.

The world's highest mountainous region, which includes Nepal, are known for idioms as "the Water Tower of Asia" (Singh et al., 2020) and the "third pole" due to its largest snow and ice store in the world (Wester et al., 2019). This recognizes Nepal as one of the richest countries in per capita renewable water availability in Asia, with more than 2.27 percent of the world's water resources (HEMS, 2015). However, it is the most water insecure countries in the region (Wang et al., 2019). It is ranked fourth most water stressed in South Asia region after India, Pakistan and Afghanistan (WRI, 2019)[2]. Nepal's poorly developed drinking water system places it in the top five countries in the world (McPhillips, 2017). Lautze and Manthrithilake (2012) classification of overall water security in Nepal as 'good' may be reflective of current water availability, but much progress is required from a human perspective to utilize water effectively to meet basic needs, secure food production, manage risk and promote independence.

Increasing populations combined with a changing climate and environmental degradation is increasing the vulnerability of communities to water-induced hazards (e.g., landslides; river and glacier outburst floods) (Dixit et al., 2009). The water crisis situation has worsened in the

cities especially during the dry period. In terms of water quality, combined with improperly treated municipality-provided water, a large proportion of Nepal's water supply is classified as unsafe for human consumption (Upreti, 2017). Moreover, gender divide regarding decision-making processes for water management remains prevalent in Nepal. Further, caste-based discrimination though legally abolished,[5] still imposes a hierarchical system for accessing water and in water related decision-making and governance (Bhattarai et al, 2021; Shrestha et al., 2022). Further, Nepal lacks enough strategy to promote sustainable water practice in Nepal and is facing continual disruption to policy by constantly shifting government regimes in Nepal. In such situation, practicing the fundamental human right of water enshrined in Constitution of Nepal 2015 continues to remain a major development challenge in the country.

While the different issues regarding access and distribution, quality, institutional and policy issues, gender and social inclusion in water governance have been discussed in global and national literature, such issues in the context of interconnected challenges of climate change and rapid urbanization have been least explored, particularly in the small to mid-sized cities of Nepal. This study focuses on institutional and policy issues which has also been highlighted as an area requiring further research. This has been elaborated in the research gaps of chapter 1, based on which the research questions are framed.

2.4 Global and national responses in the water management sector

Sustainable water management, goal no. 6 of Sustainable Development Goals (SDG) is a key precursor to achieve many of the other SDG goals: 17 SDGs and over one third of all 169 targets explicitly and indirectly. While the Millennium Development Goal 7 (target 7.3) focused on improving access to safe drinking water supply and sanitation services, the Sustainable Development Goals signified a paradigm shift. SDG Goal 6 (clean water and sanitation) proposed a more holistic approach, by targeting universal access to water supply and sanitation ('Ensure availability and sustainable management of water and sanitation for all'). The goal extends beyond drinking water supply and sanitation (targets 6.1 and 6.2) to encompass water quality and wastewater (target 6.3), water use and efficiency (target 6.4), Integrated Water Resource Management- IWRM (target 6.5), ecosystems (target 6.6), and enabling environment (targets 6.a and 6.b). Further, Agenda 2030 has water at its core, with a

[5] The caste system, which has its roots in the ancient religious texts, codes and traditions derived from them, was formalized by the 1854 Civil Code. Although it was legally abolished by an amendment of the old Civil Code in 1963, the caste system, including untouchability, is still practiced in the Nepali society (ILO, 2005).

dedicated Goal 6 on water and clear linkages to Goals relating to climate change, resiliency to disasters and ecosystems, as well as water supply and sanitation, water quality and wastewater management, food and energy production, city development, and gender among others. Goal 13 of SDGs calls for urgent action not only to combat climate change and its impacts, but also to build resilience in responding to climate-related hazards and natural disasters. Another landmark global agreement is the Paris Agreement on Climate Change that deal with the water insecurity issue. Wise water management is stated as one of the keys to fulfil the goals set in the Paris Agreement. To achieve the set targets, water security has emerged as a protruding issue among water and development communities globally. The context of escalating water demand brought about by rapid urbanization and population pressures and climate change impacts (linked to goal 11 and 13), water and sanitation crisis extends beyond physical availability. Water is directly embedded within the 'New Urban Agenda' adopted by the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) held in Quito, Ecuador in 2016.

In accordance to global SDG, Nepal has set targets to achieve by 2030. As efforts towards achieving SDG, Nepal government is making investment in water related policies, infrastructure developments and institutions. The government has set a national target of basic water supply coverage to 99 percent of households, and piped water supply and improved sanitation to at least 90 and 95 percent of households respectively by 2030 (NPC, 2018).[6]

The Constitution of Nepal 2015 has acknowledged right to access water as a fundamental right of citizens and prioritized water supply and sanitation services (GoN, 2015). Article 35(4) ensures the citizens' right to access to clean water and hygiene and Article 30(1) ensures the right of the citizen to live in a clean and healthy environment while Article 30(2) discusses the right to obtain compensation to the victim, in accordance with law, for any injury caused from environmental pollution or degradation. Some recent initiatives have incorporated the services as in current periodic plan of Nepal (2019-24). More recently, National Water Supply and Sanitation Policy (N-WASH Policy 2023) has been approved. There have also been multiple initiatives of formulating water related legislations. The recent updates of Water and Energy Commission Secretariat (WECS, 2020) show 18 Acts, 10 Regulations and three Treaties related to water with mandatory provisions. And six Formation Orders, four Plan and Policies, two Strategy and Guidelines, and one Bilateral Minutes have been prepared that facilitate the

[6] 87 percent of the population had access to basic water supply services in 2015 with less than half (49.5 percent) of the households having access to piped water supply. Sanitation coverage reached 82 percent (NPC, 2018).

mandatory activities. However, the responses have not been enough to equipoise the challenges created by a dramatic shift in urban driven demands (MoUD, 2016).

Moreover, the raft of sectoral policies on urban, water and climate lack sufficient focus on urban water and effective interlinkages while the ground scenario of implementation of the policies at place is not encouraging and is subjected to multitude of constraints (Maskey et al., 2020). For instance, lack of good governance and institutional capacity, shifting government regimes in Nepal are limiting the implementation of strategy to promote sustainable water practices and managing water resources effectively and efficiently (Biggs et al., 2013). Moreover, gender divide regarding decision-making processes for water management remains prevalent in Nepal.

As responses to address the growing urban challenges, large-scale centralized water supply schemes are being implemented (Leigh & Lee, 2019). One of the prominent projects targeted to Kathmandu Valley since 2000 has been the inter-basin water transfer projects, Melamchi Water Supply Project (MWSP)[7]. The major challenge in these larger schemes can be attributed to operational efficiency, cultural compatibility, and sustainability (Ojha et al., 2020). The authors emphasize the significance of small scale and locally managed schemes as they offer greater resilience in water supply systems mainly during the times of disasters.

In regard to the responses to deal with water security concern, as explained above, Nepal has committed to universal water access internationally and has set important targets. However, previous studies have not explored what constraints are the rapidly emerging cities facing to meet such targets of supplying water and sanitation to all its citizens and sustainably managing water, particularly on institutional and policy fronts. This study thus explores the factors responsible for causing water insecurity as well as the challenges faced to address the problem of water insecurity (research questions 2 and 3).

2.5 Role of institutions in urban water management

Water is not just a natural resource; it is also a political resource (Joy et al., 2014). World's water crisis is primarily driven by poor governance (Rogers & Hall, 2003). In the water sector, governance includes institutions, organizations, policies, and practices, which shape and

[7] The project aims to bring water to the Kathmandu Valley (KV) from water sources outside the valley. MWSP plans to supply 510 million liters a day (MLD) of water in two phases: 170 MLD in the first phase by the year 2018, and an additional 340 MLD in the second phase by the year 2023 (FAO. 2012).

manage water resources, including the delivery of water services for diverse populations and industries. Literature has noted water governance as the key to solving the water insecurity problem with the role of water institutions as vital for effective and sustainable water management. As cities in developing world are growing much more rapidly and are expected to continue experiencing the stress of limited resources as water, establishment of institutional structure that represents the constitutive parts of the growing city and at the same time, generate adequate authority to govern effectively is of utmost importance (Freire, 2006).

The role of institutions towards securing water is recognized by the fact that water scarcity is beyond the physical scarcity, much more than hydrological phenomenon encompassing its economic and institutional causes (Garrido & Shechter, 2014). Water scarcity can arise in close juxtaposition with plenty of water, where there is no legal or institutional arrangement in place to improve access, or if the required infrastructure does not exist or is not functional (FAO, 2012). In the water resource sector, technology, economics and institutions interact to make water supply to meet water demand. The institutional capacity to provide the necessary water services is among the three main dimensions characterizing water scarcity (FAO, 2012)[8]. In other words, the inability of the institutions in managing water issues are considered responsible for lack of people's access to safe and secure water, not due to the quantity of water available on the earth (Shrestha, 2009). And many causes of scarcity can be predicted, avoided and/or mitigated if identified correctly (FAO, 2012).

The institutional gap leading to water crisis in most countries is viewed essentially as a "crisis of governance" (GWP 2000; Saleth and Dinar, 2004) where good governance is criteria to water security, not limited to having good water system status and fulfilment of various water system functions (Bakker & Morinville, 2013). Poor management of water is noted as one of the causes for water scarcity along with overuse of water and natural factors as droughts (Padowski et al., 2016; Rijsberman, 2006). Jensen (2019) has noted that the major problem in the water sector policy design in both developed and developing countries is how to allow or encourage regulation to adapt to new issues and priorities while keeping down regulatory risk and the associated cost of capital. The challenge to water institutions is higher now than in the past because the demand, supply and technological change in water sector was at slow rate than in other sectors but in the present scenario, the rapid scale of urbanization, climate change and

[8] main dimensions that characterize water scarcity are: a physical lack of water availability to satisfy demand; the level of infrastructure development that controls storage, distribution and access; and the institutional capacity to provide the necessary water services.

technological advancements are at greater scale. The elements of adaptive policy making as defining triggers for policy review and institutionalizing learning need to be incorporated into economic regulation in water sector (Jensen, 2019).

Therefore, robust and adaptive institutions are considered key for achieving water security along with infrastructure and information and capacity to predict, plan for and cope with climate related uncertainties (Sadoff and Muller, 2009). The ability of the institution to adapt and respond to the changing socioeconomic, political and cultural challenges determine the performance of the institutions and is not limited to the embedded design criteria (Ananda et al., 2006). Researches have suggested the need to improve the institutional arrangements and governance (Rijke et al., 2013; Van de et al., 2011) and public participation in decision making (Gober, 2018) for achieving urban water security. There are instances that development of infrastructure and institutions have helped in overcoming urban water insecurity in large cities (Padowski et al., 2016).

However, the institutional arrangements observed in the water sector of most countries, especially developing countries, remain inappropriate and ineffective in solving their water problems. Many water managing institutions have been often not well-suited to deal in solving the water related issues effectively (Regmi et al., 2013). Furthermore, knowledge about how existing water resource institutions might be modified and improved is scarce, as is information on the effectiveness or the ineffectiveness of different institutional prescriptions towards more adaptive governance (Huitema et al., 2009). For addressing issues related to institutional challenges in managing water (Kiparsky et al., 2013), a comprehensive understanding of how urban water is managed is required which is found missing from large scale availability analyses (Padowski et al., 2016).

Moreover, multiple, fragmented, top-down institutional arrangements in water governance pose a challenge for effective, equitable, and decentralized water planning and management (Pandey & Bajracharya, 2017). Institutional framework of urban water systems is often fragmented, while multiple institutions are responsible for water management and ambiguity exists in the distribution of roles on water management among the three levels of governments. Most urban water systems are excessively centralized and depend heavily on public funding. Outdated management practices and limited human capacities are additional causes of inefficient urban water management. Although water security is gaining attention in recent times, government's action lacks quick response for sustainable growth and progress of water, as a strategic resource (Sadoff and Muller, 2009). The urban actors are challenged to find

opportunities for innovative and transformative actions and responses to water insecurity caused by interaction between urbanization and environmental change (Romero-Lankao & Gnatz, 2016).

One of the reasons for Nepal's struggle in securing water despite availability of water resource can be linked to lack of good governance in water resources to manage its water effectively and efficiently. Further, a mix of political, institutional and capacity barriers to manage water resources have prevented the effective implementation of existing strong water laws and strategies on paper (Grumbine et al., 2015). It has limited strategy to promote sustainable water practice (Biggs et al., 2013). The gap in knowledge and limited capacity of the city governments in urban water management have also been noted (Jha & Shrestha, 2013). Gap between scientific information and policy making, lack of connections between defacto and dejure water management, conflicting policies, laws and rules, lack of clarity in roles and responsibilities of various agencies and staff are identified as some constraints in good water governance. Studies also show that the existing water and urban development policies and frameworks in Nepal are fragmented and ineffective to deal with the issues of climate change as they have not been able to consider changing climate to plan resilient and sustainable cities (Biggs et al., 2013; Pandey & Bajracharya, 2017).

The above discussion clarifies the importance of institutions in urban water management and has also highlighted some of the policy and institutional challenges the urban water institutions are facing, particularly the complexity in governance in presence of multiple institutions. In this context, insights from exploring how these cities are operating water management and what constraints and challenges they have been facing would be helpful to devise solutions for making rapidly emerging cities water-secure. These issues are addressed through the second and third research questions on institutional and policy responses and the constraints the water institutions are facing in the journey of water security.

2.6 Review of water security debate

In this section, I introduce the water security debate, firstly by discussing water scarcity and security, then evolution and broadening of the meaning of water security and linking its meaning in the urban context.

2.6.1 Water scarcity and security

Water is life and, therefore, a vital resource for communities to thrive. It connects across spheres of society, economy, culture, environment, politics and spirituality (Sultana, 2021). We

find the use of terms stress, shortage and scarcity to describe the gap between water demand and availability which are respectively related to: accessibility problems, population-to-volume ratio, and whatever reason (scarcity is a general term) (Rockstrom et al., 2009). Scarcity is based on the idea that resources (means) are limited whereas wants and desires (ends) are not (Fine, 2010). Water scarcity refers to the volumetric abundance or lack thereof of water supply calculated as a ratio of human water consumption to available water supply in a given area, which can be a reason for water stress. Water shortage also refers to the same meaning but is usually used to refer to a temporary or relative volumetric shortage of water. Water Risk refers to the probability that an entity may face water stress in the future.

Reduced amount of water per se does not qualify as water insecurity. Although scarcity and security have a strong bond, scarcity is not the only factor determining security (Beck & Walker, 2013). Security refers to safe, reliable and stable condition. Hence, water security refers to the acceptable levels of water related risks while balancing support for livelihood, human well-being, socio-economic development, and ecosystem functioning (Cook & Bakker, 2012; Grey & Sadoff, 2007). So, the level and extent of water security (or insecurity) is characterized by interactions between societal needs, ecosystem functioning and hydro-climatic conditions (Scott et al., 2013). The concept of security would be applicable to water when it is perceived by the people as an existential threat, in terms of societal, ecological or political concerns. According to Pahl-Wostl et al. (2016), use of word 'security' conveys the notion of urgency of water crisis at global to local levels and will instigate urgent actions.

At the same time, water insecurity often exists on a spectrum. While water insecurity can impact everyone to some extent, inequalities ensure that some remain relatively more secure than others. While some communities or individuals may face water insecurity, others may enjoy consistent access. This disparity is shaped by factors like geography, socio-economic status and political power and networks. Understanding of water security as relative can help policymakers and stakeholders better design interventions to address the needs of the most vulnerable populations. Compounding water insecurity impacts for certain groups requires recognizing systemic barriers—such as informal settlers, limited voice in decision-making, or exclusion from infrastructure planning. Equitable water governance must therefore go beyond access, ensuring that marginalized voices are meaningfully included in decisions shaping water policies and investments. Below, I discuss how the meaning of the term 'water security' has evolved; what components do the term 'water security' refer to and how it differs from urban water security. In doing so, I discuss the specificities an urban area bears with added stressors

of rapid urban development, growing population and impacts of climate change in securing water.

2.6.2 Evolution and broadening of 'water security'

Review of water security literature shows that the use of the term 'water security' emerged in the 1990s. It has received increased attention over the past decade, in both policy and academic debates (Cook & Bakker, 2012) and the use of the term has increased significantly in the past decade across multiple disciplines. It is seen to be rapidly evolving from a vision to a development imperative (van Beek & Arriens, 2013). Literature indicates that approaches to water security are diverse and evolving that cannot be easily reconciled (Cook & Bakker, 2012; Lankford et al., 2013; Srinivasan et al., 2017). An array of literature discusses that water security has no universal definition (Grey and Sadoff, 2007; Bakker, 2012, Bogardi et al., 2012; Cook and Bakker, 2012; Allan et al., 2013; Grey et al., 2013; Pahl-Wostl et al., 2013; Gain et al., 2016).

Reviewing the roots of development of the term water security, the literature reveals that the language has been changing, from integrated to sustainable and ultimately to the new terminology of water security (Hoekstra et al., 2018) (refer to Figure 1). Still, the use of other terms that are popular as adaptive water management and more recently such as water risk, water resilience, water proof, and the water-food-energy nexus (Hoekstra et al., 2018). Review shows that the term has been modified, indicated as fashionable by Hoekstra et al. (2018). Lautze and Manthrithilake (2012) described water security as the 'old wine in a new bottle' owing to its flexibility in fitting in the current time spirit with its focus on all sorts of security issues. In this context, Zeitoun et al. (2013) suggest that we should 'refrain from seeking a perfect singular definition of water security'. These different terms are in use; however, all terms imply the same goal of securing water. The modification has been influenced by particular global events/issues with addition or focus on particular components or dimensions. The meaning of the term water security was broadened recognizing complex nature of water resource management intertwined with development and social sectors (Biswas, 2004; Falkenmark, 2001). However, the term emerged from the need to balance people's needs with conserving water resources, and is reflected in SDG goal no. 6.

The concept of integrated water resource management[9] emerged mid-way through the 1980s considering the need to take into account holistic approach in water management. With the publication of Brundtland report, sustainable water resource management became popular from around 1990 that led to the emergence of the term 'water security' from 1990s and it gained popularity from 2000. The uptake of the term was due to the influence of publications of World Water Council and Global Water Partnership (Water Secure World by WWC in 2000 and Towards Water Security: A Framework for Action by GWP in 2000). Only in 2010, with the increasing impacts of climate change on water resource, the concept of adaptive water management gained popularity realizing the need of climate change adaptation.

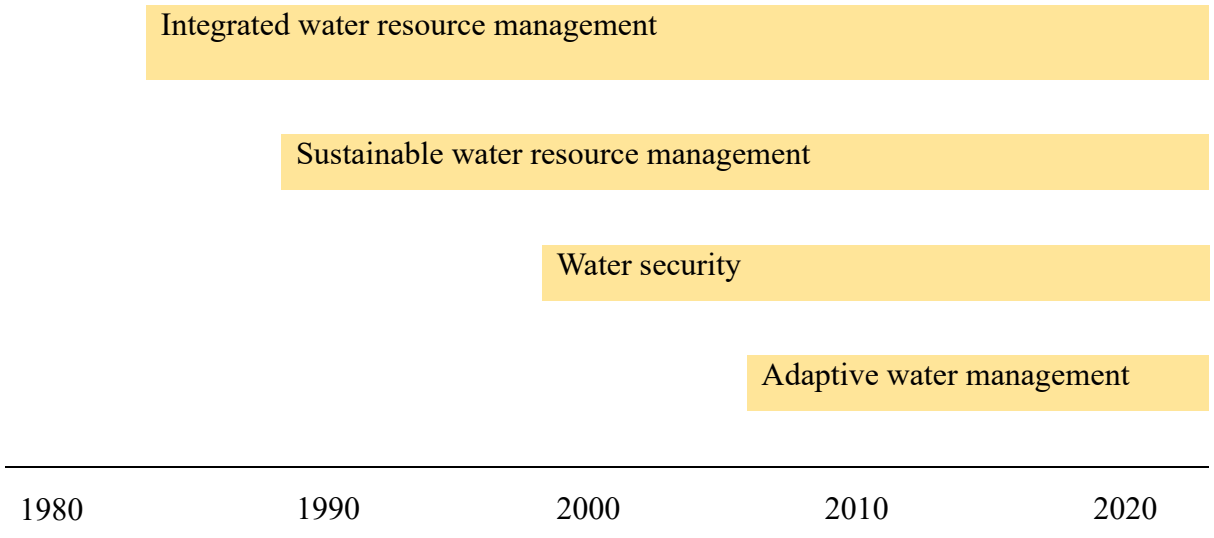

Figure 1. Emergence of new water management concepts over time.
Source: Hoekstra et al., 2018

Review of the advancement of water security finds that since its emergence in 1990, its dimensions have broadened to incorporate several themes. Initially, the term was used more by natural scientists and engineers and not by social scientists (Pahl-Wostl et al., 2016). During its evolvement, water security was linked to specific human security issues as military security, food security and (more rarely) environmental security. Water entered the domain of security studies when it reached a threshold, affecting people's lives, threatening political security of the country and sparking conflicts between countries (Thapliyal, 2011). Water entered the security discourse with the inclusion of 'environmental security' by Myres (1993) which along with the economic security, widened the security discourse from only military studies. It was only in 2000, the environmental value and sustainability issues were incorporated when Global

[9] Integrated urban water management (IUWM) is a comprehensive mitigation strategy to control water deficit due to simultaneous effects of reduction in water resources capacity and increase in water demand.

Water Partnership introduced an integrative definition of water security at the Second World Forum in 2000 that incorporated access and affordability of water, human needs and ecological dimensions.

Hence the term was widened to include environmental, economic and social issues as well as security in other sectors as food security (since 1960s), energy security (since 1970s) and health security (1980s) and was incorporated into the concept of the water, energy and food security nexus (since 2009). The interdisciplinary water-energy-food was introduced in FAO definition (FAO, 2014). Nexus based approach was highlighted to be important for effective water management and governance (Biggs et al., 2013; Nepal et al., 2021) and can be helpful in exploring the water use interlinkages across sectors (Rakhmatullaev et al., 2017). Nepal et al. (2021) focused on nexus approach to identify pathways to water security, by investigating linkages to water security in different water use sectors. They also suggest that Integrated Water Resource Management (IWRM) and Integrated River Basin Management (IRBM) approaches need to be broadened.

With the broadening of the water security understanding, risk perspective or destructive quality of water was introduced by Grey and Sadoff (2007) (refer to Figure 2). The focus earlier was limited to scarcity dimension. This was further referred by multiple organizations and scholars such as Beck & Walker (2013), Grey et al. (2013), Hall & Borgomeo (2013) and Mason & Calow (2012). More recently, Aboelnga et al. (2019) and other scholars mention that approaching water security with a risk perspective is more realistic (Damania et al., 2019; Garrick & Hall, 2014; Grey et al., 2013).

Water:		**'Water security'**
Both productive and destructive A source of production, health, growth and cooperation, and .. A source of destruction, poverty and dispute		Availability of acceptable quantity & quality of water for health, livelihoods, ecosystems & production and .. Acceptable level of water-related risks to people, environments & economies

Figure 2. Defining water security: water as a source of production and destruction
Source: Grey and Sadoff (2007)

Debate over water security explains the tensions between broad and narrow operational framings of water security (Lautze & Manthrithilake, 2012). A broad, integrative framing of water security is recognized to emphasize the governance issues unlike the narrow and discipline-specific approaches (Cook and Bakker, 2012). Water security bears multi-

disciplines, theoretical inclinations, institutional agendas among other factors (Gerlak et al., 2018) but most studies on water security have referred to the narrow framing of water supply security (Octavianti & Staddon, 2021). Some of them include broad framing resembling the scope of IWRM by GWP 2000, broad and integrative understanding by Organization for Economic Co-operation and Development (OECD, 2013; Ginkel et al., 2018; Cook and Bakker, 2012; Zeitoun et al., 2016) incorporating too much, too little and too dirty water.

The narrow approach focuses on 'risk' by Garrick and Hall (2014), Grey et al. (2013), UN-Water (2013), Hall and Borgomeo (2013) and OECD (2013) with accepted level of water risk or absence of intolerable risk. On the other hand, the narrow framing limits water security as matching water demand and supply (Brears, 2017; Chang et al., 2015). Beside framings, the academic debate also notes tension between developed versus developing country perspectives (Grey & Connors, 2009), engineering/natural science versus social science framings and corresponding preferred solutions to dealing with challenge of water security (Bakker, 2012; Pahl-Wostl et al., 2011). While diversity in understanding water security is encompassing to give interdisciplinary perspective and adopt integrated approach, scholars also warn that plural approaches of water security might also pose challenge in achieving sustainable solutions (Pahl-Wostl et al., 2016).

Further, since the evolution of the term 'water security' over the past three decades (see Table 2), the focus has been incongruent, in multiple dimensions, and differing from discipline to discipline, from area to area, and from theme to theme (Gain et al., 2016). Romero-Lankao & Gnatz (2016) discuss the focus of scholars as targeting specific issues of scarcity and stress (Falkenmark, 2013), water supply systems security (Paton et al., 2014), instability, or conflict and national security (Hendrix & Salehyan, 2012) while others (associated with World Water Forum) focus on integrated approaches incorporating issues of access (GWP, 2000, Rijsberman, 2006; Gain et al., 2016), affordability, human need and ecosystem wellbeing (Cook and Bakker, 2012). Academic scholars have mostly referred to broader meaning of water security drawn from similar themes as of GWP (Cook & Bakker, 2012), for instance, human and ecosystem needs, accessibility, continuity, and affordability (de Loë et al., 2007; Dunn & Bakker, 2009; Norman et al., 2010; Swaminathan, 2001).

Cook and Bakker (2012) capture the four main dominating themes of water security in the literature: water stress and availability, vulnerability to hazards, human development needs with focus on food security, and sustainability. The first three can be understood through a risk lens (Hall & Borgomeo, 2013) while the last is a broad catch-all for a range of different issues.

Among these variable ideas, the common factors include quantity, quality and human health, availability, accessibility, affordability, safety and stability (Hoff, 2011; Bizikova et al., 2013). Gain et al. (2016) refer to these ideas and explain 'water security; as 'the conditions in which a sufficient quantity of water resources is available and accessible in adequate quality.' In the study by Gain et al. (2016), the term 'security' is conceptualized as a function of 'availability', 'accessibility to services', 'safety and quality', and 'management'. More recently, different components of water security by researchers include basic needs, agricultural production, environmental flows, risk management (Lautze & Manthrithilake, 2012), household, economic, urban, environmental, and resilience to water-related disaster (Lohani & Ait-Kadi, 2013).

Table 2. Themes of water security

Broader themes	**Defining Water security**	**Literature**
Human centric approach	• During 1990s, water security was considered as being human centric, linked to specific human security issues as military security, food security and (more rarely) environmental security.	Cook and Bakker (2012)
Environmental and social aspects	• Myers (1993) brought the water discourse within the fold of human security. Water entered security discourse with environmental security. • GWP, 2000 (Global water partnership) incorporated ecological dimensions: "Water security at any level from the household to the global means that every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced.'' • Swaminathan (2001) described water security involving the availability of water	GWP (2000), Swaminathan (2001), de Loe¨ et al. (2007), Jansky et al. (2008), Thapliyal, S. (2011), UN (2013), Dunn and Bakker (2009), Norman et al. (2010), Falkenmark (2001), Biswas (2004), Rijsberman (2006), Cook and Bakker (2012)

	in adequate quantity and quality in perpetuity to meet domestic, agricultural, industrial and ecosystem needs. • de Loe¨ et al. (2007) explains water security as ‘‘a multi-dimensional concept that recognizes that sufficient good quality water is needed for social, economic and cultural uses while, at the same time, adequate water is required to sustain and enhance important ecosystem functions’’ • Jansky et al. (2008) defined water security as “All aspects of human security pertaining to the use and management of water” • Dunn and Bakker (2009) and Norman et al. (2010) define water security as ‘‘sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health’’ • Falkenmark (2001), Biswas (2004) broadened recognizing complex nature of water resource management intertwined with development and social sectors. • GWP (2000) and Rijsberman (2006) concept of water security echo Sen’s concern with ‘access’ and both are ‘person-centric’	
Production and Risks Dimension	• Grey and Sadoff (2007) focused both production and risk perspective. The authors incorporated the risk perspective of water security- too much and too little water as “Water security refers to the	Grey and Sadoff, (2007), Grey et al. (2013), UNESCO-IHE (2009)

	availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies" • Grey et al. (2013) focused on risk perspective, "water security is a tolerable level of water-related risk to society." • UNESCO-IHE, Institute for Water Education (2009) advocates infrastructure and systems approach to water security involving protection from water related disasters. • UN (2013) defines water security as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability balancing the needs for water management related to socio-economic development, health, disasters and ecosystems."	
Nexus Approach (Water-Energy-Food)	• FAO linked water security to food security, in which water security was the ability to provide adequate and reliable water supplies for populations living in the world's drier areas to meet agricultural production needs.	FAO (2014)

	• It is now recognized that water security cannot be treated as a stand-alone issue. Attention is turning to the water-energy-food (WEF) nexus (FAO, 2014).	
Critics	• *Critics of GWP (2000) approach to water security:* Van Hofwegen (2009) criticized GWP definition for focusing only on individual water users in an environmental context, without considering other uses as agriculture and industries. • *Critics of Grey and Sadoff (2007):* Critics of Grey have problem in the use of word 'acceptable' twice, on the two sides of the exposure to insecurity- either too little or too much water; acceptable to whom. Further, framing of water security by Grey and Sadoff (2007) is defined in narrow terms limited to the water resources themselves, while water security requires a broader approach including political and socio-economic factors related to river's freshwater resources (Zeitoun et al., 2010). • *Critics of Grey et al. (2013):* the complete emphasis on risk is most appropriate for populations who already have something and are looking at the consequences of it being taken away (Bradley and Bartram, 2013).	Van Hofwegen (2009) Zeitoun et al. (2010) Bradley and Bartram (2013)

More recently, given the complexities and specificities of cities and growing urban population, dealing with water crises in cities is extremely challenging to meet the ever-increasing water demand and impacts of climate change. Cities across the world are grappling with water

scarcity issues and are facing risk of running out of water. The section below sheds light to water security in urban context, the components of urban water security as noted in literature.

2.6.3 Urban water security

Cities are dynamic, in a constant state of flux, and undergoing changes (gradual or radical) brought about by city's internal and external environments. Hence, it is termed as Complex Adaptive Systems (CAS) (Desouza & Flanery, 2013). Urban is characterized with specificities as population density, presence of infrastructures, and provision of services, dependence on hinterland for supply; it relates to a city, being a population center that supports a community. Concepts such as smart cities, sustainable cities, smart-sustainable cities, resilient cities and specifically considering water management, water sensitive urban cities are discussed in the literature (Belli et al., 2020; Desouza & Flanery, 2013; Hoekstra et al., 2018) (refer to Table 3). Belli et al. (2020) discuss that "smart city" is a relatively recent concept but it is too technology centric and lacks attention to municipality and peoples' needs. Hence, there has been a shift to "sustainable cities" concept that includes three pillars: social, environmental and economic sustainability.

To achieve the goal of sustainable city, a city should match and not exceed the consumption of urban resources (including water) in the quantity provided by the natural environment. With its challenge to fit for the highly dynamic society with rapid change and growth, new paradigm, 'smart sustainable city' proposes a more balanced approach, combining sustainability and smartness of a municipality for depicting best urban performance. Smart sustainable city defined by Bibri and Krogstie (2017) states, "innovative cities that use Information, Communication and Technology (ICT) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that they meet the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects." Further, Brown et al. (2009) note that the concept of water sensitive city is gaining increasing attention from scientists and practitioners, though no cities in the world has met criteria of water sensitive city. It is the highest level of advancement the city can reach for securing water being adaptive, multi-functional infrastructure and urban design reinforcing water sensitive behaviors in response to climate change. The authors note 6 subsequent stages of a city, each with higher level of advancement: water supply city (focusing on safe and secure water supply), sewered city (added focus on sewerage to control epidemics), drained city (urban drainage management to manage stormwater), waterways city (cleanliness of water bodies and wastewater treatment to control pollution), water cycle city (added focus on demand

management and closing water and substance cycles in response to water supply limitation and pollution), and water sensitive city.

Cities face a number of challenges among which are climate change effects, rapid population growth, water scarcity and pollution as discussed by Belli et al. (2020). Water management is a critical aspect to ensure sustainability. The urban areas depend on hinterlands for fulfilling the water demand pressure and transport water from sources beyond their catchment areas (Hoekstra et al., 2018; Pradhanang & Jahan, 2021). In the water sector, the municipalities should be able to maintain good quality water balance and control of water pollution. For the same, digital transformation or the use of Internet of Things (IoT) based solutions for water quality monitoring, deflecting from sample tests in laboratory, smart meters are paramount for increasing the efficiency of services and making best use of existing services. From the citizens point of view, a smart city should be able to take into account peoples' quality of life, including services as water supply to all the members of community including marginalized people.

Likewise, poverty and inequality as well as governance challenges are also noted that require flexible, bottom-up initiatives, collaboration and communication among institutions. According to Arreguin-Cortes et al. (2020), for enhancing water security, it is not adequate to deal with the existing risks but it should be able to gain perspective on new future likely challenges; for instance, challenges being water scarcity, pollution, climate change impacts, water conflicts and environmental deterioration which are prominent in urban areas. The authors argue that fully reaching water security is not possible as the physical and economic conditions are dynamic requiring constant adaptation (Van Beek and Arriens, 2013) and solutions need to be context specific (for countries, basin, city or a municipal area).

As discussed above, urban water security is one of the goals of sustainable cities, but rapid urban development and burgeoning population have become major stressors to the water resources (Pradhanang & Jahan, 2021). In general, urban water security is different from water security based on in its application to the territory of urban area, a municipality or urban agglomeration (Hoekstra et al. 2018), urban water management systems and burgeoning water demand in urban areas to meet the growing population (Pradhanang & Jahan, 2021). Urban water security also differs at other levels in terms of typical governance setting with different municipality departments responsible for distinctive water-related tasks or for tasks indirectly relevant (like spatial planning), with municipal policies but national regulations as well, with a public or private water supply utility and other policy processes and stakeholders typical to the urban level. Hence urban water security is complex and dynamic requiring anticipatory and

proactive response, innovation and development in almost all technical, institutional and organizational dimensions (Hoekstra et al., 2018; Larsen et al., 2016).

Given the increasing global emphasis on sustainable city living and the recent experience of water crises in many urban communities around the world, there has not been enough interest of scholars and practitioners in urban water security despite the growing popularity of water security in general (Huang et al., 2015; Paton et al., 2014; Romero-Lankao & Gnatz, 2016). Hence, only a few scholars have discussed urban water security (Allan et al., 2018) and it has not been clearly defined and widely endorsed (Aboelnga et al., 2020). There can be multiple perspectives of urban water security as discussed by Hoekstra et al. (2018): disciplinary, problem-oriented perspectives, goal-oriented perspectives, integrated-water versus water-integrated perspectives, and policy analytical versus governance perspectives. Review of academic literature identifies limited attention with focus on two aspects 'capacity' and 'sustainability' (Chen and Shi, 2016; Romero-Lankao and Gnatz, 2016) and a third focused on 'access, safety, and affordability' and 'psychological' security (Huang et al., 2015).

Romero-Lankao and Gnatz (2016) propose framework following Scott et al. (2013) and states Urban Water Security as' *the capacity of urban water actors to maintain a sustainable availability of adequate quantities and quality of water, to foster resilient urban communities and ecosystems in the face of uncertain global change*' (see p. 3). Their framework includes five domains: sociodemographic, economic, technological, ecological and governance (SETEG). Chen and Shi (2016) take a similar approach in their definition with a similar focus on 'capacity'. Allan et al. (2019) highlighted 'urban water security' focusing on the community, cooperation between stakeholders and the need for sustainable approaches to achieve water security outcomes. Authors refer to 'urban water security' as sustainably meeting the agreed water needs of a community, where the community's water needs must be agreed between the water service provider and the community, and should be described in terms of technical, economic, environmental and social dimensions. To be sustainable, the needs must be met now and bear confidence (aligned with the community's risk appetite) that the needs can be met in the future. More recently, Aboelnga et al. (2020) captures the urban issues using DECS assessment framework considering 4 main dimensions to achieve urban water security: Drinking water and human beings, ecosystem, climate change and water related hazards and socio-economic factors.

A more recent study by Hoekstra et al. (2018) have broadly captured integrated, sustainable and adaptive dimensions. The authors discuss about the four different focus in water security

literature: welfare, equity, sustainability and water-related risks and also about multiple perspectives on urban water security: disciplinary perspectives (e.g. engineering, environmental, public policy, public health), problem-oriented perspectives (e.g. water shortage, flooding, water pollution), goal-oriented perspectives (e.g., better water supply and sanitation, better sewerage and wastewater treatment, safety from flooding, proper urban drainage), integrated-water versus water-integrated perspectives, and policy analytical versus governance perspectives.

Allan et al. (2021) refer to Allan et al. (2018) who systematically reviewed 25 unique definitions of water security in academic and institutional literature and found that the definitions are evolving with increasing complexity. The authors identified stable set of 11 themes that include water quality and human health; quantity of supply; reliability and resilience of supply systems; affordability of water services; economic productivity of water; environment and ecosystem health; sustainability of water security (including integrated urban water management and integrated water resource management techniques); water-related hazards; habitability and well-being; policy frameworks, political stability and institutional capacity; and risk and certainty. The authors proposed the meaning reflecting collaborative/ participatory approach between water users and the water providers 'sustainably meeting the agreed water needs of a community', where the agreement should be between the water service provider and the community. Equity and justice issues in water are also discussed through the dimensions of environmental justices, as distributional justice (outcome), procedural justice (process) and recognitive justice in German funded drinking water project in Dhulikhel (Pokharel, 2023; Pokharel et al., 2018; Maskey et al., 2024a), in ADB-funded Melamchi water supply project (Domènech et al., 2013) and in another ADB-funded drinking water project in Diktel (Maskey et al., 2024b; Adhikari et al., 2023).

The scholars have emphasized the importance of dealing with urban water security to achieve SDG goal 6. However, it is a complex and cross-cutting challenge to be addressed using holistic and integrated approach along with collaborative stakeholders (Aboelnga et al., 2020; Aboelnga et al., 2019). Urban water sector are increasingly dealing with complex pressures of increasing population and urbanization and changing climate, and other socio-economic and environmental strains but literature have indicated centralized urban water systems are maladapted to deal with these challenges (Marlow et al., 2013). Taking into consideration the human-water systems, the authors emphasize the need of integration of both physical and human pressures on water resources to consider human-water systems (Gain et al., 2016).

Moreover, studies find that cities suffer from water security issues related to institutional challenges and institutional failures in accessing, supplying water and dealing with water related adversities including floods and droughts (Kiparsky et al., 2013; Patterson & Huitema, 2019) and along the same line, studies establish that the governance and management aspects of water management are vital to implement sustainable approach to water security (Pahl-Wostl et al., 2013).

However, detailed analysis of how urban water is managed is often missing from large scale availability analyses (Aihara et al., 2015). Authors discuss that human dimensions as social and institutional capacities have not received much attention (Bakker & Morinville, 2013) and hence, traditional assessments of water scarcity are usually poorly integrated with the needs of policy makers and practitioners (Bakker, 2012).

Table 3. Urban water security frameworks

Concepts	**Components**	**Authors**
Smart sustainable cities	• Social (equitable water distribution) • Environmental (water scarcity as challenge) • Good water governance (inclusive decision making, collaboration and communications between institutions) • Digital transformation	Belli et al., 2020
Resilient cities (conceptual resilience framework)	• Cities as CAS (complex adaptive system) • Stressors: natural, technological, economic and human • Flexible Planning, adaptable designing and agile management	Desouza and Flanery, 2013
Urban water management transitions framework	• Water supply city (water supply) • Sewered city (sewerage) • Drained city (drainage channelization) • Waterways city (pollution management) • Water cycle city (water demand management, closing water and substance cycles)	Brown et al., 2009 cited in Hoekstra et al., 2018

	• Water sensitive city (adaptive, multi-functional and urban design)	
Systems perspective/approach (PSIR)	• Pressure (Environmental – land cover and land use change and climatic change) and socio-economic- population growth and changing water demands, urbanization) • Impacts: adequate water, affordability, quality, water related disasters as floods	Hoekstra et al., 2018
Hoekstra et al., 2018 discuss urban water security indices, p.11 given below:		
The City Blueprint framework	The City Blueprint framework for assessment of sustainability of urban water system	Van Leewen et al., 2012 Updated Koop and van Leewen, 2015
Sustainable City water index – tool to inform future improvement and long-term water sustainability	• 3 categories: resiliency, efficiency and quality	Arcadis, 2016
Sustainability index for integrated urban water management	• Composite index comprising of social, economic, environmental and institutional categories (16 indicators)	Carden and Armitage, 2009
Urban water security indices and indicators	• Water resource availability, access to water, water related risks, and institutional capacity to manage water resources	Jensen and Wu, 2018
Water sensitive cities	• Equitable, affordable, and reliable access to water supply • Infrastructure management and adequate maintenance • Safe, good water quality (nature-based solutions)	Aboelnga et al., 2019

	• No damage/water related disasters • Institutional knowledge (climate change/population trend) and coordination (good relationships) and capacity, leadership and long-term vision and commitment, water conscious committees	
National water security index from ADB, 2013, 2016	• Includes 5 aspects of which one is urban water security • Urban water security- indicators – water supply, wastewater treatment, and drainage (flood damage), with factors added as organizational rate and river health	ADB, 2013, 2016
Urban water security framework (arid American cities) SETEG	• Five domains of water management: SETEG Socio-demographic, Economic, Technological, Ecological, Governance	Díaz-caravantes et al., 2020
DECS framework integrated urban water security index (IUWSI)	• Considering drinking water and human beings, ecosystem, climate change and water related hazards and socio-economic factors	Aboelnga et al., 2020
Global Water Security Index (GWSI)	• Availability (demand and availability and withdrawal, groundwater depletion, accessibility to services) • Safety and quality • Management (effective governance, rule of law, control of corruption, political stability, transboundary risk)	Arreguin-Cortes et al., 2020

Source: Author, 2020

Having discussed the evolving or expansion of meaning of water security and urban water security, it is obvious that improving water security is not limited to managing water supply and demand but requires an understanding of multiple facets as discussed by different scholars.

The review shows that the traditional concepts have resulted in technocratic, infrastructural or engineering responses, for instance, supplying water using technologies and infrastructures to the growing needs of the population. However, besides the engineering measures, it is very important to recognize the socio-political (hydro-social and hydro-political: how access to water and related decisions are social and political) relationship among actors which is complex and dynamic (Wang & Dai, 2021).

Achieving water security in the urban context is more complex, yet it has received limited interest. To address this gap in urban water literature and given the crucial role of governance aspect, this study contributes to the nexus of urbanization, climate change and water security and explores the important elements in the governance dimension of urban water security. Based on the above discussed meanings of water security by different scholars from literature, I refer the terms 'water security and urban water security' as water security/urban water security theory, and discuss below the conceptual and theoretical framework of water security.

2.6.4 Conceptual and Theoretical Framework of water security

This section discusses the conceptual and theoretical framework of the research.

Conceptual framework

This research aims to identify and analyze the key drivers, responses, challenges and ways to address growing water insecurity in the rapidly urbanizing cities of Nepal. The conceptual framework of this study (refer to Figure 3) delves into the pressures the cities are experiencing in the light of the widening gap between water demand, supply and governance. The center of analysis of the study lies with the rapidly emerging cities grappling with an array of stressors such as haphazard urbanization and climate change as indicated in the figure below. These stressors are indicated as drivers in the study and the first research question identifies further drivers of water insecurity in the study sites. These challenges collectively exert strain on water resources for its sustainable availability and management, thereby, create challenges for urban water governance. The interplay between sectorial surges in water demand on the one hand while gradual decline in availability of water due to haphazard urbanization and changing climate, emphasize the concerns of urban water insecurity and governance.

Cities or urban areas are dynamic, and therefore they are termed as Complex Adaptive System (CAS)—a system that is complex, adaptive, self-organized, collective in behaviour with dynamic network of interactions which consists of different components and categorization for planning resilient cities. As CAS, urban areas can be viewed as microstructures that combine

to form system of cities. These city systems function more effectively and adaptively as a collective macrostructure than individually. Scholars note that the difference between the CAS and general linear systems is that CAS are constantly evolving, adapting and self-organizing and they interact with and are shaped by interactions with other systems (Meijer et al., 2024). Pickett et al. (2001) divided the components of cities to physical and social spheres. Physical sphere includes physical resources within boundary of a city and with others that engage in cities' interaction. Social sphere includes people, institutions and activities. People are the social component whose role is critical for making cities resilient as they can manage and control other components. There are continuous interactions within and among these components of social and physical sphere and they determine the city's environment. For example, for water services in the city, there are interactions between water resource and policies/ institutions for managing water supply systems with the water users who use the services and pay for the amount of water used. Water institutions including the water users' committees and municipalities manage water through certain processes such as rules, regulations, policies, and institutional mechanisms. They engage in activities such as conserving watershed and water sources in order to secure water to implement water schemes. The institutions interact with water users/ the downstream and water providers/the upstream communities while negotiating for bringing the water sources from within the municipal jurisdiction or beyond. This interaction continues beyond the source leading to negotiation for supporting the upstream people to ensure sustainable access of water to downstream communities. In this way, there is continuous interactions between the **social** and the **physical spheres.**

Understanding the city as CAS will enable this study to incorporate the dynamism, and multiple interactions with physical and social spheres, and uncertainty cities face when it comes to securing water, allowing it to suggest the measures in this larger context. Thus, addressing the complex issue of water insecurity in an urban setting requires a comprehensive empirical understanding of the problems encountered in rapidly emerging cities that is presented by this study.

As urbanization accelerates along with water intensive life styles, agriculture and industries, the transition from household to commercial and infrastructural development amplifies the water demand. This exacerbates tensions as residents residing in the upstream have to compromise their traditional uses of water for irrigation, fish farming, and operation of traditional water mills. This upstream-downstream dynamic reflects deeper equity concerns,

where upstream communities, who are typically less politically influential, bear the burden of resource sacrifice without adequate recognition, compensation, or participation in decision-making. Addressing urban water security must therefore account for these power asymmetries, ensuring that upstream stakeholders are not disproportionately disadvantaged and are meaningfully included in planning and benefit-sharing processes.

The growing demand of water also leads to increased competition of different sectors such as agriculture, drinking, industrial and household water usage. Consequently, competitive water demands emerge, exacerbated by the limited availability of water in certain areas and losses due to technical issues, results in uneven and intermittent water distribution as well as pollution. Climate-related phenomena, including both water scarcity and surplus, contribute to the complexity of the challenge, with excessive water leading to inundation in some areas. These factors stimulate multifaceted water crises, triggering conflicts among various stakeholders and exacerbating tensions between upstream and downstream users and multi-sectoral horizontal water demands.

Managing multiple stakeholders and institutions, upstream-downstream conflicts and sectoral water need, policies and practices for effective and efficient water distribution, access and sustainable water supply demands robust and adaptive institutions and policies (Sadoff and Muller, 2009). Literature has indicated that effective water governance is imperative in addressing water insecurity, especially in rapidly growing cities in which water institutions' role have also been highlighted as crucial (OECD, 2011; Allan et al., 2019). As discussed in the literature review chapter, in the developing countries, gaps in institutional mechanisms and capacity and poor governance have been responsible for limiting the effective performance and outcomes, limiting access to safe and secure water, even when water is plentiful. Hence, governance and water institutions are focused in this study. The figure below shows the conceptual framework of this study.

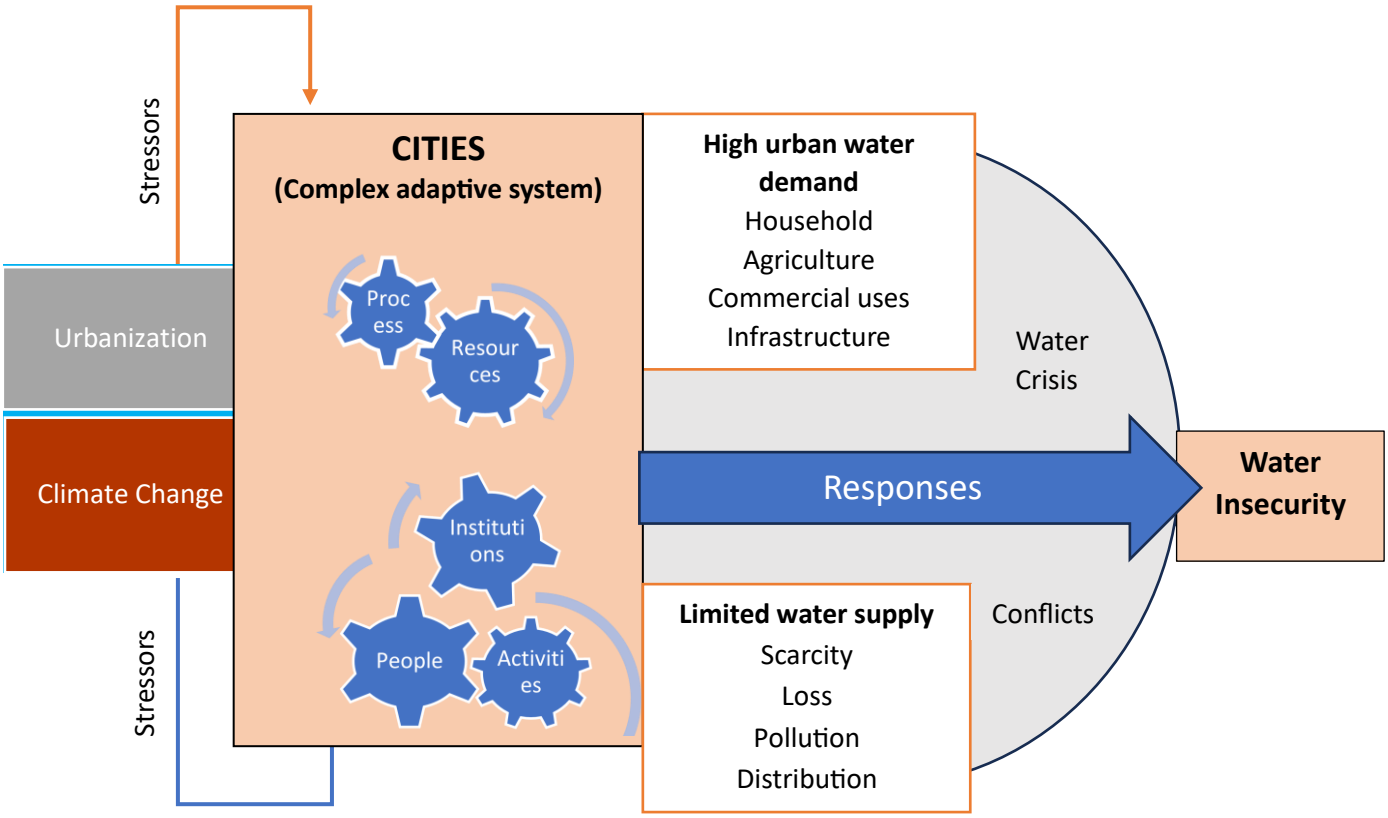

Figure 3. Conceptual framework of the study

In this context, achieving water security in the urban context is challenging owing to the multiple stressors and the city with its interplay of social, political, and environmental dynamics and uncertainty associated with these interactions. This study, hence, explores the drivers of water insecurity, responses of the water institutions and, the constraints and challenges faced by the institutions in delivering effective water management in the two rapidly urbanizing cities.

In sum, this conceptual framework explains the complexities faced by the cities in addressing urban water needs amid various stressors, including multi-sectoral water demand and conflicts. The intricate interplay of factors contributing to water insecurity in rapidly urbanizing cities highlights the need for institutional and policy responses for devising effective strategies to address urban water insecurity. The theoretical framework below discusses about the theory of water security and its components for thorough understanding of what achieving water security means in urban context.

Theoretical Approach

A theory is a viewpoint or perspective which is explanatory and connects the researcher to the existing knowledge. According to Babbie (1989, p.46), social science theory is 'a systematic explanation for the observed facts and laws that relate to a specific aspect of life'. The theoretical framework of the research is the important aspect as it serves to be the foundation of the research that is developed logically and well-explained.

The conceptual framework explained above shows the complexity the cities are facing in meeting urban water needs amid different stressors. Water crisis situation exposes cities into multiple challenges related to multi-sectoral water demand, conflict related to sectoral as well as upstream-downstream communities, quality issues and access of quantity water supply. In such situation, institutional and policy responses towards gaining water security in cities needs to be effective for which proper understanding of the 'water security' is imperative.

In this context, this research adopts 'urban water security' theory for understanding and addressing the multifaceted challenges faced by the cities in managing water. Extensive literature review on water security (discussed in Chapter 2) shows that 'water security theory' has expanded its focus from quantity and quality to include access, affordability, sustainability and risk components (Cook and Bakker, 2012). However, emphasis is concentrated on just one or two of these dimensions (Gunda et al., 2019). Moreover, 'water insecurity' is primarily considered as the resource (physical) unavailability or quantity issue as perceived in the traditional paradigm of water security studies (Gain et al., 2016; Vogel et al., 2015). Hence, one of the key focuses for ensuring water security is considered as increasing water quantity as referred in the literature 'adequate supply of clean freshwater to support human and ecosystems at all times (Gunda et al., 2019), 'ensuring availability of adequate and reliable water resources of acceptable quantity ….' alongside mitigating water related risks and addressing conflicts (Mishra et al., 2021). Hence, increasing the quantity is considered as a solution for which technological fixes are prioritized and groundwater extraction are rampant. Such understanding of water insecurity as a technology related problem and devising problem-solving policy and institutional responses from this understanding will not provide long-term solutions.

Studies have highlighted that although water security theory has expanded from considering water scarcity to clean water, ecosystem services, vulnerability to extreme events, and incorporated social aspects as access and overall human wellbeing (Gunda et al., 2015), the governance aspect has received limited attention (Allan et al., 2019). The consensus has been

achieved that the global water crisis is more governance-based problem or management of the water resource than technology-based and that 'governance' is a precursor for achieving water security (Wuijts et al., 2018; OCED, 2011; Rogers and Hall, 2003). But the 'water security theory' and its frameworks have either missed to incorporate it while focusing other dimensions or have considered it as a minor component.

More recent literature has considered governance aspects such as 'capacity' of institutions (Allan et al., 2019) but translating this to water security within the context of urbanization and climate change remains unaddressed. While technological and engineering fixes are considered as solutions, addressing the social aspects as part of human-nature interaction such as access, equity, affordability have gained limited attention in water security theory and in practice. The role of social scientists therefore is crucial to think beyond quantity and quality aspects to consider social implications of water insecurity and hence shift fully engineered systems as solutions to multidisciplinary and socio-hydrological perspective including governance incorporating strengthening institutional capacity, water sources conservation, community awareness, social acceptance, and usage needs (Mishra et al., 2021; Gunda et al., 2018). A comprehensive analysis of governance situated in the human-centric dimension of policy and institutional aspects of urban water governance of rapidly emerging Himalayan cities remains incomplete.

Acknowledging these limitations, this research adopts 'urban water security theory' encompassing a broader ecological and social perspective to address the interconnectedness between human activities and the natural environment for securing water. The 'urban water security theory' in this research uses multiple dimensions including quality, quantity, accessibility, affordability, risks, and sustainability as well as institutional and governance aspects (refer to Figure 4). This is grounded in the extensive body of literature on water security that notes these dimensions as integral facets for a comprehensive understanding of water security dynamics in urban contexts (Aboelnga et al., 2019, Jensen and Wu, 2018; Arreguin-Cortes et al., 2020; Gray and Sadoff, 2007; Pandey et al., 2019; Hoekstra et al., 2018; Maskey et al., 2023).

In analysis part of the research, I use the DECS framework combining it with urban water security theory. The broad components outlined in DECS framework used by Aboelnga et al. (2020) consists of four major aspects: a) Drinking water and human beings, b) Ecosystem and c) Climate change and water related hazards, and d) Socio-economic factors. This framework was developed by the authors based on the UN Water (2013) definition of water security.

In this DECS framework, I have categorized the different dimensions drawn from water security theory into the framework's broad components. For instance, the dimensions of water security: quality, quantity or availability, affordability, equity and accessibility has been grouped into its first component, *drinking water and human beings*. Further, sustainability aspect has been categorized under its second component, *ecosystem*. Likewise, safety, risk or vulnerability aspect has been included in the third component of the framework: *climate change and water related hazards*. And lastly, drivers of urbanization, population growth and changing lifestyles have been categorized into its fourth component, *socio-economic component*.

Thus, the DECS framework is an important framework incorporating most of the dimensions of urban water security theory. However, it is incomplete without the 'governance' dimension, missing in the DECS framework as a central component. Hence, this study contributes to this gap and integrates 'Governance and Institutions' component in the framework to make a contribution to this framework and urban water security theory. Governance, in the study includes institutions, organizations, policies and practices that shape and manage water resources and deliver water services. Institutions are defined as laws, rules and regulations, policies and property rights that structure social interactions by shaping or constraining actor behavior and determine ownership, usage and protection/ exploitation of resources (North, 1990; Ostrum, 2007). The role and importance of institutions and governance in urban water management has been detailed out in the previous sections of the literature review chapter (Chapter 2). The contribution to the governance dimension of urban water security theory is discussed in Chapter 7 and analysis in the discussion chapter (Chapter 8).

Governance connects with all components of DECS framework and is central to urban water security framework; so it is important to explore this dimension. Governance mechanisms play a pivotal role in shaping the distribution, allocation and management of water resources among multiple stakeholders, both horizontal and vertical, in urban contexts. Institutional arrangements and policy frameworks foster equitable and sustainable water management as well as effective stakeholder participation. By emphasizing governance aspect, the research aims to elucidate the key challenges and potential pathways for enhancing urban water security.

Hence, my research considers the water security concerns in the urban context in which the water governance and institutions are dealing and responding to the increasing demand of burgeoning population and climate change impacts. Rising water demand to meet the growing population on one hand and drying of water sources and water related hazards due to impacts of climate change, demand more holistic and adaptive approaches at different scales where the

role of water governance and institutions become paramount. Considering the urban context with diverse actors, the research analyzes from governance-institutional perspective, in which the interaction of stakeholders and institutions as well as sustainable approaches in the context of urbanization and impacts of climate change are of importance to achieve water security outcomes.

This thesis acknowledges that *water security* and *water insecurity* exist on a spectrum, reflecting varying degrees of access, reliability, equity, and sustainability. The term *water insecurity* has been used to frame the study from a problem-oriented perspective, aligning more closely with the research objectives. By focusing on insecurity, the thesis seeks to identify and analyze the key drivers, institutional responses and challenges to growing water-related challenges.

Framing the issue as water insecurity also reflects to highlight the urgency of need for targeted interventions and policy responses to timely and proactively consider key governance dimensions towards addressing the problem of water insecurity as the problem is exacerbating in the future amidst rising water needs, urbanizing cities and increasing climate risks.

Moreover, existing literature (Pandey and Bajracharya, 2017) has indicated the demand–supply gaps in the study sites. The study expands study on the drivers, institutional and policy responses, and governance dimensions of urban water insecurity. The contextual analysis of the study sites in this research illustrates the growing challenges, providing a basis for treating water insecurity as the central problem to be addressed by this research.

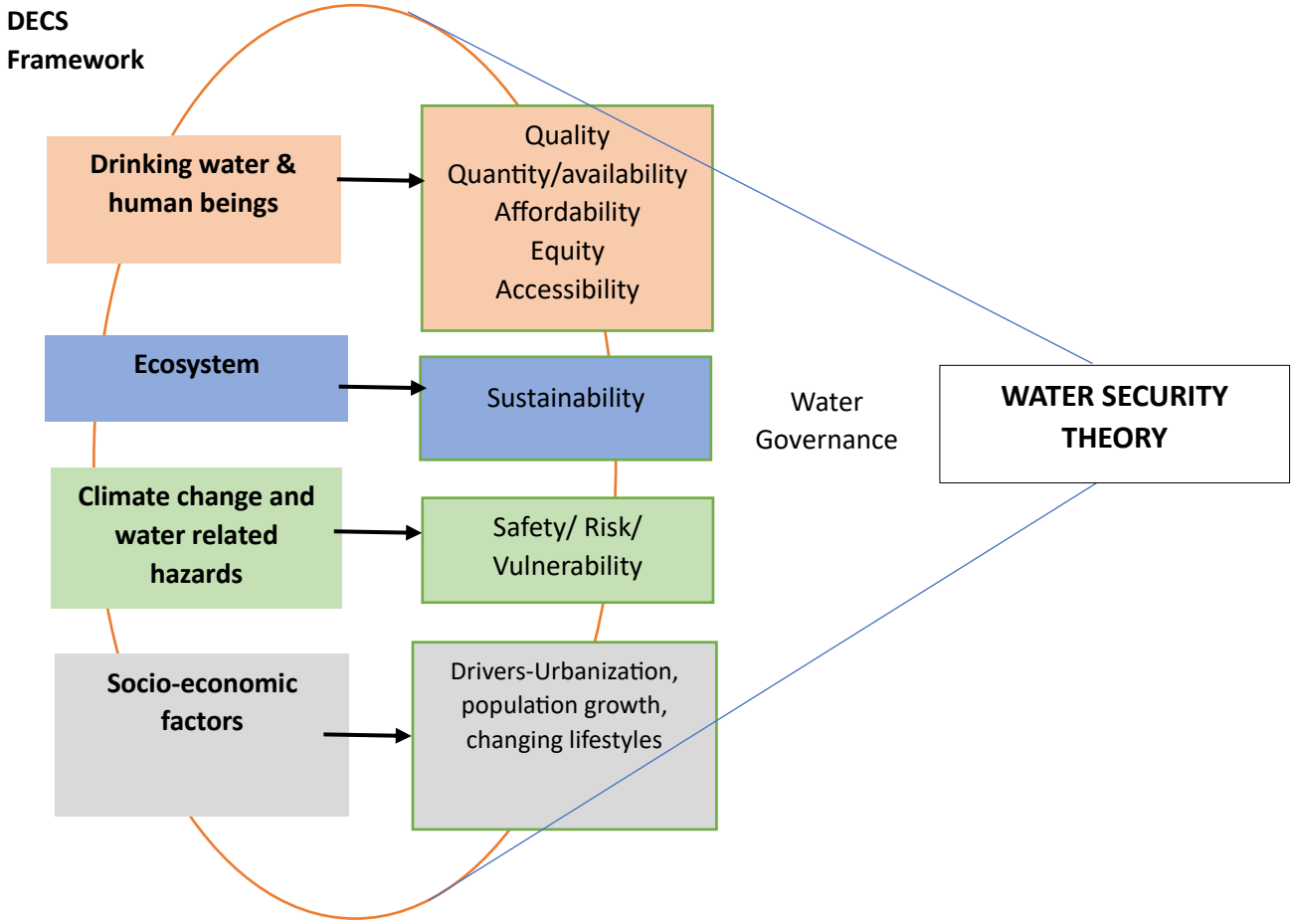

Figure 4. Theoretical framework: Urban water security theory and DECS framework, Adapted from Aboelnga et al., 2019; Jensen and Wu, 2018; Arreguin-Cortes et al., 2020; Gray and Sadoff, 2007.

In essence, drawing upon the 'urban water security theory' and focusing on the governance dimension, the research seeks to contribute to understanding of the complex dynamics shaping water security in urban settings. It also aims to contribute to the advancement of the theoretical understanding and empirical knowledge in the field of urban water governance. Further, the research offers insights for the development of effective governance strategies to address contemporary water security challenges.

2.7 Chapter summary

In this chapter, I have presented the extensive literature review to contextualize my research in the themes of urbanization and climate change, global water crisis, national context and responses to address the issues of water insecurity. The review has highlighted the gaps in literature and the contribution of this research, specifically in literature of urban water security, in the nexus of urbanization, climate change and water security. The chapter has discussed the review of evolution of the term water security and broadening of it to include its further dimensions. The chapter has also highlighted the conceptual framework and theoretical framework of this research and elaborated the complex adaptive system, urban water security theory and DECS framework. Based on the conceptual and theoretical framework presented in this chapter, the following chapter will highlight the research methodology of the study.

CHAPTER THREE: RESEARCH METHODOLOGY

In this chapter, I present the methodology of the research on urban water insecurity in two study sites, Dharan and Dhulikhel representing two emerging cities of Nepal. The research includes in-depth study of determinants of water insecurity, responses towards securing water and the constraints or challenges in securing water in these two towns. In doing so, the study used qualitative-led mixed method approach combining both the qualitative and quantitative data applying various research tools, using data from both primary and secondary sources. Qualitative data is collected through in-depth interviews, focused group discussions and observation through participation in relevant forums. And for the quantitative data, I used surveys in the study sites.

This chapter highlights the philosophical standpoint of conducting research and explains why mixed method best suits the topic of water security. It further illustrates on how different tools of qualitative and quantitative methods are used for data collection. The chapter provides a concise description of the study sites with basic features and justification for sites selection. It also elaborates some methodological reflections gained throughout the research process and learnings including the researcher's positionality, data analysis and ethical considerations. Lastly, the chapter highlights the limitations of research.

3.1 Research Philosophy

Various individuals can perceive a social reality in different ways that determines their thinking and reasoning of the observed phenomenon (Bhattacherjee, 2012). Philosophy refers to the set of beliefs and various perspectives on how the world operates. Such belief systems that organize our reasoning and observations are also referred as 'paradigms'. It shapes the research approach in understanding the reality, knowledge and existence and guide the researchers to their investigations design, methodology and interpretation of their findings. In social science research, there are three research paradigms: positivism, interpretivism and pragmatism.

Positivism holds that science or knowledge creation is limited to observable and measured reality (Bhattacherjee, 2012). It places emphasis on tangible facts and observable phenomena (Davies & Fisher, 2018). Positivist researchers believe reality is one and static. They emphasize pure data and facts and the use of quantitative methods, seek to identify patterns and regularities and aim for objectivity by minimizing the influence of personal biases (Alharahsheh & Pius, 2020).

While the notion of interpretivism believes that a singular, objective reality does not exist rather our understanding of reality or knowledge is subjective and is formed by individual perspectives (Hiller, 2016; Tuli, 2010). Interpretivists believe access to reality happens through understanding of social interactions 'through the eyes of the participants' (Cohen et al., 2002) or interpersonal engagements. Therefore, subjective reality can vary with individual's own beliefs, values and experiences (Alharahsheh & Pius, 2020). The interpretivist assume that reality is socially constructed (Maulana et al., 2022). Hence, the interpretivist research uses qualitative methods and observation to gain deep understanding of the complex understanding of human behavior (Omodan, 2022). However, the researchers need to be mindful to personal biases and assumptions that can affect the research findings.

Pragmatism accepts the possibility of both single and multiple realities that are open to empirical inquiry; hence using the lens of positivism and interpretivism as per the context (Creswell & Clark, 2017). Pragmatic scholars believe that there exists an objective reality beyond human experience, yet this is grounded to the environment and can be caught through human experience (Morgan, 2014). Pragmatism suggests the researchers to adopt the philosophical approach that best fits the specific research problem, allowing to draw liberally from both quantitative and qualitative methods (Kaushik & Walsh, 2019). It is often associated with use of mixed methods research (Creswell & Clark, 2017). Biesta (2010) explains pragmatism as a problem-solving set of philosophical tools, hence it is used in applied research to identify practical solutions to social problems (Creswell et al., 2011).

For my research, I have adopted pragmatic worldview. This philosophical standpoint best fits my study on urban water security as it uses both positivist and interpretivist paradigms. Pragmatism opens the door to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis. As pragmatic worldview agree that research always occur in social, historical and political context, my research best fits this paradigm. The research aims to explore the issues of water security in the context of urbanization and climate change that includes the identification of drivers, responses and constraints/challenges in securing water; hence it is applied research. I need both the subjective and objective data for in-depth and best understanding of the water security related issues and pragmatism provides the flexibility to the researchers to use any methodological tool as stated by Kaushik & Walsh (2019) 'what works' to address the research question. Hence, I have adopted mixed method drawing from both qualitative and quantitative methods. Next is that the pragmatic research paradigm concerns with solution to real-world-problems as discussed

by Creswell et al. (2011) and Patton (2002). In my research, the identification of these challenges in policies and practice help the water related stakeholders (local government, water institutions, and community) towards developing climate adaptive and equitable water management practices, specifically at the study sites and can be replicated to other Himalayan towns as well. Further, while the positivist approach is deductive in nature and the interpretivist research is inductive, this pragmatic research provides the opportunity to transition between deductive and inductive approaches.

The research paradigm encompasses assumptions regarding ontology, epistemology, methodology and methods, and axiology, according to Lincoln and Guba (1985). As the research paradigm serves like a lens through which we interpret the world's reality and engage in its systematic study, it is important to have a good understanding of these components. The section below will discuss these components adhering to 'pragmatism' as my guiding philosophy for my research.

3.1.1 Ontology

Ontology is defined as "the science or study of being" and it deals with the nature of reality (Baikie, 1993). In philosophy, ontology is the study of what exists, in general study of what is real. Ontology is associated with a central question of whether social entities need to be perceived as objective or subjective. Accordingly, objectivism and subjectivism can be specified as two important aspects of ontology.

Subjectivism (also known as constructionism or interpretivism), perceives social actors are connected and hold a crucial role in construction of social reality. Formally, constructionism can be defined as "ontological position which asserts that social phenomena and their meanings are continually being accomplished by social actors" (Bryman, 2012). On the other hand, objectivism "portrays the position that social entities exist in reality external to social actors concerned with their existence" (Saunders et al., 2009). Objectivism "is an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors" (Bryman, 2012).

Ontology enables the researcher to examine his/her underlying belief system and philosophical assumptions to orient his/her thinking about research problem (Kivunja & Kuyini, 2017). Accepting a particular ontological belief system guides an individual towards specific epistemological assumptions (Rehman & Alharthi, 2016). My research builds on the ontology that the reality can be objective and subjective which is dependent on the individual's context

and experience (Kaushik & Walsh, 2019). The topic of my study requires the subjective approach as it explores the perspectives of different stakeholders ranging from the water users to water managers in terms of water distribution and management, perception on impact of different drivers affecting water security as well as challenges and constraints in addressing the issues. These perspectives vary with the stakeholders.

The concept of water and water security extends beyond a mere resource, encompassing human, community and societal connections. It covers social, hydrological and broader ecosystem processes, reaching beyond engineering and water pipes to ensure water access to all. The importance of water transcends the point of consumption to encompass its source. Water transcends across scales – beyond administrative jurisdictions, at waterscape level having multiple actors' engagement. Yates et al. (2017) have highlighted that it is imperative to recognize that the well-being of water flows cannot be ensured by isolating water consumption from its intricate ecological interconnections, e.g., source water protection. Simultaneously, I also consider the topic as an objective reality and gather independent data from participants on various aspects including water sources, usage, household water requirements and others.

3.1.2 Epistemology

Epistemological branch of philosophy is concerned with the nature, origin, scope of knowledge and 'how we know what we know'. Epistemology serves as the lines through which we explore the process of acquiring knowledge delving into the details of understanding how we ascertain truth or reality (Kivunja & Kuyini, 2017). As articulated by Cooksey & McDonald (2019), it delineates what qualifies as knowledge within our experiential world. Epistemology provides the philosophical underpinning, the credibility, which legitimizes knowledge and the framework for a process that will produce, through a 'rigorous' methodology (full range of research methods), answers that can be believed to be valid, reliable/replicable and representative/typical (Sumner and Tribe, 2004). Epistemological view analyses the knowledge of the phenomenon from which methodological issues come from. It refers to our assumptions about the best way to study the world, if we use objective or subjective approach to study the social reality.

Quantitative research, rooted in positivism assumes an objective reality independent of researchers' and research participants' perceptions (Slevitch, 2011). It adopts an etic view, positioning researchers as outsiders who measure the truth objectively. In contrast, qualitative

research adopts an emic view that takes into consideration the interactions between the researchers and the research participants (Teddlie & Tashakkori, 2009). In my research, I have adopted mixed method approach utilizing both qualitative and quantitative epistemology. Hence, I have exhibited interactive approach while collecting and analyzing qualitative data. I have been independent with the research participants while collecting and analyzing quantitative data, hence taking a pragmatic approach.

For instance, I have adopted subjective approach in analyzing the drivers of water security and institutional responses and constraints where the water stakeholders' perspectives have been important, gained through interaction with the participants in their natural setting (Creswell, 2013). Such information helped in gaining in-depth understanding of what dimensions constitute a 'water secure city'. On the other hand, my stand for quantitative data collection and analysis was objective in which I collected the data being independent with the participants on certain aspects such as the water sources, use, household water need, time taken to fetch water, water quality and quantity, perception on climate change impact to water sources, and institutions and management related questions, as part of survey. The research is primarily analytical, driven by a goal to understand and explain water insecurity. However, it is often informed by ethical considerations, especially when addressing issues of equity, justice, and sustainability and discussing equitable access to water, inclusivity and representation in the study.

3.1.3 Axiology

Axiology studies judgements about the value and assess the impact of the researcher's personal values throughout every phase of the research process. It can be associated with the research participants and safeguarding of research subjects. It is important aspect as the researcher's values affect the process of conducting research and what the researcher values in research. It pertains to the sincerity in interpreting the data, presenting research findings, recognizing the implications of research actions and treating the research participants equally. Axiology concerns with what value the researchers attribute to different research aspects such as participants, data and audience (Moroi, 2021). The researchers favoring objective approach or value-free nature of research have highly objective perception and is not filtered through the researcher's own understanding while the researchers adopting subjective approach are engaged in interpretation of data. Axiology is the study of ethics involved in the chosen research method. As a critical component of research philosophy, axiology guides the

researchers in recognizing the dynamic interplay between values, methods and contributes to the transparency and integrity of the research process.

Researcher's stance can be characterized as value-free to those laden with personal biases, or a combination of both, depending on the paradigm (Kivunja & Kuyini, 2017). In my research, my axiological position has been the combination of value-free and value-laden, as per the context. As my philosophical stand is pragmatism and have adopted mixed-method research, I have adopted value-laden approach during collection of qualitative data while I adopted value-free approach during quantitative data collection. During qualitative inquiry, I adopted emic perspective interacting closely with the research participants, being aware of the fact that my perception and interpretation of data might be affected by the way and the place I have been brought up, my beliefs and understanding, gender and ethnic association etc. On the other hand, I conducted the quantitative inquiry adopting etic perspective without connecting to the research participants, as an outsider. I have also taken care of ethical considerations while doing my research for instance, clarifying the objectives of the study and research outputs, taking prior consent, anonymizing the researchers' identity, among others (details in section 3.8).

3.1.4 Methodology

Methodology delves into the exploration of how the researcher can obtain valid knowledge (Aliyu et al., 2015). It thus provides guidance to collect data and it determines the use of research methods for the specific paradigm the researcher follows. In other words, it refers to the systematic research design and process to analyze a research problem that includes steps from data gathering to analysis (Kivunja & Kuyini, 2017). Quantitative research uses statistical tools while the qualitative research engages with rich description of the phenomena and interpretation of the research problem from the perspectives of the researchers and the research participants (Guba & Lincoln, 1994). In my research, I have followed pragmatism as the research paradigm, bearing the value to the academic literature, policy and practice. The research has adopted mixed-method research design combining both the qualitative and quantitative methods.

3.2 Research Design: Mixed method approach

Research designs are types of inquiry in a particular research approach that provides a specific direction to guide the research, also known as 'strategies of inquiry' (Denzin & Lincoln, 2011). This study applies mixed method approach combining both qualitative and quantitative research approaches for the purpose of breadth and depth of understanding and

corroboration/validation (Johnson et al., 2007; Creswell et al., 2011). Mixed methods research is a type of research in which the investigator collects and analyzes data, integrates the findings, and draws inferences combining elements of both qualitative and quantitative research approaches for the purposes of breadth and depth of understanding and corroboration (Tashakkori & Creswell, 2007). The purpose of the mixed method research is to provide a more complex understanding of a phenomenon that would otherwise not have been accessible by using one approach alone (Creswell & Clark, 2011; Morse, 2016). Collection of both qualitative and quantitative data is useful in minimizing the weakness of each form of data. The research employs both inductive and deductive reasoning, utilizing in-depth qualitative interviews and data gathered through household surveys.

For this research on water security, the mixed method approach is used for overcoming bias that stem from single methodologies. The mixed method approach is based on the pragmatic knowledge claims. Discussing about this research, 'water', a vital yet scarce resource, is the subject of intense competition and conflict as individuals and groups bargain and struggle to advance and maintain their access to it. As the research is on exploring issue of water security, water security is a complex socio-environmental issue which demands greater communication and integration between knowledge communities through multiple research approaches (Zwarteveen & Boelens, 2014; Klenk & Meehan, 2015; Loftus, 2015; Jepson et al., 2017). The concept of water security is not limited to quantity and quality but encompasses other components as accessibility, affordability, sustainability, equity and governance aspects. Environmental, socio-demographic factors, economic, power and political context play around the issue of water access, supply, distribution and management (issue of who gets what water, when and how). For instance, one might not have access to water system although his/her neighbors receive tap water (Molden et al., 2020). The inequitable water distribution is related with a number of factors. The research demands an in-depth identification of the drivers affecting water security, how the institutions are responding and what are the institutional constraints and prospects and how the people are affected with those responses. Given the wide spectrum of factors influencing different aspects of water security and responses in securing water, mixed method inquiry can help better investigate the spectrum of drivers. Hence, mixed method research is considered to be most appropriate for this research.

Mixed methods research has been distinguished as qualitative dominant, pure mixed and quantitative dominant (Johnson et al., 2007). This research adopts a qualitative-led or dominant mixed methods approach. Johnson et al. (2007) defines qualitative-dominant mixed methods

research as the type of mixed research in which one relies on a qualitative approach while also recognizing that the addition of quantitative data will benefit the research. Creswell and Clark (2007) have categorized such mixed-method research as embedded design. In this type of mixed method research, one data set provides a supportive secondary role to the other type of data.[10] My research thus follows embedded design in which quantitative data plays a secondary role to interpret the findings from the qualitative data.

This design also allows flexibility in the data collection sequence. Following the preliminary qualitative exploration in the field sites, the quantitative data was collected which was followed by further qualitative data collection. This research uses data collected over a period of four years 2018-2021. The first set of data collection was done by 2018, and follow-ups were done in the following years. COVID-19 was an unexpected situation that led to lockdowns and mobility restrictions in 2020.

I used the qualitative approach to find the insights regarding the factors affecting water security in the case study sites- the exploration of reasons, opinions around water scarcity/ availability, impacts of climate change and drying of water sources, water quality and access, distribution, responses and challenges in urban water management. Qualitative data in this research is obtained through the in-depth interviews, group discussions, transect walks, informal conversations and participant observations. The exploration of all the research questions uses qualitative method: drivers affecting water security, institutional responses and challenges in achieving water security in the cities. Qualitative data is used, firstly to understand the existing scenario of water supply and demand, existing water sources and the management practices. These helped in setting the context while further exploration with research participants helped in understanding the approaches of securing water in the cities and the barriers they have been facing as well as on exploring what could be the key governance dimensions for securing water.

Household questionnaire survey as quantitative method was used for exploration of water sources, use, household water need, availability and distribution, time taken to fetch water, impact of climate change and urbanization in water security, water quality, gender roles in water management, water institutions and governance related challenges. The data also helped to triangulate the qualitative data collected through in-depth interviews and focused group discussions. Quantitative data served important for the study as it provided demographic

[10]Other types include the triangulated design to obtain different but complementary data, the two-phase explanatory design, which builds or explains quantitative results; and the exploratory design, which is also two-phased but led by the qualitative.

variables of the sites under study and perception-based data on climate change, water quality and water management. In this way, the qualitative study provided greater context for interpreting the quantitative results, and quantitative study helped to illustrate further the findings from qualitative study and in establishing linkages and interrelationships between the variables of study. The mixed method approach thus provided better understanding of research issues than a stand-alone approach.

While I conducted several field visits for data collection in both the sites, a few follow up interviews were done virtually through zoom and telephone, during 2020 COVID-imposed lockdown period. The insights on how the water institutions functioned during the COVID crisis and whether they have developed any long-term plans for such unexpected disasters as COVID-19 was also explored as such unprecedented risks such as COVID-19 impacted the water management. This part of exploration was not planned initially but with the spread of COVID-19 worldwide including Nepal, and its impact on lives and livelihood of people, water sector could not remain out of its impact. Hence, the water institutions' immediate response and long-term planning was considered to be important part of developing risk resilience of urban water system, along with other climate induced disasters such as floods and landslides.

3.3 Field reflections

I have consolidated some field reflections during the research process in this section. I have discussed the situations and challenges I have encountered during my research and the strategies I adopted in such situations. I have further discussed regarding the reflectivity and positionality while conducting my study.

3.3.1 Strategies adopted during interviews and discussions

First and foremost, I discuss about the insights gained on conducting qualitative interviews. The researchers are well known of the challenge in extracting the information within limited time. The qualitative interviews I conducted were semi-structured allowing space for the participants to share relevant issues within the broad questions. The level of information extraction depended on the attitude of the participants as some participants when introduced with the topic of research, begun sharing information and stories. At some points, the participants also shared long stories and was difficult to intervene and bring back to focus on the main agenda. While other few participants shared limited information upon the questions raised as they spoke less.

I was aware about the value of 'listening' to the stories of participants even though sometimes they deviated from the topic of inquiry. While reading the transcripts during analyzing phase, I could feel that those sharing were important in setting the context and understanding more about the participants. Therefore, giving space to the participants to tell their story in a way helped to know more about them and the context- details that might not be directly relevant but created room to let people share their point of view of their world. Specifically, the situation sometimes became emotional while the participants shared emotional experience of conflict related to access to water, perception about climate change, taking them back in the time period or reflective mode requesting them to 'think back- when they were child, or got married and had to collect water here, think back how they got water every day prior to the water scheme'.

Another important quality of the interviewer is to strategically handle the emotions of the participants and be empathetic to them (Giri et al., 2020). During the data collection, I was careful to be empathetic to the participants as 'Empathy' during interviews is important as we are interviewing human being and during the conversation, we came across emotions as pain, suffering and sensitive topics. Pillow (2003) has mentioned about the need of the researcher to be non-exploitative and compassionate towards the research subjects. I also realized that the participants become more willing to share their experience while researchers are sympathetic to the situation of the respondents as discussed by De Tona (2006).

During the COVID time, I encountered that a few participants were themselves infected by COVID or their close family members were infected. In some cases, they even lost their loved ones. While conducting telephone interviews and online interviews with them without knowing about their situation, I was cautious to listen to them and comfort them first. The major time of conversation was spent in getting acquainted with the COVID scenario listening to the situation of the family members in hospital and assuring them, especially the female working committee members before jumping in to inquire how the drinking water users committee are handling the COVID situation. One of the close relatives of the participant in Dhulikhel was admitted in hospital and was serious. I shared my similar experience of my late father how difficult it was while he was admitted to hospital for months and some of the close relatives who could fight COVID and regained their health. This helped to develop trust with the participants and strengthened personal relations by connecting emotionally with them that provided space of sharing. Sometimes, to maintain the personal relations, out of topic telephone calls were made to just say hello and get the update how they are doing. This helped to strengthen the researcher-

researched relationship, and participants were more open to share information which would otherwise not happen.

At the same time, I myself as a researcher, could not remain unaffected by the ongoing situation. Particularly during the peak COVID-time when there was restricted mobility and I had to stay at home, frequent news about the death toll created anxious situation and I too got infected with COVID. Handling my own emotions and supporting the research participants and comforting them was not easy. Similar situation is explained by Bloor et al. (2008) stating that some emotional labor is needed in establishing and maintaining good fieldwork relations and that can sometimes be draining too.

Next is regarding the strategy to be flexible during field works depending on the context of the interview or the environment at the place of interview or discussion. For instance, I tried to schedule interviews and discussions at the time appropriate to the participants. In the morning, they were in a hurry to complete household chores and send their children to school, particularly the women. I talked to them later when they were free and organized the discussions mostly after 9 am.

I also noted how the presence of other people around made the participants uncomfortable to answer the questions and I had to adapt accordingly. For instance, while interviewing female participants of water users committee separately within office premises in Dhulikhel, the participants were uncomfortable while a male member entered the space. I could immediately understand the indicative gesture of the participant (the female participant pinched me) and that what she shared after that about the committee members' attitude in participatory decision making was not the real story. We then consciously diverted our conversation to another topic. I captured such instances in the detailed field notes.

Likewise, I was flexible to allow the research participants to attend their unanticipated important agendas though they had scheduled an appointment for interview with me. For example, Deputy Mayor of Dhulikhel had not managed to have lunch due to the delay of previous program and we met in the set appointment. I requested her to have lunch and I calmly waited for some time more. Sometimes, during the midst of the interviews, the participant had to leave for collecting the drinking water from the taps to store water in the drums; as sometimes, the timing of distribution of water was not according to the schedule.

3.3.2 Reflexivity and positionality in research

Reflexivity in research is one of the important tools for researcher to be self-aware and be self-critical constantly throughout research. Reflexivity is the internal dialogue and self-evaluation of the researcher's positionality. Situating oneself socially and emotionally in relation to research participants forms an important element of reflexivity (Berger, 2015). The author also mentions about 'reflex reflexivity' meaning reflect on reflexivity.

I took into consideration 'self-reflexivity' to reduce the possible biases in research due to my positionality in relation to the research topic, political and social engagement. I practiced self-reflexivity throughout the process of research, starting from formulating research questions, selecting the research participants, interviewing, analyzing data, interpreting data and making conclusions. As a researcher, I was aware to turn lens back to oneself to recognize and take responsibility for my own situatedness within the research and the effect that it may have on the setting and people being studied, questions being asked, data being collected and its interpretation.

However, no research is free of bias, and no one can completely detach the inherited characteristics. There is no any perfect solution for biasness, but I was aware on the positionality to be able to figure out the biasness that might occur and thus tried to control the biasness as much possible, reflecting step by step throughout the research process.

Insider-outsider perspective or the emic-etic perspective reflects 'things that you see from here, you can't see from there'. Participatory observations provided opportunity to gain insider view of the power relations amongst the water users committees' members and political divisions as well as the upstream/ downstream relations as discussed in the group discussions. These would otherwise not be clear through the interviews. The women members provided detailed information of the major issues observed in the water user committee's general assembly in follow up interviews.

The gender, class, caste and ethnicity also affect the data collection and relationship with the participants. Belonging from indigenous Newar community, specifically, in Dhulikhel, it was easy for me to build relationship and talk to the core people as most of them belonged to the Newar community and I am able to well understand and speak in their local language, Newari. Mostly the old people are comfortable to speak in Newari language and some cannot explain clearly in Nepali as they can in Newari language. In Dharan, it was easy to connect to people in relation to my hometown, Birtamode in Eastern Nepal.

3.4 Study sites and justification

As part of this research on urban water security, I chose two sites, Dharan and Dhulikhel of Nepal (refer to Figure 5). The prime features of the two case study areas and justification of their selection are discussed further.

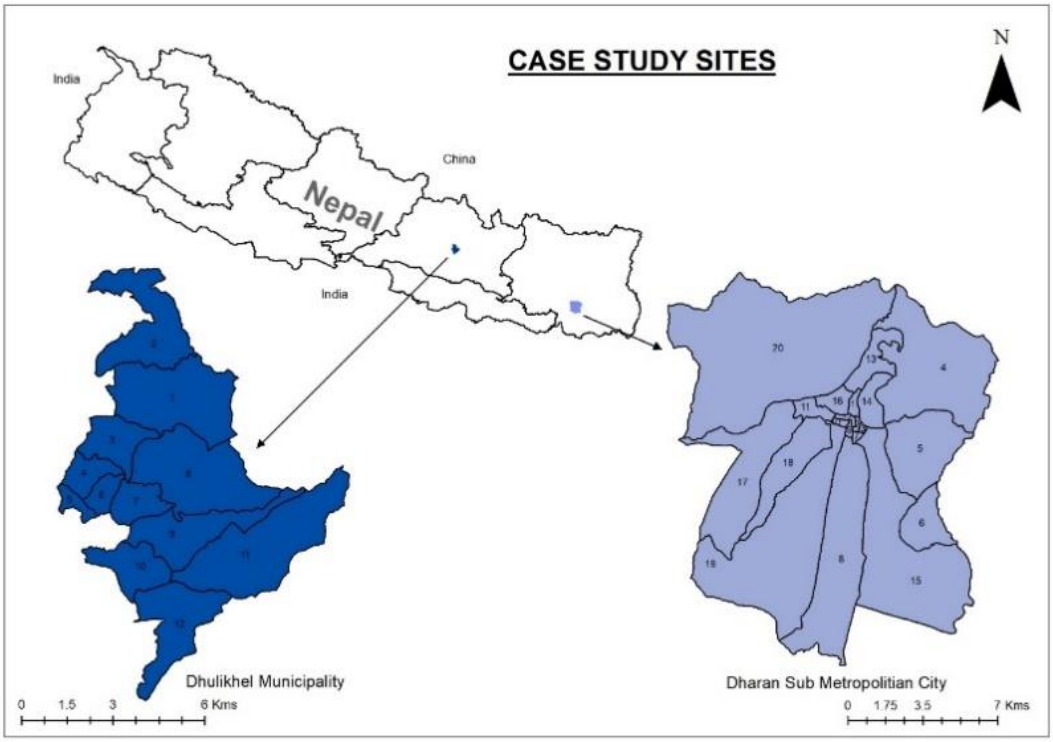

Figure 5. Map showing study sites, Dharan and Dhulikhel

3.4.1 Study sites

Dhulikhel: Dhulikhel is a hilltop city located in the mid-hill region of east-central Nepal, 30 kilometers east of Kathmandu, the capital city of Nepal. It lies within $27^0$37'N $85^0$33'E and is a part of the Kavre Valley, which comprises Dhulikhel, Banepa and Panauti as major urban centres. Dhulikhel municipality lies in Province 3 covering an area of 55 square kilometers (km^2) and consisting of 12 wards. It has total population of 32,162 with population density 585/km^2.

Dhulikhel is well-known as a hill-top town as it is situated at the top of the hill in the Nepal Himalayas where its settlements are clustered. Hence, it lacks a nearby higher elevation mountain watershed to supply water to the Dhulikhel residents. Dhulikhel is a rapidly emerging satellite city of Kathmandu, and it bears prime importance from a commercial point of view, with a trade link to Tibet, the autonomous region of China. Two highways, B.P. Highway, also known as Banepa Bardibas Highway, and the Araniko Highway, pass through Dhulikhel.

Integral components of the local economy include Kathmandu University, Dhulikhel Community Hospital, hotels/restaurants/lodges, businesses, and local farms. With its strategic location, population growth, rapid urbanization and development as touristic hub, it is experiencing increasing water scarcity. Dhulikhel is one of the pioneer towns for urban water management in Nepal and it is regarded as an exemplary city to initiate community-based water management practice since 1980s.

Dharan: Dharan is situated at the foot of the eastern Nepal Himalaya within 26°49′0″N 87°17′0″E in Sunsari District and situated at the foothills of the Mahabharata Range to the north, with its southern tip touching the edge of the Terai region. The government of Nepal upgraded Dharan municipality as sub-metropolitan city in 2014 by annexing neighbouring Panchakanya Village Development Committee (VDC) and Bishnupaduka VDC in existing Dharan municipality, extending 19 wards into 27 wards. According to recent restructuring, Dharan Sub-metropolitan city lies in Province 1 consisting of 20 wards covering area 192.32 km^2. It has total population of 137,705 with population density 716/km^2.

Its location at the foothill indicates its limited water catchment areas; hence has to rely on water flowing from higher elevations, creating a dependency on upstream management practices. It is also vulnerable to changes upstream water availability and environmental changes. Dharan serves as a gateway trading post between the hilly region and the plains of Tarai region. The major educational institutions in Dharan include traditional Sanskrit education (Pindeswor Campus, Nepal Sanskrit University), Medical Sciences (BP Koirala Institute of Health Sciences), Purvanchal Engineering Campus (Tribhuvan University), Central Department of Food Technology Hattisar Campus. It is also a business center with a number of hotels. The CBS (2011) data shows that the migration from other districts is high (41.5%) and managing water during the dry season to fulfill the demand of the burgeoning population is very challenging to Dharan residents.

3.4.2 Justification of sites selection

As illustrated above, Dharan and Dhulikhel were selected on their relevance of two key reasons. First, these are emerging cities exhibiting high rate of urban expansion with rapid population growth and are facing acute water scarcity with increased gap between water demand and supply (Pandey and Bajracharya, 2017; Pandey et al., 2019; Ojha et al., 2020). They are also facing water conflicts, management and access related challenges that are going

to aggravate in the future. Second, Dhulikhel and Dharan represent variable size and geographical features and are located in different regions of Nepal.

Here, I refer emerging cities as the cities experiencing rapid population growth and urbanization and bearing the economic prospects with their strategic locations. The study sites cover two cities with variable features: Dhulikhel being a small-sized hill-top town, located in central Nepal while Dharan is a mid-sized foot-hill town in eastern Nepal. However, both the cities are common in terms of situation at prime locations, and thus are emerging centers from commercial point of view. Dhulikhel is struggling for water supply for over three decades as it lacks its own high mountain watershed to supply water while Dharan is reeling under water scarcity with limited surface runoff from the catchment areas. These cities are implementing donor funded drinking water projects to secure water in their areas. The insights from these two cities in terms of the institutional responses and challenges in securing water would represent the issues from foothill and mid-hill cities.

In Dharan, Nepal Drinking Water Corporation has not been able to meet the demand of the population where Shardu, Khardu Rivers and ground water extraction are the main sources of water. The sustainability of the Asian Development Bank (ADB) funded ground water project is highly contested by the locals of Dharan and there is high level of uncertainty about the long-term sustainability of the water sources. Similarly, securing water for the residents in Dhulikhel has also remained a key challenge with escalating water demand with increasing development. Contestation is observed in Dhulikhel between the upstream and downstream communities on accessing water sources. The expansion of the previous municipality by integrating the neighboring village development committees has aggravated the water scarcity problem. Moreover, the equitable distribution of water among different users is a key challenge in these towns with high rate of urban expansion. In addition, institutional challenges in water management and changing governance contexts are contributing to water insecurity in these towns.

Current planning and management have proven insufficient to address the challenges of meeting diverse needs for water. Satisfying growing industrial water requirements and protecting water quality and equitable water distribution are the challenges to overcome. Therefore, the study fits in with the current adverse water scarcity problems in identifying the issues and challenges in water use and management and the study sites serve as the representative urban areas in Nepal.

These small and mid-sized cities are likely to evolve into larger cities in the near future. Focusing on these towns offers a forward-looking lens, where identifying and addressing water insecurity challenges today can inform proactive strategies before problems escalate. Given the federal context, their experiences also reflect how newly empowered local governments are grappling with the responsibilities of water governance. Therefore, Dharan and Dhulikhel offer meaningful insights into the dynamics of urban water insecurity in rapidly transforming Himalayan cities. The study in two cities is not a comparative study, rather its aim is to understand how the people in the cities are dealing with the issues of water insecurity that can offer lessons to similar emerging cities.

3.5 Data collection methods

For the research, I collected both primary and secondary data using different research methods. As explained in above sections, I adopted qualitative-led mixed method approach including both qualitative and quantitative methods for gaining deeper insights on city water management related challenges and proper planning required for securing the cities. The different methods of data collection are discussed below.

The discussion below also illustrates the sampling strategies adopted for the qualitative and quantitative data. Sampling is the process of selection of a segment of a population of interest for making observations and analysis of the population (Bhattacherjee, 2012). The sample is thus a representative of the whole population as we cannot study the entire population. Hence, the inferences derived from the sample can be generalized to the entire population. The careful techniques applied in sample selection is known as sampling strategy. I have adopted different sampling strategies for qualitative and quantitative data collection.

3.5.1 Primary data collection

As part of primary data collection in the research, I collected qualitative and quantitative data using in-depth interviews, and focused group discussions as qualitative methods and household questionnaire survey as quantitative method. These methods are listed in Table 4 and explained further in the sub-sections.

Table 4. Details of primary data collection methods

Qualitative Methods	**Dharan**	**Dhulikhel**	**Total**
In-depth Interviews	26	32	58
Focused Group Discussions	7	7	14
Quantitative Method	**Dharan**	**Dhulikhel**	**Total**
Household questionnaire survey	273	211	484

3.5.1.1 In- depth interviews

In-depth interviewing is a qualitative research technique that involves conducting intensive one-to-one interviews with a small number of participants to explore their perspectives on a particular issue. For this research on urban water security, in-depth interviews with the participants aim to explore the water related issues, specifically on identifying the drivers of water insecurity, institutional and governance responses and challenges in the context of climate change and urbanization. According to Gill et al. (2008), in- depth interviews are appropriate where detailed insights into the issue are required from the interviewers.

For the data collection, I identified the participants through purposive sampling, a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources (Palinkas et al., 2015). This involves identifying and selecting individuals or group of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Cresswell & Clark, 2011). I was open to the number of research participants until I felt data saturation, as referred by Malterud et al. (2016). I tried my best to ask and focus the interview based on the core expertise of the participants as discussed by Bernard (1998).

The interviews were semi-structured and open-ended to capture the point of view of the participants on water related issues. The in-depth interviews consisted of several key questions that helped to define the areas to be explored and allowed the interviewees to respond in detail. The one-to-one in-depth interview explored issues in detail with the interviewee, using probes, prompts and flexible questioning styles. A total of 58 in-depth interviews: 26 in Dharan and 32 in Dhulikhel were conducted. I identified the participants on the basis of different stakeholders engaged in water management. For instance, the people in policy making – the newly elected representatives of the municipalities, representatives of different institutions engaged in water

management and related decisions as water users committee members and those in key positions, different institutions' representatives as that of Nepal Water Supply Corporation (NWSC), Water Board and water supply projects. Further, representatives of civil society groups, water corporations, women networks and water users were included as participants.

I explored the qualitative information on issues and challenges of water insecurity and sustainability in urban context and perception-based data on role of climate change in water security, participation in decision-making, challenges related to governance and others. I prepared and referred to a checklist to facilitate the interviews. The series of interviews were conducted with the participants and some of them were approached for follow up interviews for updated information and details as per the requirement (refer to Table 5).

Table 5. In-depth interviews details

Types of research participants (Representatives from)	**Dharan**		**Dhulikhel**		**Total**
	Male	*Female*	*Male*	*Female*	
Municipal/wards representatives	6	1	14	1	22
Water management institutions (NWSC, Water Board, Water Users Committee)	2	1	1	3	7
ADB funded water project representatives	2		1	1	4
Civil society groups (struggle committees) / NGOs	3	1	2		6
Water Users	2	4	3	3	12
Private sector representatives	4		2	1	7
Total interviews	19	7	23	9	
	Total= 26		Total= 32		58

3.5.1.2 Focused Group Discussions

Another method I applied as part of qualitative data collection, was the focused group discussions in both Dharan and Dhulikhel. Owing to the diverse issues on water security raised in the individual interviews, bringing together the related stakeholders to discuss jointly on the key issues and their solutions was deemed necessary. So, the group discussions were organized for gaining deeper understanding of the issues, varied perceptions of the stakeholders, and possible solutions in addressing the water security related issues. Some of the group discussions

had diverse stakeholders while a few others had issue-specific stakeholders. In the discussions, the elected municipal representatives including Mayor and Deputy Mayor, drinking water officials namely Dhulikhel Drinking Water and Sanitation Users Committee (DDWSUC) in Dhulikhel and Nepal Water Supply Corporation (NWSC, Dharan), representatives from ADB funded drinking water project, Hotel Association, Chamber of Commerce and Industries, larger water users, hotels, schools and university, elected municipal women members, academicians, representatives from upstream communities, participants from neighboring municipalities and others participated.

The discussion incorporated the issues ranging from water availability, demand and supply, scarcity to urban water management challenges, gender issues, upstream-downstream relations and sustainable, climate adaptive, equitable and sustainable solutions for securing water. The discussions were not only helpful for gaining deeper insights on the water scarcity and governance challenges in the case study sites but also provided a participatory platform for discussing the issues in presence of relevant stakeholders to devise solutions in securing water. It also helped in raising the major issues and voices of different stakeholders which was followed up in the in-depth interviews with clarification on issues that were noted in the in-depth interviews. A total of 14 focused-group discussions: 7 in Dharan and 7 in Dhulikhel were organized. Out of these, one focused group discussion in Dharan and one in Dhulikhel was women-only and the other four focused group discussions were mixed groups including both male and female. The women-only focused group discussion centered around the gender issues and the women were open to share the challenges they faced in accessing water as well as in decision-making processes.

3.5.1.3 Participant Observation and Transect Walks

Another method used in gaining the qualitative field insights was the participant observation and transect walks. During the field work in the study sites, I could gain deeper insights and could relate the issues raised in the interviews and focused group discussions through the observation of, for example, key sites such as water storage and filtration structures, treatment technology, location of water sources, slum areas, and community settlements and other key infrastructures, land use types etc. Initially, to get the understanding of the study sites, I walked around the settlements with community members, participants and sometimes on my own. Further, I could also broaden my understanding by participating in relevant forums such as in General Assembly of Drinking Water Users Committee and water forums and observed the protests done by the struggle groups. The discussions in these events and the varied perceptions

during such events and simply observing how the events were conducted, who participated and who did not was helpful to me to gain important insights. I captured the photos and video clips of the key sites during visits for future reference.

The discussions in the focused groups were noted in detail for analysis also highlighting which group of stakeholders put forward their specific reflections and sharing. For instance, the municipal leaders, civil society organizations representatives, the drinking water project representatives, downstream water users or the upstream community's representatives shared their opinions and claims from their respective sides. The non-verbal and contextual behaviors and interaction of individuals in formal as well as informal settings were observed. These included attitudinal behavior of the interviewee or the gestures during the group discussions as domination of a certain group or experience of uncomfortable feeling due to the presence of some other participants.

3.5.1.4 Household Questionnaire Survey

I used the questionnaire survey for data collection, with the intent of generalizing from a sample to a population (Babbie, 1990). The aim of this survey was to understand the access and use of drinking water at the household level, institutions engaged in water management, their perception in climate impacts on water quality and quantity, governance, and others.

After preparing a comprehensive questionnaire, it was piloted in Dhulikhel. I revised the questionnaire incorporating the reflection of piloting, particularly in reorganizing the questions, removing some questions while rephrasing a few others. I led the questionnaire survey in Dharan and Dhulikhel and discussed closely with the enumerators on each of the questions and responses. Closed-ended questionnaire was used. The survey data was analyzed in Ms-Excel for the descriptive analysis. Along with the demographic information of the respondents, the surveys covered the questions on water sources of households, availability and distribution, impact of climate change and urbanization in water security, water quality, gender roles in water management, water institutions and governance related challenges. Some statistical analyses were also done (t-test and chi-square test) for quantitative data in Statistical Package for the Social Sciences (SPSS).

For quantitative data, in Dhulikhel, survey was carried out for 211 households in 13 wards while in Dharan the survey was done for 273 households in 20 wards. I used Yamane's formula (1967) for determining the sampling size.

Sample size (n) = N / (1 + N (e2) where,

N = population size (total number of households)

N= sample size,

e = Margin of error

Yamane's formula is used when we are not able to study an entire population, as in this case, provided that the entire population size is large, a smaller sample is taken using a random sampling technique. This formula allows the researcher to sample the population with a desired degree of accuracy.

Sampling strategy: To determine the sample size, the total number of households considered as a population in Dhulikhel consisted of 4,321 households[11] and 32,693 households in Dharan (CBS, 2012). Applying the above formula, at 93% confidence level in Dhulikhel (e=0.07), the sample size is calculated as 195 while in Dharan, at 94% confidence level (e=0.06), the sample size is calculated as 275. The total sample size taken for the survey consisted of 211 households in Dhulikhel and 273 households in Dharan. So, the total sample size for the survey in Dhulikhel and Dharan is 484.

A slightly higher sample size was taken for Dhulikhel (16 more households) for higher reliability and in Dharan, the sample size used is 273 (as two household data had errors). After the identification of sample size, proportionate sample size was calculated in each ward, 13 wards in Dhulikhel and 20 wards in Dharan in which simple random sampling was done.

3.5.2 Secondary data collection

For the secondary data collection, I reviewed the relevant scientific literature and grey literature published nationally and internationally. These included the key journal articles published in the theme of water security concepts and methodology, water and urbanization, climate impacts on water, institutional and governance responses and challenges in water scarce regions, water related conflicts, assessment of water security in cities. These articles consisted of review articles, theoretical and empirical papers. I utilized my six-months Erasmus exchange stay at the Bielefeld University in Germany and tapped the opportunity in accessing the international journal articles relevant for my study.

Besides, national policy documents, municipal profiles of the study sites, websites of the governmental and non-governmental organizations engaged in water management, their reports, media articles, relevant news and Op-Eds and blogs were also referred. For a specific

[11] District/VDC wise Population of Nepal, Kathmandu, Nepal (2012), Rai et al. (2019)

sectoral policy response in my research, I also reviewed key policies in water, urban and climate themes to analyze the sectoral coherence. Demographic, socio-economic and climatic data, and maps were collected from various sources as Central Bureau of Statistics (CBS) and municipal profiles. Secondary literature on climatic data analysis was also referred.

3.6 Data analysis and management

I collected data using mixed method approach, through qualitative and quantitative research methods and using primary and secondary data. As explained in section 3.2, the research used qualitative-led mixed method in which both qualitative and quantitative data were collected. The quantitative data collection was a one-time data collection while qualitative inquiry formed part of research throughout the thesis writing period. Insights from both field data collection along with literature review on water security concepts helped in building the idea of research.

The **qualitative data** collected through in-depth interviews and focused group discussions were analyzed using content analysis/ thematic analysis. The data collected were first transcribed, and transcription analysis was done by coding, categorization & theme analysis, as discussed by Henn et al. (2009) and Yin (2009). A typological coding methodology was employed which requires the researcher to sort data into typological categories in order to discover patterns and develop themes (Hatch, 2002). Codes developed were compared across all interview data to search for overlapping trends in meaning and redundancy.

The major themes of the research were aligned along the research questions. For instance, the key themes included water supply and distribution, drivers affecting water security including climate change and urbanization, institutional responses, challenges and barriers in securing water among others. Further, the theme on drivers of water security included categorization of different drivers (socio-economic, political, technological, governance) as sub-themes. For the second theme on responses, the sub-themes included policy responses and institutional responses. Likewise, on challenges and constraints, the emerging themes such as challenges related to water systems' resilience, water sources and watershed conservation, institutional and governance challenges were coded. The different dimensions of water security such as water availability, quality, affordability, equity, and governance were also noted in the text while reviewing the issues identified by the stakeholders and their suggestions of addressing water insecurity.

The observations and key thematic reflections and methodological reflections were noted. The checklist developed for the in-depth interviews to meet the objectives of the study were referred

while doing the analysis. The insights from the field notes of interview and participant observations were also added to the analysis. While making the transcript analysis and note taking, discrepancies were identified and signs of surprise, emotions as feeling of happiness, anger, frustration and domination were noted for meaning making.

The **quantitative data** collected was cleaned and anonymized. Then the data was entered in MS-Excel and analyzed based on the research questions. Simple descriptive analysis was carried out in the analysis. Analysis of the major water sources, water use and need, availability and distribution, time taken to fetch water, perceptions on change in water quantity and quality, coping strategies adopted, perceptions on climate change and drivers affecting water security, and institutional and governance related issues, such as participation in decision making, satisfaction with the water services, etc., were carried out for both the study sites. Some statistical analyses were also done (t-tests and chi-square tests) for quantitative data in SPSS.

While quantitative data broadly provided the perceptions of people regarding drivers affecting water security, the main drivers being urbanization, climate change and a combination of these factors, the qualitative exploration provided in-depth insights of multiple drivers that were categorized into socio-economic, environmental, technological and governance related drivers. Quantitative data provided information about the perception of climate change and its impacts on water sources, institutional management related issues, gendered roles in water management, and possible solutions for securing water; while the detailed insights and perceptions were obtained during the interviews and focused group discussions.

For the research question on institutional responses and challenges, the quantitative data was able to note the key institution engaged in the water management and the perception of households if they were satisfied with the current water management services and the solutions to address the water scarcity issues. Qualitative data were used to analyze what were the challenges/ constraints the key water institutions were facing to manage the water distribution. The temperature and precipitation data of Dharan and Dhulikhel were collected from DHM. As per the station data availability, data from the past 31 years (1993-2024) of Dhulikhel and past 26 years (1998-2024) were analyzed. The detailed methods of data collection for each research question are given in Table 6.

Table 6. Methods for data collection

Research questions	**Key research themes**	**Methods used**	**Data management and analysis**
R.Q. 1. What are the key drivers and nature of water insecurity in emerging cities of Nepal?	Drivers including urbanization and climate change	In-depth interviews, focused group discussion, and observations Survey questionnaire Temperature and precipitation data analysis (DHM data) Secondary research on climate analysis	Thematic coding and analysis of interviews and focused group discussion transcripts, field reflections and observations - for qualitative data Descriptive analysis & some statistical analysis (t-tests and chi-square tests) for quantitative data
R.Q. 2. How are the responses to growing urban water insecurity organized in the study sites?	Institutional and policy responses	In-depth interviews, focused group discussion, and observations Review of sectoral policies on urban, water and climate themes	Thematic coding and analysis of Interview and focused group discussion transcripts, field reflections and observations Analytical review of policies and review of secondary literature
R.Q. 3. What challenges and limits are being faced in securing water for the future?	Coherence of policies in urban, water and climate theme to address water security concerns	In-depth interviews, focused group discussion, and observations. Survey questionnaire	Thematic coding and analysis of Interview and focused group discussion transcripts, field reflections and observations - for qualitative data

	Institutional and governance challenges		descriptive analysis for quantitative data
R.Q.4. What elements of governance dimension are imperative in the urban water security theory and why?	Governance dimension	Literature review on urban/ water security concepts Analysis of the above questions and findings	Review and analysis from literature and empirical data.

(Source: Author, 2017)

3.7 Reliability and Validity of data

Reliability refers to the consistency of the analytical processes used throughout the research. And validity pertains to the soundness and proper use of the methods employed, ensuring that the findings accurately represent the data. To establish the reliability and validity of the data, I adopted the triangulation method by using more than one data-collection method, such as in-depth interviews, focused group discussion, household survey, and review of articles and policy documents. Qualitative validity involves the researcher verifying the precision of their findings through the application of specific procedures (Gibbs, 2007). Surveys used as quantitative method was used to inform the qualitative data and also for the data triangulation. The questionnaire survey was designed carefully to collect the data required for the research and was tested before finalizing it. The questionnaire was revised incorporating the reflection from the field-testing. I also trained the enumerators explaining each of the questions and shared reflection with them on any issues noted while collecting the survey data.

Validity in qualitative research means to assess the accuracy of findings from the perspectives of the researcher, participants or readers, and includes trustworthiness, authenticity and credibility of data throughout its design and execution (Creswell & Miller, 2000). For this purpose, I adopted methodological strategies as acknowledging and reflecting personal biases in data collection and analysis, detailed record keeping, being open to different perspectives, including rich verbatim of participants. I used multiple research methods while collecting the

data to enrich the data quality. As discussed in the sections above, I tried my best to develop strong bonding with the research participants to gain their trust. I not only approached them for collecting the field data but also continued general conversations with a few participants to build rapport with them. I also conducted follow-up interviews with the a few participants to get the updated information and verify and check the data that were unclear. In addition to the surveys and interviews, I also used my insights from the observation of the context, expressions, intent of the participants for instance, by participating in the events. This helped in validating the data collected. I followed some of Gibbs (2007) suggestions in ensuring reliability, for instance, checking the transcripts to ensure that no mistakes are made during the transcription and checking the codes. Primary data was also verified and substantiated with the secondary data referring to the journal articles, blogs, government and municipal websites.

3.8 Ethical considerations

As research engages with people and collects data about people from the people (Punch, 2013), abiding by the ethical considerations is imperative while conducting research. My research is primarily a social science and environmental study involving exploration about water security related issues. I conducted the research implying by the research ethics as protecting the research participants identity, being sensitive in conflict sensitive issues, avoiding disclosing the harmful information, taking prior consent for photos and recording interviews and others. These were considered throughout the research period and applied to both qualitative and quantitative research methods. Creswell & Creswell (2017) mentioned that the attention to consider the ethical issues involve from designing research to data collection and analysis, reporting, sharing and storing the data.

During the survey and interviews, the purpose of the research and how the conversation with them would help to identify the key issues relating to water security was shared. To avoid expectations with the researcher, I also explained to the participants that participation was voluntary, and they could withdraw or not answer any question that they did not wish to. Furthermore, prior consent was obtained for their participation. In case of household surveys, verbal consent was taken prior to the conversation while for the in-depth informant interviews, the prior appointment was set and a reminder call was given before meeting the participants. I was careful in taking the consent with the participants at the start of the interview to record the conversation and when the participants were uncomfortable, I took only notes and did not record the conversation. Depending on the situation, sometimes, I took note of only a few keywords in the mobile notes or just remembered and noted it later after the conversation.

Further, I also made a note of the interesting issues and events that occurred during the course of the interview for better understanding of the context. I was careful to set the interviews with the participants in the appropriate time of their availability.

I anonymized the participants' name with appropriate coding in the research database and kept with myself and have kept the information provided by the participants confidential, also maintaining the anonymity in publications. I have provided due acknowledgement to the contributors in my research publications.

However, there are chances to identify the participants when the excerpts are mentioned in the thesis or articles because in some cases, when a specific position of a person is referred, for example Mayor/Deputy Mayor of Dharan/Dhulikhel, it is obvious to the readers who the participant was. However, for others as member of drinking water users committee, representative from water supply project, inter alia, the identity of the participant cannot be revealed. In cases of contentious and sensitive issues (for instance, the upstream-downstream conflict issues discussed in the focused group discussions), I adopted careful strategy in facilitating amongst diverse group of stakeholder participants to share their concerns but avoid any disputes or unwanted situations and provide chances for every participant to put forward their thoughts. Also, sometimes it is not possible to record the whole event during participatory observations as in case of Drinking Water Users Committee's general assembly. In that case, I made careful observations of the event and recorded only a part of the event, such as the speech of certain relevant speakers. This was done as the speech was public hence it did not entail ethical issues.

3.9 Limitations of the Study

The study acknowledges certain limitations that help clarify its scope and focus of my research. Firstly, the study does not assess the level of water security index in the cities or develop any sustainability indicators as these do not form the focus of the study. This has been indicated as an area requiring further research.

Secondly, this research primarily focused on urban water security and governance to understand how governance structures and institutional responses shape access to water in rapidly urbanizing towns, without placing water justice as the central analytical framework. As a result, in-depth analysis of aspects such as distributive, procedural and recognitive justice and in-depth intersectional analysis in terms of gender, class, caste and ethnicity has been a limitation. However, these aspects are covered in general and the empirical insights and

literature review has come up with water equity and justice as an important dimension for ensuring water security. Further, this research has expanded scope of water justice and recommended focused study on equity and justice within urban water governance.

And thirdly, this study focuses specifically on urban drinking water and domestic water use, without extending its scope to other sectors such as irrigation or flood control. However, it acknowledges the importance of intersectoral linkages and recommends future research adopting a nexus approach to better understand and address the interconnected dimensions of urban water insecurity.

3.10 Chapter summary

This chapter provided an overview of research philosophy, ontological, epistemological, axiological and methodological approaches that has been adopted in the study. It further explained about the mixed-method research combining both qualitative and quantitative research in the study. Further, the chapter has also discussed the experiences of challenges, learnings in the field and how the situations were handled at the same time about the researcher's reflexivity and positionality in research. The chapter has discussed about the sites, two rapidly emerging cities and has provided the justification why the sites are ideal for the study. The chapter detailed out the different primary and secondary methods used in data collection, how the data analysis was done and what ethical considerations were taken. Lastly, the chapter has listed the limitations of the study.

CHAPTER FOUR: DRIVERS OF WATER INSECURITY

In this chapter, I present the findings of the first research question about the nature and drivers of water insecurity in emerging cities of Nepal. Taking cases of two rapidly urbanizing cities, Dharan and Dhulikhel, the research examines the nature and drivers of urban water insecurity in the context of rapid urbanization and climate change. In this chapter, firstly I introduce the water scarcity situation in the study sites as the context. This details out the water demand and supply, water sources, water need and distribution in the study sites, combining qualitative and relevant quantitative data. This is followed by categorizing the drivers or factors affecting water security in two cities broadly into socio-economic, environmental, technological, and management and governance aspects. Further, how they are contributing to affect the various components of water security as quantity, quality, accessibility, affordability, equity and sustainability aspects are also discussed. These drivers are identified primarily from in-depth interviews, focused group discussions, observations as well as from literature review.

4.1 Rising water demand and dwindling supply in the study sites

Dharan metropolitan city is constantly under pressure of acute water shortages in the recent years (Rai et al., 2019) with huge gaps in demand and supply side particularly in dry seasons. The growing demand for water in Dharan has out-stripped the municipal supply with shortfalls being most severe during the dry season, which typically falls between the months of October to May (Bajracharya et al., 2019).

According to government of Nepal, about 98% of Dharan households have access to piped water. Nepal Water Supply Corporation (NWSC) is serving 81% of the population of the town. Although the water demand is about 30-35 million liters per day, Nepal Water Supply Corporation (NWSC) has only been able to supply 15 million liters of water and this water supply is largely confined to rainy season, with the supply being intermittent, untreated and unsafe (Pandey & Bajracharya, 2017). In the dry season, a household receives 144 liters less water per day (Rai et al., 2019). The corporation distributes water 1–2 hour/day in wet season and average 1–2 hours/day in every alternative day in dry season. This indicates the acute water scarcity particularly in dry season. As the existing water sources and reservoirs are found to be highly contaminated and polluted, municipal water users are vulnerable to serious water borne diseases (Pant et al., 2016). Moreover, the squatter settlements in Dharan that covers population size of nearly 35000 also face severe water crisis in terms of both water quantity and quality.

Sardu khola and Khardu khola serve as primary surface water sources in the north, while groundwater from Charkoshe Jhadi, natural forest to the south supports Dharan's water supply. Surface water and ground water sources serve the drinking water supply (Turral et al., 2011). Ground water supplies 11% and 77% of municipal water in the rainy and dry seasons respectively (Dharan Municipality, 2014). Earlier, the water was extracted through 4 deep boring while the Asian Development Bank (ADB) funded drinking water project has added 8 deep-boring, with altogether 12 deep boring.

The increased sectoral demand also has used the groundwater sources, in the form of deep tube wells. The commercial users such as large hotels and industries, private water suppliers including bottling companies and drinking water projects have been extracting groundwater. For instance, BP Koirala Institute of Health Sciences (BPKIHS) in Dharan has its own 3 private deep tube wells inside its premises, at the lower part of the Campus. Easy Riders, Bhatbhatini and Gorkha Complex are reliant on groundwater extraction without getting approval from the concerned authorities. The ADB-funded drinking water project also pumps groundwater through tube wells in the forest as other options were not viable. Project officials in Dharan claimed that they had examined 32 places in Dharan for drilling and found it good for extraction.

> *"We dug 8 wells in the forest and there are 12 wells now (4 were dug by the Drinking Water Sansthan, NWSC). They can yield 8 to 15 lakh liters of water, and the ground water level also has not decreased. Drinking Water Sansthan had made a well 30 years ago and the water level has not decreased even in that well till now."*

Dharan faces water scarcity problem in almost all regions as the water is supplied to the households in alternate days but with variable access to water. Geographically, lower region has more water supply relatively than the higher region. Some households near the water tank get more water than households at farther than the water distribution tank. Leakage of pipes is maximum due to which only half of the water distributed reaches the household. It is also found that some of the users have connected their household level water supply pipes from below the main supply system so as to get more water than other pipes connected above the main supply pipe as per the rule (Pandey et al., 2019). To address the water scarcity issue, ADB funded drinking water project is implemented in the town. Table 7 details out the water sources and management in the study sites.

Table 7. Water sources & management in the study sites

Brief introduction of sites	Population and households (HH) number	Water sources and management
Dharan sub metropolitan city is situated at the foot of the eastern Nepal Himalaya, approximately 300 km east of Kathmandu, with limited surface runoff from the catchment areas.	Total population: 173096 (90413 F, 82683 M) HHs: 42396 Area: 192 km^2	Nepal Water Supply Corporation (NWSC) supplied water since 1982 and is merged to Dharan Water Supply Management Board. The Sardu and Khardu khola are the major surface water sources and Charkoshe Jhadi forest is the ground water source. The city has two ephemeral streams on two sides, river Koshi (13 km) and Tamor (25 km away).
Dhulikhel is a hill town located at 30km east of Kathmandu, situated at an altitude of 1441 meters above the sea level.	Total population: 32162 (16678 F, 15484 M) HHs: 7061 Area: 55 km^2	Water is managed through community managed water supply system (DDWSUC-Dhulikhel Drinking Water and Sanitation Users Committee). Three major sources supply water to Dhulikhel dwellers i.e., piped water from Bhumedanda, local springs and ground water. Kavre Valley Integrated Water Supply Board (KVIWSB) has been formed.

Source: Author, 2018

Dhulikhel lacks its own high mountain watershed to supply water, as in some Himalayan towns (Ojha et al., 2020a). Its geography as a hilly town and limited water sources has increased its dependency on surface water sources from distant source and ground water extraction. The town has been tapping water from the Roshi River since the early 1980s, which is a small stream 13.5 kilometers away in Bhumidanda located in the south-west of the city. It also experiences variable rainfall regime. With all its efforts towards managing the growing need as contributing in social and infrastructure development in upstream,[12] gradually decreasing

[12] through series of negotiations in 1983, 1985 and 2011

volume of water in the existing surface and ground water sources has intensified the water scarcity problem.

The water demand in Dhulikhel has increased from 2.31 million of liter per day (MLD) to 3.9 MLD but the supply has increased from 1.38 MLD to 1.8 MLD (McManus et al., 2021). The data shows the gap in demand and supply side and does not account to the individual average urban water requirement of 130 liters per person (capita) per day (LPCD) as recommended by World Health Organization (WHO) for Nepal. If we calculate the individual water need for 2017 population of the municipality (32162) as per WHO requirement of 130 LPCD, the need is at least 4.1 MLD without taking consideration of a large number of floating population and businesses.

In such scenario of escalating water demand, securing water for the residents in Dhulikhel has remained a key challenge. The city has piped connection to 48% of households for water supply but these pipes do not supply enough water to a larger number of the households (GoN, 2015). Contestation is observed in Dhulikhel upstream and downstream communities on accessing and sharing of water sources. The expansion of the previous municipality by integrating the neighboring village development committees has aggravated the water scarcity problem.

Dhulikhel is also dependent on groundwater through deep boring wells. Hotels, as well as Dhulikhel Hospital also use water partly from these deep boring wells. The Chairperson of ward no. 5 in Dhulikhel showed concerns about sustainability:

> *"The existing water sources will dry, and deep boring cannot be sustained forever. For the next 2-4 years or 10 years, the KVIWSP (ADB funded water scheme) will fulfill our demand. We have requested to conserve the forest and dug ponds for rainwater in the jungle."*

As DDWSUC has been unable to fulfil the increasing water demand, ADB funded drinking water project KVIWSP is being implemented to add water supply to service areas of DDWSUC in Dhulikhel, and Banepa and Panauti of Kavre valley. The project is near to completion.

The above description of the water demand-supply gap is further illustrated by the quantitative data collected from the study sites in terms of understanding the household water need, type of water sources, water availability and distribution.

As discussed above, the household survey data shows that maximum households had reach to piped water connection either into their dwelling or to yard which they used for drinking

purpose (refer to Figure 6). In Dharan, greater number of households had piped water supply into their dwelling (56%) while 39% of the household survey respondents had piped water into dwelling in Dhulikhel. A greater percent of households depended on piped water to yard in Dhulikhel (48%) than in Dharan (31%). The survey results also showed that the households depended on more than two sources in Dharan (11%) and public tap (9%) in Dhulikhel.

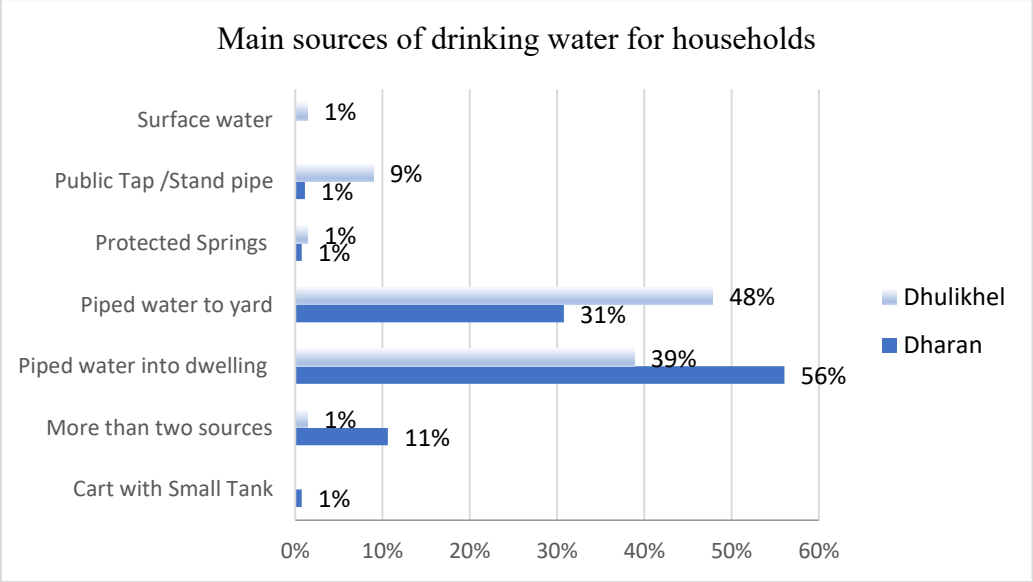

Figure 6. Main sources of drinking water for households

The survey results also showed that most of the survey households (77% in Dharan and 51% in Dhulikhel) had private water connection (refer to Figure 7). In Dhulikhel, 32% of the respondents depended on community-managed water supply and 16% in public water supply, while in Dharam 11% depended on community managed water supply.

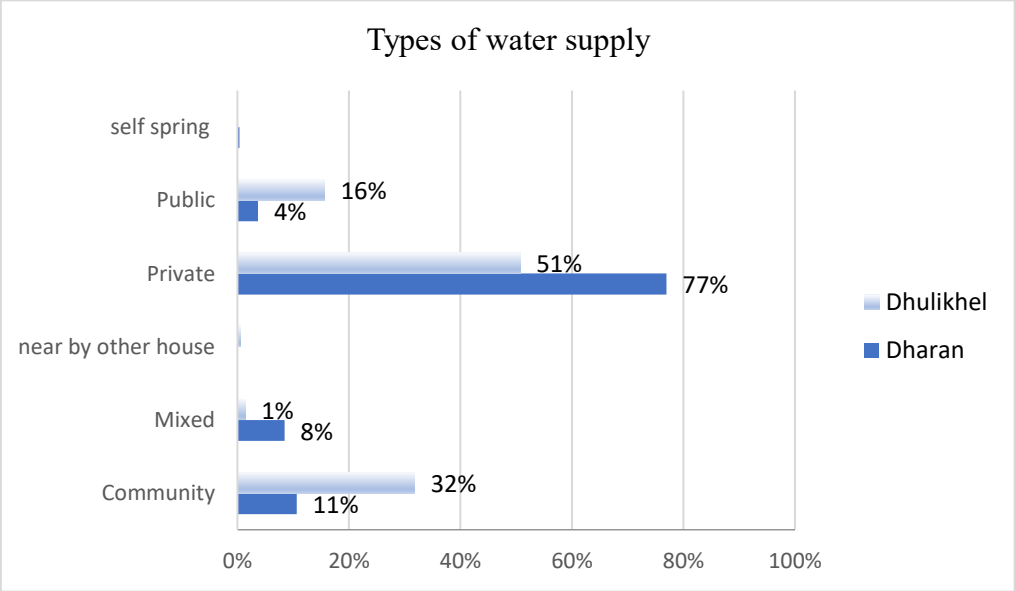

Figure 7. Distribution of types of water supply in each municipality

The survey data noted that most of the respondents in Dharan and Dhulikhel did not have to fetch water (56% in Dharan and 52% in Dhulikhel) (refer to Figure 8).

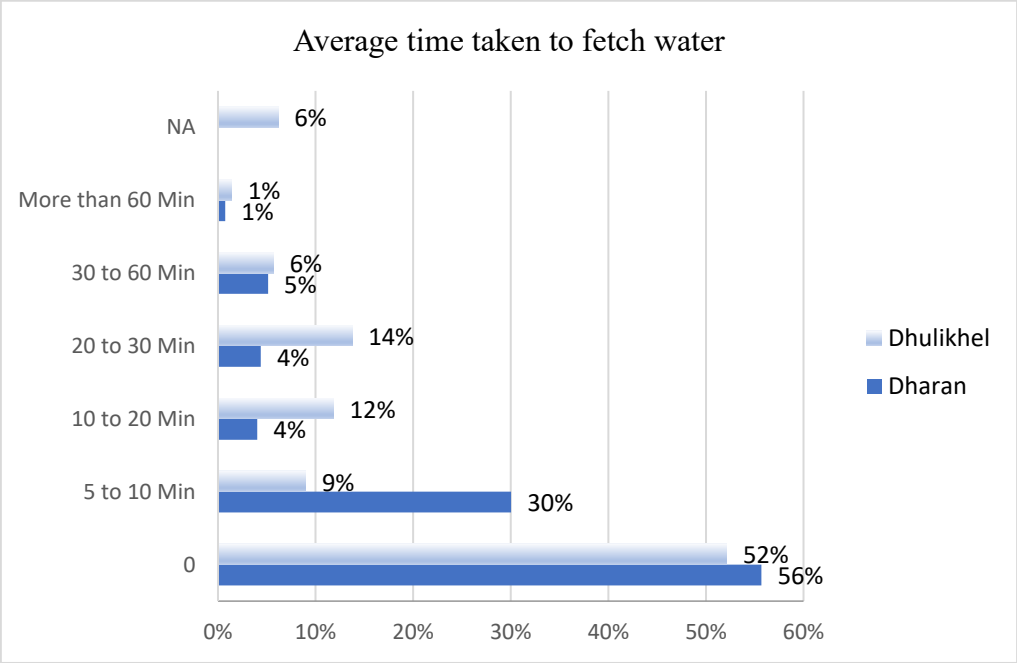

Figure 8. Average time taken to fetch water

The above discussed data showed that most of the households had piped water access near their residence, but the major issue discussed during the study that were strongly shared by the respondents, was the intermittent water supply. They received water from their taps for only a few hours and only during certain times of the day.

Further to analyze the differences in the two sites, analysis using Chi-square test was done (refer to Table 8) that showed there is significant difference in time taken to fetch water in Dhulikhel and Dharan. The Pearson Chi-Square is calculated as 123.103 with corresponding p-value (2 tailed) of 0.000. Since, 0.000<0.05 we reject the null hypothesis (H0: There is no significant difference in time taken to fetch water in Dharan and Dhulikhel; H1: There is significant difference in time taken to fetch water in Dharan and Dhulikhel). As shown in the figure above, Dhulikhel residents had to fetch water from a little farther than Dharan (12% required 10-20 mins and 14% required 20-30 mins), while in Dharan, the residents fetched water from nearer distance (30% fetched water from a distance of 5 -10 mins). The average time taken to fetch water in Dhulikhel was 11.6 minutes while in Dharan it was 7.5 minutes. Dhulikhel' s water supply consists of community and public taps at greater numbers than in Dharan and some residents, despite having private tap connection fetch water from community

taps owing to intermittent water supply and some even value the better taste of communal taps, hence prefer communal taps' water, as shared during interviews and discussions.

Table 8. Chi-square test for time taken to fetch water

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	123.103[a]	4	.000
Likelihood Ratio	147.917	4	.000
N of Valid Cases	484		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.57.			

Households managing water needs

The survey results showed that most of the households used water for different purposes among the family members as most of them did not have rented out their house. From the data explained below, for at least 5 members of household members, assuming basic water requirement of 300-500 litres of water per day, the total amount of water need equals to (300 litres * 5 members- 500 litres * 5 members) = 1500 litres -2500 litres per day. But the intermittent water supplied to the households is inadequate compared to the water need.

In another question about if the respondents rented their house, only 16% households in Dhulikhel rented out rooms in their houses while only 2% in Dharan. This entails that the water use was mostly done by the members of the house. For the households who have rented rooms of their houses (16% in Dhulikhel), 9% of the households have up to 5 members of rented family using the water.

The water need of household is also determined by the type of toilet. The survey showed that 94% in Dharan and 79% in Dhulikhel use pit latrine while in Dhulikhel, the flush toilets are growing in numbers (16%) (refer to Figure 9). With increasing urbanization and changing lifestyles, the flush system will soon replace the pit latrines, particularly the new houses being and hotels being built are with the flush system that requires greater amount of water.

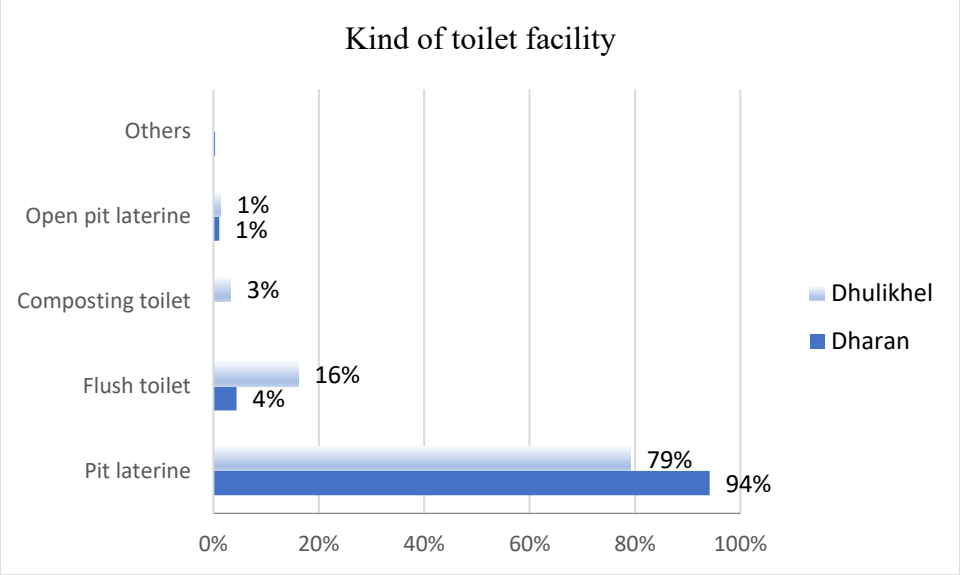

Figure 9. Kind of toilet facility

Number of people using water in house

The survey results showed that about half of the households in Dharan and Dhulikhel have the family size upto 5 who use water (53% in Dharan and 54% in Dhulikhel) while 37% of households in Dharan and 33% in Dhulikhel have 6-10 members of households using water in house (refer to Figure 10). While there were very few households with extended number of households. In Dhulikhel and Dharan, the average number of people in the household including the tenants was 6.62 and 6.23 respectively.

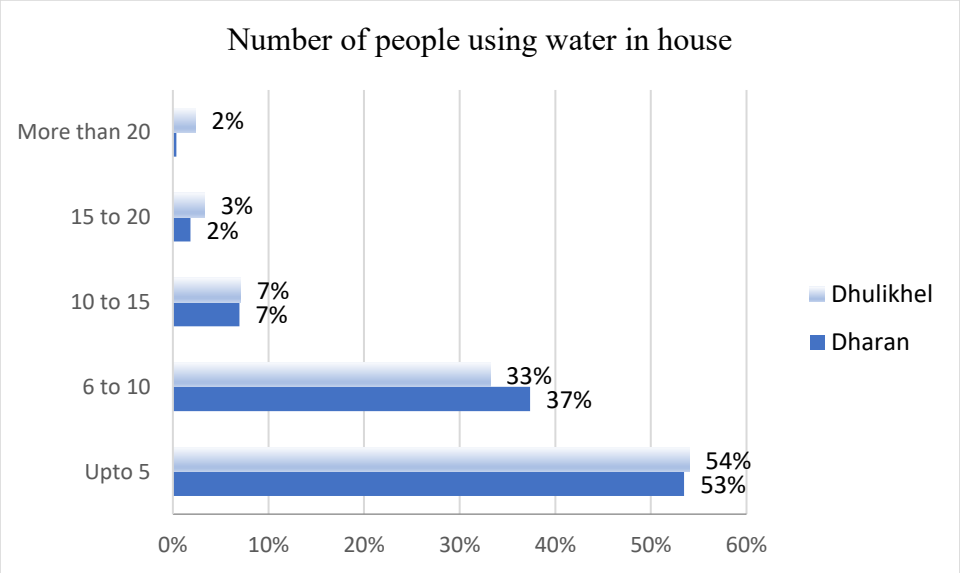

Figure 10. Number of people using water in house

Further, to analyze the differences in number of people using water in the households of the two sites, t test was conducted. The t-test conducted showed that the statistic is 1.062 with 482 degrees of freedom, and the corresponding two-tailed p-value is 0.289. Since the p-value is greater than the significance level of 0.05, we accept the null hypothesis (H0: There is no significant difference in the number of people, including tenants, using water in Dhulikhel and Dharan; H1: There is significant difference in the number of people, including tenants, using water in Dhulikhel and Dharan), indicating that there is no significant difference in the number of people, including tenants, using water in Dhulikhel and Dharan.

The survey question on water needs per day found that most of the respondents (36% in Dharan and 41% in Dhulikhel) required 300 to 500 liters, followed by the need of less than 300 liters (30% in Dharan and 36% in Dhulikhel).

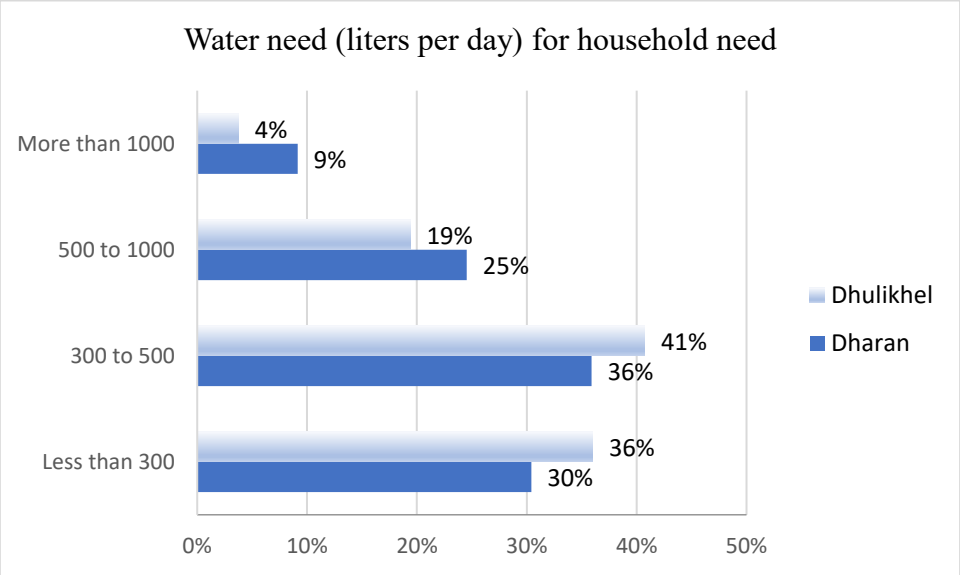

Figure 11. Water need (liters per day) for household need

Further analysis using the Pearson Chi-Square calculated the value as 8.302 (as shown in Table 9) with corresponding p-value (2 tailed) of 0.040. Since, 0.04<0.05, the null hypothesis is rejected (H0: There is no significant different in water need at household level in Dhulikhel and Dharan; H1: There is significant difference in water need at household level in Dhulikhel and Dharan). Hence, the analysis showed that there is significant difference in water need at household level in Dhulikhel and Dharan. Although the analysis (number of households using water) above showed that there is no significant difference in the number of people, including tenants, using water in Dhulikhel and Dharan, the difference in water need can be due to greater use of water in hot climate in Dharan. The analysis above also justifies the greater water need in Dharan. It showed that the household water need per household was greater in Dharan for

larger quantity of water (500-1000 liters and more) while most respondents used water quantity of up-to 500 liters of water in Dhulikhel which was greater than in Dharan (refer to Figure 11).

Table 9. Chi-square test for household water need

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.302[a]	3	.040
Likelihood Ratio	8.642	3	.034
N of Valid Cases	484		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.39.			

The household survey data in Dharan and Dhulikhel on water need and availability revealed that most of the respondents had access to piped water supply but the major problem they were facing was the intermittent water supply. They shared that having access to water in their households or yards did not solve their water problem as water supply was irregular and not supplied to fulfill their basic needs, even to the family of average of 5 people. In the household with rented people, the problem is worse. In an average, household water need was found to be between 300-500 liters for most of the households. Although the surveyed households used pit latrines, with the changing lifestyles, water demand is increasing for instance, the development of flush toilets, showers in new homes and growing number of hotels.

4.2 'Drivers' of water insecurity in Dharan and Dhulikhel

Water plays a central role in human development, the value of which is recognized in the Sustainable Development Goal no. 6 targeting the availability and sustainable management of water and sanitation for all. However, achieving this goal is challenging in the context of rapid urbanization in the era of climate change and is subjected to multiple factors. In this section, we discuss our findings on the drivers of water insecurity in Dharan and Dhulikhel. This means that these drivers are responsible for drinking water problems that need immediate attention of the water institutions including the local government. The chapter also discusses how these factors are found to affect different components of water security. The details about the drivers are listed in the Table 10.

Table 10. Drivers of water insecurity

Drivers	Drivers in detail	Implications and impacts in water security components	Linkage of Drivers
Socio-economic - urbanization and annexation, population pressure	Urbanization (haphazard built-in structures, annexation) Population Pressure (in-migration, increase in sectoral demand, floating population) Tourism (flourishing economy, hub for touristic activities) change in lifestyle (comfortable lives demanding more water)	Increased water demand Impacted water availability, quality, sustainability, equity and access, water related hazards Annexation in particular is causing inequitable water distribution (Equity component of water security). Change in land use Pollution at sources	Annexation leading to population increase; population growth causing urbanization or vice versa
Technological - Use of water pumps for drawing water - Leakage	Use of water pumps (resulting in inequitable water distribution with and without access to water pumps) Leakage (leakage at places reducing water at supply point)	Inequitable water supply between those who can access technology and who cannot (rich versus poor) at household level Intersectoral (hotels and industries drawing more underground water than impacting the household use)	
Environmental	a hilltop town and foothill town, strategic location	Difference in topography causing inequitable water	

- Topography, geography and location - Climate change	for flourishing economy, sloppy geography Change in climatic patterns (temperature and precipitation patterns)	distribution between hills and plain areas Climate change causing too little and too much water. Drying of water sources affecting availability, hence all components of water security. Climate induced disasters as floods and landslides risk to safety of water infrastructures.	
Management and governance	Non-coordination among water related institutions Federal context challenges (overlapping of roles and responsibilities, limited capacity of local governments) No proper watershed conservation plan/ground water depletion Lack of mandatory municipal policies, challenges in implementation of	Inefficient water management causing inequitable water distribution Sustainability component Planning could not be climate resilient -lack of forecasting future climate and population- leading to inequitable water distribution.	Ambiguous or lack of policies for institutional set up.

	piloting and response of water institutions		

Source: Author, 2019 (from empirical insights and review)

a. Socio-economic factors

The study finds that water security in Dharan and Dhulikhel is affected by population pressure, urbanization and annexation which are interlinked. For instance, annexation has led to population increase and urbanization; and population and urbanization are also interlinked. These factors categorized under socio-economic impact almost every component of water security. These are responsible for increase in water demand which means less water availability to increased number of people, increase in per-capita water demand, pollution at sources, and limited water supply making water distribution unreliable. Moreover, with the increased gap in water demand-supply as explained above, groundwater extraction is rampant affecting the sustainability component of water supply. Further, annexation of the nearby villages to the municipality during restructuring has caused inequitable water distribution in both the study sites where the annexed peripheral areas are devoid of water distribution by the operating water institutions.

The quantitative data also revealed the socio-economic factors as important drivers of water insecurity. In the household survey, respondents consisted of 52% male and 48% female in Dharan and 42% male and 58% female in Dhulikhel. In Dharan, 64% of the respondents consisted of Janajati ethnicity whereas in Dhulikhel, 50% were Janajati. Dharan is inhabited by Rai and Limbu communities while Dhulikhel has dominant percentage of ethnic Newar communities. were the mostly engaged sectors. The household survey data showed that the respondents in Dharan and Dhulikhel perceived combination of factors such as urbanization, climate change and population growth as the major factors affecting water insecurity in both Dharan and Dhulikhel (39% in Dharan and 29% in Dhulikhel). Other than that, climate change, urbanization and population growth were considered as the important factors affecting water availability in the area (refer to Figure 12).

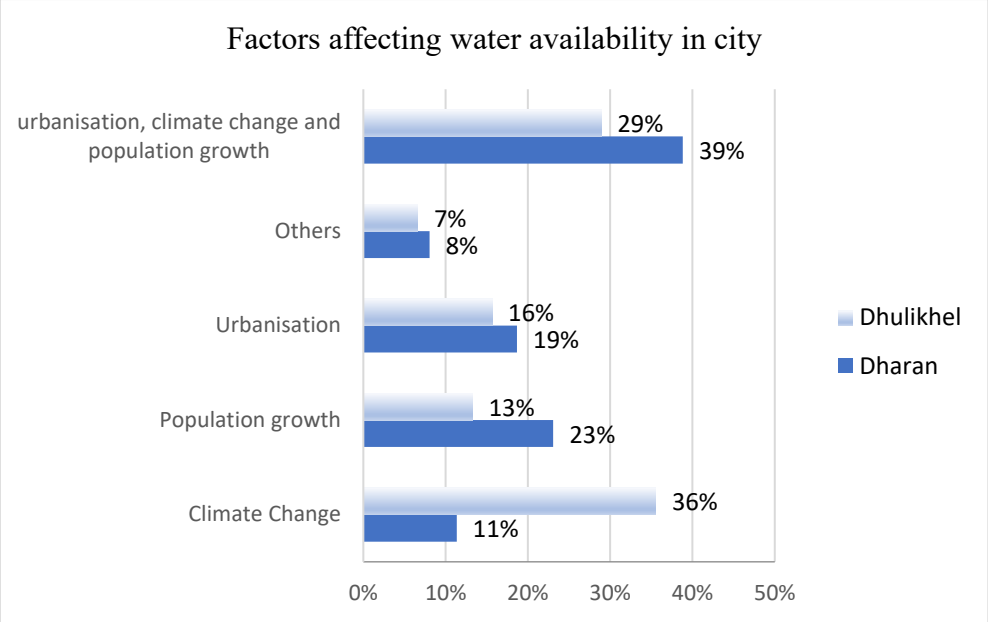

Figure 12. Factors affecting water availability in city

The socio-economic factors that include population pressure, urbanization and annexation affecting different components of water security are explained below:

- **Urbanization and population growth**

First and foremost, as highlighted in the context and literature review, population pressure and urbanization have been prominent drivers of water insecurity under the socio-economic factors.

As discussed in the study sites, both the towns are vibrant bearing prospects of education, tourism and economic development leading to increased water demand. Both Dharan and Dhulikhel are rapidly emerging cities and are experiencing rapid growth in population brought about by rural-urban migration, changing lifestyles of people, establishment of academic institution, flourishing tourism industry and hospitals that has increased the water use creating water stress. The interviews and focused group discussions emphasized that such rapidly urbanizing areas face the growth in population with increase in water demand-supply gap which the two study sites are facing as illustrated in explanations below.

Dharan is a sub-metropolitan city serving population of 1,66,531 with 42,396 households while Dhulikhel Municipality is smaller city with population of 33,726 with 8,570 households (CBS, 2021) (refer to Table 11). These are the resident population in the towns. If the floating population who are engaged in pursuing education, businesses and other purposes are also taken into account, the number would rise significantly. They vary in size and location, Dharan

being a foothill town and Dhulikhel a hill-top town but both bearing the water scarcity problems.

In Dharan, population in 2011 was 1,37,705 with 27,796 households (CBS, 2012)[13]. The population has increased to 1,66,531 with 42,396 households in 2021 (CBS, 2021) increasing in-migration to this foothill city. According to CBS (2011), 41.5% people migrated from other districts during 10 years from 2001 to 2011. The increase in population and in-migration was also triggered by the then Maoist insurgency and Madhesi movement by further developing new areas of urbanizing Dharan. People also migrated from the hills for employment and other amenities and lived in squatter settlements. Better prospects for business and industry are also causes of higher population growth in Dharan being the gateway to the Eastern region. More than five hilly districts rely on Dharan for everyday supplies, higher education services and other amenities of a modern town.

Population pressure is observed in Dharan especially in Vedetar, a touristic area after the development of Koshi Highway (also known as Dharan-Dhankute route). The increase in squatter settlement was brought about with urbanization within the city and establishment of B.P. Koirala Institute of Health Sciences in 1997. Of the total population, nearly 35000 with 6621 households reside in about 84 squatter settlements. Most of these settlements are in the flood plain areas of Seuti and Shardu Rivers and some sloppy hills and nearby forest areas. Although from 2048 to 2050, water distribution system improved but in-migration led to water scarcity problems.

Table 11. Total population, households and water demand and supply in the study sites

Municipalities	Total population	Households	Annual Population growth rate	Water demand	Water supply
Dharan	1,37,705 (CBS, 2011) 1,66,531 (2021)	32,693 (CBS, 2011) 42,396 (2021)	2.6%	30 MLD	20 MLD
Dhulikhel	32,162 (CBS, 2011) 33,726 (2021)	7,061 (CBS, 2011) 8,570	4.10%	3.9MLD	1.8 MLD

[13] CBS, District/VDC wise Population of Nepal, Kathmandu, Nepal, 2012.

		(2021)			

Source: CBS, 2011 and Pandey, 2020; McManus et al., 2021; National Population and Housing Census (NPHC), 2021.

Table 12. Total population in Dharan & Dhulikhel

Year	1961	1971	1981	1991	2001	2011	2021	2031†
Dharan								
Total population	13998	20503	42146	66457	95332	119915	166531	209889
Annual growth rate	-	4.6	10.6	5.8	4.3	2.6	3.4	3.4
Dhulikhel								
Total population	-	-	-	-	29,982	32,162	33,726	
Households	-	-	-	-	5,670	7,061	8,570	

Source: CBS, 2011 Bajracharya et al., 2019, Municipal profiles; †Projected

Further, rapid urbanization and growth in population brought about by rural urban migration, and its strategic location, development as touristic hub has heightened demand of water in Dhulikhel. The population in Dhulikhel in the last decade has increased from 32,162 in 2011 to 33,726 in 2021 and household numbers from 7,061 in 2011 to 8,570 in 2021 (refer to Table 12). Dhulikhel is a rapidly emerging satellite city of Kathmandu, and it bears prime importance from a commercial point of view, with a trade link to Tibet, the autonomous region of China. Two highways, B.P. Highway, also known as Banepa Bardibas Highway, and the Araniko Highway, pass through Dhulikhel. In one of the interviews with Deputy Mayor, the challenge faced by DDWSUC is highlighted:

> *"DDWSUC is facing big challenge. Earlier, it had to serve a smaller number of households, and the water supply was enough but now, it is rapidly urbanizing and they need more water. There are many big institutions in Dhulikhel as Kathmandu University, Dhulikhel Hospital, a number of hotels and businesses. They all need more drinking water. Dhulikhel also receives the internal and external tourists' flow. Due to all these reasons, DDWSUC is facing challenge on how to provide drinking water to all."*

One of the ward chairpersons in Dhulikhel explained the situation of increasing population density as:

> *"The population density in the bazaar area is increasing. For instance, considering the water from 1-inch pipe from the source- if I used to bath alone many years ago, the condition now is like 50 people are bathing from the water through same 1-inch pipe, it is and will be a problem."*

The impacts of urbanization are similar to the above section of annexation and population increase which is the increase in population hence raising the demand-supply gap in the cities. What is specific about the urban development is the concretization of the surfaces leading to increased runoff and the problem of stormwater management which has been a great concern, particularly in Dharan. This has also affected the recharge of groundwater affecting the sustainability component of water security, as explained by the municipal officer of Dharan municipality:

> *"Due to population increase and urbanization, the concrete flooring and building infrastructure prevents the recharge and there is no infiltration. I think the main problem in cities and Dharan is the concreting of the floor that has contributed to water scarcity. The storm water volume has drastically increased and mixes to the river."*

As explained in the case study sites, being vibrant towns, migration of people from rural areas have increased the density in the municipality. At the same time, as explained in the annexation section, urbanization is subjected to annexation of the adjacent areas to the municipality.

- **Annexation:**

The population growth is also attributed to the annexation of the nearby Village Development Committees (VDCs) time and again to Dharan and Dhulikhel. The annexing of the neighboring VDCs has increased the number of wards and population in the cities. Dharan municipality was previously divided into nineteen wards. Dharan municipality was upgraded to sub-metropolitan by annexing two adjoining Village Development Committee (VDCs) *Panchakanya* and *Bisnupaduka* with the cabinet decision in 2014. With this annexation, Dharan has increased its number of wards to 27 and the population also increased. The old 19 wards had some provisions of drinking water but the annexed 8 wards have been managing with local spring water but there is huge water deficit in the demand side. The new ADB funded project has only prioritized 19 wards of Dharan and excludes the newly annexed wards. In these 8 wards, there is only one deep boring used for irrigation purposes and *Bisnupaduka* area has nothing except small stream

water sources. More drillings can be the only options to provide water service to the rest of the wards. According to Federal restructuring Commission decision, Dharan is again restructured into 20 wards (Dharan Municipality, 2019).[14]

In Dhulikhel, annexation of the nearby villages time and again in 1986, 2015, and 2017 has led to the exclusion of the newly added wards in terms of piped water access supplied by DDWSUC. Back in 1990s, to be eligible for implementing German Technical Cooperation Agency (GTZ) funded drinking water project, adjacent villages of the then Dhulikhel Village Panchayat (*Vajrayogini, Shrikhandapur* and some part of *Kavre* village *Panchayat*)[15] had to be merged to covert to Dhulikhel municipality, raising the population to 10,000. The annexation was done for the second time in 2015 when the *Kavrebhanjyang* VDC was annexed with additional 4 wards.[16] In 2017 March, these wards were readjusted to 12 wards (annexation details in Table 13).

Table 13. Annexations and water supply in the study cities

Cities	**Year**	**No. of wards**	**Water supply**
Dharan		19 wards	
	Cabinet decision in 2014, to upgrade Dharan municipality to sub-metropolitan	Annexation of *Panchakanya* and *Bishnupaduka* VDCs (27 wards)	NWSC and ADB funded drinking water project (Water Board)
	2017 federal restructuring	Restructured to 20 wards	

[14] The annexing of the neighbouring VDCs had increased the no. of wards from 11 to 19 wards in 1978 (1978 A.D./2035 B.S. by annexing Bajgara Gaupanchayat in the east, some areas of Ghopa Gaupanchayat in the west), 23 wards (May 8, 2014/2071 B.S. Baisakh 25, as per the cabinet decision by annexing Panchkanya VDC) and finally 27 wards (Dec 2 2014/2071 B.S. Mangshir 16 as per cabinet decision by annexing Bishnupaduka VDC). According to Federal restructuring Commission decision, Dharan is again restructured into 20 wards.

[15] Dhulikhel Municipality annexed neighbouring Kavre Nitya Chandeswori VDC as per the cabinet decision in 2015.

[16] Recently, the 2017 restructuring has integrated two villages Rabiopi and Devitar. Prior to annexing the adjacent areas, the project was able to supply water for 24 hours to each of Dhulikhel households but with increase in households and population, the water supply fell short and rationing of water continue to exist.

Dhulikhel	1986 annexation	Adjacent villages (*Bajrayogini, Shrikhandapur* village panchayat and certain parts of Kavre Village Panchayat) merged to covert Dhulikhel village panchayat to Dhulikhel municipality, 9 wards.	DDWUC supplied water to these wards since 1990s. DDWUC extended water supply to these wards. KVIWSP will also supply drinking water to these wards.
	Annexed after the cabinet decision in 2015	Expanded to 13 wards by adding 4 wards (*Kavrebhanjyang* VDC annexed)	These are not covered by DDWUC and also not by KVIWSP. Dhulikhel Municipality's one house one tap program.
	Mar 2017 (Falgun 2073) federal restructuring	Readjusted to 12 wards (Annexation of *Rabiopi* and *Devitar* village and readjustment of other wards)	Dhulikhel Municipality's one house one tap program

The annexation in Dhulikhel was explained in one of the interviews with the Deputy Mayor of Dhulikhel,

> *"Ten years ago, Dhulikhel municipality was a small municipality with only 9 wards- the core bazaar areas. During that time, water was supplied through German project to the core area that covered 4 wards 2, 3, 4, 5 while parts of wards 4, 5, 6, 7 and 9 had limited water supply. Only few households had water supply while most of the households had no access to drinking water. People then residing in ward no. 5 were drinking water from the source in Chaleshwor Ban, ward no. 4 Shrikhandapur from Dhulikhel source, ward no. 3 from forest there. Population then was less and settlements were not so developed. With State restructuring, Dhulikhel municipality has been extended to big municipality, 6 rural municipalities were also annexed to the municipality forming 12 wards. German water supply project was not able to fulfil demand of the present need. So, the people of periphery wards even protested."*

In Dhulikhel, the peripheral wards do not fall under the service area of DDWSUC and KVIWSP will also not cover these wards. Majority of settlements in these wards are on hilltops or hillside and depend on natural water sources as spring, well and stream for drinking water. The ward-chairpersons of these wards expressed that lifting water from rivulets to these distant uphill settlements is tedious and costly and people are forced to encounter water scarcity. The one house-one tap program is being implemented in the peripheral wards along with other wards in the core. Under this scheme, the municipality has set target of operating 5 drinking water projects covering the water supply to 2000 households. But the progress has been very slow and it has finished few projects supplying water to around 700 households. It is difficult for DDWSUC to extend its water distribution services to new wards as it does not have the capacity to supply water to all households and if one house gets water and the neighboring one does not get, then there will be conflict imminent.[17]

- **Changes in lifestyles of people and change in land use:**

With urbanization, changes in lifestyles of people have been identified as the major factor influencing water security. Modern technologies as flushing toilets and shower faucets and changing hygiene habits with western influence has increased the per capita water consumption or water demand at the household level. Dharan and Dhulikhel primarily had common public taps and not piped water to individual households' decades earlier, so had limited water use. Likewise, in both the cities, with addition of hotels and improved housing style, the water use has significantly increased.

Changes in land use has affected the availability and quality of water in both Dharan and Dhulikhel. The analysis of land cover map of the Shardu watershed, from 1997 to 2017 showed the increase of forest and shrubland, and settlement area whereas decrease in agricultural land, streams and flood plains, grassland and barren land (Wagle, 2017). The study also found that the agricultural and settlement area related negatively with the water quality hence decreasing the water quality status of Shardu River. The effects of upstream stone quarrying nearby water source and land use change impacts have affected the water quality in Dhulikhel. Increasing built-up areas and decreasing forest and natural vegetation, has resulted in limitaed infiltration

[17] The 2017 restructuring has integrated two villages Rabiopi and Devitar. Prior to annexing the adjacent areas, the project was able to supply water for 24 hours to each of Dhulikhel households but with increase in households and population, the water supply fell short and rationing of water continue to exist.

into the ground and increased rapid runs off outside the catchments of the cities to downstream areas (Bajracharya et al. 2019).

Recent studies have analyzed the land use and land cover changes in Dharan sub-metropolitan city using data from 1986-2020. The analysis revealed that the built-up areas has been expanded significantly from 2.65% to 10.87% from 1986 to 2020 with overall 9.12% yearly increase. While the agricultural land has decreased from 19.66% to 16.09% (at the annual rate of -0.53%) and the forest decreased by 74.21% to 68.13% (at the annual rate of –0.25%) in the past 34 years. The area of water bodies has increased slightly from 3.28% to 4.91% (as shown in the Table 14). The authors have indicated about the possible high rate of expansion in the future given the increasing haphazard urbanization and the associated risks of urban hazards and pollution, requiring proactive planning and risk-resilient policies (Rai et al., 2021).

Table 14. Land-use and land-cover change in Dharan sub-metropolitan city (1986-2020), area in km^2

Land use/cover types	**1986**		**1990**		**2000**		**2010**		**2020**		**% change / Year**
	Area	%	Area	%	Area	%	Area	%	Area	%	
Agriculture	38.11	19.66	27.08	13.97	25.66	13.25	22.97	12.09	31.20	16.09	-0.53
Built-up	5.14	2.65	7.50	3.87	9.20	4.78	15.89	8.20	21.07	10.87	9.12
Forest	144.23	74.41	153.50	79.17	149.79	77.23	148	76.78	132.07	68.13	-0.25
Water-body	6.36	3.28	5.80	2.99	9.20	4.74	6.96	2.93	9.51	4.91	1.46
Total	193.85	100	193.85	100	193.85	100	193.85	100	193.85	100	

Source: Rai et al., 2021

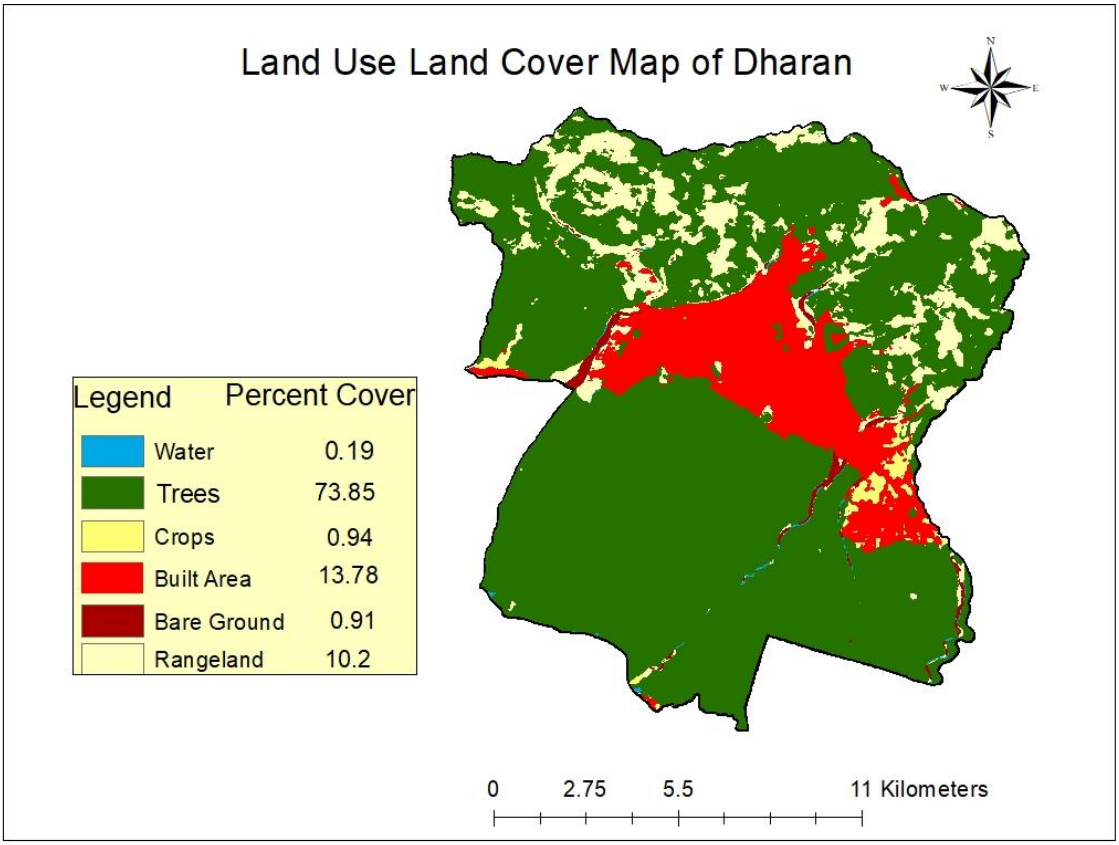

Figure 13. Land use and land cover map of Dharan, Source: Author, 2024

Further analysis of land use and land cover in Dharan using 2024 data (refer to Figure 13) showed that built-up areas covered the second largest percent coverage, 13.78% after the trees (73.85%). Built up areas covered only 10.87% in 2021, showing 2.91% increase.

Similar study by Khanal et al. (2023) of land use pattern in Itahari sub-metropolitan city closer to Dharan lying in the same ecological belt has revealed that urban development has led to significant increase in built-up areas with diminishing agricultural land and open space. The built-up areas have increased from 1.44 km^2 in 2005 to 2.32 km^2 in 2013 to 5.71 km^2 in 2019, after the declaration of Itahari as sub-metropolitan city in 2014.

Likewise, a recent study conducted by Shrestha et al. (2021) in Banepa and Dhulikhel municipalities using the remote sensing and GIS showed that over the period of 38 years from 1992-2020, forest and agricultural land reduced by 8.27 sq. km (7.57%) and 8.12 sq. km (7.44 %) respectively, whereas built-up and barren areas increased by 12.39 sq. km (11.3 6%) and 3.99 sq. km (3.66 %) respectively as shown in the Table 15.

Table 15. Land use and land- cover change in Dhulikhel and Banepa municipalities (1992-2020), area in km^2

Land use/cover types	**1992**		**2002**		**2012**		**2020**		**% change**
	Area	%	Area	%	Area	%	Area	%	
Agriculture	60.89	55.79	59.01	54.06	56.72	51.96	52.77	48.34	-7.44%
Built-up	5.19	4.76	7.12	6.53	11.52	10.55	17.59	16.11	11.36%
Forest	41.88	38.36	40.68	37.27	37.13	34.02	33.61	30.79	-7.57%
Barren	1.17	1.08	1.68	1.54	3.76	3.45	5.17	4.74	3.66%

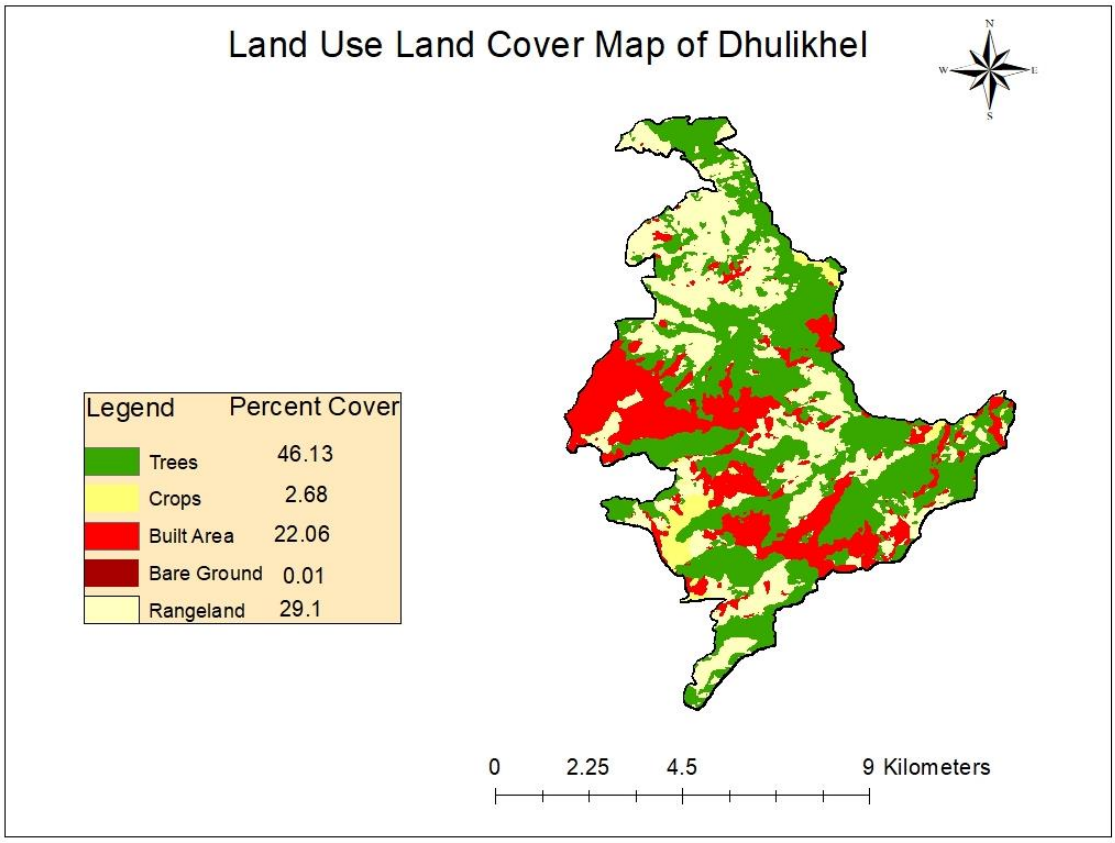

Figure 14. Land use and land cover map of Dhulikhel, Source: Author, 2024

Further analysis of land use and land cover in Dhulikhel using 2024 data (refer to Figure 14) showed that built-up areas covered a significant percent coverage, 22.06% after the trees (46.13%) and rangeland (29.1%).

b. Technological factors

The study finds that the technological factor is another determinant of water security. In the study sites, this factor has led to inequitable water distribution among those having access to technology and those deprived of access to technology. This is linked to the economic status of the water uses that determines the access to technology. In this case, use of water pumps is the privilege used by people who could afford to pull more water. The study showed firstly, the large water users as hotels, industries and mineral water bottle companies' extraction of underground water affects the household water use (intersectoral water use). The issues of the possible over-extraction of ground water resources are brought about by the proliferation of water-related businesses and private deep wells. For instance, the private companies as Bhatbhatini, Gorkha Complex, Easy Riders and other factories started pumping on their own. Former Water Board member and NGO representative illustrated,

> *"Bhatbhatini and other complex extracted the water without any permission, but we have requested them to register at the municipality and need to monitor- to those who are extracting and who plan to extract underground water. Easy riders have opened a factory called Dharane paani, that uses ground water and further Bhatbhatini and Gorkha complex also use ground water."*

Further, Dhulikhel, despite imposing restrictions in pumping water and imposing fine if found to be using it, according to the DDWSUC working committee members, its implementation is very weak. One of the committee members complained,

> *"Despite DDWSUC's efforts to restrict the use of pumping machines and our proactive measures in confiscating upon their use, it was beyond our control. This was as the people did not stop using the pumps in absence of monitoring. Although not all households have pumping machines to pump water, a single household using machine to pump water will devoid tentatively other 5 houses from water supply."*

The committee members further revealed that the people who belong to the poor economic status cannot afford the technological support to access water unlike those with affordable capacity belonging to high economic status. Another technical issue is the leakage of water supplying pipes that are high in both the sites. It is believed that only half of the water distributed reaches the households. It is also found that some of the users have connected their household level water supply pipes from below the main supply system so as to get more water while other pipes connected are above the main supply pipe as per the rule.

c. Environmental factors

The study has identified two major environmental factors affecting the urban water security in Dharan and Dhulikhel: topography and climate change. **Topographical differences** within the different areas of the municipality have caused inequitable water distribution in both the sites. While climate change impacts have led to the drying of water sources directly impacting the 'Resources' or 'Quantity' component of water security and indirectly, the quality, access, equity aspects. Further with too little water, too much water is also another impact of climate change, hence affecting the 'Safety' of the urban water system from the climate induced disasters as floods and landslides. Also, the sustainability of the water sources is at risk due to increasing drying of water sources due to climate change impacts as discussed in the global and Nepal literatures.

Detailing about topographical issues, in Dharan and Dhulikhel, the interviews and focused group discussions organized in these sites highlighted 'geography' (plain area or hill area) as one of the determinants to access water. The participants further pointed out that even the households within the same wards do not receive the same amount of water. They receive variable hours of water supply starting with 15 minutes to 7 hours. Households at greater height gets less water due to reduced water pressure. So, among the households in the core areas where water is supplied by Water Board in Dharan and DDWSUC in Dhulikhel, this variation in water supply occurs leading to inequitable water supply also within the core areas. The participants informed that a pressure feeder has been installed in some areas to control this problem.

In one of the water scarce areas in Dharan, Fusre, one of our participants (NGO representative and Board member) explained the issue of topography resulting the area near the water storage tank to be struggling for water supply.

> *"The tank in Fusre is at higher level, the water is released early morning and flows in a speed due to slanting height and reaches Tinkune and as pipe fills and water flows down, bazaar area people would have already pumped the water using motors. So, when the water reaches at our place, only air is available."*

Further, the location of Dharan, a foothill town (located at the foot of lower hills) in a warmer physiographic zone than the hills lead to higher per capita water demand. The geographical location of Dharan is situated as a gateway to entire Koshi hills from the vast southern plain, this strategic geographical position has flourished the city in educational and health institutes, business, industries and trade, hotels and tourism, private water suppliers including bottle

companies with rapid urbanization and population growth. This has increased the sectoral water demand. Geographically, Dharan has steep gradient due to which the rainwater drains out rapidly despite high permeability of the soil.

Climate change, another environment factor was also reported to be one of the determinants of water security in Dharan and Dhulikhel. Peoples' perception about their experience of change in temperature and precipitation was documented along with the analysis of temperature and precipitation data collected from DHM and secondary literature on climatic data analysis. In both the sites, climate change impacts, felt through particularly increase in temperature and change in rainfall pattern have been indicated to cause drying of water sources.

Temperature trend in Dharan and Dhulikhel

The trend analysis of the temperature data collected from DHM (Dharan Bazaar meteorological station) of the past 26 years (1998-2024) shows increase in both the minimum and maximum temperature at the rate of 0.1084^0C and 0.0343^0C respectively (refer to Figure 15), suggesting warmer winter months in Dharan.

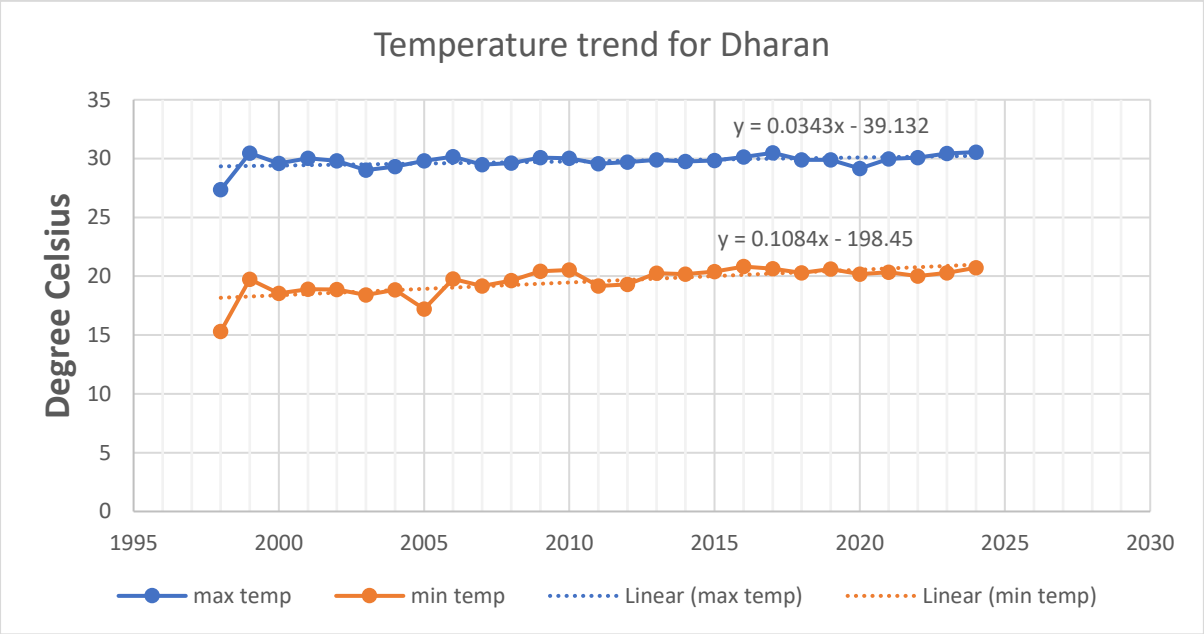

Figure 15. Temperature trend analysis in Dharan, DHM data (1998-2024)

A recent study by Bajracharya et al. (2019) had also observed a significant increase in minimum temperatures (0.098^0C), while slight decrease was observed in maximum temperatures (-0.003^0C) as shown in Table 16.

Table 16. Temperature trend at Dharan and nearby stations

Location	Temperature trend (^{0}C/yr)	
	Maximum	Minimum
Tarahara	0.007	0.018
Dharan	**-0.003**	**0.098**
Dhankuta	0.182	0.023
Mean	0.062	0.046

Source: Bajracharya et al., 2019, calculated from 30-40 years data of DHM (2015)

The trend analysis of the temperature data collected from DHM (Dhulikhel meteorological station) of the past 31 years (1993-2024) shows increase in both the minimum and maximum temperature at the rate of 0.0391 and 0.0553 respectively (refer to Figure 16).

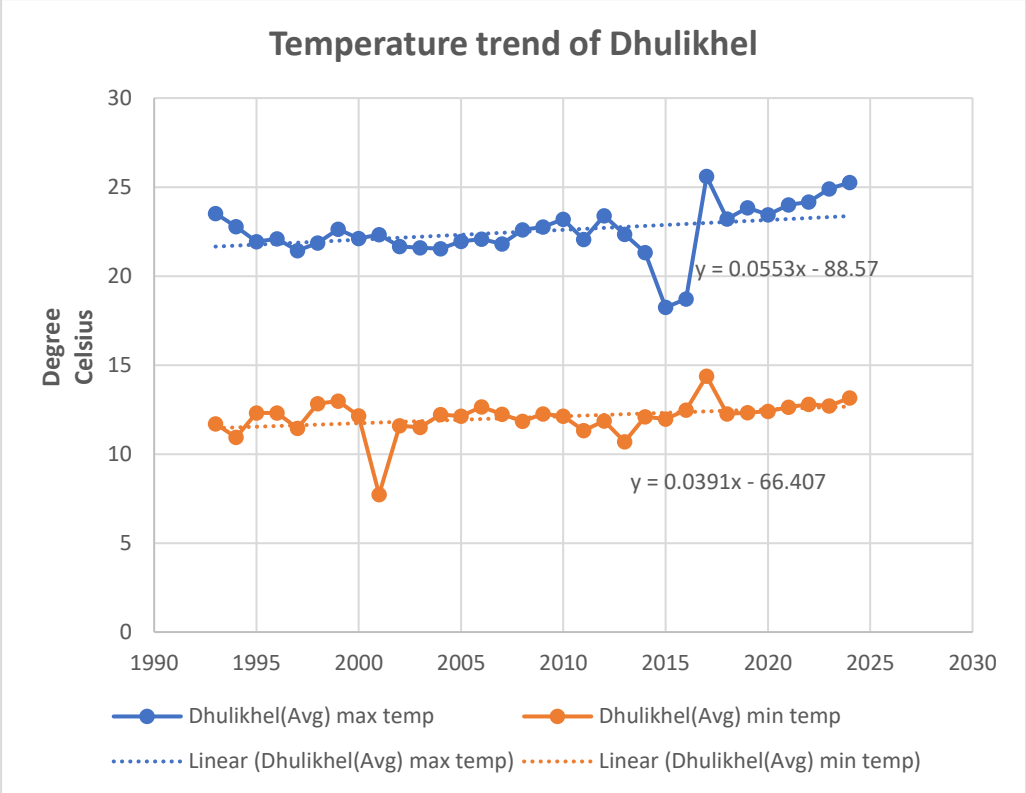

Figure 16. Temperature trend analysis in Dhulikhel, DHM data (1993-2024)

The studies have also discussed about the changes in climatic parameters (Dahal et al., 2019; Bajracharya et al., 2019). Bajracharya et al. (2019) showed that Dhulikhel observed similar trends of increase in maximum temperature (as shown in Table 17). Dahal et al. (2019) analyzed the temperature data of 1971-2014 of Roshi watershed that is located in the western part of Kavre district and supplies water to Dhulikhel, Panauti and Banepa. The analysis showed

warming of the region by 0.03°C/year (Godavari station), with increase in maximum and minimum temperature, at a rate of 0.067 °C/year, and 0.005 °C/year respectively.

Table 17. Temperature trends at Dharan

Season	Temperature trend (^{0}C/yr)	
	Maximum	Minimum
Winter	0.122	0.024
Pre-monsoon	-0.025	0.008
Monsoon	0.005	-0.006
Post-monsoon	-0.021	-0.029
Means	0.020	-0.001

Source: Bajracharya et al., 2019, calculated from 35-40 years data of DHM (2015)

In line with the climatic data analysis, in the household survey conducted, the respondents perceived an increase in average temperatures at both the sites during the last 20 years (85% in Dharan and 73% in Dhulikhel) while only a few respondents perceived no change or a decrease in temperature (refer to Figure 17).

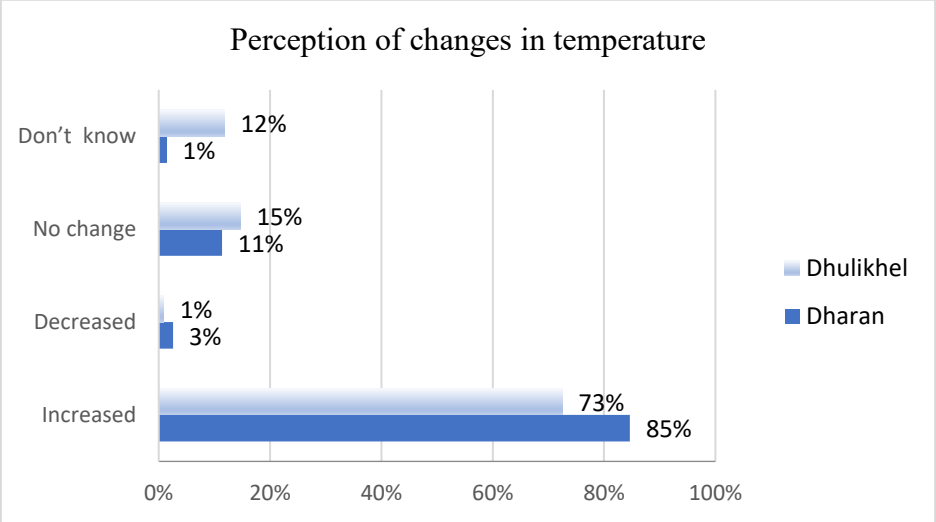

Figure 17. Perception of changes in temperature

Precipitation trend in Dharan and Dhulikhel

Further, the analysis of the annual precipitation data collected from DHM (Dharan Bazaar meteorological station) of the past 26 years (1998-2024) shows decreasing trend at the rate of -1.4813 mm per year, as shown in Figure 18.

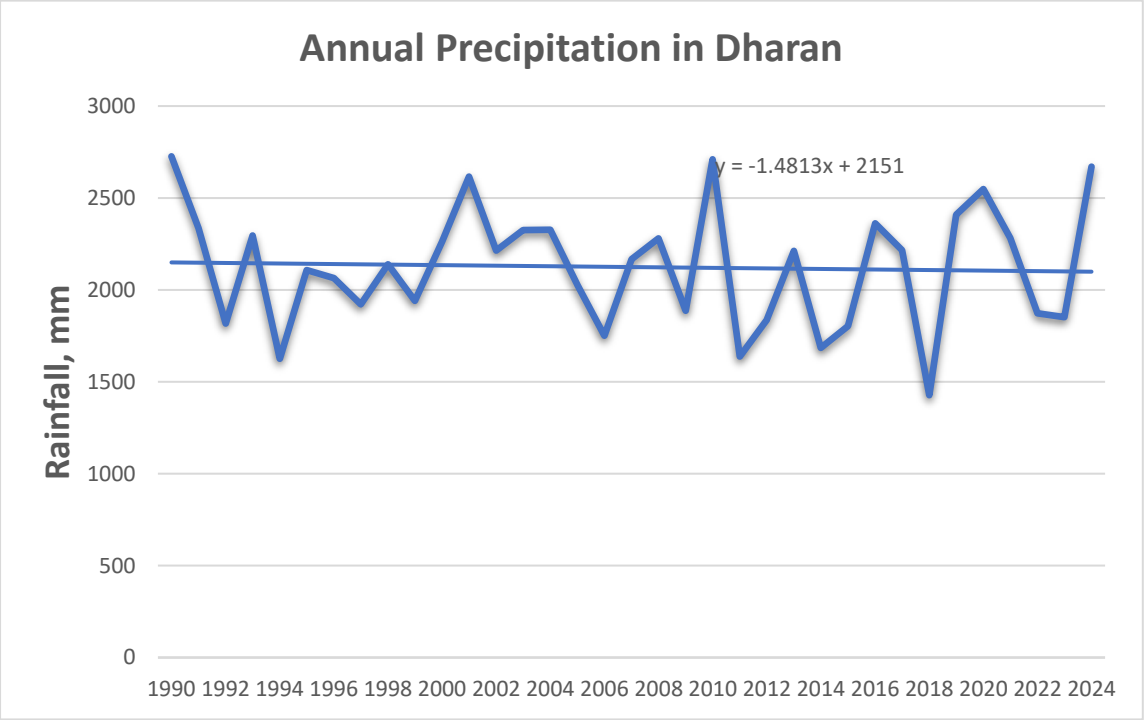

Figure 18. Precipitation trend analysis in Dharan, DHM data (1998-2024)

The past analysis by Bajracharya et al. (2019) also showed that while precipitation is increasing at lower elevations (Tarahara 2.155 mm/yr), the higher elevation stations of Dharan and Dhankuta show decreasing trends (-7.141 mm/yr in Dharan and -4.946 mm/yr in Dhankuta) in total annual precipitation (refer to Table 18).

Table 18. Precipitation trends at Dharan and nearby stations

Location	Precipitation trend (mm/yr)
Tarahara	2.155
Dharan	**-7.141**
Dhankuta	-4.946
Mean	-3.311

Source: Bajracharya et al., 2019, calculated from 30-40 years data of DHM (2015)

One of the participants (hotel representative) from Dharan shared,

> *"Dharan receives high amount of rainfall, next to Pokhara. It sometimes receives unseasonal (bemausami) rainfall. The intensity also varies. It is too hot during Baisakh/Jyeshta. The temperature seems to have increased in the last 10 years. The winter is just leaving (Feb 27), but it feels hot and less cold. This should be the impact of climate change. Water scarcity has increased as the precipitation has delayed and intense rainfall during short duration has increased the flooding problem."*

The changes in precipitation patterns have affected the stream flows of Shardu River in Dharan and Roshi River in Dhulikhel and the decrease in rainfall and water flow availability will severely affect the urban water security of Dharan and Dhulikhel.

In the survey conducted (refer to Figure 19), most of the respondents (75% in Dharan and 75% in Dhulikhel) perceived change in rainfall pattern over the last 20 years. The change was experienced by the respondents through decrease in rainfall over the decades (38% in Dharan and 28% in Dhulikhel) while others also reported more rainfall in a year (17% in Dharan and 10% in Dhulikhel) and experienced erratic rainfall (7% in Dharan and 15% in Dhulikhel) (refer to Figure 20).

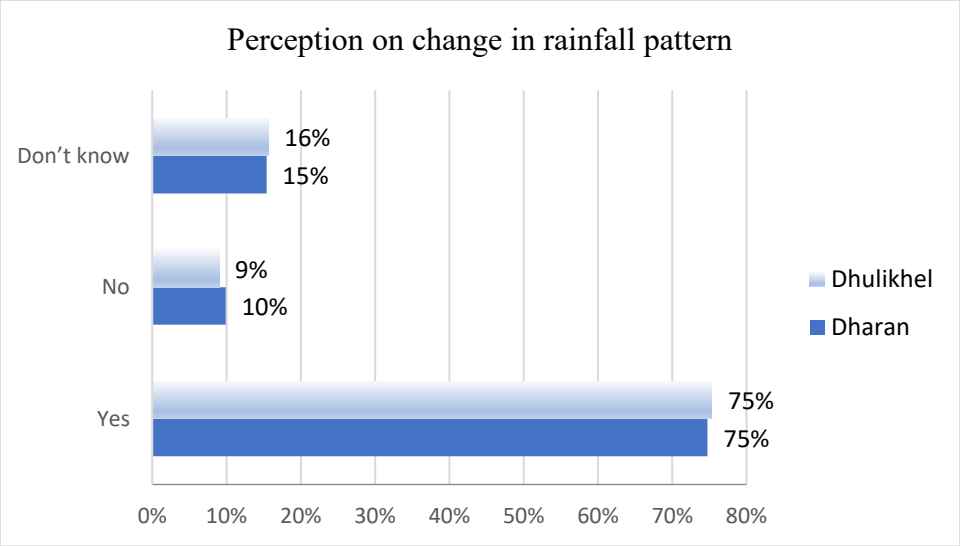

Figure 19. Perception on change in rainfall pattern

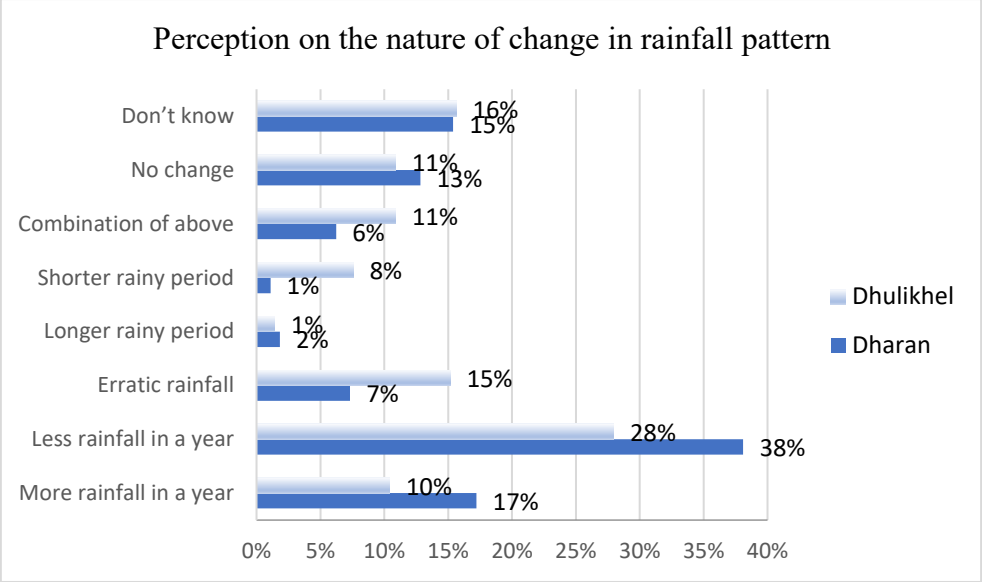

Figure 20. Perception on the nature of change in rainfall pattern

Although Dharan receives comparatively higher amount of rainfall with more than 2000 mm mean annual rainfall, about 80% of the rain falls during the four months in monsoon and remaining spreads over 8 months. Secondary data also showed that Dharan and its surrounding localities, in recent years, is observing shifting precipitation patterns of various intensities, as effects of climate change (Neupane et al., 2019).

In case of Dhulikhel, the analysis of the annual precipitation data collected from DHM (Dhulikhel meteorological station) of the past 31 years (1993-2024) shows decreasing trend at the rate of -11.342 mm per year (refer to Figure 21).

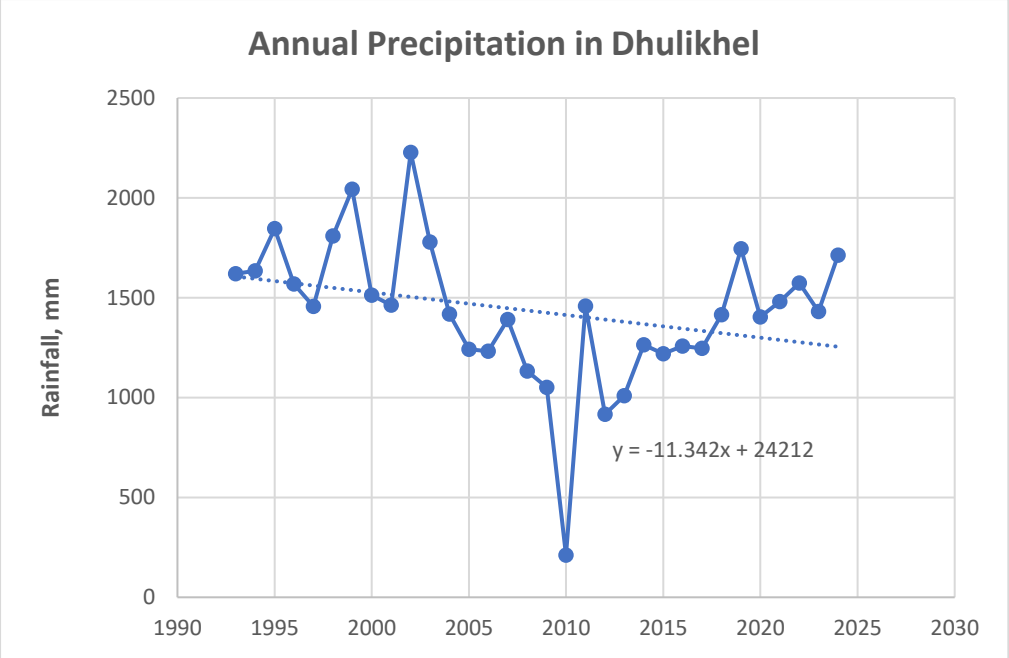

Figure 21. Precipitation trend analysis in Dhulikhel, DHM data (1993-2024)

Similar observations were also noted from the past studies by Dahal et al. (2019). According to this study, the area observed significant decrease in precipitation, i.e., -9.1 mm per year in Dhulikhel (-10.4 mm/yr in Godavari and -6.3 mm/yr in Khopasi), with increasing dry spells and decreasing wet spells. It has further established that change in precipitation and land use have caused gradual decline in mean annual discharge of Roshi river at - 0.015m^3/s/yr. Another study by Bajracharya et al. (2019) showed that Dhulikhel observed similar trends of decline in annual precipitation (as shown in Table 18).

Seasons	**Precipitation trend (mm/yr)**
Winter	-0.053
Pre-monsoon	-0.185
Monsoon	-5.500
Post-monsoon	-2.840
Means	-2.145

Source: Bajracharya et al., 2019, calculated from 35-40 years data of DHM (2015)

Further, the analysis of survey data showed that most of the respondents in Dharan and Dhulikhel have experienced decrease in quantity of water in the last 10 years (59% in Dharan and 64% in Dhulikhel) (refer to Figure 22).

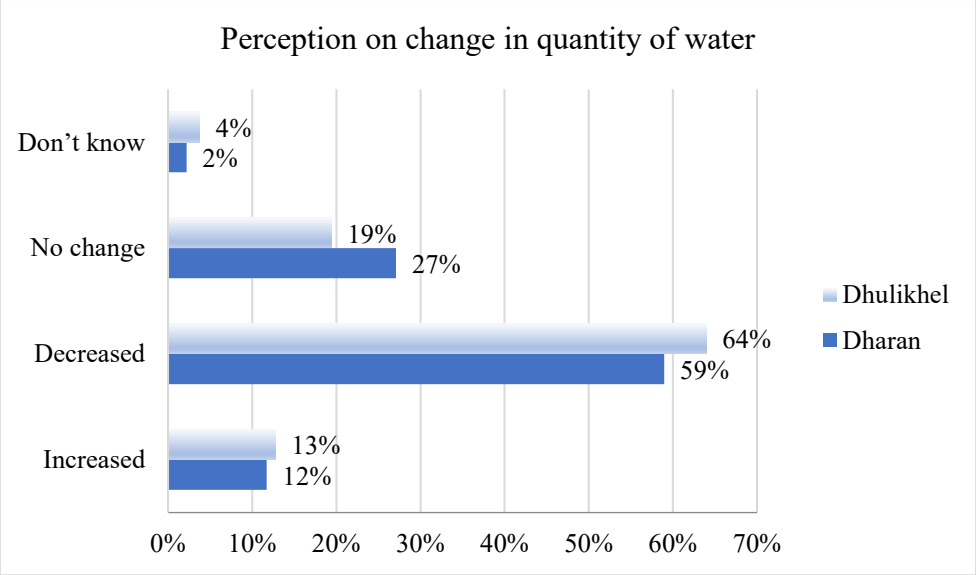

Figure 22. Perception on change in quantity of water

Interviewees recalled history of streams and springs and also shared experience of water sources drying indicating the need of water sources conservation. A wide variety of water sources are considered to be vulnerable to changing rainfall pattern. Most of the respondents in Dharan noted rivers (35%) and streams (25%) to be most vulnerable in terms of changing rainfall pattern. In Dhulikhel, most of respondents (59%) responded 'local springs' to be most vulnerable followed by the combination of sources (refer to Figure 23).

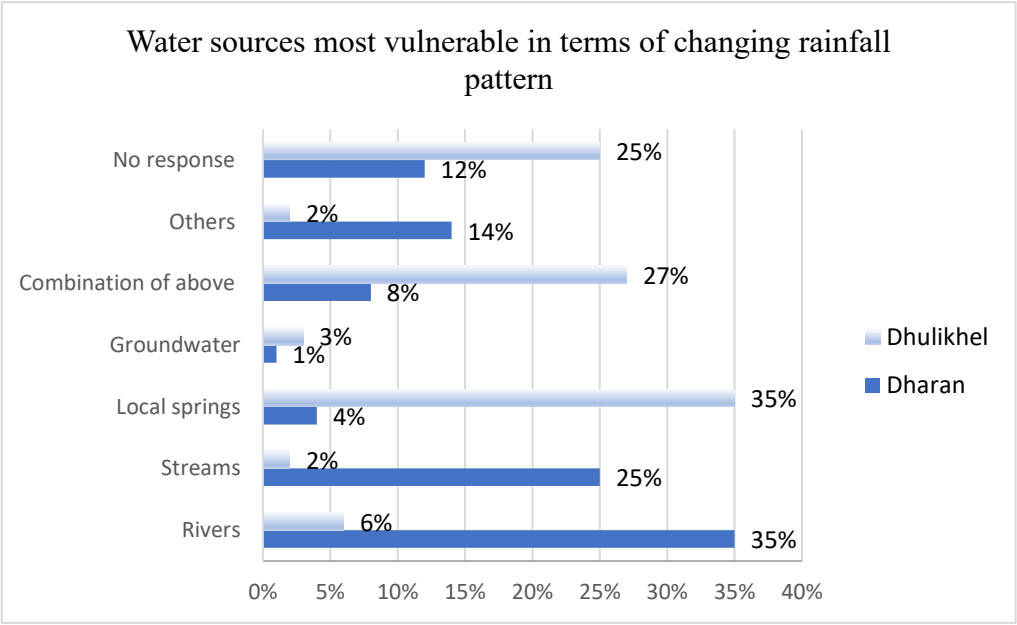

Figure 23. Water sources most vulnerable in terms of changing rainfall pattern

Drying of the water sources was caused due to a number of factors. The participants during the interviews and discussions also referred to climate change impacts causing the drying of water

sources. Additionally, the participants shared that 2015 earthquake led to drying as well as increasing water in some of the sources, while some of the sources were shifted. Construction of infrastructures such as roads were also noted as the reason of drying of water sources as the sources are disturbed. Deputy Mayor of Dhulikhel indicated climate change impact on water sources. She shared,

> *"The impacts of climate change are leading to drying of water sources. So, it is difficult to provide drinking water to all people.")*

Another participant*, a female member of DDWSUC recalled:*

> *"Earlier, people used water from the forest as we had no piped water connection. We had own water source in our farm (upland unirrigated area). In monsoon season, water from the source was available for 24 hours and dried a bit in summer. The source in my area dried 7-8 years ago, now the water sources have also almost dried and few available sources are not conserved as people are hopeful to KVIWSP and people have become luxurious and purchase tanker water."*

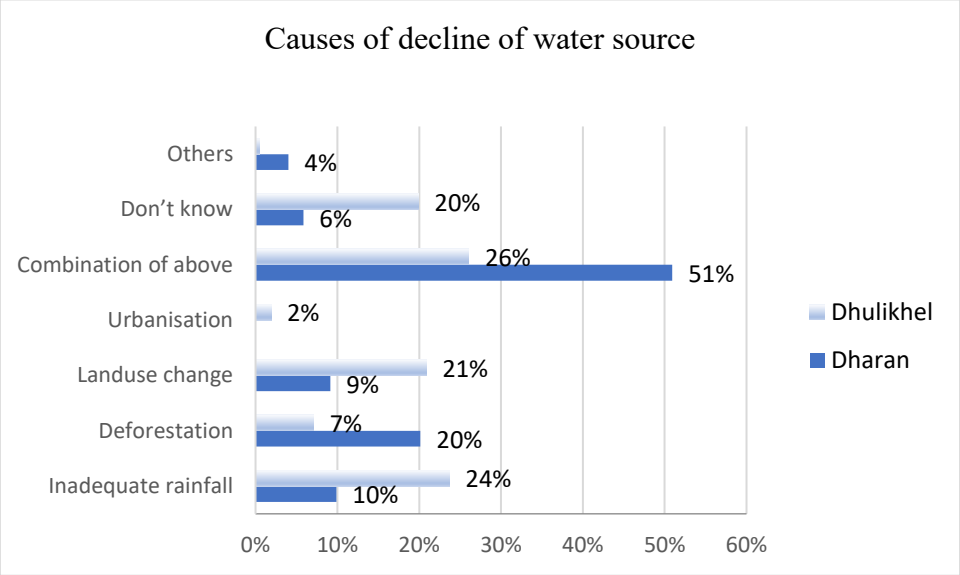

Figure 24. Causes of decline of water source

In both the sites, most of the respondents experienced a combination of factors (deforestation, land-use change and inadequate rainfall) as factors causing decline of water sources (51% in Dharan and 26% in Dhulikhel). Other prominent factors included inadequate rainfall (24%) and land-use change (21%) in Dhulikhel and deforestation in Dharan (20%) (refer to Figure 24).

d. Institutional and governance factors

Nepal's Constitution 2015 and Local Government Operation Act (LGOA 2017) have devolved power and authority to the local government to manage natural resources including water in the federal context. However, Dharan and Dhulikhel municipalities have been facing many challenges owing to the transition or the early stage of the local governments. The study found that the challenges and ambiguities hindering water governance in these cities are broadly associated with the overlapping roles and responsibilities of institutions in managing water and non-coordination amongst the federal, provincial and local governments (details in Chapter 6).

One of the important factors identified from the study is that the change in institutional structures have posed further constraints and delayed the institutional responses. For instance, one of the most critical issues both the cities are facing is the modification of the institutional structure with the implementation of ADB funded drinking water project. Local governments have been mandated the role of water management by LGOA (2017) hence the municipalities of both Dharan and Dhulikhel are provisioned to manage water supply and distribution. However, previously, Nepal Water Supply Corporation (NWSC), a government entity in Dharan and Dhulikhel Drinking Water and Sanitation Users Committee (DDWSUC) was managing water supply and distribution in Dhulikhel. The in-depthinterviews, particularly with the water managers have reflected that the institutional modification in water management brought about by the newly declared 'Water Board' in both the sites has raised various contestations.

Drinking Water Supply Management Board Act (2006) envisioned the existing Water Users Associations, like DDWSUC in Dhulikhel and Nepal Water Supply Corporation (NWSC) in Banepa and Panauti, of Kavre Valley would be merged gradually into newly formulated Water Board. Water Board has envisioned bigger scale and higher-level mechanisms, while the relations between the existing water management institutions and user committees like NWSC and DDWSUC, and newly introduced Water Board lacks clarity. How the existing water institutions will function under the leadership of Municipality is a matter of concern in the situation where the user committees or NWSC is reluctant to function together. The Deputy Mayor of Dhulikhel highlighted DDWSUC's uncordial relationship with the municipality highlighting an example of General Assembly organized by DDWSUC.

"The General Assembly program execution was unorganized and there was least participation of the users. Hence, the program had to be postponed. We would provide our advice but it was done in its own way, so I think program was unorganized."

In Dharan, NWSC has merged with the Water Board but the process has been greatly contested. The representatives from the water institutions, during interviews highlighted that the insufficient technical capacity, human resources and infrastructure deficit are additional challenges the municipality is facing. More importantly, the limited knowledge and expertise in promulgating the local laws, climate resilient planning considering the future water demand and population etc. have made the planning inefficient.

Further, the initiatives undertaken by the municipality and water institution lacked continuity. For instance, the discussion platforms initiated by the municipality as 'water forums' had created space for dialogue amongst the key water stakeholders. However, the continuity of such efforts is at crossroads with municipality not being able to prioritize amid multiple roles and engagement. One of our participants representing the municipal officer shared, "*unless such initiatives are inserted and budgeted in the municipal plan, they get unnoticed and hence their implementation are uncertain despite commitments by the municipality*." Institutional mechanisms as Water Forum, Water Council and Water Board formed or envisioned to address water issues bear the risk of duplication of efforts to establish many institutions with same agendas. In Dharan, the water source and watershed conservation has fallen between the chairs of the water related institutions as it seems the role of all water institutions but has formed the priority of none of them. These constraints will be discussed in detail in Chapter 6 that has challenged the water security of the cities.

These constraints demonstrate why the prevailing water institutions have not been able to meet the challenges of supply and demand management of water to improve supply practices for equitable distributions amongst core city and remote areas. As the institutions play a crucial role in achieving water security, clarifying the roles and relationships among various categories of institutions is required to be able to deliver both climate resilience and equitable water access. Otherwise, it might further add institutional complexity in the water governance landscape.

4.3 Drivers' interlinkages with water security components

In the above section, we discussed that the socio-economic drivers as rapid and haphazard urban development and increasing population, changing land uses, tourism activities and adoption of comfortable lifestyles have exacerbated competition for water with significant water demand in the case study sites and the cities are struggling to meet the rising water demand. The socio-economic factors affect the water availability, quality, equity, safety, affordability and sustainability components through increased water demand and competition, pollution at sources, groundwater extraction, implementation of large-scale water schemes tapping water beyond the municipal jurisdiction (as indicated in Figure 25).

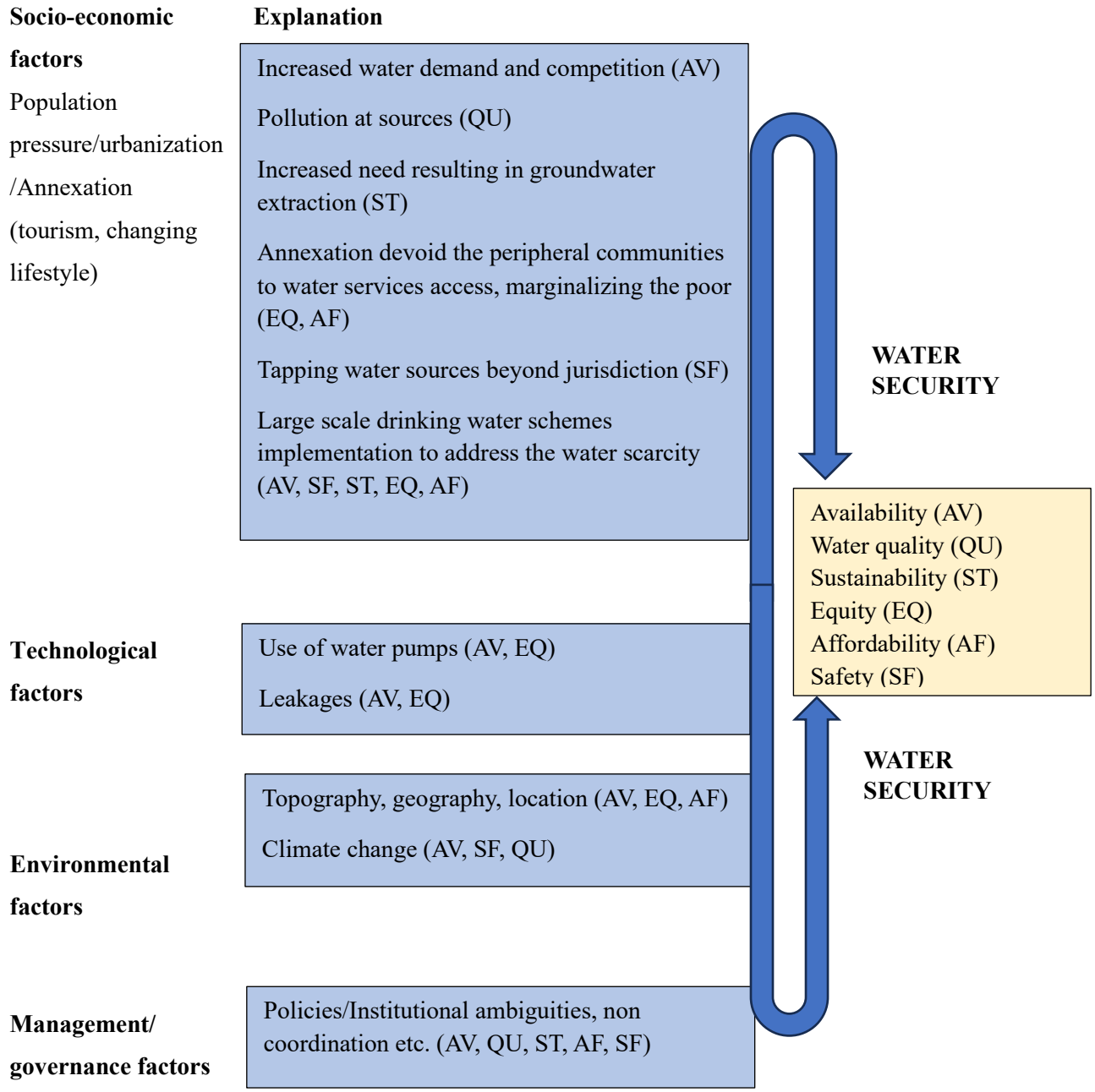

Figure 25. Drivers affecting water security components

Further, the environmental factor, namely, climate change, is causing drying and declining of water sources affecting the 'water availability' component of water security on one hand while on the other hand, the excess water due to climate induced disasters as floods and landslides have posed risk to the city dwellers. At the same time, such disasters also increase the risk to the safely of water infrastructures causing disruption of water supply during the monsoon. Technological factors such as leakage in the pipes also causes reduced availability of water reaching the tap from the source, while loss of water when leakage is the supply point. In

addition, changes in land use and pollution at sources are risking peoples' health with impact on 'water quality' component.

Annexation of the nearby areas to the municipality, one of the socio-economic drivers in particular is determined as the root cause of inequitable water distribution in both the study cites, affecting the 'equity' component of water security. Annexation created the core-periphery division excluding the peripheral communities or the newly added households to piped water access. Moreover, water pumps, a technological factor, are also responsible for causing inequitable water access among those who can and cannot afford (rich versus poor) to use this technology. It is found that the hotels and industries' commercial water need fulfillment through drawing underground water has compromised the household water availability. Moreover, topographical differences are also responsible for inequitable water distribution in the areas at higher and lower elevations.

A combination of socio-economic, technological and governance drivers as increased water demand, pollution, underground water extraction, lack of clear institutional and policy mechanisms for water sources and watershed conservation has had a significant challenge to the 'sustainability' of the water sources and the water supply.

The different categories of drivers discussed above: socio-economic, environmental, technical, management and governance are interlinked in one way or the other and at the same time, different factors discussed with the same category (intra and inter drivers) also show linkages to each other. For instance, annexation leading to population increase and population growth causing urbanization or vice versa.

From the research insights, it can be concluded that overall governance factors are very crucial for efficient water management that can lead to equitable water management across variable sections of society and across variable topographies, ensure the availability and quality of drinking water, effectively manage and conserve the water sources and watershed and ensure the sustainability of water sources. Institutions and policies at place can plan and perform climate resilient planning projecting the future water demand. But the limited capacity of the local government, ambiguous roles and responsibility, policies and institutional non-coordination have posed challenges in implementation of institutional responses to water security.

4.4 Chapter Summary

The chapter discussed the insights on different categories of drivers, socio-economic, environmental, technological, management and governance. The chapter also discussed how these factors individually or in combination is impacting the components of water security that include water availability, quality, affordability, equity, sustainability and risks. The findings from the study have indicated institutional and governance factors as crucial drivers to shape water security in both the cities. Efficient water management, encompassing equitable water distribution across diverse societal structures and geographic terrains, hinges significantly on the broader governance framework. Such governance plays a pivotal role in guaranteeing the accessibility and quality of potable water, proficiently overseeing and preserving water resources and watersheds, and upholding the enduring sustainability of this vital resource. The next chapter engages with this important aspect of governance, on institutional and policies responses in securing water.

CHAPTER FIVE: KEY INSTITUTIONAL AND POLICY RESPONSES TO GROWING WATER INSECURITY

In this chapter, I introduce the water management institutions in the study sites and discuss the findings of the second research question on the key institutional and policy responses towards securing water in the two cities, Dhulikhel and Dharan. 'Institutional responses' include any activities initiated or reforms carried out by the formal and informal institutions to respond to the water insecurity. These activities contribute to increase in water quantity, and quality, contribute to equitable water distribution, sustainable water use, improved water governance and reduce water related risks. In this chapter, situating the historical context of development of water institutions in the case study sites, I explain how the institutions are responding to the issue of water insecurity. The study engages with only the formal institutional responses, although I recognize that informal institutions also have a major role in securing water and are interlinked with formal institutions.[18] The formation of institutions itself is considered as responses to deal with water insecurity. The key responses in securing water in two cities included a) National Policies (National sectoral policies in water, urban and climate themes) b) Projects focused institutional responses at different time periods, b) Local responses (municipal responses that includes, networking, partnerships and collaboration; and watershed conservation, city level Water Forums as deliberative platforms, and d) Private sectors' efforts in optimizing water use.

5.1 Responses in securing water

Institutions are broadly defined as rules, or sets of rules, that structure social interaction by shaping or constraining actor behaviour (North, 1990; Knight, 1992). In the context of natural resource management, institutions are laws, regulations, policies and property rights that define ownership, disposition and use rights to a natural resource, as well as the policies for protection and exploitation of a resource (Ostrom, 2007). Institutions are created by humans to bind their social interactions and impose as constraints in the form of codes of conduct to reduce uncertainty expectations regarding behaviour. Institutions set restrictions on the behaviour of humans and thus add a degree of predictability regarding their actions (Dobler, 2009). Institutions influence the distribution of resources and power in society as they favour the

[18] Formal institutions function as the regulatory pillar of a nation and tend to have their rules enforced by a state actor. Formal institutions are written or formally accepted rules and regulations which have been implemented to make up the economic and legal set-up of a given country. While informal institutions convey socially shared rules that may be self-enforcing or enforced outside of official channels.

resources and powers who had created them (Campbell, 2004). Helmke and Levitsky (2003) argued that institutions are responsible for creating social interactions among actors, which is the way actors behave. So, by referring to water institutions, it means the institutions and policies that aim to address the issues related to water management. The key responses in securing water are discussed below that include the national policy responses as well as institutional responses at different levels. The summary of responses is presented in Table 19.

Table 19. Key responses in addressing water insecurity

S.N.	Key Responses	Description
1.	National Policies	Sectoral policies in urban, water and climate themes
2.	Projects focused institutional responses	Institutional evolution with time widened responses-technical response as project implementation
3.	Local (municipal responses)	Networking and partnerships Watershed conservation City level Water Forums and Municipal policies (recharge pits in municipal policy, others)
4.	Private sector responses	Optimizing water use

5.1.1 National Policies

As the study on water security is in the context of urbanization and climate change, the review in the interlinked sectors of urban, water and climate sectors found that there is an array of policies in these themes formulated at different time periods. The policies are listed in the Figure 26 and their analysis on sectoral coherence focusing 'urban water' has been discussed in chapter 6. The policy context with their objectives is discussed below.

The key water related legislations formulated include Water Resource Act (WRA, 1992), Water Resource Regulation (WRR, 1993) and Drinking Water Rules (DWR, 1998), National Water Supply and Sanitation Policy (2014). WRA (1992) is an umbrella act governing drinking water and other water uses and overall water management in Nepal. The WRR (1993) provides procedural mechanisms for implementing the WRA (1992) and covers the formation of Water User Associations and District Water Resource Committees. The DWR (1998) regulates the use of drinking water, registration and licensing of Drinking Water User Associations. National

Water Supply and Sanitation Policy (2014) targets to upgrade the existing basic water supply and sanitation services to medium and high level in rural and urban areas by 2027. Recently, the National Water Supply, Sanitation and Hygiene Policy 2023 has replaced Rural Water Supply and Sanitation National Policy 2060 (2004) and Urban Water Supply and Sanitation Policy 2066. Prior to this policy formulation, Water Supply and Sanitation Act 2022 was formulated, these being the most recent regulations in the water sector.

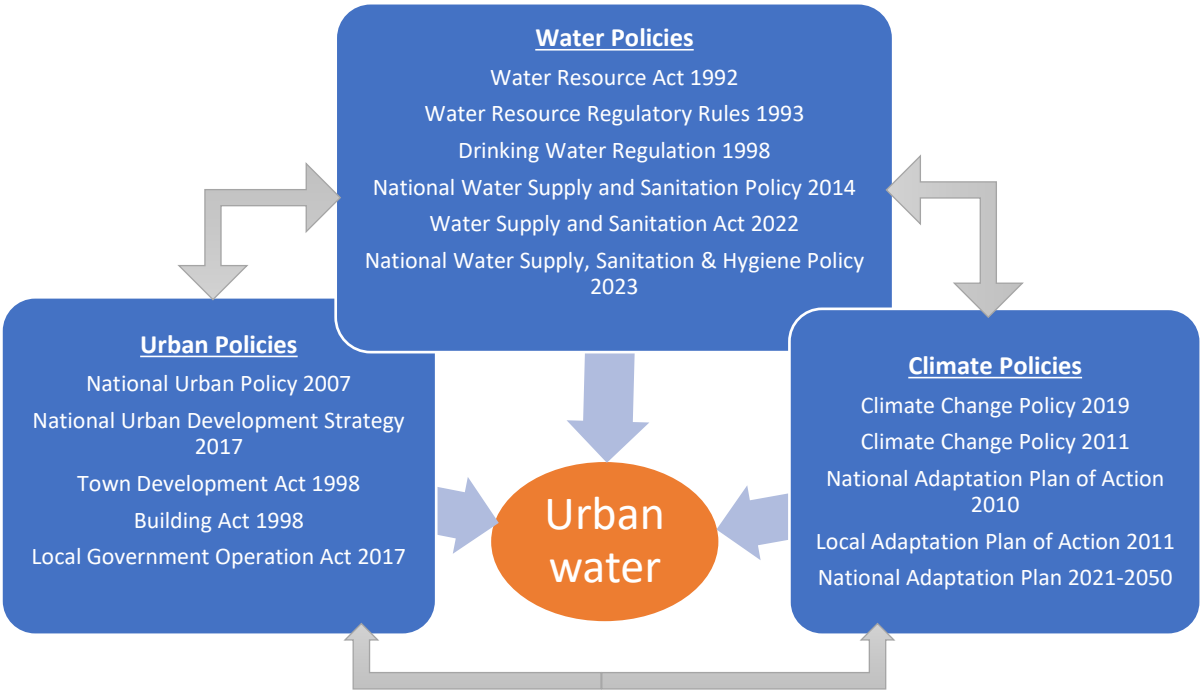

Figure 26. Sectoral policies in urban, water and climate sectors

Likewise, in the climate change sector, Climate Change Policy 2011 (CCP 2011) has been replaced by Climate Change Policy 2019 (CCP 2019). The Climate Change Policy was revised to operate climate change adaptation and mitigation programs in the federal context, integrating climate issues into policies and programs of all three levels of government. Other climate related regulations formulated are National Adaptation Plan of Action (NAPA 2010), Local Adaptation Plan of Action (LAPA 2011) and National Adaptation Plan (NAP 2021-2050). Review shows that from 1997 onwards, the policy framing inclined towards protecting people from natural disasters. From 2003 onwards, Nepal framed strategies focusing on natural disasters role in increasing vulnerability and risk of the poor. 2009 marked as a significant shift in Nepal's policy landscape with climate change adaptation as a key policy paradigm. Policy documents such as NAPA (2010), CCP 2019, LAPA framework 2011 focus on the adaptation

strategies to reduce the climate change impacts. Further, to supplement the inadequacy of NAPA, the UNFCCC forwarded the concept of NAP[19] for a planned adaptation to address climate change impacts in the future.

Urban sector related legislations include National Urban Development Strategy (NUDS, 2017), National Urban Policy (NUP, 2007), Town Development Act (TDA, 1998) and Building Act (BA, 1998). To introduce the policy context in brief, NUDS (2017) has been prepared aligning with the NUP (2007), the Sustainable Development Goals (SDGs) and the New Urban Agenda address the critical challenges of urbanization and unleash its potential in driving national development. While NUP has provided guidance for urban development, NUDS has shaped following the need of strategic direction to guide the urban development process. TDA (1998) was formulated to provide necessary services to the town residents and Building Act (1998) to regulate the building construction works to protect building against earthquake and other natural calamities. Further, in the federal context, Local Government Operation Act (LGOA, 2017) replaced Local Self Governance Act (LSGA, 1999) that specifies the roles and responsibilities of urban and rural municipalities. Table 20 has outlined the objective of the legislations in water, climate and urban themes.

Table 20. Key policies in urban, water and climate themes and their objectives

Water Legislations	**Objective of legislations**
Water Supply and Sanitation Act (WSSA, 2020)	• The act ensures to provide the clean and high-quality water supply and sanitation services and to make necessary provisions regarding waste-water and sewerage management, while respecting, protecting, and fulfilling the fundamental rights of all citizens to receive such services. • It establishes a robust foundation for inclusive WASH initiatives across the country. • It has provisions regarding the source and rights, duties and responsibilities as well as operation of water supply and sanitation services.

[19] Nepal has already initiated and is in the process of preparing NAP.

	• It has also provisioned regarding tariff and service charges, quality and standards, monitoring of services, and related offence and punishment measures.
National Water Supply, Sanitation & Hygiene Policy (N-WASH Policy) 2023	• The policy has replaced rural and urban water supply and sanitation policies. • The policy aims to achieve the SDGs by 2030 and aims to provide 'safe, secure and universally available drinking water and sanitation services' to all by 2043 (2100 B.S.), in coordination with the federal, provincial and local governments. • It adopts the policy to strengthen sectoral capacity by integrating climate change and disaster risk management in drinking water and sanitation services. Further, it provisions to enhance capacity of local level and community to implement climate mitigation and adaptation strategies to address the risk from natural hazards and climate change at three levels of government. • The policy promotes conservation of traditional ponds, stone spouts and water sources, and promotes rainwater harvesting in urban areas and construction of recharge ponds.
Water Resource Act (WRA, 1992)	• Prioritized 'Drinking water and domestic users' under first priority. • Persons willing to make use of water resources for collective benefits on an institutional basis may form a Water Users Association as prescribed. • Mentions Government of Nepal (GoN) shall pay compensation to the concerned person for the land, building, equipment or structures relating to the utilization of the water resources
Water Resource Regulation/ Rules (WRR, 1993)	• Formation of Water User Associations and District Water Resource Committees, licensing • Provides a dispute settlement mechanism in relation to water use service charges • Sets out the process to be followed by the State in relation to land acquisition and compensation

Drinking Water Regulation (DWR, 1998)	• Regulates the use of drinking water, registration and licensing of Drinking Water User Associations, control of water pollution • Maintenance of quality standards for drinking water and provisions for the acquisition of house and land and compensation
National Water Supply and Sanitation Policy (NWSSP, 2014)	• Considers water supply and sanitation to both urban and rural areas • Sets the objective of drinking water source protection and conservation of the catchment areas of urban and rural water supply sources & creating appropriate environment for the private sector to participate in the urban water supply delivery.
Climate legislations	**Details**
Climate Change Policy 2019	• Climate change Policy 2019 contributes to socio-economic prosperity of the nation by building a climate resilient society. • Sectoral policies, strategies and working policies specific to water and urban themes include 'Forest, Biodiversity and Watershed Conservation, 'Water Resource and Energy' and 'Rural and Urban Habitats'. • The policy provisions management of wetland that are at risk of climate change. • The policy provisions to mainstream climate change adaptation programs while adopting integrated watershed management. • Promotes development and promotion of technologies for storage, multiple use and efficient use of water in climate risk prone area, rainwater harvesting.
NAPA 2010	• Water resource & energy' and 'climate induced disaster' identified as thematic areas. • In Water Resource and Energy theme, effects of climate change on water resources and implication of too much and too little water and its impact on hydropower discussed. • In Climate induced disaster's theme, susceptibility to climate induced disasters as floods, landslides and droughts highlighted.

	• Prioritized rainwater harvesting, ground water recharge and promotion, rehabilitation of traditional water sources, recycling & treatment of wastewater.
LAPA 2011	• LAPA framework has identified water and sanitation as crucial along with watersheds and microfinance, education, local infrastructure, disasters and other environment-related issues • LAPA steps recognized vulnerability of women from water scarcity
NAP 2021-2050	• Thematic group addressing water issues: 'water resource & energy' and 'climate induced disasters' • In Water resource and energy theme, inadequacy of planning & policy instruments for strengthening community capacity to deal with changing scenarios and climate change induced • Disasters highlighted • In climate induced disasters, it has been pointed out that the current level of efforts in integrating climate change into disaster risk reduction policies & plans is slow.
Urban Legislations	**Details**
National Urban Development Strategy (NUDS, 2017)	• NUDS aims to develop the medium/long term strategic vision of a desirable and realistic national/sub-national urban system • It establishes standards for urban infrastructure, urban environment, urban planning and management, and urban governance • It identifies key issues in urban development and offers innovative strategies to address the issues of urbanization and climate change. • The strategy also provides suggestions about the institutional framework and legal instruments for implementing and monitoring NUP and urban strategies.
National Urban Policy (NUP, 2007)	• The policy broadly provides a strategic roadmap for fostering balanced and sustainable urban development in Nepal. • It emphasizes the importance of sustainable urbanization, the policy addresses key issues such as infrastructure development, land use planning, housing, and environmental sustainability.

	• It seeks to create well-planned and resilient urban areas that accommodate the growing population while promoting social inclusion and economic growth. • The policy envisions integrated governance mechanisms and collaboration between different levels of government to ensure effective implementation.
Local Government Operation Act (LGOA, 2017)	• LGOA 2017 defines the structure and functioning of local governance entities in the context of Nepal's federal system. • The act aims to strengthen democracy, promote decentralization and improve services of delivery at the local level by allocating the roles and responsibilities of urban and rural municipalities.

5.1.2 Institutional evolution and implementation of large water schemes

The section below illustrates how the water management institutions emerged in the study sites in relation to the higher-level policy and institutional dynamics. The analysis is made in relation to the time periods during Panchayat, post 1990s democratic period and after Federalization. This will provide a context of how the different water institutions pursued donors funded projects and support as a key response to securing water in both the case study sites.

The study found that at different time periods, different institutions evolved and dealt with managing water needs. The historical evolution of different institutions and their responses in Dharan and Dhulikhel in the journey towards water security has been technical or infrastructure focused. One of the key responses was the ADB-funded drinking water projects' implementation in both the sites and German funded drinking water project in Dhulikhel. These large-scale drinking water projects is viewed by the municipalities as a significant milestone in achieving urban water security and leaders since Panchayat era persistently pursued for the implementation of the project. The large-scale drinking water projects in the cities is being supported by funding from the Asian Development Bank (ADB) and implemented as part of the Secondary Towns Integrated Urban Environmental Improvement Project (STUEIP). Nepal government, in collaboration with ADB initiated STUEIP in 2010, as support to municipalities in strengthening urban infrastructure of the cities near Kathmandu in which the agreement was made between ADB and the municipalities of Banepa, Panauti and Dhulikhel (as KVIWSP). In Dharan, water project was implemented under Integrated Urban Development Project (IUDP) that aimed to develop the urban environmental infrastructures, funded by ADB.

The explanation below also shares about important responses or modifications made by the village leaders/municipalities to fulfil the criteria of bringing and implementing the water projects for instance, upgrading Dhulikhel from former VDC to Municipality for German funded water project and forging consensus between the three municipalities, Dhulikhel, Banepa and Panauti for the ADB-funded KVIWSP. While for Dharan, institutional restructuring, merging of NWSC to Water Board[20] for the implementation of ADB funded drinking water project proved to be contentious. Rounds of negotiations and renegotiations with the upstream community in securing water sources for these projects by the then institutions are the key efforts. The whole process over the period of time and with democracy became complex with growing number of actors, struggle committees, complex institutional mechanisms, and growing awareness of the upstream communities regarding water rights in the context of growing water needs and climate change impacts. The issue of inequitable distribution of water with the merging of adjoining villages to the municipalities were other challenges faced by the project.

Evolution of water institutions at different time periods:

- **Panchayat Era:**

Drinking water was managed in the past through traditional and community managed water management practices like stone spouts, ponds, wells and lakes and Raj *kulos* were famous for irrigational purposes. The modern development of public water supply in Nepal was initiated by the development of Nepal's Five- Year Plan (1956-61). Further developments were the establishment of the Department of Water Supply and Sewerage (DWSS) in 1972, the Water Supply and Sewerage Board in 1973[21], Water Supply and Sewerage Corporation in 1985.[22]

The Panchayat era was featured by the single party-political system functional under the direct rule of the Monarch. The history of water distribution in Dharan is marked with the initiative of the then Rana Prime Minister Judda Shumsher who constructed a water tank in Fusre in 1938 where water from Sardu-Khardu stream was collected and then distributed to the city residents. The water demand in Dharan raised sharply due to its strategic location as connecting place between the Tarai and the Hills. In 1959, the city faced further population pressure being a transit point for Nepali British soldiers with the establishment of the British Gorkha Camp.

[20] The Board possess the authority to take over the management responsibility of the water supply system (under the leadership of Mayor) from the existing water management institutions (NWSC in Dharan and DDWSUC in Dhulikhel), and devise and enforce the policies.
[21] under the 1957 Development Board Act
[22] under the Corporation Act of 1965

The soldiers' bought land and settled in the area. The then Dharan City Panchayat was responsible for water distribution to the residents until 1977. The Dharan City Panchayat established a water division and distributed water to around 7,000 private taps at a cost of Rs 11 per month. In the same year, drinking water distribution responsibility was handed over to the government entity, Nepal Water Supply Corporation (NWSC). In 1987, a ductile pipeline was installed in the city with a financial loan and aid from the World Bank to fulfil the growing water needs.

In Dhulikhel, the Village Panchayats (village councils) authorized under the Village Panchayat Act 1961 exercised power to hear cases relating to encroachment of water outlet, embankment of water resources and irrigation water and others. With the increasing water demand and rumor of shifting of the district headquarter to another town due to water scarcity issues, the community leaders of Dhulikhel made continuous efforts to approach the then Prime Minister, Judhha Shamsher Rana who installed 7 standpipes in Dhulikhel bazaar and successfully convinced the Indian Embassy in Nepal to install water tank in 1982 in Dhulikhel.

The first tap water supply in Dhulikhel started through Judha Dhara (1932-1945). In 1982, the Indian Embassy in Nepal funded the first water project with 27 public taps for Dhulikhel initiating the history of water institutions (Tiwari, 2008). This was known as old water supply system in Dhulikhel. The initiative of 1982 was small in scale and was not able to serve water matching the demand of the time. Dhulikhel suffered from water scarcity due to population growth in the town.

Bringing in the German aided water project in Dhulikhel was not easy and negotiating the water source beyond the municipal jurisdiction was even more difficult. Constant efforts of community leaders' of Dhulikhel in approaching the German colleague to Dhulikhel, approaching a government representative from German Embassy that even enraged the government initially, only could pave the way of successfully building the project in the 1987[23] (Byanju et al., 2020). GTZ demanded a request letter from the government, and to fulfill GTZ's other criteria of upgrading itself into a municipality from VDC, the adjoining villages were merged.[24] GTZ along with Dhulikhel Development Board approached the residents of Kalanti Bhumidanda, alongside Roshi river (as water source) for tapping their water source to Dhulikhel.

[23] The then Bhumidanda village panchayat made an agreement on July 27, 1985

[24] This increased the population of Dhulikhel to 10,000.

Post 1990s democratic era:

History shows that the post 1990 decentralization policies opened up space for engagement of multiple water related stakeholders and institutions such as local governmental and non-governmental organizations, community groups and private sectors. In Dhulikhel, this can be traced with the formation of Dhulikhel Drinking Water and Sanitation Users Committee (DDWSUC).[25] After the completion of the project in 1991, Government of Nepal handed over the project to DDWSUC on 7th July 1992 which also undertook the responsibility of the old drinking water system in Jan 1993[26]. DDWSUC though formed in ad-hoc basis initially, started exercising its democratic processes of forming elected user committee since July 1993 and established itself as a local community-based water management institution in the later years.

Further annexation of the village development committees in 2014 created the core-periphery divide in accessing drinking water. The project's focus of water supply was in the core Dhulikhel that covered wards 2, 3, 4 and 5 (old). But the project could not fulfil the increased water demand and could supply water for only seven hours per day in the core while the peripheral areas received daily water supply for less than three hours or even merely 15 minutes (Pandey and Bajracharya, 2017).

This period has also been marked for the proliferation of multiple struggle committees formed in Dhulikhel and Dharan to assert claims over water sources and negotiate. These were primarily formed by the group who had claims in people accessing water sources (irrigation and other water uses being impacted) or representation in decision making (such as upstream/ peripheral communities), or those marginalized in accessing water (such as those residing in peripheral region or squatter settlements). The sources area people protested for their trade-offs on agricultural water need and water mills; and several committees were formed for the negotiations and re-negotiations (three agreements done in 1985, 2010 and 2011) with the upstream Bhumidanda communities. For instance, people from upstream communities formed Local Concern Committee demanding for inclusive decision making. Likewise, people from outside core Dhulikhel formed Struggle Committee claiming equitable water distribution; and Roshi *Khola* Concern Group represented farmers whose irrigation was affected by the drinking water project for raising their compensation demands. It was noticed that the agreement process

[25] under the provision of Decentralization Act 1981 and later under Water Resource Act 1992

[26] Department of Water Supply and Sewerage (DWWS), Government of Nepal; German Government through German Development Agency/Urban Development through Local Efforts (GTZ/UDLE); Dhulikhel Municipality and Dhulikhel Drinking Water User's Committee are the stakeholders of this project.

during 1985 was a smooth process with limited demands (as school building construction) but the second negotiation process took nearly 11 years (agreement in 2011). The introduction of the multi-party-political system made the negotiation process chaotic due to involvement of multiple actors. In absence of elected local bodies during this transitional period, the political leaders of APM (All Party Mechanisms) took over the local level decision-making practices and played a significant role in negotiation. The claims and voices of the civil society organizations and upstream communities have led to positive outcomes such as support to upstream communities.

Likewise, in Dharan, various protests followed by negotiations were observed during the time. Similar to Dhulikhel, Dharan municipality also faced annexation of neighboring Panchakanya and Bishnupaduka VDCs in 2014 (that raised its wards from 19 to 27). Within the city, the squatters have been occupying the land from a long time and with the pace of urbanization and establishment of B.P. Koirala Institute of Health Sciences in 1997 brought a considerable increase in squatter settlement. They have provision of communal tap in the squatter settlement; however, water is insufficient for them.

The frustration due to unavailability and limited water supply and unfulfillment of continuous demand to provide approval for pipeline connections took the form of protests in Dharan. The movement involving the slum settlements' communities led by a national level NGO 'Nepal Settlement Protection Society' (Nepal *Basobas Basti Samrakchan Samaj)* took its rife. In 2010, the slum settlements' residents protested with activities as padlocking the room of Chief Executive Officer of the Municipality demanding for private pipeline connections in the squatter settlement. They also protested in a group chanting slogan at Nepal Water Supply Corporation (NWSC)'s office and marched rally from the squatter settlements to a mass gathering at the municipal office. Later, the dialogue among key water stakeholders NWSC and the municipality solved the issue and the slums residents started getting individual drinking water connections as the municipality recommended NWSC.

Another important institutional change in water management was brought about by the idea of Water Board in 2006. The provisioning of Water Board by Water Supply Management Board Act (2006) for the implementation of ADB funded water projects required the existing water institutions to merge. However, increasing reluctance of DDWSUC in Dhulikhel and NWSC in Banepa to merge to Kavre Valley Integrated Water Supply Board and NWSC to Drinking Water Management Board in Dharan has been a contentious issue. In Dharan, NWSC has been

recently merged to Dharan Water Management Board which is managing the water supply in Dharan.

- **The Federal Context:**

The 2015 Constitution adopted federal governance, with three tiers governance system i.e., Federal, Provincial and Local. The Constitution envisions policy regarding the conservation, management and use of natural resources. It has provided the scheme of distribution of power among the Federal, Province and Local levels; devolved power and resources to the federal level and given autonomy for the local institutions. It also mandates the federal government to conserve water resources and develop policy and standards for multi water uses, and provincial government to manage water resources within their provincial jurisdiction. LGOA (2017) provides the legal framework for local government to operate and provides authority to the local government to prepare legislations related to drinking water.

The Constitution of Nepal (2015) and Local Government Operation Act (LGOA 2017) have empowered the local governments devolvong specific powers, including the management of the water resources within its jurisdiction. The Federalism has provided an opportunity to the local governments to take leadership in developing policy and institutional mechanisms for water security in the study sites. Local governments have formulated the local laws in managing water resource namely, Water Resources Utilization Regulations of Dhulikhel Municipality, 2078 (2021) and Environment and Natural Resource Conservation Act 2077 (2020) in Dharan. Dhulikhel showed leadership in chairing the Water Board established in 2015 (Mayor as Chair) and also the Kavre Valley Drinking Water Direction Committee as well as in negotiation processes with the upstream communities.

In both Dharan and Dhulikhel, the local governments have extended their engagement and collaboration with diverse actors and taken initiatives to lead and facilitate some innovative informal institutional practices and collaborative approaches towards sustainable urban water management (details in section 5.1.3). For instance, to increase the coverage of water supply system in all the wards of the municipality, Dhulikhel municipality has been engaging with Panauti and Banepa municipalities to expedite the Kavre Valley Integrated Water Supply Scheme. However, despite the devolution of power and authority at the local level, the local governments have been facing the multiple challenges such as insufficient technical capacity, lack of infrastructure and human resources, and limited knowledge and skills in promulgating local laws and others (details in Chapter 6).

5.1.3 Local/ Municipal responses

Besides the role in bringing large scale water schemes (explained in the institutional response section above), the key local (municipal) responses have been on networking and collaboration with organizations, optimizing water use and watershed conservation, integrating nature-based solutions in the municipal program as well as initiatives for deliberative platforms which is explained in this section.

a) Extending networking, partnerships and collaboration

Both the municipalities extended their partnership and collaboration with various national and international organizations such as Federal government, Drinking Water Department, research organizations and Universities (Kathmandu University in Dhulikhel), and international governmental organizations. The new political context with the elected local representatives has provided municipality the space to lead and facilitate some innovative informal institutional practices and collaborative approaches for securing water. Dhulikhel initiated efforts[27] to localize SDGs in 2018 and is also affiliated to global network 'Cities with Nature'.

In an attempt to generate and consolidate water management knowledge, local water conference was organized in Dhulikhel in 2018. The conference brought together key stakeholders to discuss on research findings presented by researchers, innovative ideas and sharing on managing water and also Dhulikhel's initiatives in water management was showcased. The policy dialogues in the conference paved way for future policies and actions pertaining to address the water management problems at different levels. The conference also provided an opportunity of collaboration with key research organizations as Southasia Institute of Advanced Studies (SIAS), Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Institute for Social and Environmental Transition in Nepal (ISET-Nepal) and Municipal Association of Nepal. Dhulikhel got an opportunity to demonstrate its initiatives towards water management to wider audiences.

With this conference and the city level water forum's initiative, Dhulikhel Municipality's leadership have internalized the value of research in sustainable water management. Further, during the interview, Mayor of Dhulikhel Municipality shared its intention of extending research-based collaborations. It has listed out the activity of conducting research on the

[27] The leadership has utilized the opportunity in introducing Dhulikhel to the world as becoming the first city in Global South and South Asia to endorse the Fossil Fuel Non-Proliferation Treaty; achieving 4 SDGs and many others.

conservation of Roshi Watershed area and the potentiality of Jhiku Khola watershed in Annual Policy and Program.

Dharan Municipality also discussed the importance of evidence-based policy making in sectors including water management. Dharan takes research as an opportunity to utilize its strength as an educational hub. In one of the interviews, Deputy Mayor clarified that, for the four academic institutions in Dharan, the municipality allocated NPR 500,000 for open expense collaboration in last fiscal year (2019). But only Pindeshwor college approached the municipality and hence collaborated with them, and one of the academic institutions bought a photocopy machine from the fund, while others did not approach the municipality. In the FGD held in 2020, concerns were raised that the efforts have been inadequate to grab the utmost opportunity of research from academic institutions due to lack of research mechanism. The major gap accepted by the municipality and the academic institutions was in the communication and collaboration in research and management and policy hurdles which left the municipal leaders ignorant of the past and ongoing research by the university. As shared by the Deputy Mayor, '*Those who have expertise and have done research should approach and share with the local government. Local government is like a guardian; they should come and discuss. That might bring some solutions.*' On the other hand, the university professionals had grievances with the local government for not being able to connect the research to the policy making.

The municipality has expressed commitment to collaborate with the academic institutions in research for research-based policy making and development. Deputy Mayor, in an interview and in group discussions, stated that the municipality is interested in research-based findings for decision making requesting the academic institutions/ researchers to share the research findings to the authorized body. The municipality planned to initiate with the formation of the research committee in the municipality. Possible areas of further research, students' engagement in data collection through collaboration of municipalities with academic institutions, setting up of institutional mechanism as research team/ expert team formulation were some of the ideas identified for future collaboration. In Dharan, change in leadership and unstable political upheavals are found to have implications in effective implementation of the commitments made in the water management sector.

b) Initiatives in watershed conservation

There have been several institutional responses for watershed conservation, improvement and management, responses through policy and planning initiatives in the last 3 decades by the government and NGOs, but the persistent efforts have not been highly effective.

The local Act of Dhulikhel 'Water Resource Utilization Act 2076 (2021)' takes into consideration the protection of water sources and controls water pollution by prohibiting any activities as waste disposal, discharge from industries, chemicals etc. Likewise, 'Environment and Natural Resource Conservation Act 2077 (2020)' in Dharan has provisioned the water sources conservation, mapping and documentation of the sources within the municipal jurisdiction; their conservation and management considered as a municipal role. Likewise, the Act also prohibits the activities pertaining to pollution and encroachment of public land within the watershed. However, the water quality and quantity remain a concern in downstream areas of Dharan (IUCN Nepal, 2011). Government of Nepal[28] initiated the *Shardu khola* watershed protection program in 1976 to conserve drinking water sources in which upland part of the watershed was prohibited for settlements and 209 houses were relocated to Morang district. However, due to administrative problems, the relocation program was not effective, and settlements prevailed (Rai et al., 2016). Some local NGOs, national and international organizations have been carrying out research and conservation in the sector of drinking water. Centre for Environment and Tourism Development (CETD), a local NGO in collaboration with INGOs International Union for Conservation of Nature (IUCN) and International Center for Integrated Mountain Development (ICIMOD) have been doing awareness programs and research on PES. CETD with support from IUCN and ICIMOD conducted research and published a book and guidelines have been provided for the watershed conservation. IUCN Nepal worked with local stakeholders to create a master plan for the *Sardu khola* watershed to enable improved water quality and quantity (IUCN Nepal, 2011).

Promoting Dhulikhel as a touristic town and clean and green city, the municipality has prioritized forest conservation, plantation on both sides of roads, establishing nurseries, and has adopted 'one ward, one park' provision. Taking into consideration the impacts of climate change leading to reduced water sources, and decrease in ground water level, this program will be continued and traditional wells and ponds conservation will also be included for

[28] Upland part of the watershed was prohibited for settlements after enacting the oral declaration in the legal documents (in Nepal Rajpatra). The declaration concerning the protection of the watershed area was declared by Late King Birendra Bir Bikram Shah Dev in 1976.

conservation. Rainwater harvesting, storage, technologies to reduce water use in irrigation as drip-irrigation are also encouraged by the municipality. It has also been active in managing the solid waste, being a part of Kavre valley Integrated Solid waste management project. Water recharge in dry hills through water recharge ponds has already been successfully piloted and is being further extended in partnership with NGOs and private sectors. In Dhulikhel, the municipality has collaborated in making recharge ponds in the forest area for augmenting the water discharge. The municipality has also brought forward the concept of 'one ward, one pond'. The municipal has also put in efforts to identify other existing water sources in order to sustain the water supply in Dhulikhel on-a long-term basis.

Both the cities have demonstrated efforts in watershed conservation by supporting upstream water source area communities. The continued support and contribution made by Dhulikhel as downstream water users to the upstream communities serve as an important learning for the cities that depend on upstream for water source. Dhulikhel Municipality has contributed to the social and infrastructure development as construction of a school building, bridge, health and educational facilities for the upstream inhabitants and water source conservation. It has also made financial contributions for the improvement of water mills and supported drinking water supply and irrigation projects. In terms of institutional mechanism, Dhulikhel opts for establishing a 'Water Council' as an inclusive institutional structure for dealing with water related issues of upstream and downstream communities, not limiting to the payment issues.

c) Institutional and policies innovation

The local governments in Dharan and Dhulikhel initiated a series of discussions termed as water forums in the federal context. These forums are termed as '*Paani Chautari*' and are formed as a loose forum with representation of water related stakeholders. The overall aim of water forum is to create a common platform where all water related stakeholders could raise and discuss water related issues, in order to identify solution, forge collaboration in water management, distribution and conservation. The water forum participants envisioned the forum to act as a knowledge hub to tackle problems in drinking water, climate change and other environmental problems and as an exemplary platform for discussion, advocacy and strategic planning. This forum intended to avoid duplication in water related activities and promote collaboration hence reducing water related conflicts. The participants of water forums ranged from 25-40 persons representing municipality officials, women networks, users' associations, Federation of community forest users Nepal (FECOFUN), private sectors, researchers, civil

society organizations, journalists, NGOs, elected representatives and others. The initial water forums organized in Dharan and Dhulikhel discussed about the mandate of water forum, governance, its sustainability and other issues while the following water forums gained momentum on discussing the issues, with wider stakeholders' participation and identified the viable options for water sustainability. Between November 2018 and February 2020, seven *Paani Chautari* series were held in Dhulikhel and Dharan each on multiple issues around water management in the town.

The reflective dialogues among the participants in both the cities representing wide stakeholders supported the development of context specific local strategies in managing water stress. The water forum was not only limited to discussing the issues related to water, but it has exhibited some remarkable outcomes as participatory decision making, extension of ownership and collaboration, innovation in managing city water systems commitments, influential actions and policy uptake, from the ideas generated and options identified in the forums.

For instance, Dharan Water Forum III and IV organized by the municipality, offered space in identifying recharge pits as one of the viable options to be made mandatory for ground water recharge, amongst the water stakeholders, owing to the high infiltration capacity of the soil. This was considered to contribute towards solving the problem of too much and too little water, with issues of decreasing groundwater levels and increased runoff causing floods. This issue is brought about by the land sealing due to rapid urbanization. Former Mayor of Dharan expressed his commitment to adopt ground water recharge in the municipal policy in Water Forum-III and in the following water forum IV, shared commitment to implement required policies also indicating the challenge of policy implementation.

> *"As Dharan city can't stand alone from the environmental and climate change impacts, it is high time to implement the required policies and rules. I am committed to perform the required institutional roles of Dharan municipality and implement the policies effectively. Although the policies are formulated effectively, there exists gap in implementation in any sector which ultimately challenges the sustainable development in the long run."*

Following up, the Dharan municipality adopted a policy, making the recharge pits mandatory for getting approval to build new private and public houses. In this way, the concerns raised by the water related stakeholders regarding groundwater sustainability in the water forum was put together with research and empirical data by various institutions.

Similarly, the water forums in Dhulikhel engaged the private sectors in adopting water conservation techniques, especially adopted by the hotels and rainwater harvesting. One of the concrete actions and exemplary outcome from the city level water forums discussions in Dhulikhel was the decision to construct recharge ponds for water source conservation. Recharge ponds have been piloted in Dhulikhel Municipality which has recognized the benefits of recharge ponds and adopted policy of revitalizing existing and building new ponds in wards. Such collaborative approaches with the municipality have been very effective. Dhulikhel municipality's strategy and initiatives for the fiscal year 2018/20 emphasized a commitment to upholding its "One Ward, One Pond" initiative, aiming to safeguard groundwater recharge. Furthermore, the municipality has allocated resources for the collection, storage, and efficient utilization of rainwater, employing appropriate technologies. This evidence-based policy making is one of the appreciable outcomes or intervention of the discussion forums as 'water forum' or it can be said that water forum exhibited contribution in building a community of practice around urban water security. Ojha et al. (2019) also discusses how a rich hybrid knowledge pool engaged through research initiatives and local stakeholders can be brought into conversation with formal decision-making practices.

Dhulikhel municipality is dedicated to achieving universal, safe, and affordable drinking water access through the "One House, One Tap" policy, supported by a NRs 3 billion budget. Several projects have already provided tap water to about 700 households. In the fiscal year 2019/20, the municipality planned to operate five more projects, expanding services to 2000 households, particularly in extended areas of wards 1, 2, 8, 9, 10, 11, and 12. Notably, five of the 17 ongoing projects involve deep boring, supplying water to critical areas, including Kavre (ward 9), Batase (ward 10), Saankhu, and ward 11. This underscores Dhulikhel's commitment to improving water accessibility.

In Dhulikhel, one of the instant outputs of the event observed was the joint declaration of the organizers to contribute in managing water, in which Dhulikhel Municipality expressed its commitment on up-taking research to policy, Hotel Association and Chamber of Commerce in investment of water efficient technologies, while implemented project like 'Cities and Climate Change' in backstopping technical knowledge from research and sharing global practices.

Mayor of Dhulikhel Municipality expressed his commitment in concluding session of water forum-IV that focused on private sector engagement for efficient water management in Dhulikhel:

"Recognizing the high demand of water for hotels and business in the touristic city and increasing urbanization and impact of climate change, Dhulikhel municipality is committed to adopt the incentive-based provisions of supporting businesses that adopts water efficient technologies such as rainwater harvesting and water recharge."

Municipality has now provisioned subsidy to industries that install rainwater harvesting system to run their businesses. Likewise, the fifth water forum led to commitment of municipal leadership to prioritize women's issues in municipal planning and policy making, and participatory decision-making. The sixth water forum forged together the upstream and downstream communities and proposed 'Water Council' as an institutional mechanism for fostering improved water relations among upstream and downstream communities which are exemplary.

Such discussion forums not only have generated the innovative ideas, but also has developed as a learning platform through sharing of national and international good practices to integrate in its new plans and policies. For example, Representative from Dharan Municipality shared some policies and international practices such as density bonus, tax credit, soft loan, speedy building permit process, defining sealing percentage, green rating system and tax abatemenn that could be adopted. In order to develop required skills for constructing recharge pits and implement policy into practice, the fifth water forum in Dharan trained the local manpower/mason in constructing household level recharge pit.[29]

The idea of water forum was perceived positively not only by the stakeholders but also was of deep interest to the leadership as Mayor and Deputy Mayor of the municipality. This was as water supply was within the broad agenda of the political leaders in their manifesto during elections and with the initiation of evidence-based findings and discussion by researchers and all stakeholders proved as the best platform to contribute towards fulfilling their vision. However, the challenge of the water forum is observed in its sustainability with major role of coordination (details in chapter 6). Dhulikhel expressed the will to establish 'Water Council' as an inclusive institutional structure having technically capable representatives of upstream and downstream communities. The council's focus is thought to be dealing water related issues

[29] Standard recharge pit: A pit of 1-meter length, 1 meter in breadth and 1.5 meter in diameter, first tilled with stones and then gravel and later with coarse sand. A wall was constructed on it all sides. However, the shape, size and location are designed flexibly as per the individual household needs.

and establishing amicable relations between the upstream and downstream communities But the idea of Water Council is not materialized yet.

d) Private sectors efforts in optimizing water use

With increasing water-intensive private enterprise in the study sites such as hotels, industries and supermarkets, the water demand to operate this business have drastically increased. Proliferation of such enterprises, for instance, the hotels, have increased water need for facilities as swimming pools, restaurants, landscaping gardening and laundry etc. The private sector is facing challenge in fulfilling the growing need hence the hotels in Dhulikhel have installed bore wells for private use. Likewise, in Dharan, four bore wells were officially registered in 2018, specifically for the Catechu powder industry (Shrestha et al., 2018).

These cities facing water insecurity require the strategic involvement of entities beyond public and community sector- the private sector for achieving sustainable water management. Large, medium, and small private enterprises hold the potential to implement water-saving practices, invest in efficient technologies, and contribute to the conservation of water resources (Shrestha et al., 2019).

The survey results showed a mixed response on whether the private sector should engage in water management (refer to Figure 27). In Dharan, while 47% people think that private sector involvement in water business would be okay, 18% think it would be good, compared to 25% and 34% respectively in Dhulikhel, suggesting that it is perhaps more favored by some residents in the latter area. A similar proportion of respondents in both areas consider this to be a bad or very bad idea (Dharan - 7%, Dhulikhel - 7%), and large proportions of population in both areas take a neutral stance (22% in Dharan and 31% in Dhulikhel) provided water is a public good but prolonged scarcity has not left them any choice except to depend on water tankers and bottles.

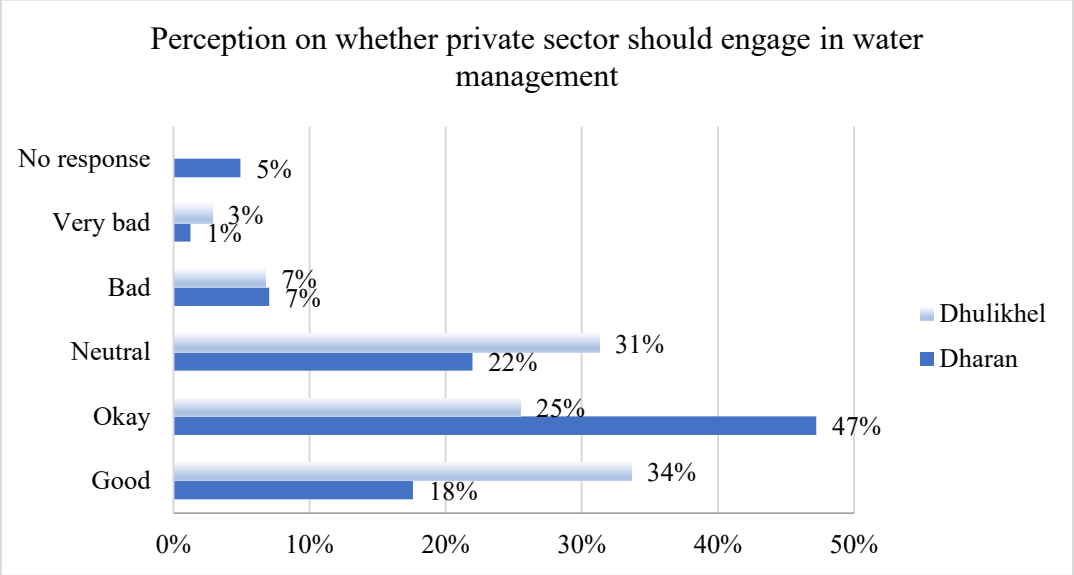

Figure 27. Perception regarding whether private sector should engage in water management

Interviews and discussions have identified some initiatives adopted by the private sectors in Dharan and Dhulikhel as response to managing available water. Of the various water saving tips, private sectors in Dharan and Dhulikhel took an initiative of introducing the stickers at hotels pasting them at places of water use. Since hotels have maximum water demand, the initiation of placing the stickers proved helpful in reducing the water requirement of the hotels, that has helped in raising awareness regarding saving water by not wasting it. The former Chairperson of Hotel Association of Dharan shared

> "*As the sticker is pasted in the wall next to the wash basin/where the tap is, it is noticeable by the person using water. This has directly influenced in giving a thought in saving water or not letting it waste and has eventually reduced the amount of water use in the hotels. As the water scarcity problem is yet to stay, this effort can help in minimizing the water scarcity level.*"

Other initiatives at small scale by few hoteliers were observed as water sensor installed in some institutions, water recycling and water treatment systems by some of the private institutions, practices as managing the available water as rotational system in the university level. Regulations for imposing monetary fines were also developed and implemented for avoiding households to use water pump machine yet this rule has not been effective due to the lack of continuous monitoring in both the cities. Taking into consideration the water quality issues,

Dhulikhel municipality has adopted policy that guest rooms or touristic hotels with more than 50 rooms, and the other buildings used for business purposes, need to treat the wastewater released on their own. The Municipality has also implemented a novel incentive-driven policy, offering a business tax rebate of 10-15% to private enterprises that adopt water efficient technologies or establish wastewater treatment facilities.

Beside these, despite their potential, the study has found that the private sector has yet to play significant role owing to the limitations and failures of the public sector water institutions in the study sites. The private sector involvement is currently limited to meeting intermittent household level demands through water tankers and bottled water. The lack of privately managed water systems in the study cities, coupled with limited strategic thinking by companies and investors regarding climate-related water risks, highlights the need for their proactive engagement.

5.2 Chapter summary

The sections above discussed the key policy and institutional responses towards securing water. One of the key responses included the sectoral policies formulated in the water, urban and climate themes to address the key issues of urban water. Secondly, the study found that the evolution of different institutions at different time periods focused their responses towards infrastructure focused technical response which was implementing large scale donor funded water schemes. Next, there have been many efforts at the local level in which the municipalities in both Dharan and Dhulikhel extended the networking and partnerships with NGOs, Universities and research organization, extended efforts in watershed conservation, took the initiative in organizing city level water forums as deliberative platforms as well as promoted recharge ponds and recharge pits in the municipal policies. Lastly, the chapter has also discussed the initiatives of the private sector in optimizing water use.

These responses are at the municipality level in which, the municipality, as an institution, is involved along with the collaboration of donor and Nepal Government in the case of project introduction. In regard to policy and water related discussion forums as response towards sustainable water management, municipality is the lead institution coordinating with the stakeholders, including water users. Private sector awareness in water conservation has also engaged them in responding to limit water use by the customers. Amid these responses, there remain challenges with regard to developing capacity of local water management bodies and other stakeholders. At the same time, the initiatives and capacity of the local governments in

developing sustainable and resilient water systems amid the impact of growing population, urbanization and climate change and sectoral policies incoherence have been noted as challenges of water management in the cities.

CHAPTER SIX: CONSTRAINTS AND CHALLENGES IN SECURING URBAN WATER

Water security is a comprehensive and intricate issue that encompasses several interconnected dimensions such as quantity, quality, affordability, access, risks, and sustainability. Further, securing water in cities is challenging as it engages multiple institutional and governance complexities, multi-sectoral water users, multi-use associated with upstream and downstream communities and other issues. This chapter analyses the constraints and challenges faced in the journey towards securing water in the institutional and policy responses. This chapter discusses the constraints and challenges that limit the effectiveness of the responses made by the water institutions. As discussed in Chapter 5, various responses are underway to tackle the current demand-supply gap. For instance, progressive sectoral policies of water, urban, and climate themes, as well as different institutional responses in the study sites in securing water, discussed in Chapter 5. However, various limits and challenges have constrained these efforts and further actions from being effective and sustainable.

6.1 Constraints and challenges in securing water

The study finds that the existing policy responses to secure water are incoherent. Further, institutional ambiguities in managing water such as overlapping authorities in water management in the federal context, coordination gaps and trust issues among multiple institutions, inequitable water distribution, water system's resilience related challenges, fragmented initiatives in water sources and watershed conservation, and limited participation of women and marginalized in decision making amid rapid urbanization and climate change impacts. The section below discusses these limits and challenges.

6.1.1 Incoherent Policy responses

As discussed in the introduction chapter about the interlinkages and impacts on water due to urbanization and climate change, it is evident that the sectoral policies in urban and climate themes need to address urban water. At the same time, the water policies need to address specifically urban water. This means that the interconnected policies must have provisions dealing with issues regarding water management in urban areas. However, the review and analysis of the sectoral policies in urban, water and climate sectors found that only few policies are coherent that have considered the interlinkages amongst urban, water and climate themes.

Table 21 presents the key provisions in addressing ‘urban water’ in the key policies in urban, climate and water sectors.

Table 21. Key provisions in addressing 'urban water' in the urban, water and climate sectors

Water Legislations	**Specific provisions on ‘urban water’**
Water Supply and Sanitation Act (WSSA, 2020)	• The Act envisions coordination among all three levels of government to keep rural and urban settlement clean through health and sanitation campaigns. • The Act discusses provisions about obtaining license for construction, operation and management of water supply and sanitation services for commercial and industrial uses, waste water management, buying or selling water in bulk for uses including commercial and industrial uses (which refer to urban context though not mentioned explicitly). • The Act also shares that the three levels of government can provide financial and technical assistance for rainwater collection and other technical services where surface or groundwater sources are not sufficient and controlling floods and landslides (this also looks relevant to urban context). • The Act has further provisioned for the financial and technical assistance for rainwater collection to address the problem in water scarce areas.
National Water Resource Policy (NWRP, 2023)	• The policy provisions to draft legal documents for implementing and monitoring groundwater extraction and use in urban and peri-urban areas. • It also promotes rainwater harvesting in urban areas and links recharge to building construction provisions.
Water Resource Act (WRA, 1992)	Not addressed
Water Resource Regulation/ Rules (WRR, 1993)	Not addressed

Drinking Water Regulation (DWR, 1998)	Not addressed
National Water Supply and Sanitation Policy (NWSSP, 2014)	Yes (urban and rural areas)
Climate Legislations	**'Urban water' specific provisions**
Climate Change Policy 2019	• It mentions about the development and implementation of standards for sustainable use of groundwater recharge in urban areas. • The revised policy does not clearly show the relationship between climate change impacts on water resources and management and the context of rapidly urbanizing pattern and is silent on how to cope up with the rising demands of urban areas in the era of climate change.
NAPA 2010	• Not mentioned explicitly
LAPA 2011	• Not addressed • LAPA includes water as the entry point, the urban water issues have not been highlighted.
NAP	• Under theme (6) urban and rural settlements, it addresses the disturbances in lives and livelihoods of rural and urban populations due to shortage of water supply due to drought, increase in temperature and extreme precipitation. • Besides, themes on water resource and energy promotes climate resilient water resource and energy infrastructure, and climate risk informed urban and rural development plans.
Urban Legislations	
National Urban Development Strategy (NUDS, 2017)	• Guiding principles – 'Green' to save, protect water body, protection and management of fresh water sources • Integration of rainwater harvesting within the building permit system, institutionalizing water recharge provisions in public

	spaces, monitoring, strengthening system to produce and deliver safe water • internalizing regular monitoring system to assure water quality standard; promotion of community water storage facilities; facilitating private sector investment in water supply, and augmenting investment in waste-water treatment systems Minimum water provisioning, water security, safety and sanitation coverage proposed
National Urban Policy (NUP, 2007)	• Empowers municipalities to plan and implement water supply-related activities • Provisions of subsidy in basic infrastructural services for encouraging private investment in drinking water and canals, conservation of natural resources as rivers and watershed and forest for sustainable use • Aims to contribute to water augmentation necessary for urban activities by implementing appropriate collection techniques for rainwater collection • Mentions 'drinking water and drainage' as pre-requisite for declaration of urban area as municipality
Local Government Operation Act (LGOA, 2017)	• Roles and responsibilities of urban and rural municipalities – about implementation and regulation of policies, laws, plans of local drinking water, drinking water management and tariff fixation at the local level • Has specific provisions of function allocation related to drinking water to the local level committees • Role of data management related to water source, ponds, well taps, stone spouts to the ward committee (clause 12) • Role provisioned to rural/municipality for conservation of assets including the water structures as ponds, canals, taps, wells within its jurisdiction (sub-clause 97)

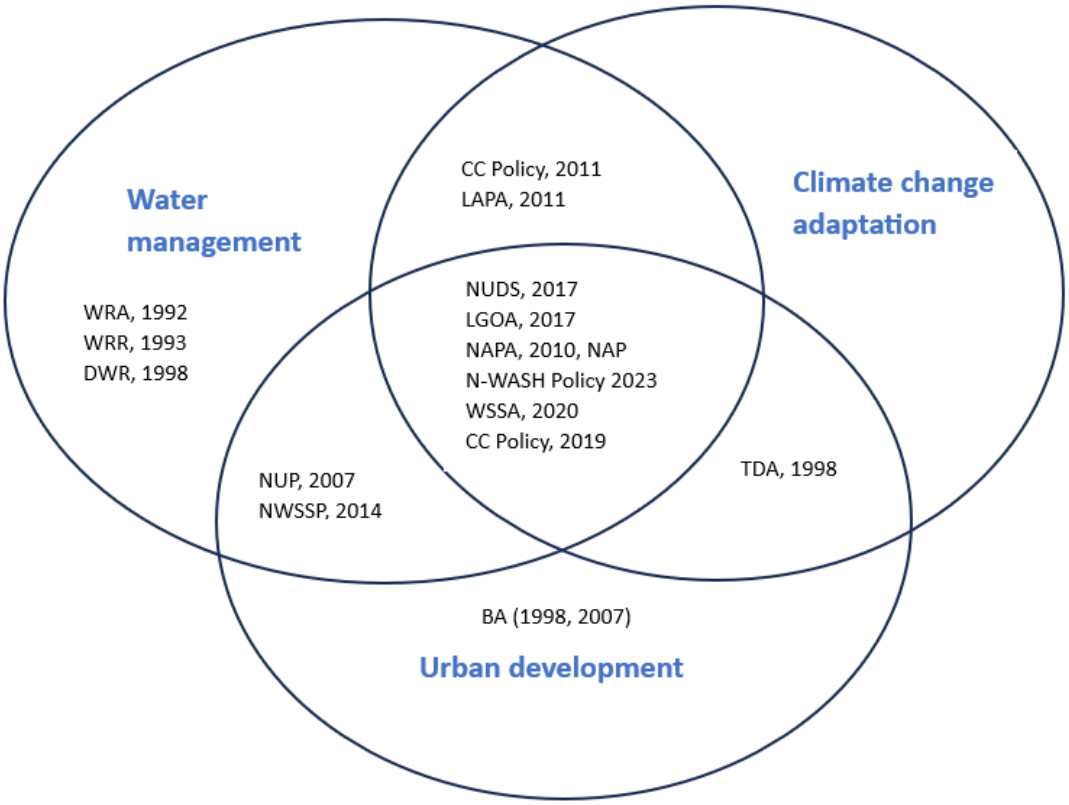

Figure 28. Interlinkages among urban development, water and climate policies

Analysis found that the recent policies, specifically those developed after 2015 under the federal structure are progressive in terms of sectoral linkages of urban-water-climate themes, specifically NUDS (2017) and LGOA (2017) from urban legislations, NAP (2021-2050) and Climate Change Policy 2019 from climate legislation, WSSA (2020) and N-WASH Policy (2023) from water legislations. Figure 28 clarifies which sectoral policies are stand-alone, which policies integrates any two or all of the themes on urban-water-climate. And the table above provides the detailing of how these policies have addressed or not addressed the thematic interlinkages.

It is also found that most of the sectoral policies formulated prior to 2015 were not effectively interlinked and had disconnected themes. The legislations formulated before 2009 in Nepal deal with disasters only, as climate change adaptation emerged as a new policy paradigm in Nepal during 2009. Review analysis has found that NAPA 2010 has also integrated climate and water as one of the thematic sectors. Hence, the incoherent sectoral policies identified through the policy analysis are the major constraint in addressing water insecurity.

Although policies such as NUP (2007) and NWSSP (2014) address urban-water connections, TDA (1998) focuses on urban-climate linkages, and CCP (2011), LAPA (2010) explore

climate-urban linkages, these plans fail to connect the urban-water-climate nexus. The legislations BA (1998), WRA (1992), WRR (1993), DWR (1998) remain in isolation.

6.1.2 Institutional ambiguities in water management

The study revealed that multiple institutions in the federal context, working in water management and changes in operating water institutions has created ambiguity in managing water. The challenges and constraints identified from the study include institutional ambiguities brought about by overlapping authorities in managing water in the federal context, coordination issues amid multiple institutions and their dynamism, and trust related issues.

6.1.2.1 Overlapping authorities in water management in the federal context

Interviews with the key actors such as local elected representatives and focused group discussions with different stakeholders raised the issue of overlapping authorities in managing water in the federal context. The participants shared that the multiple institutions at the federal, provincial, and local levels with overlapping roles and mandates have created ambiguity in water resource management. The Constitution of Nepal (2015) and Local Governance Operation Act (2017) have given autonomy to the local governments for water management and conservation and developing local water management-related policies. It has mandated the federal government to conserve water resources and develop policies and standards for multi-water uses, and the provincial government to manage water resources within their provincial jurisdiction. It is found that 'drinking water and watershed management' lies under the jurisdiction of the local government. However, water resource management is also under the concurrent rights of three levels of government. This issue has been indicated as responsible in bringing ambiguities in the implementation of roles, hence limiting effective water supply and watershed management. Such ambiguities in the roles and responsibilities have resulted in confusion and inefficiency in managing water resources, according to the local government representatives and the water managers.

Further, the early stages of the local government in the transition to the federal context also have set limitations in the effective formulation of policies. For instance, the Deputy Mayor of Dhulikhel explained about the transition situation and ambiguities associated with the overlapping roles of the local and provincial government and non-collaboration:

> *"The Constitution of Nepal (2015) and LGOA (2017) have decentralized more authority to the local level, one of which is to prepare drinking water-related legislation. On this basis, considering our context-specific geography, and situation, we prepare acts. The*

confusion is that the rights of the local government and the provincial government, and also, to some extent, of the federal government are common. In such a situation, we faced difficulty initially as we, the local government, are in a hurry to work but the provincial government has not prepared appropriate laws. It would be easier if the laws were all prepared in collaboration with the local government."

However, the participants have also acknowledged the opportunities in the Federal structure with respect to the devolvement of power to the local level in managing natural resources including water. In the Federal context, the issue of overlap of authority was also stressed (in managing risk due to excess water such as floods and landslides) by the representative of the Disaster Unit in Dharan, which explains the Municipality's resistance or denial with district authorities MoHA (Ministry of Home Affairs). The Disaster Risk Reduction and Management Act (2017) provides executive roles to the Home Ministry with the coordination role of disaster risk management. At the same time, the power of disaster management is devolved to the local governments. Such overlapping authorities have created ambiguities leading to delayed and ineffective responses in addressing the issues. Hence, ambiguities in water supply and distribution as well as managing water-induced disasters such as floods and landslides were observed due to unclear authority distribution.

Further, the study has also found that the policies contradiction on the institutional mechanisms has caused institutional conflicts and inefficient services. For instance, the policy contradiction between the Water Board Act 2006 and Local Government Operation Act 2017. The LGOA 2017 has devolved the authority of water governance of respective jurisdictions to the local governments while the Water Board Act 2006 has delineated central role of water supply management to the water board.[30] Such concurrent roles of water institutions have spawned legal disputes in Dharan as NWSC filed public lawsuit. Such situation diverted the attention of the water institutions, away from their primary mission of efficient water delivery.

6.1.2.2 Coordination gaps and trust issues among multiple institutions

The study found that there exist gaps in coordination among multiple and dynamic water institutions. Evolving new institutional mechanisms are facing the challenge of duplication of water institutions carrying similar agendas and are facing the trust issues.

[30] including acquiring, building, expanding, reforming, and rehabilitating the service system.

The previous chapter (Chapter 4) has explained how the institutional modification in water management brought about by the newly declared 'Water Board' in both the sites has raised various contestations. DDWSUC in Dhulikhel and NWSC in Banepa and Panauti, which enjoyed full autonomy in water management and financial matters, are reluctant to merge to Water Board. After the KVIWSP starts supplying water, DDWSUC will be merged into a municipality holding the responsibility together, according to a Municipal representative who also foresees this challenge. He opined,

> *"As DDWSUC is facing challenges to fulfill the water demand, merging with the municipality would be efficient. However, it is problematic for DDWSUC to merge as they have been working in their own way. While we proposed merging, DDWSUC took it negatively. We have assumed DDWSUC as that of the municipality so there are sayings that the two have to be merged. The water users' group will be the same, some addition and reduction will be done and will continue to work."*

In Dharan, the unwillingness of the NWSC to merge to the Water Board created ambiguity in implementing the water management and conservation roles. After years of contestations, NWSC has been merged with the Water Board in Dharan. This tussle created much disturbance in piloting the ADB-funded drinking water project and both NWSC and the municipality were engaged in supply and distribution. The water users faced issues of water connections, water quality, and water-tariff-related issues and both institutions were non-accountable to the users rather sidelined the issues to one another.

The participants also indicated about the perceived conflict at the federal level, between the Ministries at the national level. NWSC is under the Ministry of Water Supply and Sanitation and the KVIWSP Board is under the Ministry of Urban Development. The shifting responsibilities among the existing and emerging water institutions have become the standard operation procedure (Pandey et al., 2019).

In the discussion of the water policy dialogue[31], contrasting views among the water user's federation and the local government was noted. The local government authorities put forward the point that merging the existing water users committee into a Board could result in more effective and manageable water service delivery. They also claimed that institutional, leadership, technical capacity, and financial capital are much needed for management roles, hence it should be examined which institution is more effective and capacitated. While the

[31] National level dialogue with key water stakeholders organized in Kathmandu on October 4, 2021.

Federation of Drinking Water and Sanitation Users Nepal (FEDWASUN)[32] representative opined that the water users committee needs to be capacitated and empowered to lead the operational and managerial responsibility instead of merging them.

Another concern is that the multiple institutions with overlapping mandates, though may contribute to addressing the water issues, are likely to become hostage to duplication. These may instead create confusion and dilute the efficient integrated approach to achieving urban water security. Examples include the newly formed water board in both the sites and another envisioned local platform like the 'water council' in Dhulikhel that is yet to be finalized, formed, and operated. Water Council was proposed by the Mayor in one of the FGDs[33] which appears as an ad-hoc institution with similar mandates as that of the water board although the Mayor in Dhulikhel claims it to make it focused on resolving upstream-downstream conflicts.

The participants also put forward the issue of the non-coordination of ADB funded drinking water project with the existing water institution in Dharan (NWSC) since the beginning which created a sense of marginalization to NWSC rather than going hand-in-hand to meet the common goals. At the same time, the lack of implementation of the commitment declared by the Integrated Urban Development Project (IUDP) on producing the quantity of water has been criticized and argued in filing the case against it. NWSC also had complaints that on-ground problems of removing the pipes of NWSC and fitting in pipes by that of the project were non-cooperative. The opponents of the project shared the lack of trust and prevailing corruption would soon engulf the institution while its set goals will not be fulfilled.

Further, the quantitative data showed that 16% and 19% of the survey respondents in Dharan and Dhulikhel respectively answered that the water supply management was 'Poor' (refer to Figure 29).

[32] FEDWASUN is a people-based umbrella organization of drinking water and sanitation user's groups in Nepal.
[33] This FGD was specific to discuss the upstream-downstream related issues and opt for solutions in managing the issues.

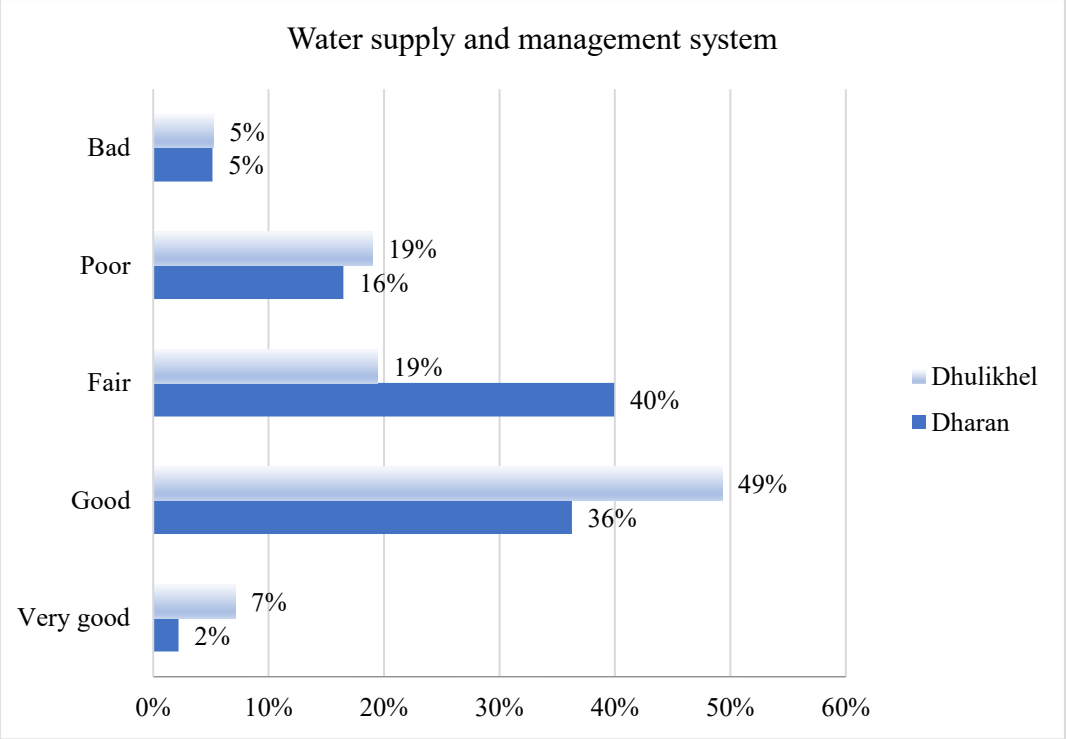

Figure 29. Current water supply and management system in the study towns

While 36% of respondents answered 'Good' and 36% 'Fair' in Dharan; and 49% of respondents answered 'Good' and 19% 'Fair' in Dhulikhel. The survey respondents also referred their dissatisfaction in water distribution as well as issues related to access, distribution, quality, affordability and sustainability linking the poor water management due to the institutional ambiguities.

In both Dharan and Dhulikhel municipalities, we found an inimical relationship between existing water-related institutions with the municipality. For instance, DDWSUC members in Dhulikhel indicated that they were engaged in a tussle with the municipality and DDWSUC often claimed that they faced a weak financial situation with a lack of contribution and support from the municipality. On the other hand, the municipal authorities, including the Mayor and Deputy Mayor, blamed DDWSUC for not cooperating with them.

The conflict between the institutions raised at such a level that the civil society organisation (forum for peoples' concern) had trust issue with the ADB-funded project in Dharan that led to filing a case to the Supreme Court. The leader of the organisation, during the interview said,

> *"We don't trust the municipality that it will be able to provide water to the Dharan residents as agreed. The project committed that it would produce 1,52,20,000 (1 crore 52 lakh 20 thousand) litres of water as mentioned in point no 11 of the agreement but*

the municipality has not been able to implement any of the agreed points. Our protest is against the corruption in the municipality. We argue that the loan amount will be misused. We are protesting the process. It is fine to take the loan for the water project but it has to be made participatory, including ward to ward discussions and also including us. As NWSC is unable to provide water, we are also protesting against them."

In the interviews later, concerns were raised that the Water Board has not been able to be transparent as the income and expenditure have not been made public. Hence, the current approach of the municipalities in dealing with the issues of water management has been constrained by the key institutional challenges such as overlapping authorities, coordination gaps and trust issues among multiple and dynamic institutions and the initiatives has gained limited priority of the local governments.

6.1.3 Inequitable water distribution

Dharan and Dhulikhel, rapidly urbanizing towns have embarked upon a range of initiatives to deal with the pressing challenge of water scarcity. As discussed in Chapter 5, both municipalities negotiated large scale donor funded water schemes, engaged in rounds of negotiations with upstream communities, and collaborated with wider stakeholders. Dhulikhel municipality, in particular, pioneered community-based water management and also is developing large scale inter-municipality water supply project called KVIWSP (targeted to Dhulikhel, Banepa and Panauti of Kavre valley). At the same time, the municipality is taking forward one-house-one-tap program in rural areas annexed during restructuring in 2017. Likewise, in Dharan, the ADB funded drinking water scheme has already been piloted in few wards and is being distributed by newly formed Water Board.

However, the study finds that although access to drinking water has been improved due to these initiatives, these have not been able to improve access to all people and hence have not been able to equitably distribute water. Inequitable water distribution has been noted in terms of access to water between the core and periphery (spatial), rich and poor/ marginalized communities, and people at different geographical locations (as discussed in Chapter 4 explaining drivers of water insecurity).

The water supplied by the water schemes have covered only the core areas in both Dharan and Dhulikhel while people in peripheral areas are deprived of piped water. The local level representatives shared that annexation of the nearby areas to the municipality during restructuring in 2017 was the key reason for not being able to supply water to the annexed

areas. The project designed earlier did not take into consideration this possibility. Now when the water schemes are bearing the challenge to deliver the promised quantity of water, and issues being faced with the drying of water sources, it is not possible for the project to supply water to the annexed areas. In Dhulikhel, the annexation of the nearby villages in 1986, 2015 and 2017 has led to the exclusion of the newly added wards to water supplied by DDWSUC (details discussed in Chapter 4). DDWSUC provides water only to core wards 3, 4, 5, 6, 7, and 8, but not to periphery wards 1, 2, 9, 10, 11, and 12. Kavre Valley Integrated Water Supply Project (KVIWSP), near completion in Dhulikhel, Banepa, and Panauti, has also not targeted these peripheral areas for distributing water. Likewise, in Dharan, the total of 19 wards were divided into 27 wards in 2014 annexing Panchakanya and Bishnupaduka VDCs to upgrade municipality to sub-metropolitan city and further rearranged to 20 wards in 2017 restructuring. Further, in Dharan, the squatter settlements reside in the flood plain areas of Seuti and Shardu Rivers. These communities have high prevalence of poor water quality and water borne diseases. They have provision of communal tap in the squatter settlement; however, water is insufficient for them. The annexed area communities were dependent on traditional and community managed water management practices like stone spouts, ponds, and ground water and spring sources that are inadequate to the increasing water demand.

Inequitable water distribution among the core and periphery has hence marginalized the poorer sections of the society as the peripheral communities are economically weaker segments of society. The study found that they are not only devoid from piped water access but also from safe water in terms of quality. Likewise, the difference in topography (area at height and low area) has led the households within the same wards receive variable amount of water supply. Some of the water users also shared their grievances that those with access to technology such as pumping machine extracts more water leaving other households devoid of water supply.

Squatter settlement in Dharan represent the structural and spatial inequities in urban water access. Despite having communal taps, the supply is insufficient to meet daily needs, leading to chronic water scarcity and exposure to waterborne diseases due to poor water quality. This inequity is not only infrastructural but also institutional. Residents have long struggled to gain recognition for individual water connections. The frustration due to unavailability and limited water supply and unfulfillment of continuous demand to provide approval for pipeline connections took the form of protests in Dharan, and the residents are still facing problems in getting the water connections (details in section 5.1.2). These communities are not only underserved but also often left out of decision-making processes. Further, a group of poor

women mainly from the squatter settlements cultivating the herb known as sim saag[34] (*Rorippa nasturtium*) faced challenges to their livelihood. The herb planted along the upstream of Shardu watershed faced accusations of polluting water sources, despite the womens' claims of sustainable practices. There have been competing claims from the cultivators and non-cultivators including the municipal officials on whether the herb is responsible for water pollution. The women claimed, *'sim sag cultivation does not have bad impact on water quality as they do not use any kind of chemicals, instead it contributes to filtration due to the network of roots*.' The accusation resulted in banning of its cultivation few years ago (Bhattarai et al., 2021) (p.102). This highlights how marginalized groups are disproportionately blamed and excluded from governance processes.

Inequitable water distribution has also led to water related conflicts. During the survey, although only a lesser percent of respondents responded that they experienced some forms of water related conflicts themselves or heard about the conflicts (altogether 38% in Dharan and 33% in Dhulikhel), maximum percentage of respondents had access related conflicts in their area (51% in Dharan and 70% in Dhulikhel). Source related conflicts were also experienced by 30% respondents in Dharan while multiple reasons were noted by 23% respondents in Dhulikhel as illustrated in the Figures 30 and 31.

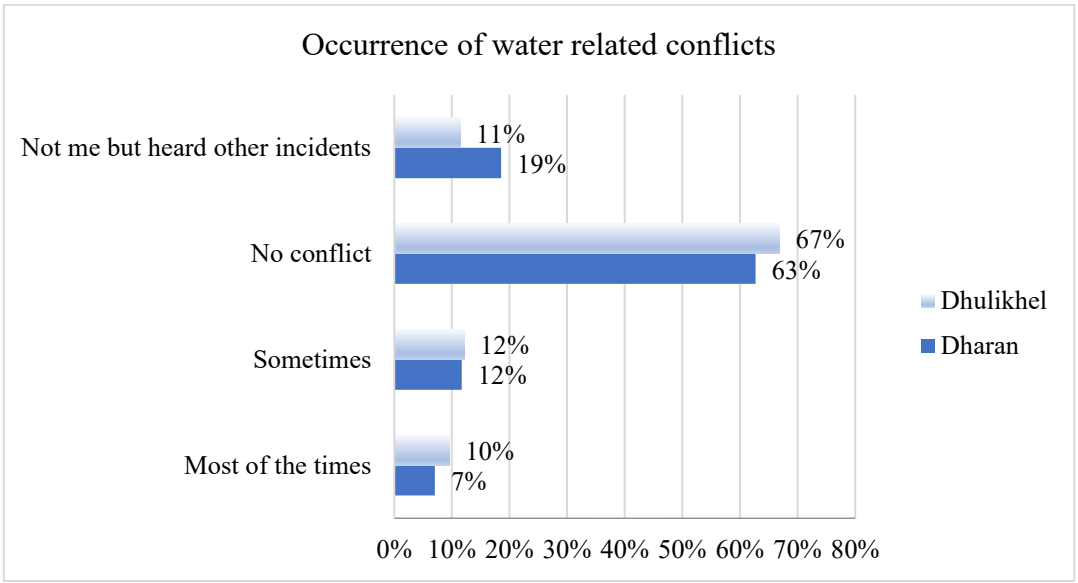

Figure 30. Occurrence of water related conflicts

[34] This herb is used as a vegetable that saag in fresh running water, and are sold at good price in the market.

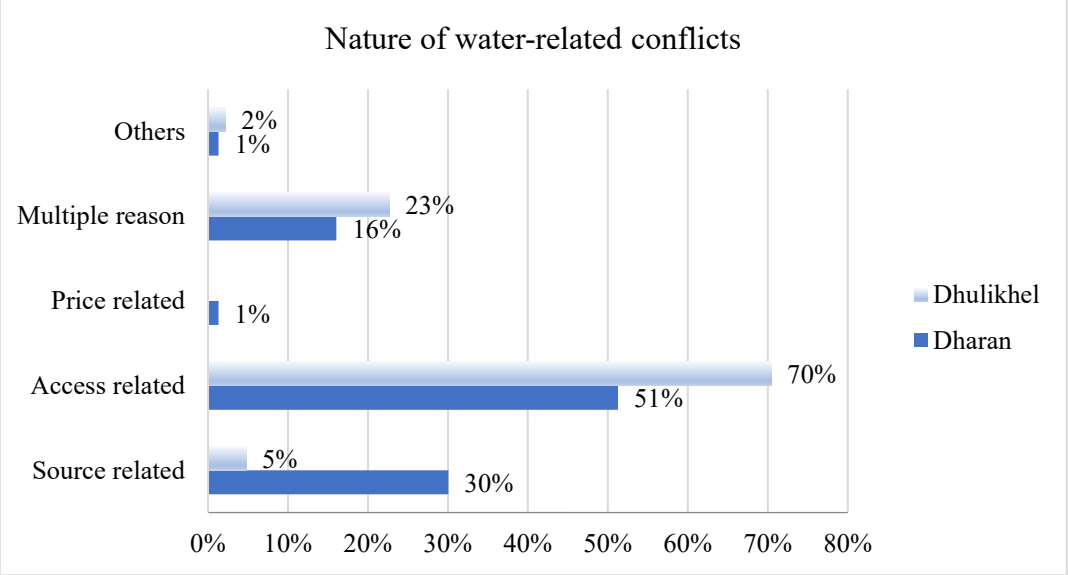

Figure 31. Nature of water-related conflicts

6.1.4 Water systems' resilience related challenge

The study has identified damage to the water infrastructure due to climate-induced disasters such as floods and landslides as a key challenge in both the sites. Dhulikhel brings water from a distant Roshi river, 13.5 km away, beyond its local jurisdiction, and is susceptible to damage to water infrastructures due to floods and landslides during monsoon every year. As the pipelines travel a long distance, there are often problems associated with the breaking of pipes and having to deal with compensation related to multiple demands of the affected people along the way. In May 2020, the water pipeline of Dhulikhel was damaged by the pre-monsoon flood of Kharkhola and Punyamata rivers. It is obvious that the damage to these pipelines had implications for water supply and distribution for at least a few days until the infrastructures were repaired. Investment in Kavre Valley Integrated Water Supply Project can experience huge losses if such disaster preparedness is not considered. One of the water users shared,

> *"After the sweeping away of pipe, they don't have a plan of what next? They don't even have a water tanker, to serve water when needed urgently. They have the infrastructure but no backup during the crisis. If the water source in the forest could be tapped and reserved, at least one time, this water can supply water to the users."*

The Chair of the small water users committee in Dharan shared that the pipes are managed by hanging through poles which are damaged by floods every year in monsoon. Moreover, the participants shared that NWSC in Dharan supplied water through degraded water infrastructure for the last 35 years before the merging of NWSC with the Water Board. The poor water

infrastructure, during floods further degraded and lowered the quality of filtration and water distribution. The recent change in the institutional mechanism of water governance with the advent of the Water Board has upgraded the water infrastructure.

Therefore, dependency on such large-scale water schemes is also found to be problematic during such crises and takes time for repair and maintenance or to solve conflicting issues (as compensation). The key officials of drinking water institutions shared that the ADB-funded drinking water scheme in Dharan was impacted due to COVID-19 with a delay in its progress and completion. They faced restricted mobility that led to a lack of laborers and construction materials. Likewise, KVIWSP is at times halted due to the issue raised by the local people, according to the project representative.

For the resilient urban water system, long term strategic planning that include climatic risk analysis as well as future water demand forecasting is crucial. However, the study found that the limited capacity of the local government and water management bodies in terms of technical capacity has emerged as an important constraint in planning for sustainable water management in both the sites. For instance, the ADB-funded drinking water projects in both Dharan and Dhulikhel are unable to meet the demand of the annexed areas after restructuring as the areas are beyond their supply services. Further, the planning has not taken into consideration the water demand of the floating population of these rapidly urbanizing cities with medical and university centers. While groundwater extraction has been one of the major water sources, its science and recharge importance is not well understood. The initiatives such as construction of recharge pit, though made mandatory in Dharan, and recharge ponds in Dhulikhel, could not gain continuity. These were identified as climate adaptive water management strategy in Dharan through discussion amongst the relevant stakeholders. Recharge pit was even demonstrated in the municipal premise. These strategies would help in solving both the issues of water scarcity and excess (by controlling runoff) but their discontinuity has posed as a challenge in ensuring the water security of the cities.

Such challenges are also attributed to the limited capacity of the local governments with the expertise in strengthening the urban water systems. One of the ward officials in Dhulikhel indicated the gap in long-term planning for managing water.

> *"We are at the verge of increasing population density by being a hospital and educational hub. But no homework has been done taking into consideration the future*

population. Now only KVISWP is targeted for fulfilling the demand. DDWSUC is increasing reservoirs, but they could make use of those already existing reservoirs too."

In the response part, the participants also shared that municipal action is often delayed. Also, in the case of drinking water that is needed immediately for people affected by disasters, the municipality does not give the required attention while its focus is on providing immediate relief to the affected people. One of the participants shared, "*They come and distribute food and other relief materials, but they do not give much importance to drinking water. Bottled mineral water is sometimes distributed but that is not sufficient"*. The participants have also shown concern over a number of constraints in disaster response effectiveness as a lack of expertise in disaster response. For instance, the unfulfilled position of an environmental engineer was noted in Dharan. The Deputy Mayor of Dharan also pointed to the problem that lack of expertise hindered the development of disaster-related Acts and policy and institutional mechanisms. They see the need for enhancing technical capability. There is no attention towards making the local government strong and capacitated in terms of human as well as financial resources.

Further, COVID-19 struck the urban water system exposing the critical gaps existent in the system that was unprecedented. One of the key issues faced was the financial constraint brought about by the delay in tariff collection (halted from 3 to 5 months) from the water users. To all the water institutions, water tariff is the primary source of income and inability of its collection due to COVID imposed lockdown led to financial crisis to the committee and institute managing water supply and distribution. They had to cope up with the loss long after the lockdown was lifted.

In community managed water user system managed by the water users' committee in Dhulikhel (DDWSUC), the fund deficit had been the issue prior to COVID and COVID magnified the financial deprivation. For instance, the DDWSUC committee member also shared that the deficit fund in the present DDWSUC account has posed challenge in operating the committee itself to pay staff salary. It has used all the fund in the account and there are no sources of income. NWSC in Dharan managed water supply during the COVID period but the office closure had implications on water billing and tariff collection for 3 months. In both the sites, the lack of funds hence affected the payment of salary to the staff which was also delayed in absence of other income sources. The water institutions did not receive any financial support from the government, municipality or any organizations. Moreover, the meter reading that resumed after lockdown also added burden to the users as they had to pay the combined bill,

greater amount at once. In Dhulikhel, the decision implemented by DDWSUC general assembly had increased 20% tariff rate. Further, lack of fund has affected to fulfill the water need for instance, DDWSUC member shared, '*If DDWSUC would have more fund, we could go for extending deep-boring. Wait is for KVIWSP which seems to delay further*.'

At the same time, the water institutions struggled in delivering basic water services while none of the water institutions in Dharan and Dhulikhel took initiative for the long-term planning on building the resilience of the water systems to unprecedented shocks such as COVID-19. Their efforts have been on managing the water supply and distribution and mobilizing a few staff for distribution and leakage control. NWSC representative in Dharan referred that the corporation was confident that the guidelines that were made by the government and at the ward level were adequate and they did not feel the necessity of any long-term planning or guidelines in regard to the COVID-19 pandemic. Hence, they neither made any guidelines nor did any tasks separately for COVID-19 management. The working committee meeting, organized even during the time of COVID did not discuss the plan to deal with COVID-19, as shared by DDWSUC members. According to one of the membrtd, *'I think whatever will be the situation if COVID-19 is prolonged, the committee will plan accordingly during that time.'*

Although there is the realization that new technologies such as digital water payment would ease the situation and reduce the financial crisis, they are not in a position to implement it practically due to a lack of confidence that users would be able to properly handle the technology. The situation is further complicated when the water institutions have to deal with multiple disasters in the same period of time.

6.1.5 Fragmented initiatives in water source and watershed conservation

The study has found that amid rapid urbanization and growing water demand and further climate impacts, securing water sources have been challenging. The projects in Dharan and Dhulikhel also had to face numerous protests by various struggle committees and claims and contestations from the upstream communities. This has clearly indicated that the large-scale water projects will face much difficulty to secure water source in the future. However, the initiatives in water source and watershed conservation have been fragmented. Testimonies from the research reflected that the sustainability of the water sources and watershed have not been taken as a serious concern by the water institutions. Further some of the initiatives have not gained continuity, the meetings have been irregular (affecting the discussion on key issues

demanding attention) and the changing leadership has also been a challenge as discussed in subsections below.

6.1.5.1 Limited attention to sustainability aspect

Although water sources and watershed conservation form integral part from the project design, it has not formed priority among multiple water institutions during institutional transition. The interest of the municipalities towards project-oriented solutions engaging in extensive groundwater extraction for managing water scarcity has ignored spring water conservation. Such approaches are favored considering quick solution and visible outcomes while overshadowing spring sources and deep aquifer depletion issue.

The ADB funded drinking water project in Dharan and Dhulikhel had to depend on groundwater extraction to fulfill the required amount of water sources. In such context, amid the drying of water sources due to climatic impacts, source sustainability has been a huge challenge.

With regard to alternatives, in Dharan, according to the participants, another option to bring water from the Tamor River through the tunnel is not easy owing to its high cost (as the river is at a very low altitude). And diversion from Koshi River at a distance of 14 km would be very expensive as it requires filtering and treating the river water which contains a high sediment load. A survey was done but as the water has to be brought through two villages, the people will be claiming compensations to let that happen. Likewise, in Dhulikhel, it is very difficult to manage the rising expectations of the upstream communities. Further, stone crusher factory in the upstream area has led to water quality issues. These are also the reasons that make watershed conservation very important, as the alternatives to conservation are very difficult, according to the participants.

Some of the participants, specifically the ward chairs in Dhulikhel referred to deep boring as the solution and said that deep boring has led to solve much of the water problem. The concern put forward is that deep boring needs electricity and incurs high cost in comparison to drinking water from rivers. The sustainability issue in this case is thought about only when water is not available while making deep bore wells.

However, most of the interviews reflected that water sources and watershed conservation is one of the most important ways of ensuring future water availability. One of the ward chairs in Dhulikhel expressed,

"We need to conserve the water sources identified through plantation, forest sources conservation, replacement of pine trees by other tree species as it is perceived that pine trees contributes in drying of water sources."

Some of the interviews also revealed that there is lack of ward level efforts for sources conservation or on sustainably managing water. Instead, wards are dependent on the municipality. Ward's development plan is more focused on road, or health education related issues as they seem tangible to the people as measurement of their success during the tenure.

KVIWSP representative replied, *"We requested Watershed conservation office for support of sustainable water supply as water will reduce - making check dams, but nothing has happened yet*." Further, household survey data concurs with the qualitative data in considering water source and watershed conservation's key role in ensuring urban water security.

In the survey, the respondents were asked about what they think can address the water scarcity issue they are facing in their cities. The responses included initiatives in infrastructure, water source conservation, and equitable water distribution. And further responses included the integrated approach combining multiple options. Survey results showed 'water source conservation' is considered as the best response strategy in both Dharan (33%) and Dhulikhel (23%). Equitable Distribution is the next most common response in both areas, at 14% and 10% in Dharan and Dhulikhel respectively, followed by infrastructural responses (9% in Dharan and 7% in Dhulikhel). Under the 'others' category, responses included privatization, afforestation, and new source (refer to Figure 32).

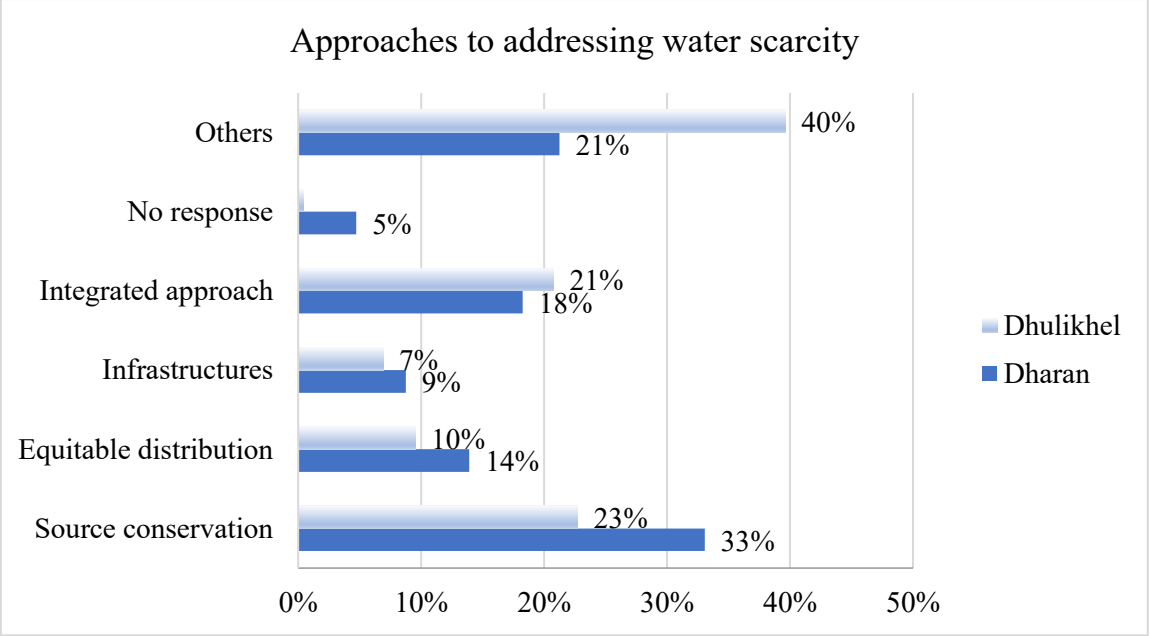

Figure 32. Approaches to addressing water scarcity in the study towns

Meanwhile, water sources and watershed conservation, groundwater recharge, and revival of traditional water sources have not been the priority of the municipalities and water institutions. The participants in FGDs expressed high concerns about the sustainable extraction of groundwater and its possible implications. One of the Ex-British Army official shared,

> *"We are not experts- there must be layers of water underground- at some places, water might be stored but if the water is extracted continuously, it must finish at some point of time."*

NWSC focus in Dharan was on distributing water fetching from the source and running administrative works but without intention of watershed conservation and no investment in conservation. Moreover, during the merging phase of NWSC to Water Board in Dharan, the water sources conservation role was up-taken by none of the institutions. One of the water users shared,

> *"Though the people are paying for the water they are using, the drinking water office has not set any provision of allocating some money in the conservation and management of the watershed. We tried to approach them several times for this but they were not concerned at all. They were only extracting the water without any limitations and conservation activities."*

In Dharan, although the municipal policy has made the recharge pit mandatory for approving house construction, it has not been implemented effectively in practice. According to the

municipal engineer, this was due to a lack of clarity regarding the responsible agency for its monitoring. Likewise, in Dhulikhel, the efforts made in constructing recharge ponds seem to be at risk in absence of upscaling and maintaining the initiative due to a lack of monitoring and priority. Dhulikhel is progressive in terms of water management and source conservation. There is one ward one pond program by the Palika; however, most of the ponds are graveled in their bottom. Further, infrastructure-focused development such as roads and towers has gained momentum that has affected the water sources.

A representative of an organization working in the conservation sector in Dharan noted grievance about NWSC's neglected role in watershed conservation. He shared,

> *"Our organization with the experts from IUCN has been always focusing on two things i.e., the conservation and management of the watershed area. Drinking water Sansthan (NWSC) is just a white elephant fed by the government which only builds tanks, sells the water, and distributes the benefits among them only. They are only after feeding their own staff and running the office. They have no other intention and they will not spend a penny for the watershed as they do not have the policy."*

6.1.5.2 Discontinuation of water forums

Another initiative by the municipalities that could not gain continuity is the discussion forums. As discussed in Chapter 5, attempts were made to institutionalize informal institutional collaborative platforms for discussion and collective decision-making. The municipal official revealed that due to the multitude of issues to be dealt with by the municipality, the organization of the water forum has been side-lined and relegated to low priority despite the interest and commitment shown by the municipalities. Initially, it was not easy to convince the municipality to be a part of the water forum process as their priorities were set on physical developments rather than institutional solutions. The follow-up interviews with the municipal representatives shared that these remained limited to 6 forums each in Dharan and Dhulikhel from the period of 2016-2018 in Dharan and 2016-2020 in Dhulikhel. Another municipal official shared that for the continuation of such forums, these need to be planned as a part of the municipal plan with budget allocation, otherwise, these do not gain priority amid important municipal agendas.

Another challenge faced during the water forums was that there was no fixed date or time interval for organizing the meetings. Therefore, it was not considered mandatory to organize the event in a timely manner, hence reducing the opportunity to discuss water-related issues and problems. A few informants also raised the point that sometimes they found it challenging

to come up with topics or issues to be discussed in the forums. Further, the engagement of diverse stakeholders in the city stirred contradictory views during the discussion, which was not always welcoming and sometimes triggered conflicts. For instance, such issues were prominent while dealing with contested issues such as upstream-downstream relations. In one of the water forum meetings held in Dhulikhel which included various stakeholders such as stone miners, farmers, individuals impacted by the proposed water supply project, and political actors, the discussions entered in heated arguments with conflicting interests and stakeholders' minimal willingness to compromise.

6.1.5.3 Irregular Water Board meetings

During our in-depth interviews, an official of Dharan shared that even the mandated 'Water Board' meeting has not been regular. In Dharan, after the unanticipated demise of the Mayor, Deputy Mayor has been acting as Mayor, and water board members often complain that the municipality, being the coordinator of the water board, is unable to organize timely meetings of the Water Board. The participants raised the concern that the municipality being in the coordination role as chairperson of the Water Board has not been effective due to its multiple roles and responsibilities and has limited the space for discussing water-related issues. The participants also clarified that not being able to organize the Water board meetings led to compilation of water issues to be discussed and decisions to be made on addressing them.

Further issue that was raised in the in-depth interviews was the lack of members with expertise in water institutions for solving the water insecurity issues. For instance, in Dharan, a former member of Water Board shared his disappointment regarding political appointment of its members. He shared how he, representing NGO working in water sector was replaced by ward chair who, for the formal requirement only, registered the watershed conservation committee and became the chair of the committee.

In Dhulikhel, the participants suggested policy level intervention on mandatory representation from ward committee into DDWSUC committee as according to the informants, the ward committee representatives in water users' committee will reflect the real challenges of water insecurity the people in their area are facing and hence can plan and implement the plans and solutions in addressing the issues. In the present situation, the DDWSUC committee members and the ward representatives have remained disconnected and hence lack of coordination is observed. One of the participants shared, *"The people should also understand that while*

choosing the representatives, having general knowledge and education need to be considered for efficient and effective drinking water management."

6.1.5.4 Changing leadership as a challenge

Interviews with ward chairs indicated that there are no ward level efforts for sources conservation or efforts for managing water sustainably. Instead, wards are dependent on the municipality. Municipal development plans are more focused on tangible developments including investments in infrastructure as road, health and education to be able to measure the success during the tenure.

Next, the conservation efforts are driven by the interest and exposure of the people in the leadership position, and changing leadership has led to the discontinuation of the positive conservation initiatives. For instance, Dhulikhel's municipal leadership has been continuous and politically influential. The existing municipality's Mayor also chaired the Municipal Association of Nepal, an umbrella organization of municipalities. The Mayor has been raising water issues since his early youth and has been politically active. He has garnered rich understanding of the issue, and has good networking and has undertaken research initiatives. Further challenges related to the tussle of KVIWSP with the municipality are discussed in the section above.

The people in different positions of DDWSUC have differing priorities during their tenure, in terms of fund mobilization. For instance, DDWSUC faced the challenge of dealing with false financial allegations. As shared by a DDWSUC committee member,

> *"The fund amount of 4 crores deposited by the previous committee, in a way, blurred the image of this committee. The previous committee highlighted the fund amount to reveal their good deed (during the general assembly) while not completing the required task which this committee had to do as soon as they were elected. Such works used the fund available while, on the other hand, creating a perception among the users that the present committee spent all the amount saved by the previous committee while not thinking about the services delivered. Likewise, the good fund amount publicized by the previous committee also showed they did not require external financial support."*

Dharan exhibits a varying political leadership scenario. According to the participants, the change in leadership has affected the conservation initiatives in Dharan. For instance, in Dharan, one of the organizations working in watershed conservation elaborated,

"We had requested the Mayor to form a watershed conservation committee and initiate the payment for Ecosystem Services (PES) mechanism based on its feasibility study with IUCN. But they have not yet understood the importance of it. We had almost convinced the municipality but the whole system changed and with the appointment of new municipal leaders, we are back and need to repeat the circle again. We have to start the process again and have no one to support us. We had really worked hard for many years, prepared everything but all our hard work is useless now. If the new Mayor had only made a committee and facilitated the coordination that would be a great initiative towards watershed conservation."

By saying this, the participants meant that their organization had well engaged and convinced the municipal leadership on watershed conservation but the change in leadership with newly elected local representatives turned their efforts futile. With the un-sudden demise of the Mayor elected (in the 2017 elections), Deputy Mayor had to take up the role of the Acting Mayor for some time after which a new Mayor was elected who was reluctant to operationalize the advice offered. His prior affiliation and engagement in advocating water issues through civil society organizations have been controversial and put him in a difficult situation to handle the contested water issue. He was with the group protesting ADB funded drinking water project claiming the project to be unsuccessful prior to being elected as Mayor. After his appointment, he needed to take steps towards successfully implementing the ADB-funded drinking water project. There was increasing pressure from the Ministry as well as ward members for the merging of NWSC and to Water Board but the handover process was delayed.

Another similar grumble shared by the participant includes,

"In the amount that we are paying now, i.e., NPR 120, we had thought of adding 5% amount as a watershed conservation charge. Previously, the municipal leader had agreed but after, the representatives changed and they are not up with the idea. The Mayor reduced the charge and even after we gave him the idea to collect the money separately for watershed conservation, he did not agree. Only if the political leadership positions such as Mayor, is conscious, the watershed will be conserved or else everything will be destroyed in no time."

At the same time, the water sources conservation responsibility in the presence of multiple water institutions was observed to be shifted among each other. For instance, in Dharan, when

the merging of NWSC to Water Board was in process, the municipality and NWSC shared that the water conservation agenda should fall on each other's responsibility and no promising initiatives have been undertaken by them. Likewise, the same can be the context of DDWSUC and KVIWSP.

Hence, we found that the water management and conservation initiatives in the study sites have not gained enough attention from the water institutions. Further, the initiatives are driven by the interest and background of the ones in the leadership position and their network and influence. However, changing leadership has led to the discontinuation of the water sources and watershed conservation initiatives and resulted in a blame game for proving their tenure successful.

6.1.6 Limited participation of women and marginalized in decision making

Women are the primary managers of water bearing the responsibility of managing water at the household. In the research, we also observed many instances when women could not participate in the meetings organized during the morning time due to household chores and during the time when they had to fill water. Although women are the prime managers of water, the gender issues in water management are not observed seriously. In one of the focused group discussions organized in Dharan, one of the male participants said, "*Gender issues are not of concern in urban areas as the water comes to the tap and women need not fetch water from far unlike rural areas*." In the same forum, the Deputy Mayor criticized the narrow understanding of the stakeholder and explained how she herself, despite bearing leadership position, is responsible to get up early in the morning to ensure that water is filled up for the household chores. She highlighted, "*mostly, women are responsible to manage water in the household even if we do not have to fetch water from far*."

The survey data showed that for the households who fetch water from sources outside their household premises, it is mostly women or other member of the family depending on the availability (refer to Figure 33). For the households who fetch water, it is mostly women (51%) in Dhulikhel and in Dharan, the respondents shared that it is not specific as both men and women take turns to fetch water as per the situation at the household. However, the respondents referred that women (19%) are more engaged in water management at the household in comparison to men (8%).

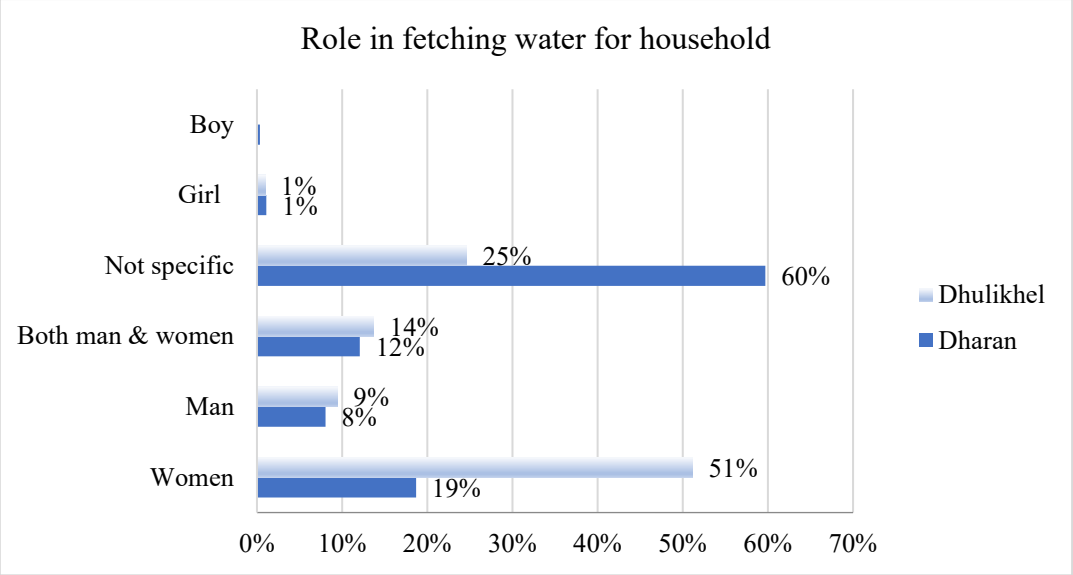

Figure 33. Role in fetching water for household

Despite women's primary role in managing water, representation and meaningful participation of women in the decision-making process is noted to be challenging. In the case study sites, the inclusion of women in key positions of decision-making bodies has been noted as an issue. In regard to the women representatives in the water board, the Drinking Water Supply Management Board Act 2006 that forms the board has not made the women's representation mandatory which has restricted the women's participation in the decision-making authority. The Water Board provisions that all seven members under the leadership of the Mayor with a representative from the Federation of the Chamber of Commerce (FNCCI), a drinking water user's association, a local NGO representative working in the water and environment sector, a water expert and an engineer from the division (government) office. As none of the representing organizations are headed by women hence excluding women from being members of the board, this institution looked like a means for systematic exclusion of women.

In Dharan, the Water Board is chaired by the Mayor, and only as the Deputy Mayor was the acting Mayor of the Dharan sub-metropolitan, single women were represented in the Water Board. One of the male members of the Water Board highlighted the need for female members as he felt that male members will not be able to understand the nuances of the problem women face in managing water. However, another male member of the water board also opined that he too feels a lack of expert members in the water board but is also conscious of the required capacity of the women. He shared,

> *"Female representation in Water Board is important but should not come on the basis of quota or political party affiliation; it should be unbiased based on their expertise*

related to water sector and the ability to contribute to the emerging water related issues. If female without expertise would be added, the board will have challenge to work towards its objective."

The participants shared a similar situation in KVIWSB in Kavre valley consisting of Dhuikhel, Banepa and Panauti. The discussion to merge DDWSUC to KVIWSB is on rife and there might be no women when Board comes into action as it is again not mandatory in Water Board Act 2006.

In Dhulikhel, there is a progressive provision in DDWSUC. In the community managed water supply system's working committee, women inclusion can be observed with 6 female and 9 male members (of total 15 members); the vice-chair and 5 members are female. However, good representation of women in the committee does not mean that the decisions are inclusive and their voice is heard. Women committee members shared during the in-depth interviews and discussions that they feel excluded in major decision-making. The women members of the drinking water users committee shared that they need to make extra effort to prove their capability as that of men. The important decisions related to fund management and tariff fixation are made with men members' influence while the female members are given the responsibility of conducting the activities such as cleanliness campaigns. Another point is not all members speak equally against non-participatory decisions as they are likely to face trouble as they do not want to challenge the status quo.

Despite representation, the FGDs also had negligible women's participation. In one the FGDs, the Deputy Mayor shared her experience of how she performs dual roles, household chores, and political leadership-related roles, and ensuring water collection for household use lies on her part of responsibilities. This indicates about the additional burden women are facing who step up in public roles. One of the women leaders shared that being unable to undertake household chores alongside public leadership roles ruined her family environment and ended in divorce. Another prominent women leader in Dhulikhel shared that her son was angry with her engagement in the drinking water users committee as the vital position demanded time but with her old age, her family is concerned of her health condition.

During the General Assembly of DDWSUC organized on 12th Jan 2020 in Dhulikhel in which I participated, there was minimal water users' participation in the General Assembly, mainly in the discussion session (*banda satra*), which is intended to approve/ disapprove the proposed agendas by the working committee and was followed by the formal program. Of these 10%

users, the women participants represented not more than one-fourth of the participants. Due to low participation, the session had to be postponed for a week. In the General Assembly, there were 2300 users who attended during the whole day; however, the number of participants during the important discussion session was only about 25- 30. One of the users shouted, "*We do not even represent 10% of the users and how is it possible to make this happen*."

Therefore, despite the progressive changes, it is challenging for meaningful participation and leadership of women in the water management bodies unless the guiding policy or the procedural documents explicitly mandate the women's position in key roles. The meaningful participation means being able to contribute in the discussions of the meeting by presenting the views strongly and influence the decision making.

Similar results were shown by the survey data. The questions asked to the respondents' regarding the participation in water management decision-making and planning and whether the participation have been meaningful or not, concur the qualitative findings. The female participation in water management decision and planning was lower in comparison to male. For instance, in Dharan, while only 4% female responded that they 'mostly' participated in such meetings, 9% male mostly participated in such meetings. Likewise, 5% female mostly participated in such meetings in comparison to 6% male in Dhulikhel. Further, maximum percent of female respondents (58% in Dharan and 60% in Dhulikhel) responded that they never participate in such meetings. On male part, 43% Dharan and 43% in Dhulikhel replied the option 'never' (refer to Figure 34).

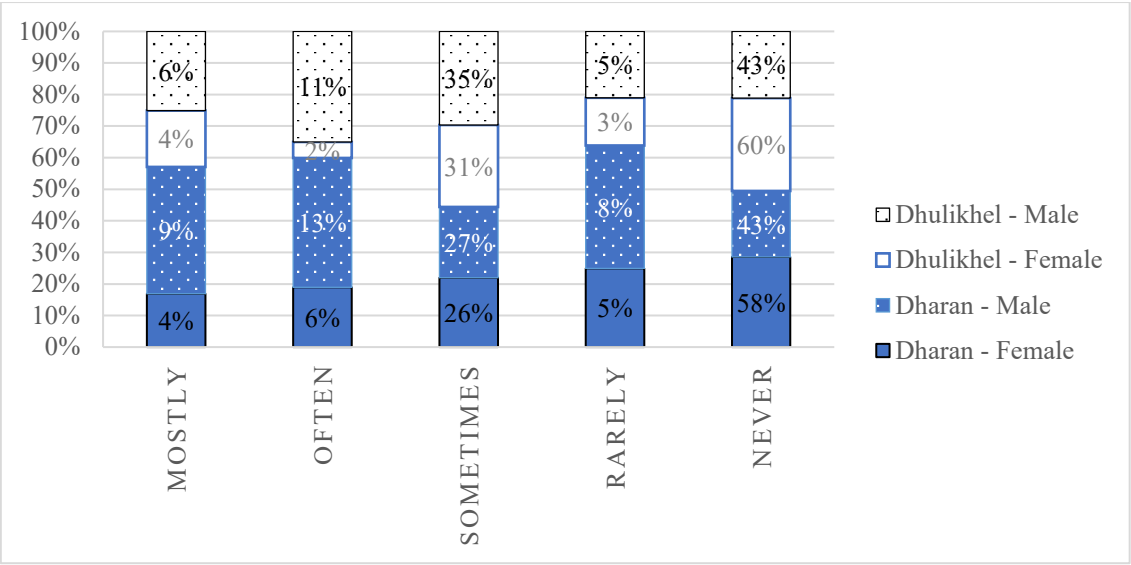

Figure 34. Frequency of participation in water management decision and planning

Further analysis of participation of the respondents in water management decision and planning using Chi-square test (refer to Table 22) showed that there is no significant difference in the respondents participating in water management decision and planning in Dhulikhel and Dharan.

The Pearson Chi-Square is calculated as 8.269 with corresponding p-value (2 tailed) of 0.1420. Since, 0.142>0.05 we accept the null hypothesis (there is no significant difference in the respondents participating in water management decision and planning in Dhulikhel and Dharan refer to annex for details). The analysis reinforces that the situation of participation of the respondents in water management decision and planning is similar in both the sites, Dharan and Dhulikhel which draws the need of ensuring meaningful participation of women and marginalized in key decision making and improve their leadership skills and capacity.

Table 22. Chi-Square test for participation of respondents in water management decision and planning

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.269[a]	5	.142
Likelihood Ratio	8.818	5	.117
N of Valid Cases	484		
a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is .44.			

On further inquiry with the roles during participation, the survey data evidently showed least participation of female in major roles such as decision-making and planning in comparison to male.

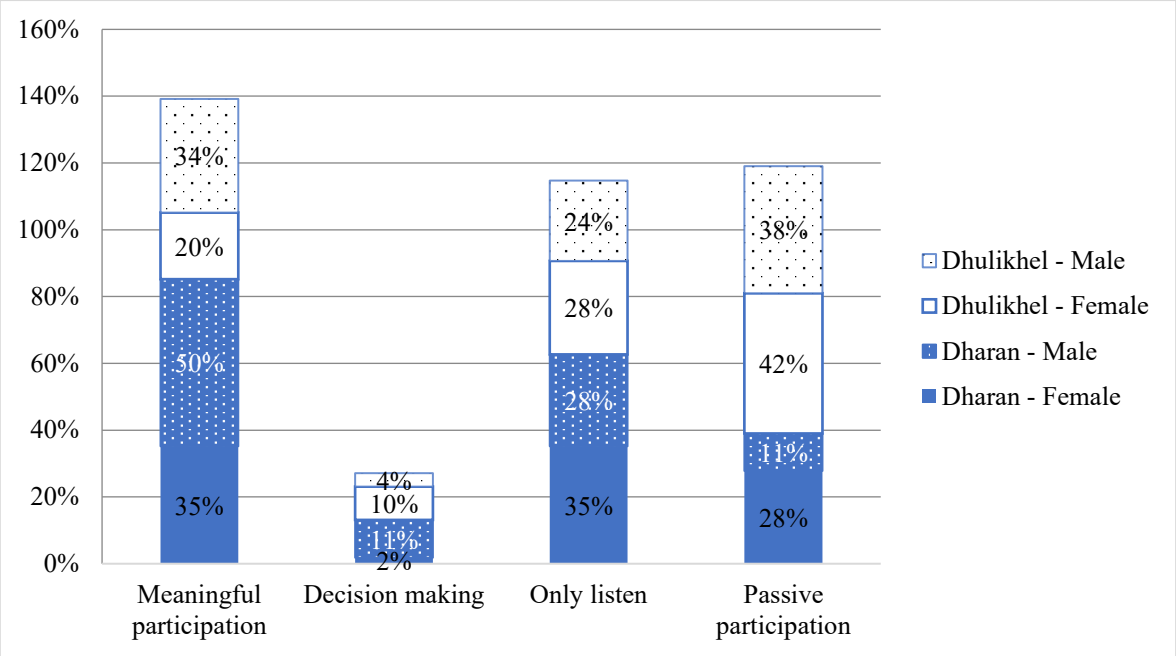

Figure 35. Roles of men and women during participation in water management decision and plannings

For instance, from the users who participated in meetings, in Dharan, 2% female only participated in decision making (in comparison to 11% male) and 35% female only engaged in meaningful participation (in comparison to 50% male). The same case was observed in Dhulikhel also with only 20% females' engagement in meaningful participation (in comparison to 34% male). While a slightly higher percent of female responded that they were engaged in decision making (10% female in comparison to 4% male). In both Dharan and Dhulikhel, greater percent of female responded that they only listened to the meetings and participated passively in comparison to men, as shown in Figure 35. Here, 'decision making' is the highest level of engagement being able to influence and shape decisions, followed by 'meaningful participation' involving active involvement and their inputs are considered seriously. Further. 'passive participation' includes minimal forms of engagement such as agreeing without contributing substantively to the discussion. And, 'only listening' refers to the lowest level of engagement of the individuals who are present but are totally silent in the meetings.

6.2 Chapter summary

In sum, the chapter discussed the key constraints and challenges in securing water in cities of Dharan and Dhulikhel. The first challenge identified was the incoherence among the sectoral policies of urban development, water and climate sectors in addressing urban water. Next, the institutional ambiguities experienced by the water institutions in responding to water insecurity brought about by the overlapping roles in water management of multiple institutions and governance levels and related issues of non-coordination. Further, inequitable water distribution, fragmented initiatives and discontinuity in efforts conserving water sources and watersheds, and limited say of women and marginalized people in key decision making have collectively posed a challenge to addressing the water insecurity problem in these cities. The following chapter will present the key elements of 'governance dimension' of urban water security that will help in achieving lasting water security amid the discussed constraints.

CHAPTER SEVEN: KEY ELEMENTS OF GOVERNANCE DIMENSION IN WATER SECURITY THEORY

Water security literature has highlighted 'governance' as one of the important dimensions to achieve water security (as discussed in Chapter 2). Further, the urban water security literature which has received limited attention, also refers to some aspects of governance such as capacity of the actors. However, detailed discussion about the governance dimensions is lacking in the urban water security theory. Hence, in relation to the literature review of the water security theory and governance dimension within the theory, and empirical insights from the study, this chapter will identify, categorize and elaborate the key elements of governance required for securing water in the context of urbanization and climate impacts, and establish why these elements are important. This chapter hence discusses the findings of third research question: which elements of governance dimensions are imperative in urban water security theory and why. These elements emerge from the challenges experienced by the urban water system in the study sites. While the empirical insights from Dharan and Dhulikhel explain about these governance dimensions' importance, review of literature identifies the gaps in literature to address why these dimensions are necessary to integrate in 'governance' dimension of 'urban water security theory'.

7.1 Key elements imperative in 'governance' dimension of urban water security theory

This section discusses the key insights on the governance dimension of urban water security theory that needs to be considered and explains their significance. The key governance elements identified from the literature and empirical insights are listed in Figure 36.

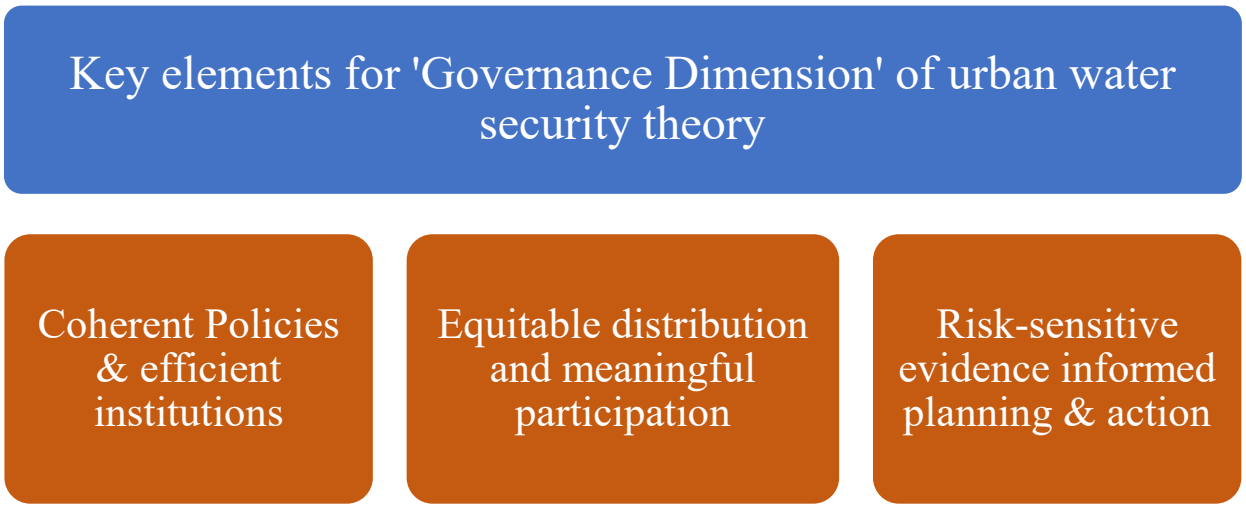

Figure 36. Key elements for governance dimension of urban water security theory

(Author, 2024)

The constraints discussed in the previous chapters and the key elements needed as part of the 'governance' in urban water security theory to address these constraints are listed (in Table 23) and further discussed:

Table 23. Key governance dimensions of water security

Themes	**Constraints/Challenges**	**'Governance' in urban water security theory**
Policies and Institutions	• Incoherent policy responses • Institutional ambiguities in water management (Overlapping authorities in water management in federal context, coordination gaps and trust issues among multiple institutions) • Fragmented initiatives in water source and watershed conservation	Coherent policies and efficient institutions
Distribution and Participation	• Inequitable water distribution • Limited participation of women and marginalized in decision making	Equitable distribution and meaningful participation

Planning	• Water systems' resilience related challenge	Risk-sensitive and evidence informed planning

7.1.1 Coherent Policies and efficient institutions

The analysis of the sectoral policies as part of this study revealed that only a limited number of sectoral policies on urban, water and climate exhibit a coherent consideration of the intricate connections between urban, water and climate dimensions (as discussed in Chapter 6). Water policies, in particular, are often placed a significant emphasis on promoting "water for economic growth", yet they tend to disregard the far-reaching effects of climate change, the critical need for resilience, and the mounting pressures stemming from rapid urbanization that drive up urban water requirements as observed in emerging cities as Dharan and Dhulikhel. Due to such incoherent policies to address the urban-water-climate nexus, key concern in urban water insecurity has remained unaddressed (Maskey et al., 2020). Therefore, the sectoral policies need to be coherent and transformative in addressing urban water issues in the context of rapid urban transitions and climatic changes.

In Chapter 6, it has been discussed that the delay of policies formulation at the higher level during the transition stage of federalism affected the local level policies formulation, which had been pointed out by the participants as the constraint at the policy formulation level of the local government in Dharan and Dhulikhel. Additionally, in the focused group discussions, the participants brought forward the view that the formation of Water Board (in Dharan and Kavre) and integrating the existing community-based water management institution as DDWSUC in Dhulikhel and NWSC in Dharan into the Water Board is a national policy issue. This was also suggested to be an issue requiring national level attention. This illustrates that what is happening at the local level is not independent of national level policies and politics; and policy inconsistency has posed as constraint in effective service delivery.

Thus, beyond the coherent sectoral policies, for addressing the existing water insecurity issues at the study sites, the higher-level policy instruments such as National level acts/policies should guide timely to the local level policies and local policies should consider context specific solutions. In sum, vertical as well as horizontal coherence among policies and institutions is a key to urban water security.

Next identified aspect imperative for achieving the water security outcomes, is the 'efficient institutions. As explained Chapter 6, this study has clearly revealed that despite multiple institutions engaged in water management, the institutional ineffectiveness has posed as a hindrance in operationalizing the strategies towards sustainable and resilient water management in the study sites.

The institutional ineffectiveness was due to the institutional ambiguities in terms of overlapping authorities in water management in federal context among multiple institutions and formation of new institutional mechanisms, gaps in coordination among diverse institutions and trust related issues among multiple institutions. For instance, as explained in Chapter 6, the water institutions in both the study sites, DDWSUC in Dhulikhel and NWSC in Dharan were undergoing the institutional transition. Dharan presented a comparatively contested case given the rife of the conflict associated with the ADB-funded drinking water project having several protests and grievances; and also, the new institutional mechanism 'Water Board' was formed during the study period. While in Dhulikhel, issues were raised but still the merging of DDWSUC to Water Board has not been done. Despite the project interventions, ADB in Dharan and German Aid/ADB in Dhulikhel aiming to augment the water supply in the cities, unclarity in institutional roles and their unamicable relations resulted in complications in delivery of their outcomes.

Particularly in Dharan, the merging of NWSC to Water Board affected efficient water service delivery and the transition period affected the water users with a few households facing the problem of installation of connections from both institutions and hassle to pay the water bills, and confusions in roles of these water institutions. Likewise, in Dhulikhel, the formation of Kavre Valley Water board under the ADB funded water scheme is likely to experience issues.

Further, the study identified gap in terms of proactiveness of the institutions that resulted into fragmented initiatives towards sustainable water management. The study found that the sustainability aspect was a key concern raised by the participants as the water schemes in Dharan and Dhulikhel are reliant on either surface water or groundwater. However, water sources and watershed conservation have not formed a priority of the water institutions such as NWSC in Dharan and DDWSUC in Dhulikhel. There have been many initiatives by the municipalities such as water forums as discussion platforms as well as water sources and watershed conservation initiatives. But most of the initiatives suffered discontinuation owing to a number of constraints, discussed in the previous chapter (Chapter 6). The fragmented

initiatives in Dharan and Dhulikhel was observed due to limited priority given by the municipality and water institutions on water conservation and the capacity related constraints in envisioning sustainability related challenges.

Urban water security theory has considered governance central to achieving water security and have emphasized the capacity of urban water actors/ institutions to maintain sustainable and adaptive water management in the city and foster resilient urban communities and ecosystems through coordination among the stakeholders (Allan et al., 2018; Chen & Shi, 2016; Jensen & Wu, 2018; Romero-Lankao & Gnatz, 2016). It has also discussed about the key role of institutions in addressing the issue of growing water insecurity as they are concerned with managing the scarce water resources as well as ensuring the sustainability of water resources (Steduto et al., 2017). The theory has indicated that the resilient cities are dependent upon the ability of the urban water actors to manage them sustainably (Allan et al., 2018; Chen & Shi, 2016; Jensen & Wu, 2018; Romero-Lankao & Gnatz, 2016). Institutions and policies govern water resources; hence these aspects are imperative to manage the water distribution and supply, coordinating with multiple actors. However, there has not been enough discussions in articulating the issue of water insecurity as a policy challenge and sectoral policy incoherence, a challenge identified by this study, has not been identified as an important consideration.

The empirics of this study has found that capacity of the institutions is directly linked to the coherent policies and institutions among others. Coherent sectoral policies in themes of urban, water and climate; and coherent federal to local policies can only address the urban water issues in the context of urbanization and climate change. At the same time, coherent institutions congruent to policies can deliver the water security outcomes. The issue of policy translation also can be explained under the capacity, highlighting the need of regulatory framework required for the effective implementation of the policies.

Another important finding of this study, among others, is that achieving the intended outcomes of water security requires efficient institutions that are proactive and capacitated in responding to the need of the cities in managing water. Institutional capacity is also related to its ability to manage water supply to meet the water demand and manage water related disasters (Jensen & Wu, 2018). Demand over supply approach is argued to manage urban water demand management (Mishra et al., 2020a). Hence, water policies and institutional sensitiveness to demand management is also crucial particularly for urbanizing cities like Dharan and Dhulikhel in the context of increasing water demand brought about by rapid population growth and hence

growing sectoral water need. A shift from supply-oriented management to demand oriented management can manage the urban water need. As these aspects have not come out clearly, this is one of the key elements within governance dimension in urban context drawn from empirical insights that has added contribution to the existing urban water security theory.

This research has established in Chapter 5 and 6, how the incoherent polices and inefficient institutions has affected the sustainability of the urban water systems. This study has added a new insight from the cases of Dharan and Dhulikhel that considering upstream-downstream relations is important and engaging the upstream source area community in key decision-making bodies can only make the sustainable water governance efficient. It ensures holistic resource management by integrating diverse perspectives, fostering cooperation, and ensuring the protection of vital water resources. Hence, "coherent and efficient institutions" are key as coherent policies provide the necessary guidelines and frameworks for sustainable urban water governance, while efficient institutions ensure that these policies are effectively implemented, monitored, and adapted to evolving challenges. Together, they can create a resilient, equitable, and sustainable urban water system.

7.1.2 Equitable distribution and meaningful participation

The discussion in Chapter 6 about the key issue of inequity in water distribution is primarily a governance problem. Although 'water for all' is the essence of the recent policies aligning with national constitutional targets and global commitments such as SDG 6 (water to all)/ SDG 13 (climate action), the study found that the issue of inequity still persisted in Dharan and Dhulikhel. The responsible factors for inequity are identified as socio-political factors as part of urbanization process such as annexation, and institutional transition (particularly in Dharan with the merging of NWSC to Water Board), technological and environmental factors (such as topographical differences), discussed in Chapter 4 as the drivers of water insecurity. At the center of the issue, lies the gap in water institutions' capacity of not being able to envision the water demand and future population, climate risk to water sources and manage the water sources appropriately for equitable water distribution. Studies have also confirmed this adding the argument that the inequity in water distribution also devoid the peripheral areas from good quality water, the area mostly resided by marginalized communities (Maskey et al., 2021).

Urban water security literature discusses the 'access' dimension referring that the supply of water should be reliable without interruption, safe, affordable and in enough quantity (Mishra et al., 2020c). Connecting piped water to households as an infrastructure solution is widely

considered as important initiative in addressing urban water problem. Jensen & Wu (2018) has regarded access dimension in terms of the extent of water access for fulfilling domestic and industrial use considering water treatment capacity, coverage and affordability. A study by Grasham et al. (2022) raised the concern of intermittent water supply as a major issue in getting reliable and fair water security as it brings uncertainties as well as water quality concerns.

This study has explored beyond what the literature have discussed regarding the 'access' dimension. The water governance dimension needs to integrate equity into access, hence 'equitable access and distribution of water'. The examination of equity within intermittent water supply systems has been approached through optimization modeling, advocating for enhanced infrastructure to address the issue (Ameyaw et al., 2013). Simultaneously, hydrologists employ the term 'equity' to advocate for a geographically balanced distribution of water (Ameyaw et al., 2013; Ilaya-Ayza et al., 2017). However, the empirics of Dhulikhel and Dharan analyzes that equitable access and distribution to all areas within the municipal boundary (core/periphery, higher/lower pressure nodes) and to all segments of society is an important dimension to achieve water security. Managing water distribution equitably falls under the governance dimension of urban water security as governance encompasses the policies, institutions, stakeholder engagement, conflict resolution, transparency and accountability required for ensuring just and equitable water distribution to all its residents.

However, as discussed in Chapter 6, gap in the policy provisions have raised the issue of inclusion of women representatives in institutions such as water board in both the sites. Not making the provision of women representation mandatory in the Water Board has led the areas of maneuvering and no representation of women in the Water Board. The Constitution of Nepal 2015 has recognized access to water as a fundamental right and have prioritized inclusion of different social groups. Likewise, Nepal's commitment to SDGs (goal 6: Ensure access to water and sanitation for all, and goal 5: Achieve gender equality and empower all women and girls) demands inclusive water governance. Further, the most recent National Water Supply, Sanitation and Hygiene Policy (N-WASH Policy 2023) has included 'gender equality and social justice' in its approach and have envisioned municipality wide inclusive sanitation plan. These show a progressive picture in terms of inclusive water governance and promoting gender equality and representation in decision making. However, policies changes have not translated to a greater extent to practice.

There have been progressive changes from Water Resource Act 1992 which had provisioned water users' associations but was silent about GESI, to Drinking Water Regulation (DWR 1998), which has mandated women's representation. However, DWR has included only the numeric provisions[35] and have not made any provisions of inclusion of women in vital positions. Further, National Water Supply and Sanitation Act 2022 has provisioned women position as mandatory in vital position (at least 1 woman in either Chair or member) of Water Tariff Fixation Commission and at least 4 female members in the Coordination Committee. Although the policy intent is positive, the set eligibility criteria for member is at least bachelor's degree with 7 years' experience and for chair, at least masters and 10 years' experience. These provisions of eligibility criteria based on academic qualification and the number of years' experience limits the possibility of candidates and further, mention of the clause 'it is not applicable if eligible candidates are not found' will not ensure the participation of women in such decision-making bodies. This implies the need of capacitating women in education and capacity building to be able to take up leadership positions.

In practice, although there have been positive changes in terms of representation and participation of women, visible changes have not been observed in terms of their meaningful participation. For instance, the DDWSUC has considered including women representatives in the committee— and the composition is of six female and nine male members. However, the representation is being mediated by pre-existing social differences. For instance, the water users committee members represented the residents from the core area, economically powerful and the leadership position of women is also the representative of the women in the core area. In Dhulikhel, the elite control in water security systems with no participation of people from the annexed or the peripheral areas was observed since the 1992 committee. Here, the Newars, an ethnic group mainly engaged in the business sector, of the core areas dominated the committee (Pokharel et al., 2018). Hence, it is important to assess 'who among women are those representing in decision-making bodies' and whether they represent the poor and marginalized sections of the society facing day-to-day water problems.

It is also important to note that the increased number of women in the committee does not mean all the members will speak out their concerns in the meetings. As discussed in Chapter 6, even the progressive water users committee could not ensure the meaningful participation of women

[35] 9 membered executive committee of consumer organization should include least 2 women members

in key decision-making and stereotypically 'feminine' roles were offered to women. In contrast, male members were offered technical and higher-level decision-making roles.

Further, observation from the research process showed that in the local governance spaces in the form of the 'water forums' termed as *Paani Chautari* (in Nepali), although females attended, they were not adequately engaged in raising their voices and concerns in the discussion despite the facilitators' attempt to create environment for presenting their views and issues. It was also observed that the limited time availability due to the household chores responsibility was one of the constraining factors for effective leadership delivery, particularly for those stepping up in public roles. Women in public leadership is appreciated but their tradeoffs with the family relationships was found to be ignored.

The current decision-making process is exclusionary, with dominant water institutions like DDWSUC and NWSC taking center stage, sidelining entities like water user committees, local groups, and municipalities. Despite this, the existing water institutions have struggled to effectively address water supply challenges, leading to unequal distribution between urban cores and remote areas.

Although inclusive decision-making and gender inequity in urban water sector is considered as crucial in ensuring water access (Bhattarai et al., 2021; White & Haapala, 2019), urban water security literature has not explicitly marked it as one of the dimensions of urban water security. As discussed above, mere representation in the decision-making bodies or 'formal provisions' in the policies do not ensure meaningful participation of women, marginalized people and upstream area communities. Structural constraints faced by women and marginalized communities have to be addressed to ensure meaningful participation and hence equitable water distribution.

The policies and institutional aspects need to be gender-transformative, with mandatory key positions for female leadership, including marginalized people' meaningful participation. The insights also highlight the need to amplify focus on leadership enhancement and capacity building through pre-event engagement for effective participation and empowerment of women in raising their voices in the forums. Another important insight from the study is the need to adopt the 'intersectionality lens' that helps to capture the nuances of how women's varied identities and experience intersect to influence their access to water; and analyze whether women representing in such bodies are the women facing day-to-day hardship (Prakash et al., 2024). It helps to identify which women is left out or excluded from decision making. Beyond

simplistic categorizations like "women", how different groups of women experience water insecurity differently based on their unique socio-economic and cultural positions. In sum, another important element of governance dimension is the equitable distribution of water to the core-periphery, across topographical differences and across different social groups. Further, meaningful participation of the poor and marginalized people in key decision-making bodies of water management is equally important governance dimension that can be added to the 'urban water security theory'. Achieving water security is hence beyond the physical water shortage. The need to consider the social dynamics and engagement of women and marginalized in conserving and managing water is also considered crucial in a recent study (Prakash et al., 2024).

7.1.3 Risk-sensitive evidence informed planning and actions

Firstly, the study identified that the urban water systems in Dharan and Dhulikhel had to experience multiple forms of risks and uncertainties that exposed the limitations in water governance. For instance, both the study sites Dharan and Dhulikhel struggling to manage scarce water, are at the same time vulnerable to climate induced disasters such as floods and landslides.

Next, the study also found that the large infrastructural drinking water schemes were impacted due to earthquake and COVID with delay in its progress and completion. The water infrastructures had to bear the damage; for instance, damage of the pipelines during the earthquake. Particularly in Dharan, the problems the water scheme had to face included restricted mobility that led to lack of laborer and construction materials. COVID related protocols did not allow them to continue the work and it was completely stopped for 3 months. There was no distinct observation of impact on Kavre valley project as more than COVID, the project is at times halted due to the issue and demand raised by the local people time and again, according to the project representative. However, the water institutions during COVID struggled in delivering the basic water services while did not take initiative for long-term planning on building resilience of the water systems.

The previous chapter discussing constraints (Chapter 6) has detailed out the water systems' resilience related challenges such as its exposure to climate induced disasters as well as uncertainties as COVID-19 in Dharan and Dhulikhel. The situation faced during these risks-for instance, water infrastructural loss due to sweeping away of pipes, financial crisis of the water institutions during COVID, disruption in water supply during the crisis, have thus raised

high concern to the urgent need of risk-sensitive water management planning that includes climate risk analysis as long-term strategic planning for risk resilient urban water system.

While the constraints such as lack of expertise in formulation of risk-sensitive policies, inimical relations between the water institutions and municipality, and limitations in financial resources and the capacity of the water institutions identified in the study (discussed in Chapter 6), have limited the climate adaptive water management responses such as developing the water infrastructures that can withstand water-induced disasters. Climate risk analysis and its impact on water sources have not yet formed the priority issue of consideration in local level planning in the study sites.

Efforts made by the municipalities, for instance, mandatory provision of building recharge pits for new private and public structures in Dharan in an effort to manage water during scarcity and control excessive runoff has not been implemented effectively in absence of strict monitoring. The damage of water-related infrastructures during floods and landslides are to be managed by water institutions while the disaster management unit in the municipalities focus their response in providing relief aid and rescue operations during such disasters. For instance, although Dharan has an Environment and Disaster Unit, the impacts of floods in the water supply are managed through the Water Board and it has upgraded the old water infrastructures of NWSC (with flocculation and good filtration capacity) only recently.

Further, climate related risk and risks from other unprecedented disasters faced by urban water system is one example informed by evidences in the study sites and beyond. From the insights of the study, it can be said that evidence-informed planning is one of the important governance dimensions of urban water security. Local level planning hence requires analysis based on evidences of risks the water system is going through yearly from the known risks such as floods and landslides and unknown risks such as COVID-19, hence focusing on risk-sensitive planning. Municipal planning or local development planning needs at the same time to consider water source related as well as upstream-downstream conflicts, water demand and supply scenarios, and opt for solutions through participatory forums where evidence is presented and discussion among the related stakeholders presents context specific solutions. This entails for the need to consider ‘evidence informed planning’ as key governance dimension of water security. Empirical evidence or analysis based on reliable data and research can facilitate more effective and sustainable policies and actions planning, decision making and implementation. This approach enables identification of current and future water needs, assessment of potential

risks, and possible implications of targeted interventions, helping in more resilient and equitable water governance.

Evidence of risks management strategies in other similar cities have showed the value of embracing diversity in water governance. Restriction in mobility during COVID-19 had implications to the ADB-funded drinking water projects in Dharan and Dhulikhel. During such unprecedented disasters, the community managed water systems and traditional water sources became critical water safety nets for accessing water during the time of crisis in other Himalayan towns such as Diktel, a mid-hill emerging town in eastern Nepal (Khotang district) and Bidur in central Nepal (Nuwakot district). The mobility restrictions halting the project maintenance led the residents to rely on smaller community managed water supply systems during the time (Ojha et al., 2020b). Hence, alongside these schemes, embracing diversity in water governance has come out as an important risk management strategy. It helps to face the risks by maintaining balance between large and the smaller community managed water systems and traditional water sources such that they can complement each-other during the time of need.

Although in the urban water security literature, 'safety from water related risks' has been discussed as requisite for securing water, there is a gap in emphasizing risk-sensitive planning and overall, evidence informed planning in securing water. Water planning and governance practices and responses are unapprised by evidence from research particularly on climate change and urbanization. The literature discusses safety or water related risks as safely managing water and refers to good water quality and sanitation services. Along with that, water related risks are considered to be the destructive nature of water. Gray and Sadoff (2007) definition bring in the element of acceptable level of water related risks, to people, environments and economies– leading to water insecurity; and the resilience of water infrastructures to water induced-disasters such as floods and landslides.

Although these dimensions of water security are discussed in literature, limited attention is found in the urban water systems ability to design risk resilient water system which comes under the governance dimension and is related to the 'capacity' aspect of urban water actors. Water security cannot be ensured by only dealing with water inadequacy without building a resilient water system and robust institutions (Maskey et al., 2023) and without embracing diversity in water governance to foster resilience and adaptability.

In sum, amid the interplay of complex social and physical spheres of urban systems, ensuring urban water security requires enhancing risk resilience of urban water system. These needs identifying evidence-informed key risks, shocks and stresses faced/ likely to be faced by the urban water systems, clear policies and implementing strategies to build resilience of urban water systems which comes under the governance aspect. Hence, 'risk-sensitive and evidence informed planning' forms an important dimension of governance aspect of 'urban water security' theory.

7.2 Chapter summary

This chapter, thus, underscores the importance of incorporating specific components into the governance dimension for ensuring urban water security: a) coherent policies and efficient institutions, b) equitable distribution and meaningful participation and c) risk-sensitive evidence informed planning. These components have emerged from the empirical study in Dharan and Dhulikhel and the gap in the literature in why explicitly incorporating them is necessary have been discussed in this chapter. The following chapter is on Discussion of the research findings.

CHAPTER EIGHT: DISCUSSION

This chapter discusses the key research findings of the study in relation to the research questions. The research analyzed the key drivers of water insecurity, followed by the responses in securing water and the constraints and challenges faced in securing urban water. It further identified the key governance dimensions to ensure water security and explained why these dimensions are important to consider. Further, the findings are discussed and interpreted in the context of existing global and national literature. The findings are also discussed in relation to the urban water security theory and its governance dimension, cities as complex adaptive system and DECS framework. The chapter concludes by summarizing the key findings of the study. Finally, the implications of the study for the policies and practices in urban water management are discussed in light of the challenges of urbanization, population growth, and climate change and the direction for future research is identified.

8.1 Nature and drivers of water insecurity in the context of rapid urbanization and climate change

This study has identified the key drivers of water insecurity and broadly categorized them into socio-economic, environmental, technological, management and governance drivers. These factors individually or in combination is found to impact the components of water security that include water availability, quality, affordability, equity, sustainability and risks. The socio-economic drivers as rapid and haphazard urban development and increasing population, changing land uses, tourism activities and adoption of comfortable lifestyles have exacerbated competition for water with significant water demand in the study sites, affecting the water availability, quality, equity, safety, affordability and sustainability components. Further, environmental factor, climate change, is causing drying and declining of water sources affecting the 'water availability' component of water security on one hand while on the other hand, the excess water due to climate induced disasters as floods and landslides have posed risk to the city dwellers and have affected the water infrastructure. Technological factors as leakage in the pipes also caused reduced availability of water reaching the tap from the source, while loss of water through leakage was also noted. In addition, changes in land use and pollution at sources were found risking peoples' health with impact on 'water quality' component.

Similar to these findings, in a recent study done in Dharan, growing population, rapid expansion of residential areas, steeper slopes, changing lifestyles, natural hazards, technical

and management issues are identified as contributing factors of critical issue of water scarcity (Yadav et al., 2023). Likewise, challenges of climate change, rapid growth of urban population and haphazard urbanization are argued to build significant stress on urban water security in Dharan and Dhulikhel (Pandey, 2021).

These drivers can broadly also be further classified **into biophysical and socio-political drivers:** biophysical being the climate change (climate change leading to drying of water sources and climate induced disasters such as floods and landslides), and socio-political relating to rapid urbanization and population growth, conflicts and contestations, and the institutional and governance factors. Such factors have also been distinguished into environmental (natural resource) and socioeconomic pressures in other studies (Hoekstra, 1998; OECD, 2016; Van Leeuwen and Chandy, 2013) affecting water availability. A more recent study by Hoekstra et al. (2018) considers 'urbanization' as an important socio-economic factor that urges over-exploitation of surface water as well as groundwater. In addition, continued population growth and changing water demands are identified as socio-economic pressures. Further, the environmental pressures highlighted include the land use and land cover changes and climatic changes within the urban area, and changes external to the urban area as changing water availability in the rural area where the urban area is dependent on (Hoekstra et al., 2018). A study by Nepal et al. (2021) have categorized the drivers of water insecurity into physical and socio-economic drivers in which physical drivers included climate change and disaster risk and socio-economic drivers included population growth and competing water uses.

These factors in the **systems perspective**, come under the 'drivers' or 'pressure' driving water insecurity. In the water security literature, Pressure-State-Response (P-S-R), Pressure-State-Impact-Response (P-S-I-R), and Drivers-Pressure-State-Impact-Response (D-P-S-I-R) frameworks have been widely used to analyze water problems (Hazarika and Nitivattananon, 2016), and holistic water management challenges (Liu et al., 2012; Sun et al., 2016). While focusing on the urban water system, 'Pressure' is defined as the basic factors, root causes, and trends that influence and determine the state of the urban water system (Pires et al., 2016). Identification of pressures or drivers help in framing responses to address them.

In the past studies, climate change, rapid population growth and unplanned urbanization, and changing lifestyles are noted as pressures from a systems perspective that views the Himalayan cities are exposed to urban water insecurity (Pandey et al., 2019; Pandey, 2021). As found in Dharan and Dhulikhel, socio-economic factors including population growth, and rapid and unplanned urbanization are highlighted as the key determinants of water access (Gomez et al.,

2019; Asthana, 2012), and studies discuss its combination result in heterogeneity in accessing improved water supply system (Florke et al., 2018; Pandey, 2021; He et al., 2018).

Recent water research has also used this framework in identifying the pressure to the water security system. For instance, Ginkel et al. (2018) developed 56 indicators based on the pressure-state-impact-response (PSIR) framework and applied to ten cities to capture different characteristics of their water security. Hoekstra et al. (2018) studied urban water security using the DPSIR structure as an analytical framework and linked to the 'urban water transitions framework'. An assessment matrix with the identification and description of the indicators was constructed classifying them according to the DPSIR framework (Pires, 2016) and Gari et al. (2018) used the DPSIR framework to analyze water quality problems within the community council.

The rapid **urban expansion** in Nepal is primarily driven by rural-to-urban migration and adjustments in administrative boundaries to meet the minimum population requirements for municipality declaration (Sapkota, 2022). Merging or annexation of the rural administrative units to designate them as municipalities, one of the socio-economic drivers in particular is determined as the root cause of inequitable water distribution in both the study cites, affecting the 'equity' component of water security. Annexation created the core-periphery division excluding the peripheral communities or the newly added households to piped water access. In both Dharan and Dhulikhel, restructuring led to the formation of core and peripheral areas. The annexation of the nearby administrative boundaries for declaration of the municipality has thus been identified as one of the major reasons resulting in inequitable water distribution in the study sites. The drinking water projects were centered to the core areas while the areas annexed later have remained devoid of access to piped-water supply services. Further, urban fringe remaining out of piped water infrastructure and dependence on natural water sources have also made the periphery people devoid of good quality water (Maskey et al., 2021). Further, Pokharel et al. (2018) has noted about the elite control in water governance system in Dhulikhel with dominance of Newars of the core area while there was no participation of people from the annexed areas in the 1992 water users committee.

In line to this finding, studies have shown that the process of haphazard urbanization develops urban fringe, both, spatially and relationally that become physically and politically marginalized (Ranganathan & Balazs, 2015; Swyngedouw, 1995). While the term 'urban' may suggest a separation from 'rural' water security, there is no clear distinctions between urban and rural areas. Studies have discussed that the rural-urban divide can be perceived as a

continuum rather that distinct dichotomy (Wratten, 1995). Such hybrid space are also explained using the concept of 'urban fringe' (Ranganathan & Balazs, 2015), or 'peri-urban' as partly urbanized rural area, according to the OECD and as peri-urban spaces that are institutionally and socially fluid (Shrestha et al., 2020), and rurbran area (Bhattarai et al., 2023). Such processes underlying these dynamics need focus during planning (Shrestha et al., 2019).

The peripheral areas are predominantly occupied by economically marginalized individuals. Economic and infrastructural development in these peripheral expansions is lagging behind and often exhibits discriminatory practices, leading to increased inequality from the core to the periphery (Dutta & Das, 2019; Filion & Keil, 2017). Other cities of Nepal have also been facing this distributional inequity related contestations (Devkota et al., 2018). Wealthy individuals typically enjoy superior water access and quality, whereas impoverished residents in informal settlements face water scarcity (Malama & Kazimbaya-Senkwe, 2004), as observed in Dharan. This water marginalization issue in the fringe area is not only a problem of Global South but also a common problem of Global North (Ranganathan & Balazs, 2015). Achieving equitable distribution of water to residents in both the core and peripheral regions, thus requires long-term planning and transformative policies that address socioeconomic challenges. According to Mukherjee et al. (2022), water insecurity of a city stems from the intersecting disadvantages, inequalities, and exclusion in society. Hence, additionally, it is crucial to address the deeper structural divide between the core and peripheral area (Maskey et al., 2021).

Further, the study also illustrated how urbanization spawns requirements for water, concurrently diverting water resources from agriculture and rural households in the study sites in order to cater to the burgeoning urban, residential, industrial, and recreational demands of the city area as discussed by Narain et al. (2013). Hence, traditional agricultural and rural water needs get compromised. Particularly in Dhulikhel, the communities in the water source area who had been using traditional water mills and irrigating agricultural lands from generations had to compromise water diversion for drinking to Dhulikhel. Likewise, in Dharan, the extensive industrial water usage was at the cost of diminishing water availability for residential households. Hence, 'urbanization' is found to be a crucial socio-economic factor driving over-exploitation of surface water as well as groundwater. The growing population and water demand in the cities necessitates the extraction of both ground water from hinterlands beyond the municipal boundaries from the same catchment as the city or from other catchments (McDonald et al., 2014), potentially leading to conflicts with other water users. In Dhulikhel and another Himalayan town Bidur, water related conflicts and contestations over access to

water between the upstream and downstream areas are found to be due to declining water sources and competing demand exacerbated by climate change and urbanization (Devkota et al., 2018).

Adding **climate change** scenarios has further intensified the uncertainties and complexities in the water systems in Dharan and Dhulikhel. The drying up or decline of water sources has decreased the water quantity and exacerbated the inequity in water access caused by the other different factors in the study sites.

As noted in the findings chapter about the experience of climate change impacts on water in terms of perception and survey data, a recent study in Roshi watershed of Dhulikhel found that the watershed has undergone changes in climatic parameters. The area has warmed up by 0.003%/year and experienced significant decrease in precipitation, with increasing dry spells and decreasing wet spells (Dahal et al., 2019). The study on Koshi basin (Dixit et al., 2009), where Dharan is located, and Dharan specific study found the area to be grappling with unpredictable monsoons, higher flood risks along the river banks (Shardu and Seuti rivers of Dharan) and prolonged drought spells (Aksha et al., 2020).

The uncertainties surrounding the water systems of Nepal and other Himalayan cities in relation to climate change has deepened. The Himalayan towns, in particular, are experiencing a growing issue of water scarcity as the natural springs are drying (Rai & Nepal, 2022). Besides, changing rainfall patterns and increasing water usage, anthropogenic activities such as land use changes triggered by demographic shifts and haphazard excavation of mountainsides for infrastructural development have further contributed in the drying of water sources (Shrestha et al., 2023). Studies revealed that particularly in the past decade, there has been decrease in water flow in over 70% of Nepal's western hilly region' springs (Adhikari et al., 2021); and in 73.2% of springs in Thulikhola watershed of Nuwakot (Poudel & Duex, 2017). The latter study also found that 12.2% of springs had dried up over the decade.

Further, study by Pandey & Bajracharya (2017) and Poudel & Duex (2017) also conclude that the impacts of climate change are adding to water availability uncertainties and water stress. Climate change is hence exerting increasing pressure on urban water systems by increasing the frequency of prolonged dry periods (Isler et al., 2010) and at the same time, by aggravating flood hazards (Hallegatte et al., 2013). With the increase in population and the impact of climate change leading to decrease in rainfall, water quantity and quality is predicted to worsen, and

sanitation pollutants behave differently as a result of changes in environmental parameters (Duran-Encalada et al., 2017).

8.2 Responses to growing water insecurity and limits/ constraints

The responses of the water institutions to address the issue of water insecurity has been discussed as infrastructure focused implementation of large-scale water schemes in both the sites, Dharan and Dhulikhel and the policy responses through formulation of different sectoral policies and legal frameworks. These are discussed in the sections below:

8.2.1 Infrastructure focused responses

In response to the second research question on how responses to growing water insecurity have been organized and its limits and constraints, firstly, the study found that the key responses in securing water in the study sites are focused as technical response through large-scale water schemes implementation by tapping water from the sources. In both the sites, the Asian Development Bank (ADB) funded large-scale water schemes have been put into place as a key technical response in the condition when the existing water institutions such as NWSC/ DDWSUC in Dharan and Dhulikhel are unable to supply enough quantity and good quality water to people in Dharan and Dhulikhel. As discussed in Chapter 5, the institutions and village or municipal leaders at different time periods Panchayat era, post-democratic era and in the federal context, pursued large scale drinking water projects as solution to address water scarcity issues and put in constant efforts in making the projects successful. Examples include the German funded drinking water project and ADB funded project in Dhulikhel and ADB funded project in Dharan.

Similar to the approach adopted in the study sites, water management practices in Nepal predominantly follow supply augmentation seeking technical/ engineered 'solutions' using the conventional approach of tapping and distributing water. Traditional paradigm places water security as a purely technical problem (Pokharel, 2023) that has driven focus towards technical solutions. This is found to be motivated by the narrative that Nepal has abundant water resources. Likewise, the recently formulated Water Resource Policy 2020 also promotes large scale water supply projects. Moreover, it has been found that the solution to the growing water needs in many regions in the world has been supply-driven technologies like dams and cross-basin water transfers (Domènech et al., 2013). One of such large-scale megaprojects is the Melamchi Water Supply, launched in 2000 to quench the water needs of the residents of urban

Kathmandu. The water is diverted from the Melamchi river through a 26 km-long tunnel (Domènech et al., 2013) .

Nevertheless, there is also a growing global trend of social opposition to these infrastructures owing to the ecological damage, conflicts and contestations between upstream and downstream communities, population displacements and financial, economic and governance challenges, and environmental injustices (distributional, procedural and recognitive) associated with such projects (Devkota et al., 2018; Domènech et al., 2013; Kovacs et al., 2019). Such oppositions from the local people to halt the projects in both Dharan and Dhulikhel were experienced by the water project authorities and conflicts and contestations between the upstream and downstream communities have also been prevalent in the study sites.

Firstly, the dependence of the water sources in the hinterlands and beyond the municipal jurisdiction for additional water sources has made the issue of securing water sources very challenging and have led to rise in conflicts among upstream and downstream communities with series of negotiations (Devkota et al., 2018). As observed in Dhulikhel, the upstream Bhumidanda village consented to pipeline expansion only when they secured investment funds for their local school through negotiation. Interestingly, rural areas seldom sought piped water for their households; instead, their requests focused on maintaining water levels and creating development opportunities, rather than pursuing more modern, in-house water access (Kovacs et al., 2019). Melamchi Water Supply project also faced rural contestation and oppositions during the diversion of the rural water (Domènech et al., 2013). The indigenous local communities in the intake area, particularly Hyolmo and Tamang reclaimed recognition of their social, cultural and religious values and advocated to form a local committee called Hyolmo Sindhu Melamchi Committee. They further demanded to change the project name to Hyolmo Water Supply Project (ibid, p.27).

Secondly, dependence on hinterlands at distant make these infrastructures prone to disaster impacts as observed in the study sites. The large-scale projects incur huge investment and bear high hopes of solving the water scarcity problem in these cities but at the same time, inbuilds an array of challenges and uncertainties. Studies on lower Himalayan towns including Dhulikhel and Bidur of Nepal and Nainital, Mussorie and Palampur of India (Kovacs et al., 2019) highlighted about the risks the large infrastructural interventions pose in fulfilling their goals that turn the projects short-term due to mismatches between community capabilities, evolving urban needs, and the role of local preferences in water resource management. The infrastructures have been susceptible to damage by floods and landslides and these projects

faced challenges in fixing technical problems during the time of earthquake and COVID-19 in other Himalayan cities as well (Maskey et al., 2023; Ojha et al., 2020b). During such unprecedented disasters as earthquake and COVID-19, the infrastructural damages could not be fixed and the local and communal water sources formed the safety nets for the people (Ojha et al., 2020b). The authors have thus recommended to adopt diversity in the water system, not solely depending on large water schemes and also conserving the traditional water sources.

Thirdly, it is found that local water sources and watershed conservation has remained challenging in both Dharan and Dhulikhel despite some good initiatives. The massive groundwater extraction due to limited surface water sources as observed in Dharan and Dhulikhel on one hand and limited priority and efforts on water sources and watershed conservation amid climate impacts is identified as one of the key challenges in the study. Although water sources conservation has consistently been the policy priority as mentioned by Water Resource Act (mentions that conservation has to be integrated with the water utilization; 1982 Soil and Watershed Conservation Act and now Water Resource Policy 2020 has envisioned declaring water resource conserved area), translation into practice is the major constraint. Similar evidences have been discussed in the previous chapter (Chapter 6) on how the recharge pits in Dharan's municipal policy and in municipal premise could not gain priority and faced implementation challenges.

Likewise, fourthly, focus on individual tap or private tap supplying water to household is disincentivizing conservation of the existing traditional water sources. Although traditional water sources have been the primary water source for a long time, the preference for the convenient water sources have left the traditional sources degraded. It is problematic while the sources are degrading, the interest is not to conserve the water sources but rather the same narrative has sparked the promotion of larger water supply projects referring to the unreliability of current water sources (Shrestha, 2023). This trend is observable in the ADB-funded projects as well as in the recently introduced National Water Resource Policy 2020 which also advocates for large-scale water supply initiatives. Further, municipal governments inclination towards human intervention such as deep borewells is due to the perception of bore wells being reliable solution to meet the future water need while investment in spring sources is not considered worth as they are vulnerable to climate impacts. Further, such quick-fix approach to water management takes precedence as it provides immediate and visible results while more protracted issues as natural springs depletion and over-exploitation of deep aquifers are overshadowed (Shrestha, 2023).

Fifth is regarding the institutional changes brought about by the implementation of the water supply projects. In the Global South, foreign aid plays a contentious role in the implementation of large-scale water supply projects. These initiatives are often linked to a shift in development principles, as highlighted by Hukka & Katko (2003). As observed in both the study sites Dharan and Dhulikhel, they extend loans with attached stipulations for the project implementation. According to Birkenholtz (2010), ADB has played a significant role in instigating water governance reforms such as involving the private sector into water governance across several South Asian countries including Nepal, Srilanka, China and India. In the study sites, merging of the existing water institutions to form Water Board was the major institutional change. During the implementation of Melamchi water supply project in Kathmandu, the institutional changes included the appointment of a foreign private operator to oversee water supply management in the Kathmandu Valley (Domènech et al., 2013).

The reason behind the institutional changes is the institutional incapacity and the changes are meant for the enhancement of performance and efficiency in delivery of water services. Donor funded large infrastructural interventions were prompted by the poor existing water supply characterized by inadequate and unreliable water quantity and poor water quality. However, it was also found that the institutional changes brought confusions and complexity in water governance of the study sites. Such vital institutional and managerial aspects crucial for sustaining existing water infrastructures are not prioritized while focus has been on visible physical infrastructures development (Kovács et al., 2019).

As the municipal governments are investing for the larger scheme under the donor driven project, the issue of high-water tariff has been challenging. Water supply projects funded by ADB includes 35% financial support as loan, 50% grant support from Town Development Fund of Government of Nepal and remaining 15% is collected from the residents of the municipality. The loan is to be paid over a 20-year period with a fixed annual interest rate of 5%, as stipulated in the project agreement. This has posed a significant challenge for the municipal authorities grappling with limited financial resources that has also led to rising of water tariffs. Further, the construction costs of the project have surged due to delays (Timalsina et al., 2021).

Sixth, the promotion or switch towards new large scale water supply system and the convenient private taps have implications in terms of equity and inclusion. Inequitable water distribution among the core and periphery has been observed in the study sites (Maskey et al., 2021b). The German funded water project in Dhulikhel managed by the DDWSUC and the ADB-funded drinking water project were designed for supplying water to the previous administrative

boundary but as the restructuring added the adjoining areas, these remained devoid of water access from the project. This has been explained in the section above on how urbanization creates core and fringe areas that creates inequity in the distribution of services including water (section 7.1). On one hand, this issue can be attributed to the restructuring in 2017. Studies have highlighted that some rural areas have been reclassified as urban as municipalities without basic services and opportunities that the urban space should possess (Timsina et al., 2020). On the other hand, it can also be linked to the limited institutional capacity of the local government and the water institutions to foresee the future water demand of growing population and the conservation of the traditional water sources.

Further, in light of the elitist influences shaping the infrastructure planning and construction, the marginalized communities in both downstream and upstream areas struggle to be represented in decision-making and having their voice heard (Kovacs et al., 2019). This issue has been discussed in Chapter 6 and 7 and in the prior studies of the study sites (Maskey et al., 2021b; Pokharel et al., 2018).

Studies have noted the issues of spatial inequity in water distribution as well as inequity in water distribution among rich and poor (Maskey et al., 2021b), unequal distribution of compensation (Domènech et al., 2013); meager representation of the rural/upstream and marginalized communities in decision making bodies and injustice in hearing their voices; as well as claims over their indigenous and local rights (Domènech et al., 2013; Pokharel et al., 2018). Multiple factors combined with discrepancies in caste/ethnicity, gender and class have exacerbated the vulnerabilities of the poor people and limited their access to and control over water resources (Pokharel, 2023).

Further, the institutional and governance challenges identified in Dharan and Dhulikhel included overlapping authorities in the federal context and institutional ambiguities and gaps in coordination, which resulted in water institutions' ineffective service delivery. Other studies have also highlighted the institutional challenges and even institutional failures the cities have faced in water access and supply and managing water related adversities like floods and droughts (Kiparsky et al., 2013; Patterson & Huitema, 2019; Pandey et al., 2023). Studies in Nepal have identified water governance and management challenges within local governments, including issues related to the efficiency and effectiveness of water services. Furthermore, water institutions in the study sites are encountering challenges in developing climate-adaptive measures to address climate risks, primarily due to insufficient knowledge and capacity as also noted in studies conducted in these cities (Pandey, 2021; Maskey et al., 2021a; Maskey et al.,

2023). Further elaboration of the local governments' capacity constraints in the water sector includes insufficient information, limited resources, technical capacity, and skills for effective responses. These constraints coupled with conflicting and overlapping water policies are found to challenge the effective and efficient management of water resources. Additionally, there is a lack of transparency and citizen trust in water service delivery (Naidoo et al., 2016). The issues and concerns relating to the overlapping authorities and unclear roles in water management between the three tiers of government: federal, provincial and local- in the federal context has been highlighted in the recent study (Nepal et al., 2021).The issues such as non-coordination among various water institutions for water planning and implementation (JVS & GWP, 2016) have also been discussed.

In the context of population growth, urbanization and changing consumption pattern leading to increase in water demand and uncertainty about future water resources availability due to climate change, water institutions need to be robust to develop new approaches and increase the capabilities of water management. For achieving urban water security, researches have suggested the need to improve the institutional arrangements and planning to consider in decision making (Rijke et al., 2013; De Meene et al., 2011). Stakeholder participation, effective governance and multistakeholder approach are considered to be precursors for achieving water security (Pokharel, 2023). As institutions shape the choices made in water governance, they impose constraints on water policies, and drive behaviors related to water sharing and use. Hence, understanding institutions and institutional dynamics is crucial for researchers, policy makers and managers concerned with water management and issues (Hassenforder and Barone, 2019).

8.2.2 Incoherent Policy responses

On policy front, the findings of the study showed the interconnected sectoral policy themes in achieving urban water security: water policies, urban policies and climate policies are incoherent in addressing the urban water issues. However, the recent sectoral policies developed particularly after 2015 have been progressive on sectoral interlinkages. Policy coherence is an important aspect to ensure the effective implementation of the policies. It does so by reducing conflicts and building synergies between and within different policy areas to achieve the outcomes associated with jointly agreed policy objectives (Nilsson et al., 2012). Shawoo et al. (2022) argue that the three I's: ideas, institutions, and interests may influence policy coherence at different policy stages. Further, Hoebink (2008) discusses that cognitive reasons are also responsible for policy incoherence along with political, administrative and

institutional reasons. Another important factor leading to policy incoherence identified is the insufficient knowledge pertaining to the effects of policy decisions and disagreeing legitimate interests (Siitonen, 2016). The historical inefficacy of water governance in Nepal has been attributed to the fragmented and incoherent policy frameworks (Biggs et al., 2013).

More importantly, while the impact of climate change was already visible in sectors including water (Regmi & Shrestha, 2018), climate change concerns incorporation has been prioritized into sector-specific policies following the release of the Fifth Assessment Report by the Intergovernmental Panel on Climate Change in 2014 (Nepal, 2019). Scholars have highlighted the lack of policy and strategy, particularly in promoting climate resilient water management practices (Biggs et al., 2013). Such historical gap in discourse on climate change within water resource and other developmental policies has been discussed by many scholars and the factors such as limited interest at political levels and development partners, centralized policy design process and climate financing uncertainty have been listed as some reasons (Ojha et al., 2016; Pant & Gautam, 2013). In such context, the authors have highlighted that the water policies in Nepal have to consider not only the additional climate change related risks and uncertainties, and adaptation measures in urban context (Biggs et al., 2013) but parallelly, integrate the socio-economic changes in the changing context (Sharma et al., 2021). Likewise, integrating urban water issues in climate legislations is a must and climate uncertainties in water sector has to be envisioned in urban development policies (Maskey et al., 2019).

On a positive note, the latest water sector policies have well-integrated climate adaptation and resilience concepts (Sharma et al., 2021) and have aimed sustainable water management (Regmi & Shrestha, 2018). Despite progressive policies, another major challenge observed in the study is the poor implementation of the good provisions made in the municipal policies in Dharan and Dhulikhel in terms of mandatory provisions in making climate adaptive recharge pits and promoting rainwater harvesting and climate adaptive recharge ponds (Maskey et al., 2019). Hence, the assessment of policy implementation in Dharan and Dhulikhel also conclude that the existing policy frameworks and strategies are unable to harness opportunities for enabling urban water adaptation to climate change. A noticeable lack of consistent enforcement of policies aimed at restricting commercial groundwater exploitation and promoting sustainable use in line with national climate change policies in per-urban Kathmandu has been discussed by Roth et al. (2019).

Such ineffective policies implementation is another key challenge even if the policies have good provisions and are well-intended (Regmi & Shrestha, 2018). Studies have noted that the

translation of policies into actions on ground, in developing countries like Nepal are slow (Sharma et al., 2021). This ineffectiveness in policy translation is discussed to be due to lack of proper operational and regulating mechanisms, action plans and guidelines (Sharma et al., 2021) and also due to limited awareness about the policy provisions (Maskey et al., 2019). For instance, urban legislation known as NUDS (2017) does have good provisions but since it is a strategy only, the legislation is not mandatory to implement. Another reason for ineffective implementation of the policy provisions is due to ambiguities in terms of roles over who has the authority to implement them given the shared and overlapping responsibilities among the federal, provincial and local governments in formulating or implementing national to local policies. Additionally, sometimes, conflicting or contradicting water policies also have created confusions in managing water, particularly WRA 1992, WRR 1993, DWR 1998, NWSSP 2014 by creating overlapping roles among water management institutions that include municipality, water board and water users' associations of Dharan and Dhulikhel (Pandey et al., 2019). Such growing conflicts among institutions, lack of clarity in the water rights framework and insufficient incentives for watershed conservation are additional reasons of the ineffectiveness (Ojha et al., 2021).

The findings of the study have also highlighted about the challenge of sustainability of the initiatives supporting context specific and evidence-based policy making through discussion forums- *Pani Chautari* in the study sites. In both Dharan and Dhulikhel, such forums proved useful in devising innovative solutions of securing water (Devkota et al., 2019). Continuation of such interactive spaces can help in devising context specific sustainable and inclusive as well as climate adaptive water management strategies and facilitate local level policy making. Ojha et al. (2019) suggests using a bricolage of hybrid forms of knowledge discussion (neither scientific nor policy around water management).

8.3 Urban water security theory and 'Governance' dimension

This section discusses the complexity of achieving water security in cities being a 'complex adaptive system' and the contribution of the research to 'governance' dimension of the urban water security theory. The discussions in this chapter thus explains the complex interactions of physical and social spheres of urban system and related challenges, in the context of burgeoning population and urbanization amid climate change impacts. Further, it discusses urban water security theory also referring to DECS framework and contribution to governance dimension of urban water security theory.

8.3.1 Cities as a complex adaptive system

As discussed in the conceptual framework (Chapter 2), achieving water security in cities is more challenging owing to their dynamism and continuous interactions with both physical and social spheres of the cities (Meijer et al., 2024; Pickett et al., 2001). The rapidly emerging cities Dharan and Dhulikhel exemplify this dynamism with rapid urbanization, increasing population and mounting water demands from household to agricultural and commercial sectors. These are also bearing the floating population residing in the cities for education, employment, business, and healthcare purposes that has further exacerbated water scarcity in these cities. The water sources are experiencing issues such as drying up, declining availability and pollution in upstream areas. The built-up areas such as buildings, roads and pipelines are found to affect the hydrological regime, and has reduced the groundwater infiltration and recharge (Shrestha et al., 2022), as observed in the study sites. Concurrently, the cities are also facing the problem of excess water leading to increased runoff, flooding roads, and other areas. Further, both the cities are grappling with the issues of inequitable water access and conflicts and contestations that emerge with the issue of access.

Figure 37 lists out the key water related issues identified in Dharan and Dhulikhel.

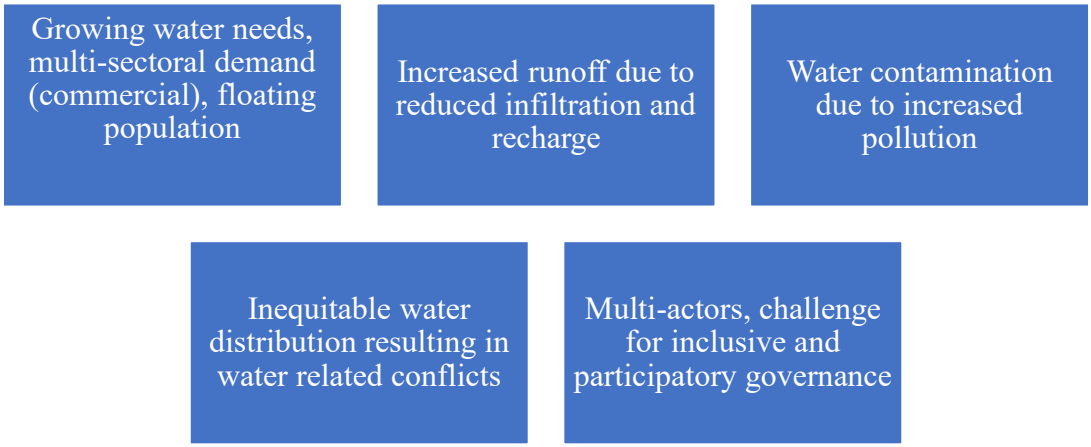

Figure 37. Key water related issues in Dharan and Dhulikhel

These issues are faced by most of the emerging cities in Nepal bearing the challenges of unplanned urbanization, poor infrastructure management and limited investment in water conservation. Not only in Nepal, several cities in the world are on the verge of water crisis. Studies have noted that the cities in rapidly urbanizing and industrializing countries are experiencing some of the world's most acute problems with access to potable water and sanitation, flooding, and pollution of waterways (McFarlance, 2010; Kookana et al., 2020).

Hence, it has threatened the water security of the cities highlighting concerns about groundwater sustainability in these cities with significant groundwater extraction (Shrestha et al., 2020; Kookana et al., 2020).

Managing water supply and distribution in such context is challenging and complex, engaging multiple actors, institutions and interconnected policy regimes. The research hence finds that these cities function as Complex Adaptive Systems (Nel et al., 2018), the state of which is determined by the components of the physical and social sphere and their interactions. The cases of two cities Dharan and Dhulikhel has illustrated that the urban system encompasses multitude of components, processes and interactions taking place within and beyond a city's physical, legal and virtual boundaries (Desouza & Flanery, 2013). It can further be elaborated that an interplay of individuals, activities, institutions, resources and processes in an urban system leads to complex, dynamic and unpredictable patterns (ibid). The diverse attributes of these urban areas foster interactions and exchanges with their surrounding hinterlands, forming a dynamic and interconnected 'system.'

Physical and social sphere and their interaction

In Dharan and Dhulikhel, physical sphere mentioned in the CAS has been modified as 'Bio-physical sphere' in the study that encompasses a) water resources, including surface and groundwater, for fulfilling multi-sectoral water needs; and b) climate change affecting the water resource. These sources are managed by various institutions such as NWSC and Water Board in Dharan and DDWSUC and KVIWSP in Dhulikhel. Additionally, water projects implemented by ADB in both sites contribute to this sphere. Physical infrastructures like storage tanks, distribution pipes and filtration structures, essential for efficient water distribution are integral components of this system. These physical infrastructures extend beyond the administrative boundaries as wards and municipalities to the upstream area.

Social sphere, on the other hand, includes the socio-political aspects: *people, institutions* and *activities*. In Dharan and Dhulikhel, different actors and stakeholders are involved in water management that includes municipal leaders and officials, representatives and members of water user committees, water technicians, and users from both upstream and downstream areas. These groups, ranging from policy actors to community users, played crucial roles in managing and conserving water. Further, institutions in the study sites, government-managed and community institutions and private sectors have engaged in multiple initiatives discussed as responses in Chapter 5, such as implementing large scale water schemes, watershed

conservation, water forums, water use optimization, networking and partnerships and securing water sources through intense negotiations.

The research found that the responses have focused on augmenting water supply through infrastructural and engineering approaches, emphasizing the physical sphere of resource availability. However, the social sphere engaging key water actors, such as people and institutions, as well as the policies and processes enacted by water managers play crucial role in determining the water security situation of the cities. In Dharan and Dhulikhel, large-scale, donor-funded water schemes represent significant investments in the physical sphere. However, the social sphere, particularly institutional and policy aspects, has received limited attention, where key challenges and gaps are prevalent. For instance, as discussed in Chapter 6, institutional issues such as institutional ambiguities, fragmented initiatives in water sources conservation, limited participation of women and marginalized in decision-making and on policy front, incoherent policy measures have been identified as key challenges in achieving water security in the study sites. Additionally, as social aspects include people, inefficient responses have led to inequities in water access and distribution between core and peripheral area water users and among different social classes, disproportionately affecting the poor and marginalized.

The water management system in the study sites exhibit clear interactions between the **physical and social spheres**. For instance, physical sphere accompanying tapping of water resources and making infrastructural response (as discussed in chapter 5) through water supply schemes for fulfilling the growing water demand have been operationalized by the water *institutions* and *people* which are the part of **social spheres**. Over time, institutional evolution has expanded the technical response of project implementation driven by key leaders at different time periods. These institutions enforced formal and informal rules, planned schedules for water distribution, and implemented policies as processes to manage water effectively. Additionally, *activities* such as securing water sources, implementing water schemes, and conserving watersheds involved interactions with both water users and upstream communities, especially when negotiating to bring water from within or beyond municipal boundaries.

Likewise, utilization or mis-use of the physical water sources, depended upon the upstream communities in terms of source conservation and on institutional and leadership initiatives. The changes in land use practices directly hampered the water users downstream (e.g., pollution affecting water quality) and the inclusion of the upstream communities in water related decision

making bodies was found to be crucial for the feeling of ownership of the upstream people who play an important role in source conservation. Further, municipalities engaged in negotiations of water from the source.

Next, the lack of adequate water supply in these cities has led to its dependency and linkage with rural upstream from where the water sources are tapped. Dhulikhel taps water from distant Roshi river beyond its municipal jurisdiction similar to what the authors have argued about dependency of urban areas to sources beyond their catchment areas (Hoekstra et al., 2018; Pradhanang & Jahan, 2021). This has engaged multiple actors in water governance, involving multiple institutions, household and commercial water users and upstream communities. Multiple actors' claims, grievances and institutional coordination has made the water governance in the cities complex. Moreover, the changing institutional dynamics has added challenges in efficient water management.

On policy part, local policies co-exist with national regulations, and public/private water utilities introduce further complexity. Adding to the challenge, unique urban stakeholders and policy processes create a complex web. Mirroring the broader water security discourse, the urban realm faces a terminology battle with overlapping and competing terms like "integrated/ sustainable/ adaptive urban water management," "urban water resilience," and "water-/ climate-proof cities," further complicating the landscape (Hoekstra et al., 2018).

Hence, empirical evidences of Dharan and Dhulikhel showed that the dimensions of urban water security theory as quantity linked with resource availability and water related infrastructures as physical spheres, are in constant interactions with social spheres which included water actors, institutions and policies, institutional responses and overall governance. These interactions collectively determine water access, equity, affordability and sustainable water supply. 'Water security' as an outcome is achieved through continuous interactions of different physical and social spheres in dynamic urban environments. And the 'governance' dimension of social sphere emerges as the most critical element for ensuring water security in rapidly emerging cities.

This complexity and unpredictability in the dynamic cities in the face of climate impacts, therefore, demands careful empirical understanding of the issues and proactive, climate resilient and inclusive governance responses. Along this line, studies have indicated that cities demand an adequate response to prevent the water system state from worsening and to appropriately fulfill functions of urban water to avoid undesirable impacts even in high-

pressure environments (Ginkel et al., 2018). Further, resilient or water secure city planning necessitates assessing the stressors, understanding organizing processes, and developing capacity to address the interactions. At the same time, gaining perspective on future likely challenges in terms of water access, conflicts and climate change impacts prominent in urban areas are crucial (Arreguin-Cortes et al., 2020).

It can therefore be concluded that owing to the complex and dynamic nature of urban water system, anticipatory and proactive responses with innovation and risk management approaches are deemed necessary for achieving urban water security (Hoekstra et al., 2018; Larsen et al., 2016). In other words, the evolving challenges in urban water management demands forward thinking approach beyond traditional reactive measures involving forecasting potential issues and taking preventive measures to address the risk related to climate impacts and future water demand. Mere availability of water does not ensure its equitable access and distribution, affordable pricing, and amicable upstream-downstream relations, for which 'governance', an aspect of social sphere is crucial.

8.3.2 Urban water security theory: Governance dimension

As discussed in the literature review chapter, 'Water security theory' is complex and multi-faceted. This theory originally perceived as 'water scarcity', has undergone a positive shift from focus on quality and quantity of water supply towards environmental and social dimensions (Allan et al., 2018). Further, it has undergone a transformative evolution, adopting a holistic approach that encompasses multiple dimensions (Chapagain et al., 2022; Cook & Bakker, 2012).

The focus of water security research has been incongruent, in multiple dimensions and differing from discipline to discipline, from area to area and theme to theme (Cook and Bakker, 2012). Some scholars focus on specific issues of scarcity and stress, while others focus on integrated approaches incorporating issues of access, affordability, human need and ecosystem wellbeing. Water security theory, since its evolution has encompassed water availability or quantity of water physically available, accessibility as ability of accessing clean water, safety in terms of vulnerability to hazards and quality, sustainability as securing water for future generations and management in terms of governance of water resources. It also encompasses broadly the headings as integrated, sustainable and adaptive (Hoekstra et al., 2018). The existing literature hence discusses that 'water security theory' extends beyond human needs; protecting the

environment, managing risks and considering all aspects of water usage, from accessibility to sustainability.

Further, focus on 'urban water security theory' has been recent and review identifies that 'urban water security theory lacks clarity and widely recognized understanding; hence bears adequate scope of improvement conceptually (Aboelnga et al., 2019; Allan et al., 2018; Cook and Bakker, 2013; Hoekstra et al., 2018). It has emphasized 'capacity' and 'sustainability' (Chen and Shi, 2016; Romero-Lankao and Gnatz, 2016) and 'access, safety and affordability' and psychological security (Huang and Yin, 2015). These have focused on the capacity of various urban water actors (Romero-Lankao & Gnatz, 2016), community, cooperation between stakeholders and the need for sustainable approaches to achieving water security outcomes (Allan et al., 2018). Further, Aboelnga et al. (2019) argue that water security in urban and peri-urban context is beyond the availability of water resources, rooted in the dynamics of proposed urban water security framework, DECS framework (with 5 dimensions to achieve urban water security: Drinking water and human beings, ecosystem, climate change and water related hazards, and socio-economic factors) including poor water governance, institutional fragmentation and ineffective water policies.

Applying the Integrated urban water security index (IUWSI) and assessment using DECS framework in Madaba of Jordan, Aboelnga et al. (2020) further concluded that the city can meet basic demands with satisfactory IUWSI but depicts inefficient water governance due to centralized decision-making. Another recent study by Su et al. (2020) discusses water resource security, water environment security, and water disaster security inter-relating to quantity and quality aspects as the three pillars of urban water security.

The review found that few urban water security theory (for instance, Romero Lankao and Gnatz, 2015; Chen and Shi, 2015; Aboelenga et al., 2019) and empirical assessment (Aboelnga et al., 2020) have discussed the governance dimension by referring to the capacity of the urban water actors and the water system and indicated inefficient water governance as constraint. While others have highlighted on sustainability aspects and water resource security. This reveals that governance is an important dimension but has not come up clearly and more importantly, in depth discussion encompassing empirical insights within the governance aspect is lacking in water security related studies.

More recently, disregarding 'governance' dimension in the indicators-based urban water security assessment has been highlighted by the scholars (Chapagain et al., 2022). For instance,

the comprehensive urban water security assessment developed by Aboelnga et al. (2019) has not included water governance as its indicator. To fulfill the gap, the scholars (Chapagain et al., 2022) have included 'governance' dimension in the 'Water Security Index', and have developed web-based Water Security Assessment Tool (WATSAT) (other dimensions included water supply and sanitation, water productivity, water related disasters, and water environment). However, the authors have indicated that socio-political dimensions including power and conflicts, gender and marginalized peoples' issues, and climate adaptive dimensions are missing in this framework.

A common issue highlighted in the water security related recent studies using urban water security frameworks in Nepal, US, Netherlands, suggest the need to emphasize on governance aspects. For instance, Chapagain et al. (2022) using integrated urban water security framework found that among the five cities in Asia (Bangkok, Jaipur, Hanoi, Islamabad and Madaba), Hanoi exhibited the strongest water security conditions. Although water security encompasses multiple dimensions, the strategies and policies implemented across these cities predominantly prioritize aspects related to water supply, sanitation, and human well-being within the framework's scope.

In US, a study by Feingold et al. (2018) used the City Blueprint Approach[36] for assessing urban water management and governance in six cities: New York City, Boston, Milwaukee, Phoenix, Portland and Los Angeles. The study found that all cities experienced heat risk and highlighted the need to improve stormwater separation, maintain infrastructure and expand green spaces to establish a resilient urban water cycle. Another critical insight from New York City highlights that the ability to learn through smart monitoring, evaluation, and learning and collaboration among stakeholders remains a critical issue requiring attention. Application of the same approach by Leeuwen et al. (2012) in three developed cities in the Netherlands in measuring sustainability of the urban water cycle indicated that effective urban water management relies heavily on stakeholder participation and engagement since the beginning, simplicity in terms of data availability, transparency and effective communication in the development and execution of measures.

[36] This approach consists of three indicator assessments: (1) the Trends and Pressures Framework (TPF), (2) the City Blueprint Framework (CBF) and (3) the water Governance Capacity Framework (GCF).

While in Nepal, the urban water security assessments based on the indicators and comparative studies among different cities have been limited. The recent study in Pokhara, a touristic city in western Nepal using water security framework WATSAT showed that it is 'water secure' with water security index 3.56 in 2023. This resembled to water security index of Bangkok city, and is slightly higher than in Islamabad. The authors discuss that the city still is facing challenges to be able to receive excellent result as in Chengdu, China. The good score of overall water security in the city is found to be due to investment of the municipality in sanitation projects focusing on drainage and stormwater management and separating disaster budget. However, the city is experiencing challenges in water supply, access, quality, resilience to water related disasters and governance issues while facing urbanization and climate issues (Shrestha and Pandey., 2024).

Further, the assessment of physical dimension using a model centered on household water use behavior in Kathmandu valley have highlighted the value of 'social capital', taking into consideration the water management initiatives by society or social groups to improve water security (Shrestha et al., 2018). Another assessment of water poverty index in various Palikas of eastern Nepal suggest for the need of policy efforts on reinforcing water management techniques to be able to use most of the existing water resources (Yadav et al., 2024).

Thus, the emphasis on institutional and policy aspects in the global and national literature, include stakeholders' meaningful engagement, learning and collaboration among various urban water actors, transparency, effective communication, policy efforts and social capital as key strategies for improving water security in emerging cities. Hence, this research, through review and empirical study, has contributed to the critical 'governance dimension' of urban water security theory.

8.3.3 DECS Framework in urban water security theory

This research adopts DECS framework, a comprehensive model used to understand urban water security (Aboelnga et al., 2019) aligning with urban water security theory. As discussed in the theoretical section of literature review (Chapter 2), it stands for four key dimensions: Drinking water and human beings (D), Ecosystems (E), Climate change and water-related hazards (C), and Socio-economic factors (S). This study utilized the DECS framework to explore various facets of urban water security theory, enriching our understanding through empirical insights (refer to Table 24).

In the study, the first-dimension **Drinking water and human beings (D)** included the key elements of urban water security theory: availability, quality, accessibility, equity and affordability of drinking water. This dimension also shows the interaction between the people as social sphere of the complex adaptive system of cities with the drinking water as a resource, the physical sphere. The study discussed these aspects by explaining the water demand-supply gap, sources, inequitable water distribution among urban core and peripheries and among different societal segments in both the sites. The findings discussed that the socio-economic drivers such as rapid and haphazard urbanization, population growth, changing land-use and lifestyles and tourism activities have affected these dimensions of water security. Changes in land use and pollution at sources were found risking peoples' health with impact on 'water quality' component. Further, institutional responses were focused in addressing 'availability' or 'quantity' (the physical spheres of cities as complex adaptive system) through large scale water schemes, funded by ADB in Dharan and Dhulikhel, while the social aspects such as accessibility and equitable distribution of water faced an array of challenges. DECS framework has not included aspects of equity although affordability and accessibility have been considered. The research filled this gap by highlighting inequities in water distribution among different core and peripheral areas of the study sites and among high- and lower-class people.

The second component, **Ecosystems (E)** in the study involved the sustainability dimension of urban water security theory. In Dharan and Dhulikhel, climate change, as the environmental driver was found to cause drying and declining of water sources, risking the sustainable water supply. It thus affected the 'water availability' component of urban water security theory, which also falls under physical sphere of complex adaptive system. On the other hand, the city and its water infrastructure beyond its jurisdiction was affected by climate induced disasters such as floods and landslides, caused due to too much water.

Maximum surface and groundwater extraction to meet the burgeoning water need of the present population posed risk to sustainability of the water sources. The institutional responses in water sources and watershed conservation in Dharan and Dhulikhel were found to be inadequate brought about by management and governance challenges such as institutional ambiguities in water management, unstable leadership, upstream-downstream contestations over sources and rights claim, fragmented initiatives in climate resilient planning and strategies, and sustainable approaches and discussion forums. Further, limited participation of women and marginalized in water related key decision-making bodies also have lightened the effectiveness in water sources conservation efforts. 'Sustainability' dimension is the important component to be taken

into consideration by the water institutions and water users, particularly in the context of climate impacts and growing water needs.

The third component of DECS framework, **Climate Change and Water Related Hazards (C)** encompasses the risk dimension of water security theory. Climate change is one the prominent environment driver identified causing drying and declining of water sources. It thus affected the 'water quantity' and 'water quality' dimension; and at the same time excess water in the study sites also damaged the water infrastructures such as pipes affecting the water distribution system laid from distant sources. The study incorporated the implications of "too much water" as a challenge, emphasizing the safety and risk dimensions of urban water security and highlighting the need of evidence informed climate resilient water governance. Further, the risk analysis has also suggested for resilient water systems and diversifying water sources considering uncertain risks such as COVID-19.

The last component of the framework, **Socio-Economic Factors (S)**, also identified as one of the categories of drivers affecting water security, explained in the findings chapter included rapid and haphazard urbanization, population growth, changing land-use and lifestyles and tourism activities in the study sites that affected various dimensions of urban water security theory such as quantity, quality, equity, accessibility, affordability and sustainability. The situation demands management beyond water supply augmentation, which is appropriate demand water management strategies. However, the responses have been centered around tapping and distributing water from the sources.

Table 24. Dimensions of urban water security theory along DECS framework

DECS Framework	**Dimensions of urban water security theory from literature supplemented by empirics of the study**
Drinking water and human beings	Water quantity or availability Water quality Accessibility Affordability *Equity not adequately discussed*
Ecosystem	Sustainability (water sources and watershed conservation)
Climate change and water related hazards	Safety (risk dimension)
Socio-economic factors	Drivers including population growth and urbanization

	Governance Dimension to add as central to DECS framework

The gap in the DECS framework is that the framework has not included aspects of equity although affordability and accessibility have been considered. Further, the 'governance' dimension of urban water security theory has been touched upon only as the context while the study has found that 'governance' dimension is central to water security and has identified its key elements. Hence, the new theoretical contribution offered by this study is the key elements of 'governance' dimension of urban water security theory.

In conclusion, the DECS framework provided a structured approach to analyze urban water security, allowing the study to cover multiple dimensions comprehensively. By addressing gaps like equity and detailing institutional challenges, the research offered an understanding of urban water security theory in the context of rapidly changing urban environments. Incorporation of equity issues and adding governance as central dimension and integrating other dimensions of its framework (with additional rephrasing of the dimensions common in literature) into governance dimension instead will help to establish the value of governance dimension in achieving all other dimensions of urban water security.

8.3.4 Contribution to Governance dimension of Urban Water Security Theory

The above discussion has shown that 'governance', despite being recognized as a key dimension to achieve water security in the literature (Bakker & Morinville, 2013; OECD, 2015), has not gained enough attention. Enhancing water governance is imperative not only to confront the challenges of water security but also to uphold political stability, economic fairness and social justice (Bogardi et al., 2012). Governance connects all components of urban water security theory. The empirical insights discussed in the previous chapter (under research question 2), has also reiterated 'governance' as a key dimension linked to other dimensions of water security theory, more importantly, in the urban context.

From the review, water security and urban water security theory has encompassed different dimensions including availability, accessibility, equity, sustainability and safety (Cook & Bakker, 2012; Brears, 2016; Maskey et al., 2023; Su et al., 2020). These dimensions have direct or indirect link to Goal no. 6 of SDGs (Ensuring availability and sustainable management of water and sanitation for all). Further indulging into the components of water security in these

literatures, '*Availability' is discussed* in terms of adequate quantities of water supply meeting the water need and '*Sustainability*' referring to the need to fulfill the future generations' water need. 'Access' is often linked to improved sanitation and wastewater collection (Marcal et al., 2021). Further, *Access* is often considered in terms of accessing the water supply through connection of piped water structures in individual pipes, and receiving continuous water supply (without intermittent distribution services); and water that is affordable to all segments of society, including the poor and marginalized communities (Adhikari et al., 2023). Resilience of water systems is linked with the ability to provide continuous water supply services to ensure water access (Rodina, 2019). While equitable distribution among the poor and rich, core and periphery people, higher and lower pressure nodes, upstream and downstream people have not been adequately discussed.

Further, 'Safety' or water related risks has been considered in terms of safely managed water/ good water quality and sanitation services. Along with that, water related risks are considered to be the destructive nature of water and Gray and Sadoff (2007) definition brings in the element of acceptable level of water related risks, to people, environments and economies– leading to water insecurity. Other studies have focused on implications of 'too much water' particularly the flooding risks to households in African city (Hungerford et al., 2019; Pandey et al., 2023) and in low-lying coastal city in Virginia (Shen et al., 2019). Thus, water security, particularly in the urban context, cannot be ensured by only dealing with water inadequacy without building a resilient water system or considering disaster vulnerability as per the evidences from the Himalayan cities in Nepal (Maskey et al., 2023). At the same time, strengthening institutional capacity is also crucial for ensuring water security as the efficient planning and execution can only be delivered by the robust institutions (Maskey et al., 2023).

Although these dimensions of water security are discussed in the literature, for instance about urban water infrastructure resilience to water related disasters, limited attention is found in the urban water systems ability to design climate resilient water system which comes under the governance dimension.

Urban water security theory also emphasizes the capacity of urban water actors to maintain sustainable water management (Romero-Lankao and Gnatz, 2016; Huang et al., 2015). Capacity has not been discussed widely which is directly linked to the institutional mechanisms and responses, policy coherence, ability to plan climate adaptive and equitable water management strategies and others. As these aspects have not come out clearly, discussing the

key elements within governance dimension in urban context from empirical insights presents an opportunity to contribute to the existing urban water security theory. The study has thus presented the crucial elements of the governance dimension of urban water security theory as a theoretical contribution to the urban water security literature. These elements include: coherent policies and efficient institutions, equitable distribution and meaningful participation, and risk-sensitive evidence informed planning and actions, as explained in Chapter 7. Figure 38 shows the new urban security framework proposed with elements of governance dimension.

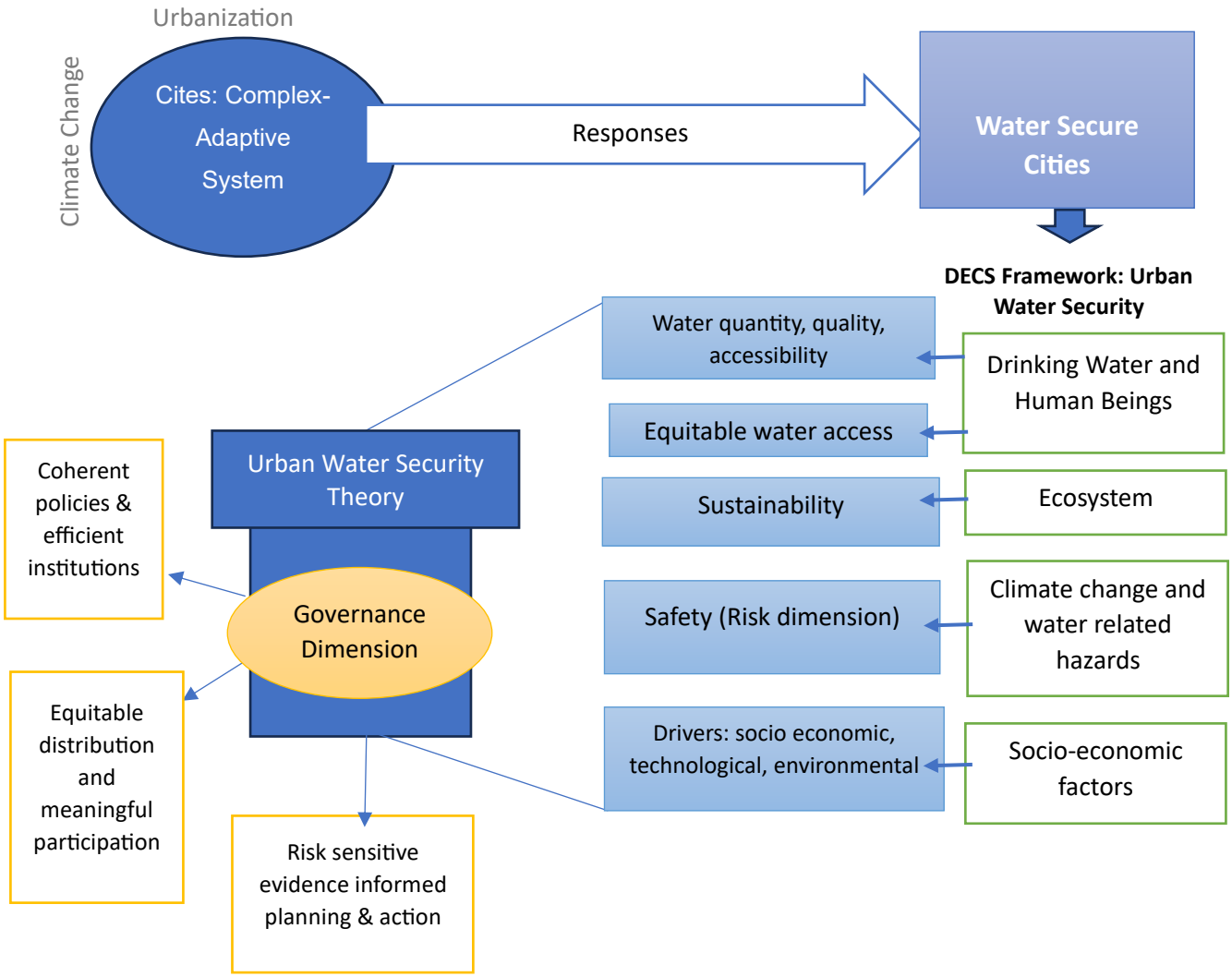

Figure 38. New urban security framework with elements of governance dimension.

The research hence contributes to the literature of urban water security theory by proposing: 'Urban water security is the condition delivered through specific water governance elements as coherent policies and efficient institutions, equitable distribution and meaningful participation, risk sensitive and evidence informed planning and actions.' The constant interaction between

the bio-physical and socio-political spheres can devise innovative solutions to water insecurity. By highlighting how governance, climate change, and urbanization intersect to drive water insecurity in mid-sized Himalayan towns, this research calls for an inclusive, adaptive, and justice-oriented approaches beyond technical fixes to ensure equitable urban water access.

8.4 Chapter summary

This chapter, thus, discussed the findings of the research questions on drivers affecting water security, responses to growing water insecurity, constraints and limits to achieving water security and presented the imperative elements of 'governance' dimension of urban water security framework. The findings of this study have been substantiated by prior research and findings of similar and other urbanizing areas. Further, it continued to explain the dimensions of urban water security theory, referring to DECS framework and integrating the dimensions of urban water security into broader elements of the framework. The discussion has also highlighted the gaps in DECS framework on equity and governance part. Further, considering the significance of governance dimension in urban water security theory, the study has identified coherent policies and efficient institutions, equitable distribution and meaningful participation and risk sensitive and evidence-informed planning and actions imperative in the theory. Both empirical evidence and literature review have been used for consolidating these findings. The following chapter concludes the thesis and notes implications of research and future direction.

CHAPTER NINE: CONCLUSION

The study on urban water security of two emerging cities in Nepal have presented empirical evidence and theoretical contribution to the water security literature in the urban context. At the same time, it has provided useful messages to the water stakeholders including the local governments to similar rapidly emerging cities of Nepal and Himalayan region. In this chapter, I provide final analysis of the thesis by presenting four key conclusions against the four research questions and also discuss the implications of research and future direction for further study in urban water security.

9.1 Addressing urban water insecurity in a changing climate

The first research question has identified the nature of different drivers responsible for causing water insecurity in two rapidly emerging cities, Dharan and Dhulikhel. The research found that these drivers of water insecurity identified as socio-economic, technological, environmental, management and governance, individually or in combination, were found to affect the different dimensions of water security such as availability, quality, affordability, equity, sustainability and risks. This establishes the interlinkages of the drivers and shows that the negative implication of drivers to any one of these water security dimensions transcends beyond to affect other dimensions as well. And addressing water insecurity challenge is not just dealing with the water scarcity issues but all of these aspects.

Water management authorities hence need to plan actions considering these drivers and related complexities and uncertainties. Since both urbanization and climate change along with increasing population and burgeoning water demand is inevitable, it is high time that the water related stakeholders including the water managers (local government and water institutions) enhance their understanding of interconnections of urban, water, climate and development and the complexity and uncertainties associated with it.

The identification of the drivers of water insecurity has provided evidence for the water institutions including the local governments to address the issues and consider them in the actions oriented for securing water. It has also added insights into planning comprehensive urban development taking into consideration the demand management. Additionally, it emphasizes that managing water sustainably, optimizing water uses in modern infrastructures, technological fixes such as leakage management, conservation of water sources and monitoring systems are crucial for addressing the water security related challenges. The study suggests

strengthening ‘governance’ aspect of water security as it has been identified as the key driver affecting water security.

The second research question delved into the responses made by the water institutions in addressing the problem of water insecurity in the cities. The exploration found that one of the key responses included formulation of sectoral policies in urban, water and climate themes. A number of policies formulated in these interconnected sectors during different time periods are guiding the water institutions including the local government towards achieving the national commitment of providing water access to the citizens; at the same time in adapting to climate change and urban development.

Further, the study also found that different institutions evolved at different time periods to deal with the issue of water insecurity. While the institutional efforts have prioritized infrastructure-based supply augmentation through donor-funded large scale water projects, there has been less emphasis on addressing social justice, equity, and sustainability aspects. Responses by the cities must therefore ensure access of water equitably across communities in core and periphery, across communities with varied social status and topographical differences and plan the water sources and watershed conservation since the designing of the project and monitor timely.

Another risk faced by the large-scale water schemes in the study sites were their vulnerability to disasters impact, technical and management challenges. Since local governments bear the authority to manage water resources, there exists an opportunity particularly, in terms of making risk-sensitive urban development and planning. This includes accounting for climatic parameters and risks to prepare impacts caused by climate change directly on water sources, climate induced extreme events and future water demand projection. By building institutional flexibility and emphasizing contingency planning, water systems can mitigate risks and ensure sustained water security under changing climatic conditions.

To enhance the resilience of the urban water system, diversifying urban water management strategies is important during the time of disasters and crisis such as floods, landslides and COVID. At the same time, diversifying water management system by integrating large-scale projects with existing community-based approaches can ensure equitable water access, especially for the marginalized groups, as observed in other cities of Nepal (Ojha et al., 2020b).

As response, municipalities in Dharan and Dhulikhel also collaborated with NGOs, universities and research organizations. The municipalities have showed good practices in leading local

efforts, such as organizing water related discussion through water forums. The water forums engaged the researchers, water related stakeholders and the local government representatives to discuss the context specific solutions in these cities as a result of which solutions such as recharge ponds and recharge pits got mainstreamed into municipal policies of Dhulikhel and Dharan respectively. Additionally, efforts were made by the water institutions in water sources and watershed conservation.

Further, the private sector has also been playing an important role in optimizing water use. In the study sites, private sector organizations undertook various initiatives to promote water conservation. These included introducing awareness-raising stickers, installing water sensors, implementing water recycling and treatment systems, and imposing fines for the use of water pumps. Though these initiatives have helped in optimizing the water use, the private sector has yet to play significant role in adopting sustainable practices and water efficient technologies. These responses by the water institutions and their effectiveness were linked to the extent to which the institutions prioritized the agenda, leadership ability and their capacity in understanding climate risks and demand management. Hence, prioritizing and strengthening these aspects is directly proportional to the effective action and hence impacts of the responses.

The third research question identified key constraints and challenges in addressing the issue of water insecurity. The constraint identified on policy responses was the incoherent sectoral policies in the themes of urban, water and climate change in addressing the urban water issues in the context of urbanization and climate impacts. Hence, coherence in sectoral policies and institutional strengthening in terms of capacity for delivering efficient, equitable, adaptive and sustainable urban water management is crucial, not only among the sectors but also coherence in policies and institutions across the three levels of government. This is as the policy and institutional aspects at the higher level was found to have implications at the local level.

This study also found that the urban water systems in the cities were facing an array of institutional and governance related constraints impacting access, equity, inclusion and sustainable water management. These included ambiguities of roles and responsibilities in water management of the three tiers of government in the federal context, conflict and coordination issues among water management institutions, limited capacity of the local governments and gaps in women representation and their meaningful participation in decision-making. The initiatives in organizing water forums and watershed related conservation efforts were facing setbacks owing to insufficient priority and changing leadership.

These constraints identified through the study has highlighted the need for both existing water institutions and emerging actors in urban water governance to assess their strengths and weaknesses and enhance capacities through the formulation of comprehensive and coherent policies, implementation frameworks and institutional mechanisms, and clarifying the ambiguous roles among water institutions and different levels of government. Addressing issues spanning water allocation, pricing, quality, conservation, rights, and service delivery is imperative in the face of rapid urbanization and climate change.

Lastly, the fourth research question has identified the key elements of governance dimension of urban water security theory as a theoretical contribution to the urban water security literature and explained why these dimensions are important. The study hence proposes 'Urban water security is the condition delivered through specific water governance elements which include coherent policies and efficient institutions, equitable distribution and meaningful participation of women in key decision-making bodies, and risk sensitive and evidence informed planning and actions.'

Governance is the key to securing water as it is connected to other dimensions of water security and hence, other dimensions of water security can be ensured through strengthening 'governance' dimension. Strengthening governance dimensions of water security, that includes the institutional and policy aspects of water management, particularly in cities executing complex governance and facing multiple challenges, is crucial. The water related stakeholders including the donor agencies, local government and water institutions' initiatives need to consider governance possessing coherent policies and efficient institutions, and equitable water distribution and meaningful participation of women and marginalized. And at the same time, risk-sensitive evidence informed planning to deliver the water security outcomes, not only in the principles and policies but also in terms of implementation are crucial.

The issue of inequitable water distribution due to the annexation of adjoining villages during the administrative restructuring in 2017 has been experienced in other municipalities with the water supply projects focusing on the core areas prior to administrative restructuring. Further, for the municipalities depending on distant water sources, damage to water infrastructures due to water induced disasters such as floods and landslides and also the issue of fixing technical complexity faced during uncertainty in earthquake and COVID-19 offer lessons for the need of climate resilient water infrastructures and diversifying the sources (implying traditional water sources conservation).

Likewise, as the water sources are constantly drying and securing water sources would be a more challenging task in the future owing to the upstream-downstream conflicts and contestations, water sources and watershed conservation need to be prioritized by the water management institutions. And for the conservation of the water sources, the source area people need to be included in key decision-making that provides sense of ownership to upstream users. Further, beyond representation, meaningful participation of women and marginalized users is key for effective water governance and recognizing their knowledge and role in water management is important. Additionally, ensuring the water access of poor and marginalized people and their affordability is equally vital to be considered by water institutions and large-scale water projects.

Good practices of the study sites like water forums playing important role in evidence- based policy making and fostering multi-stakeholder partnerships, if can be prioritized by the municipality, can present as a learning opportunity to other cities. Stakeholder engagement through forums such as water forums can be a key engagement strategy for discussing evidence-based issues, devising context-specific solutions and fostering collaborations and commitments of the water stakeholders as evident in Dharan and Dhulikhel and other cities of Nepal (Devkota et al., 2021). Further, sharing of research findings by the researchers and the organizations working in the water sector in the form of knowledge-outputs to the policymakers, other water stakeholders, and communities in local and simple language and promoting dialogues can be useful for promoting awareness, developing change in perception of the water challenges and policies, and devising solutions- that will develop improved understanding, foster cooperation and enhance the water governance of the cities (Paquin & Cosgrove, 2016; Yomo et al., 2019).

Addressing water security demands contextual solutions though there can also be common learnings. The case of two Himalayan cities have presented water insecurity challenges in Dharan, a foot-hill town and Dhulikhel, a hill-top town representing different geographies, size, population and hence, the variable water supply and demand and water institutions. Despite this variation, both the sites are emerging cities with rapid urbanization, population growth and are struggling to manage the demand-supply gap through various responses. The topographical differences and geology specific strategies were implemented for instance, recharge ponds in mid-hill region, Dhulikhel while in Dharan, recharge pits were discussed and implemented as climate adaptive strategies. Dhulikhel exhibits a long history of exemplary community-based water management system while Dharan presented an interesting case of institutional

modification of merging of government managed water institution NWSC to Water Board during the study period.

Another distinction was observed in terms of water sources beyond jurisdiction in Dhulikhel while within the municipal jurisdiction in Dharan. However, the administrative restructuring raising the issues of inequitable water distribution, issues related to institutional ambiguities and inefficiency, institutional complexities, upstream-downstream negotiations, exposure to climate risks, implementation of large-scale water supply schemes and experiences of struggles in the journey towards water security, offered common lessons for addressing the issue of water insecurity.

To conclude, the study found that both the cities are water insecure, owing to the gaps experienced in different dimensions of water security. In this context, the study has suggested to enhance 'water governance' dimension that can address other dimensions to be a 'water secure city.' It emphasizes that to achieve water security, it is imperative to embrace improved version of water governance which allows flexible, adaptive and innovative planning approaches, and tailor-made context-specific responses and interventions.

9.2 Implications of research and future direction

This research on urban water security not only contributes to policy and practice, but also adds valuable insights to the existing knowledge of water security. Hence, the research findings are useful to the policy makers, practitioners, water project developers and water service providers, water users and the researchers. The insights from the study bear relevance to rapidly urbanizing cities, both within and beyond Nepal. Particularly, it is relevant to the Himalayan cities facing rapid urbanization and growing water insecurity challenge in the context where urban water security is an emerging area in the literature but is still lacking focus.

The study contributes to the water security literature particularly, in the nexus of urbanization, water and climate related literature. Amid the socio-political and environmental changes, building water-secure cities is certainly very challenging and the issues the cities will face are anticipated to exacerbate in the future as urbanization is inevitable and the Himalayan region is highly vulnerable to the climate change impacts. Hence, broadening the theoretical understanding on urban water security and its dimensions is important to all the water-related stakeholders for their contribution on their part. Specifically, the study offers contribution to the 'governance' dimension of 'urban water security theory' as it recommends what key dimensions of water governance are crucial for water-secure cities and why, drawing from the

literature review and empirical insights. Hence, it suggests future studies on water security to incorporate 'governance' as an important component among its other dimensions. Further, the study highlights the critical role of governance, especially inclusion, participation, and institutional coherence, as core to urban water security, thus shifting the focus from purely technical solutions to more adaptive, risk-sensitive, and socially just planning in the face of climate uncertainty and evolving urban complexities.

Moreover, the study has practical implications for application to the water institutions including the local governments (municipalities), water users committee and the users, particularly in managing the drivers of water insecurity and responses and challenges in securing water. The case of two rapidly urbanizing cities of Nepal offers examples of innovative strategies adopted amid institutional and governance complexity. It further highlights the opportunity the local governments can grasp in the Federal context, utilizing the water governance authority provided by the Constitution of Nepal 2015 and Local Governance Operation Act 2017 in the progressive policy arena. Future studies can unravel in detail the institutional, policy and governance ambiguities and complexities of water management in the federal context. Action is recommended from all levels of stakeholders including the water users at household and community level, conserving the traditional water sources and making responsible water use, the upstream users maintaining the clean water flow, and collaborative efforts from water institutions, and three levels of government.

The two cities represent distinct geographical locations: Dharan a foot-hill town and Dhulikhel, a mid-hill town; hence sharing context-specific issues to consider and prospects for climate adaptive water management with variable institutional structures. Further, the ongoing responses to meeting the burgeoning populations' water need through supply augmentation and implementation of large-scale drinking water projects and government's target to meet SDG 6 of ensuring access to water and sanitation for all, needs a rethinking about various aspects of water security. This study offers valuable learning to other small to mid-sized similar cities where large scale water supply schemes are being implemented, particularly, in the changing institutional context. For instance, the formation of Water Board by merging the existing water institutions in Dharan and Dhulikhel raises an important issue that is not only limited to these cities but is a contested issue at the national level discussions. Further, the study has raised important concerns regarding equitable, sustainable and risk resilient urban water system.

The analysis of the national sectoral policies in urban, water and climate themes provide lessons of policy coherence to the national level water related key stakeholders responsible in

formulating the policies. The message provided by the sectoral policies in these interconnecting themes is relevant beyond these themes to other sectoral policies as well for instance, water and agriculture, or forest-agriculture in terms of need of policy coherence for effective implementation of policies, as the issue of policy translation is a common issue across other connecting sectors. Likewise, the insights into institutional and policy constraints can aid water managers and policymakers for effective local planning process for instance, the integration of climate risks into the water policies to establish a water-secure system.

As discussed, the devolution of authority to the local government on resource management in Federal Nepal is an opportunity to capitalize. Further, the recent policies in the urban, water and climate sectors are progressive. If the gaps in the policy translation and implementation can be addressed and the local governance capacity strengthened, there is prospect for effective water management.

Further areas of study can be detailed analysis of all dimensions of water security in not only urban, but rural context as well. And further exploration of the governance dimension of water security will help in achieving water security. Urban water security assessment combined with quantitative indicators and relationships among the key variables, for instance, by using the WATSAT tool (Babel et al., 2023), integrated urban water security frameworks (Chapagain et al., 2022) can enable city planners to evaluate city's water security situation. Comparative assessments of the cities analyzing different indicators will also equip city governments to focus on specific strategies. However, beyond assessments, detailing out the stories of struggles and challenges including the best practices as well as unsuccessful initiatives can offer learning opportunity for the water stakeholders in devising effective urban water management strategies. Further, it is recommended that future research undertake focused investigations into the water justice dimensions of water security and governance, specifically analyzing distributive, procedural, recognitive, and intergenerational justice. Such studies will be instrumental in informing inclusive and context-sensitive approaches to address inequitable water access, participatory exclusion, and escalating water conflicts in rapidly changing socio-environmental contexts (Maskey and Shrestha, 2024; Maskey et al., 2024).

Policy analysis can include water policy analysis to find how the policies have been progressive, how have the policies been overlapping and how can the overlapping be avoided, what are the gaps in terms of these different dimensions of water security and the translation challenges. Since the water-energy-food-ecosystem (WEFE) nexus approach has emerged in the recent literature and water connects beyond space, intersectoral connections and similarities

and differences in rural and urban, watershed and landscape level water management challenges can be a potential area of study.

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ANNEXES

Annex I. Thesis publications

Journal Articles:

1. **Maskey, G.,** Pandey, C.L. and Giri, M., 2023. Water scarcity and excess: water insecurity in cities of Nepal. *Water Supply*. IWA Publishing. Doi: https://doi.org/10.2166/ws.2023.072.
2. **Maskey, G.,** Pandey, C., Bajracharya, R.M. and Moncada, S., 2021. Inequity in water distribution and quality: A study of mid-hill town of Nepal. *World Water Policy,* 7(2), pp.233-252.
3. **Maskey, G.,** Pandey, C.L. and Shrestha, K. 2019. Securing water in the rapidly urbanising global South: insights from critical analysis of sectoral policies in Nepal. *New Angle: Nepal Journal of Social Science and Public Policy*, 6(1), pp.1-23.
4. Pandey, C.L., **Maskey, G.,** Devkota, K. & Ojha, H., 2019. Investigating the Institutional Landscape for Urban Water Security in Nepal. *Sustainability: The Journal of Record*, 12(3), pp.173-181.

Book Chapters:

5. **Maskey, G**., Satyal, P., Pradhan, P. and Giri, M., 2024. Applying a climate justice framework to understand inequities in urban water governance amid climate change challenges in Nepal. In: J. London, J. Adhikari, T. Robertson, Eds. 2024. *Environmental Justice in Nepal: Origins, Struggles, and Prospects*: Routledge.
6. **Maskey, G.,** Pandey, C.L. and Khatri, D.B., 2021. *Policy and institutional aspects of water management in Dhulikhel*. In: D. Khatri, K.R. Neupane, K. Devkota, eds. 2021. Dhulikhel's journey towards water security: Insights for policy and practice. Southasia Institute of Advanced Studies (SIAS) and Dhulikhel Municipality, Kathmandu.
7. Devkota, K., **Maskey, G**. and Khatri, D., 2021. *Pani Chautari as a tool for evidence-informed policy and practice: Experiences from Dhulikhel.* In: D. Khatri, K.R. Neupane, K. Devkota, eds. 2021. Dhulikhel's journey towards water security: Insights for policy and practice. Southasia Institute of Advanced Studies (SIAS) and Dhulikhel Municipality, Kathmandu.

Blogs

8. **Maskey, G.** and Shrestha, A., 2024. Maskey, G. and Shrestha, A., 2024. *Water for All?* Blog published in Southasia Nadi Sambad (Soanas), 23rd April 2024. Available at: https://soanas.org/
9. **Maskey, G**., Neupane, K. R. and Shrestha, A., 2020. Local Academic Institutions for Strengthening Local Democracy and Development. Published on Dec 31, 2020 in *SPOTLIGHT*. Available at: https://www.spotlightnepal.com/2020/12/31/local-academic-institutions-strengthening-local-democracy-and-development/

Annex II. Table for t-test

t-test (number of people using water in the households)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
19. How many people use water in your house? (including tenant)	Equal variances assumed	6.999	.008	1.062	482	.289	.390	.367	-.331	1.112
	Equal variances not assumed			1.017	361.365	.310	.390	.383	-.364	1.144

Annex III. Checklist: In-depth interviews

The interview is a part of understanding water management as part of my PhD research in Dhulikhel (and Dharan) on 'water security in the context of urbanization and climate change. The interview might take approximately one hour. I would require your consent for the time and recording the interview so that important information is not missed out. The anonymity of the participants will be maintained, and their names will not be disclosed in any publications.

Water sources and water adequacy/scarcity in Dhulikhel/Dharan

1. If you recall the environment of Dhulikhel 10 years back and compare the past with the present situation, how do you feel and what is your experience in terms of water adequacy?
2. Dhulikhel is one of the pioneer towns to initiate community-based water management practices since 1980s. What factors, do you think, led to water scarcity in Dhulikhel? And how?
    a. What is your observation in the trend of urbanization and population growth in Dhulikhel in comparison to past 10 years? How about migration?
    b. Have the road construction in Dhulikhel impacted the drinking water? Has there been any research on this?
    c. Do you see any impacts of climate change on water resources in Dhulikhel? If yes, how do you think is climate change affecting the water resource?
    d. What is your understanding of climate change? Where do you get such knowledge i.e. trainings, workshop or interest from? (Any examples or incidents from which you built your knowledge of climate change?)
    e. Have you observed any impact of 2015 Earthquake on water sources in Dhulikhel? Do you have any such examples?
3. Can you explain a bit about the water sources Dhulikhel relies on- how many surface water and ground water sources?
4. How are homes, schools, hospitals, hotels, industries and tankers, and private groups are managing the water needs?
5. In Dhulikhel, if you have to categorize the area with most water scarce and the area with plenty of water sources then which would they be? Which wards in Dhulikhel

are facing the water scarcity problem and why? What type of problems are they facing?

6. In the present scenario, how many liters of water is required in Dhulikhel per day? Is water supply in Dhulikhel enough as per its demand?

Water management

7. How many formal and informal water users are there? How do they manage to bring water from source and distribute water?
8. Is there practice of buying or selling the water source? In your opinion, do you think this process of source buying and registering a sustainable way of managing water? What is process of registering of water source (मूल दर्ताको प्रक्रिया)?
9. Can you please explain about the water management in Dhulikhel- the institutions engaged in water management and supply?
10. Are there any activities for the source and watershed conservation? What are they and which institutions are engaged in it?
11. Are there any consideration for climate change in the drinking water projects in Dhulikhel?

Water Institutions

12. How many households do DDWSUC provide water to? Why is it not supplying water to all households in Dhulikhel?
13. DDWSUC was set for providing water to core area (wards 2,3,4 and 5) of Dhulikhel, so why and how did it start supplying water to periphery areas (wards 7,8,9 and some parts of 1 and 6)
14. Is DDWSUC able to supply enough water to all the wards? If not, why? To what extent is DDWSUC able to meet the drinking water demand in Dhulikhel?
15. Please explain about DDWSUC formation and its composition.
    (date of formation, composition of members- no. of staff and their position in detail, women and marginalized members, process of selection to be a member of any water association).
16. What is the quality of water supplied to the users? Is there a water treatment plant – who manages it and is it functional?
17. Earlier there was no local level election and no elected body representatives while now the situation is different. As you have worked in water sector since then, what

kind of changes have you seen in the water management practice in the last 10-20 years? I would like to understand the changed context and potential institutional collaboration among key stakeholders for urban water management of Dhulikhel.

18. Is there any conflict between the drinking water and irrigation, or intersectoral as household use and hoteliers/universities in Dhulikhel?
19. Do you see any kind of issues between the water management institutions in Dhulikhel- for example, Municipality and Dhulikhel Drinking Water Users Committee? Or others? Please explain. How does DDWSUC coordinate with other institutions for water distribution and management? What kind of relation does DDWSUC have with the Municipality and other water related institutions?
20. Can you explain a bit about Water Board Formation and its composition?
21. How do you see the merging of DDWSUC to Water Board?
22. What kind of meetings are organized to discuss about the water issues? How often are they organized and what specific issues are discussed? Who participates?
23. How has DDWSUC been dealing with or resolving the conflicts related to water, if any? What are the causes of conflicts and how are they resolved?
24. What are the constraints and challenges DDWSUC is facing in water management and why?
25. Can you provide data on water supply to different wards, private tap connection fee, monthly water tariff, municipal plans and other data/documents available?

About ADB funded drinking water project:

26. What is the update of Kavre Valley Integrated Project? Has it started distributing water? Which area is targeted by the project to supply drinking water? What challenges or problems did the project face? Do you think the project will be able to manage the water scarcity situation in Dhulikhel? How?

Hope and opportunities with the Federal structure:

27. As you know that we have new structured local government, what do you expect from that government especially in the case of water?
28. What do you think are the opportunities with the new local government and what challenges do you see in terms of water management? Are there any unclarity and overlapping roles and responsibilities, unclear policies?

Solutions and ways forward:

29. What changes or improvement would help in better water supply management by DDWUC in Dhulikhel?
30. Has there been any research in Dhulikhel in regard to the water sources, water management and distribution, vegetation, water recharge and others? Which organizations are engaged in research (INGOs, NGOs or others)?
31. In last year's fiscal budget, how much percentage was allocated for the conservation of water source? How much was allocated for upstream and downstream? And this year fiscal budget? (also review municipal plan)
32. As the Local Government Operation Act (LGOA 2017) has provided the authority to the local government, has it made any new policy, or made any revision related to the water source and management? What are the plans of the municipality in solving the water problem? Or what type of revision plans, policies and activities has the municipality anticipated?

Thank you for your valuable time!

Annex IV. Questionnaire survey

The research is focused on urban water security and hence the questionnaire will explore about the water sources, water availability, quality and the water management issue in Dharan/ Dhulikhel.

The survey will be completely confidential and if you feel to stop the survey at any time, it is entirely upto you. Information obtained will be treated strictly confidentially, and the name of respondent will not be printed or used in any documents.

The survey will take around 30 minutes.

Name of interviewer: …….....

Consent: Would you be willing to talk to me? Y N

A. <u>SOCIO-ECONOMIC DETAILS</u>

1. Date of interview: 2. Respondents name: 3. Municipality: 4. Ward no.: 5. GPS point: 6. Age:	7. Gender: 8. Caste/Ethnicity: 9. Education Level: 10. No. of family members:

11. What is the type of house you are residing?

a) Own house b) Rented

c) By institution/ organization. c) Others (specify) ……

12. What are your major sources of income? (Multiple income sources possible, rank 1 to 5 as per priority) *Rank (highest priority 1 and lowest priority 5)

Sources	Government job	Private job	Agriculture	Business	Abroad for employment	Labour	Others (specify)
*Rank							

13. How much is the average annual income of your family? …Rs ……

B. WATER SOURCES, AVAILABILITY AND DISTRIBUTION

14. What are the sources of drinking water your household depend on? Which is the main source of water your household use? (multiple sources possible)

Water Sources	**Purpose/use for** (list the purpose like drinking, cooking, bathing, washing, cleaning, others for as many sources used)	**Main source** (Tick the main sources of dependency)
Private tap (निजी धारा(		
Public tap) सार्वजनिक धारा(		
Private well)निजी इनार(Open (खुल्ला ☐ covered)ढाकिएको (☐		
Public well (सार्वजनिक इनार) Open (खुल्ला ☐ covered)ढाकिएको(☐		
Stone spout (धुंगे धारा)		
Spring water		
Rainwater (आकासे पानी(		
Surface water (river, pond, stream, lake)		
Bottled water/jar) बोतालको /जारको पानी(		
Tanker water (truck)) टैंकरको पानी(		
Others) अन्य ((specify)		

15. If you fetch water, how much time do you spend per trip?

…….. minutes b) water on premises c) don't know

16. How many people use water in your house/block?

a) Family members:…… b) Tenants:……. c. Other specify:……

17. Does the household have land/ house ownership certificate?

a) Yes b) No c) No response

18. How much water per day does your household need?

a) <300 L/day b) 300-500 L/day c) 500-1000 L/day d) >1000 L/day

19. Who fetches/collects water in your family and how often?

a) Adult man ☐
b) Adult women ☐
c) Boy ☐
d) Girl ☐
e) All of the above ☐
f) Don't know ☐

20. How much time is spent in water management/collection each day? (for private connection)

a) <10 mins b) 10-20 mins c) 20-30 mins d) Others (specify)……

21. Do you think the quantity of water has changed in the last 10 years?

a) Increased b) Decreased c) No change d) Don't know

22. Are you satisfied with the quantity of of drinking water?

a) Highly dissatisfied b) Dissatisfied c) Neutral d) Satisfied e) Highly Satisfied

23. Do you think the quality of water has changed in the last 10 years?

a) Improved b) No change c) Degraded d) Don't know

24. Are you satisfied with the quality of drinking water?

a) Highly dissatisfied b) Dissatisfied c) Neutral d) Satisfied e) Highly Satisfied

25. How often have you experienced bad smell or foreign body or turbid in the water in the past 1 year?

a) Always b) Frequently c) Occasionally d) Rarely e) Not at all

26. Which month is bad for water supply in relation to Quantity?

a) Baisakh b) Jestha c) Asar d) Shrawn e) Bhadra f) Asoj

g) Kartik h) Mangsir i) Poush j) Magh k) Falgun l) Chaitra

27. Which month is bad for water supply in relation to Quality?

a) Baisakh b) Jestha c) Asar d) Shrawn e) Bhadra f) Asoj

h) Kartik h) Mangsir i) Poush j) Magh k) Falgun l) Chaitra

28. How do you treat water for making it suitable for drinking purpose?

a) Chlorination b) Boil c) Filtration d) Solar disinfection (SODIS)

e) Let it stand and settle f) No treatment g) Others specify ……

29. How do you manage water during the scarcity?

b) Bottled water b) Tanker water c) Local spring d) Neighbour e) Rainwater harvesting f) Others (specify)…….

30. If water shortage, how much do you spend per month for coping mechanism?

…… NPR

31. Do you pay for the water services?

a) Yes b) No

32. If yes, how much do you pay monthly?

……NPR

33. What kind of toilet facility do members of your household usually use?

a) Pit latrine b) Flush toilet c) Composting toilet d) Open pit latrine e) Others

34. Do you reuse water?

a) Yes b) No

35. If yes, do you use retreated water?

a) Yes b) No

36. Has there been any incidence of diseases due to drinking water in the last 12 months?

a) Yes b) No c) Don’t know

37. If yes, what types of water borne diseases have occurred in your family in last 12 months?

a) Jaundice b) Typhoid c) Diarrhoea d) Other (specify)

C. IMPACT OF CLIMATE CHANGE AND URBANIZATION ON WATER

38. Do you think that rainfall pattern has changed over the last 20 years?

a) Yes b) No c) Don't know

39. If yes, how?

a) Less rainfall in a year b) More rainfall in a year

c) Shorter rainy period d) Longer rainy period

e) Erratic rainfall f) Others (specify)

40. Which of the water sources have been most vulnerable in terms of changing rainfall pattern?

a) Rivers b) Streams c) Local springs d) Ground water e) Others (specify)…….

41. What are the causes of decline of water sources?

a) Inadequate rainfall b) Deforestration c) Land-use changes d) Don't know e) Others (specify)……

42. Have you felt changes in max/ min temperature since last 10 years?

a) Increased b) Decreased c) No change d) Don't know

43. What change factors have affected water availability in your city?

a) Climate change b) Urbanization c) Population growth d) All of these e) Others (specify) ……

44. Is increasing population affecting water availability in the town?

a) Yes b) No c) Don't know

D. WATER INSTITUTIONS AND GOVERNANCE

45. Who manages the water supply and distribution system in your area?

a) Government b) Municipality c) Community

d) Private sector (tanker, bottled water) e) Others (specify)

46. Generally speaking, how do you find the current water supply and management situation in the town?

a) Bad b) Poor c) Fair d) Good e) Very Good

47. Do you think the current supply system is distributing water to each household equally?

a) Yes b) No c) Don't know

48. How often did you have conflicts over water in the past year?

a) No conflicts b) Sometimes c) Most of the times d) Almost everyday e) Heard other incidents

49. What is the nature of conflicts?

a) Source related b) Access related c) Price related d) Others (specify) ……

50. Do you think that private sector should be engaged in water management?

a) Very bad b) Bad c) Neutral d) Okay e) Good

51. Which institutions play key role in water management?

a) Municipality b) Water board/user group c) Water forum d) All of these d) Others (specify) …….

52. How can water scarcity be addressed in your town?

a) Infrastructure b) Source conservation c) Equitable distribution d) Private sector e) Others (specify)…….

53. How often do you participate in water management decision and planning meetings?

a) Mostly b) Often c) Sometimes d) Rarely e) Never

54. If participated, what role did you play?

a) Decision making b) Meaningful participation c) Passive participation d) Only listening

e) Other (specify) …….

Thank you for your valuable time!