DEVELOPMENT OF A FRAMEWORK TO ATTAIN WATER SECURITY IN INDIAN RURAL AREAS

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DEVELOPMENT OF A FRAMEWORK TO ATTAIN WATER SECURITY IN INDIAN RURAL AREAS

A Thesis Submitted for the Fulfillment of Doctoral Program in Global Environmental Studies

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ABBREVIATIONS AND ACRONYMS

AC	Adaptive Capacity
ANOVA	Analysis of Variance
ARWSP	Accelerated Rural Water Supply Programme
AWDO	Asian Water Development Outlook
BDO	Block Development Office
BPL	Below Poverty Line
CDB	Community Development Block
DA	District Administration
DDI	Demand Driven Insecurity
DHDR	District Human Development Report
DPC	District Planning Committee
GoWB	Government of West Bengal
GWP	Global Water Partnership
GP	Gram Panchayat
FGD	Focus Group Discussion
IMD	Indian Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IWMP	Integrated Watershed Management Programme
LA	Local Administration
LG	Local Government
LPCD	Litre per Capita per Day
LWE	Left Wing Extremism
MoRD	Ministry of Rural Development
MNP	Minimum Needs Programme
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NGO	Non-Governmental Organization

NRDMS	Natural Resources Data Management System
NRDWP	National Rural Drinking Water Programme
PCA	Principal Component Analysis
PRA	Participatory Rural Appraisal
PRI	Panchayat Raj Institution
PS	Panchayat Samiti
RGNDWM	Rajiv Gandhi National Drinking Water Mission
RWII	Rural Water Insecurity Index
SDI	Supply Driven Insecurity
SC	Scheduled Caste
ST	Scheduled Tribe
VWSC	Village Water and Sanitation Committee
WHO	World Health Organization
ZP	Zilla Parishad

EXECUTIVE SUMMARY

Background of Research

Nearly half of the world's population, approximately 3.3 billion people, lives in rural areas, and 90% of those people live in developing countries. Rural areas in developing countries like India are characterized by a dependence on agriculture and natural resources; high prevalence of poverty, isolation, and marginality; neglect by policymakers; and lower human development. Water security is an emerging concept and has been mainly studied at national or transboundary scales. Though research on drought and water scarcity in rural areas are quite prevalent, studies on human-focussed concept of water security is significantly absent, more specifically for rural areas.

In light of such pressing issues affecting a majority of human population, it is important to assess water insecurity in rural areas, their causes, and ways in which they affect rural communities' lives. Rural areas are a multi-layered superimposition of dynamic systems in which local people live, work and interact, both animate and inanimate, for the material, sentimental and spiritual pursuits of the individual and the collective. Moreover, lives of rural people revolve around water for their daily sustenance. If the functions and resources are not adequate and appropriate in a rural area to support its inhabitants to pursue their individual and collective goals, then there will be loss of livelihood, increased hunger and poverty, migration and conflicts of use. Policy planning regarding water security is highly overlooked in rural areas. In doing so, this research proposes a methodology to assess the scale of prevailing water security in rural areas, mainly in developing countries, and formulate a localized and need-based framework to ensure water security that will work towards sustainability of water resources as well as overall upliftment of the rural people.

Research Objectives and Questions

The main objectives of this research are outlined below:

- To assess the existing status of water security in the rural area under study.
- To examine the determinants of household water consumption and the influence of socio-economic conditions on water consumption.
- To analyze the changes in local climate and their plausible impacts on rural livelihood.
- To investigate the strategies practiced by local rural communities to cope with water insecurity and climatic variability.
- To develop Rural Water Security Framework that strengthen and ensure water security.

To attain the research objectives, attempts have been made to answer the following research questions:

- How water secure is the rural area under study?
- What are the different determinants that control household water consumption and how does water consumption vary across different socio-economic conditions of the households?
- Is there any changes in the local climate, mainly rainfall, in the rural area? If yes, what are the possible impacts of these changes on local livelihood?
- How does the local communities perceive and respond to the different status of water insecurity and climatic variability?
- How can water security be ensured and strengthened in rural areas?

Research Methodology

The **first step** of the methodology involves collecting *Block* level data and applying it suitably to formulate Rural Water Insecurity Index (RWII) for the study area being analyzed. A questionnaire survey based on 3 dimensions, 17 attributes and 21 variables is carried out with *Block* officials to collect the required data. Principal Component Analysis (PCA) is used to weigh the variables and construct the index. ArcGIS® 10.3 has been applied to spatially segregate the blocks based on their scale of water insecurity. Based on the findings from step one, household level questionnaire survey is carried out in different *Blocks* in **step two**. Multiple regression analysis has been carried out to analyze the determinants that impact household water consumption. Other statistical techniques like ANOVA and post hoc tests are used to assess how household water consumption varies with household socio-economic status. **Step three** aims at analyzing the actual changes in local climate variables including rainfall, temperature and relative humidity of the study area. The data for the same has been collected from Indian Meteorological Department (IMD) and trend analysis using both parametric and non-parametric statistical tests is carried out to identify increasing, decreasing or no trends in the variables, mainly rainfall. In **step four**, different Participatory Rural Appraisal (PRA) tools have been applied in the study area to understand how local communities, including village elders, farmers and women, perceive the changes in local climate and water security, their causes and impacts, and how they cope or adapt to these variations. The **fifth step** mainly involves Focus Group Discussions (FGDs) with local communities and semi-structured interviews with local leaders who represent the local government and local administrative officials to outline the prioritized actions that can be undertaken to ensure water security, both agricultural and household. Simple descriptive analyses are carried out to assess the collected data. The findings from all the above analyses are used to develop Rural Water Security Framework.

Purulia, located in the eastern part of India, is a rural drought-prone district with higher level of poverty. The district experiences inherent water scarcity and the population is mostly dependent on natural resources for their livelihood. Application of different research methodologies and the findings in the proposed study area is hoped to bring in universality in testing the hypothesis, and pose interesting situations which can then be used to amend the initial hypothesis to make it robust.

Key Findings of the Research

Principal Component Analysis of the variables under each of the three dimensions revealed the variables that needs immediate prioritized attention to ensure water security in the study area. Supply driven water security is found to be highly compromised due to lack of consistent and reliable piped water supply. Unavailability of adequate groundwater also contributes to the supply driven water insecurity in the study area. Water demand due to irrecoverable losses like evapotranspiration and surface outflow, and increased groundwater withdrawal to meet domestic and irrigation needs are found to exaggerate demand driven water insecurity. Adaptive capacity, the third dimension, is found to be mostly influenced by larger forest areas, higher female literacy rates and higher work participation by the local communities. Impact of increased rural-urban migration demonstrates the lack of adaptive capacity and narrow coping ranges of the rural people. Spatial mapping of water insecurity displays a wider spatial variation with only 10% of the *Blocks* being relatively water secure. Though water supply and demand are the basic dimensions that play a significant role in water availability, adaptive capacity is found to minimize the impacts from insecurity due to water supply and demand provisions.

Next to segregation of the *Blocks* as per different scales of water insecurity, it is imperative to understand the extent of water insecurity at household scale. Water consumption of only 1.52 % of the sampled households are found to exceed the basic water requirements recommended by the Sphere Project for humanitarian emergency situations (7.5-15 lpcd) (The Sphere Project, 2011). Out of this 1.52%, only 4 households (0.22%) are reported to consume domestic water above 20 lpcd i.e. the recommended basic water requirement for non-emergency conditions (The Sphere Project, 2011). The availability and accessibility to water is much below the satisfactory level denoted by the higher collection time, longer collection distance, dominance of community water sources, use of unimproved water sources and dependence on single source of water. On an average, the collection time increased 7 times when the collection distance increased from less than 200 m to more than 2000 m. A decline in the collection distance (one-way trip) from more than 1000 m to less than 100 m is found to result in a 13% increase in per capita household water consumption. Per capita household water consumption was found to be influenced by demographic, economic, social and agricultural characteristics of the households along with water availability, accessibility and local conflicts etc. In addition, household socio-economic status, measured by ownership of assets, demonstrated a higher water consumption rate for well-off households compared to households with low socio-economic status. In summary, household water security, denoted by household water consumption, is found to be largely compromised in the study area.

Rainfall is the sole source of water in the district and livelihood of local communities are wholly dependent on timely availability of rainfall. An increasing trend in annual and pre-monsoon season rainfall and a decreasing trend in monsoon and winter season rainfall is noticed in the district. In addition the post-monsoon season rainfall demonstrated a highly variable increasing trend. This variability in rainfall trends, when correlated with various growth phases of paddy, is expected to heavily impact crop cultivation in the study area. Average maximum temperature also demonstrates an increasing trend in the study area.

Until now, the status of rural water security, based on data collected at different scales, is clear to a larger extent. Understanding the perception of local communities becomes imperative to recognize if the local communities can identify the causes and impacts of water insecurity in the study area. All the three communities, village elders, farmers and women, perceive the water supply scenario to be far from satisfaction. All the communities identified that significant proportion of the water supply and storage infrastructures does not function or functions much below its design and potential and fail to meet the needs of the rural people. In spite of identifying various natural factors like low yielding capacity of aquifers, lower water retention capacity of soil and undulating topography, local communities emphasize that the management factors play a havoc in lowering the water security of the study area. In addition, the perceived changes in local climate is found to match the actual changes in climate variables, mostly rainfall. The practiced coping strategies are found to outnumber adaptation strategies demonstrating the limited capacity of the local communities. The strategies practiced by village women aim at arranging water for household use whereas household level strategies mainly focus on alternative livelihood options or income sources that can assist in overcoming the loss incurred from disturbed livelihood and lack of adequate income due to water insecurity and climate variation. The strategies are found to be largely reactive and unsustainable. Water conservation or water efficient farming is found to be largely missing in case of farm level strategies.

As the problem areas get identified, the present study aims at exploring the possible solutions that can ensure water security in the studied rural area. Various prioritized actions are identified at three different levels - local communities, local government (*Gram Panchayat*) and local administration (*Block*) - that can contribute towards improving and attaining water security in the studied district. Community level prioritized actions are mainly identified to be supply based like building check dams, ponds, wells, hand pumps etc. In addition, a higher percentage of responses at community level also emphasized on the repair and maintenance of the existing water sources. Both local administration and local government level responses prioritized more on construction of new water sources i.e. mostly supply based provisions to ensure both agricultural water security (like check dams, irrigation wells and irrigation ponds) and household water security (like installation of piped water supply and hand pumps). Lack of adequate finances is identified to be one of the major barriers by both the local government and administration in addition to lack of technical and human capacity and natural hindrances like hard rock terrain, undulating topography and difficult hydrogeology of the area. *Gram Panchayats* were identified to be the main implementing agencies for all the prioritized actions proposed at three different levels with local administration and district administration identified as the main funding agencies. In summary, the prioritized actions proposed by communities are found to be quite different from the proposed actions suggested by local government and local administration. Demand-side approaches and emphasis on sustainable adaptive strategies are noticeably overlooked by the respondents. The prioritized actions are not found to be resilient to seasonal insecurity and are mostly unsustainable.

In lieu of the above findings, a local framework for attainment of water security in rural areas is proposed (Figure E.1). Considering the research findings, Local Government or *Gram Panchayat* including cluster of villages under its boundary is proposed as the boundary of implementation for the proposed framework. There are two core segments of the framework – process cycle and support system. The process cycle consists of four main components – resource assessment, source sustainability, operation and maintenance, and adaptation strategies. Resource assessment mainly includes investigating the existing status of water resource in rural areas. The methodology followed in the present research contribute significantly to the resource assessment phase. Many of the problem areas identified in the present study like frequent failure of water sources, siltation of water sources and depleted water quality can be rectified through prior survey, uptake of different software inputs (like rainwater harvesting, community awareness on need for recharge etc.) and hardware inputs (like structures that capture rainwater, surface runoff and groundwater for recharge purpose).

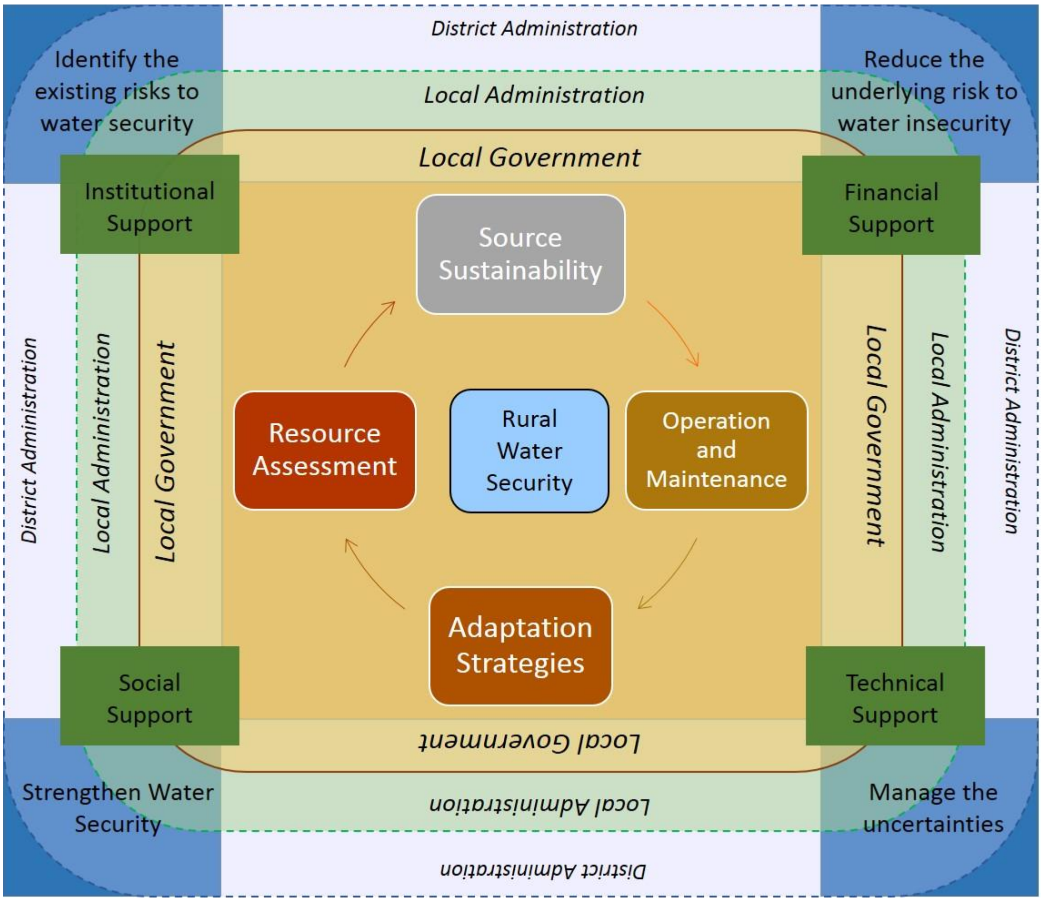

Figure E.1 Proposed Rural Water Security Framework

As source sustainability mainly suggests the provisions that should be taken care of before the construction of any new water sources, operation and maintenance phase principally emphasizes on the repair of existing water sources. This phases focusses on how the local communities can be empowered or trained to repair and maintain the water sources so that they don't have to depend on administrative personnel to come and repair them. This will help in overcoming the barriers due to lack of technical and human capacity. To help the small holder farmers, characteristic of the study area, as well as local communities overcome the challenges posed by uncertain climate variability and water insecurity, adaptation strategies are proposed in the process cycle. The support system mainly delineates the various assistances like institutional, financial, social and technical supports required for the framework to function effectively.

The framework proposes the formation of community level **Beneficiary Committee** as well as creation of **Community Fund** to aid the proper functioning of the framework. The framework also presents various options to channelize funds that may help in addressing the financial constraints. The framework proposes **outsourcing** various forms of scientific expertise that may contribute to effective functioning of the framework. **Social Audit** has been identified as a viable option to monitor the progress of the proposed works and strategies under the framework. It will also help in maintaining transparency in the whole process of implementation of the framework. Most of the propositions have mainly focussed on the modification and capacity building of the existing system in the district to avoid complexity, time and effort needed to create new support system. The proposed Rural Water Security Framework, derived from the results of the present research, is first of its kind that aims at attaining and strengthening water security in rural areas and can be taken up for consideration and implementation in other rural areas also.

Conclusion and Way Forward

The status of existing rural water insecurity, their causes and impacts on livelihood, poverty and well-being of the local communities as well as investigation of actions that can contribute towards attainment of water security have been explored using a 5-step methodology, spanning meso and micro spatial scales as well as quantitative and qualitative data analysis. Each of these five steps has useful applications towards ensuring water security in the concerned rural area. The steps 1 and 2 of the methodology involving the development of Rural Water Insecurity Index (RWII) at the provincial scale and assessment of household level water security has resulted in the identification of the water insecure provinces (*Blocks*, in this study) and the determinants of household water security by measuring per capita household water consumption. This has proved that scale of water security is significantly low in the studied rural area and household water security is highly compromised. Also, the current research proved that concept of water security is more people – oriented than resource – oriented. Step 3 of the study involving assessment of local climate variables confirmed their uncertainty over time, mainly rainfall and this significantly impacts the small holder farmers in the study area who are solely dependent on rainfed agriculture. The 4th step provides a detailed explanation about the causes and impacts of water insecurity in the study area from the perspective of local communities. The local communities are found to effectively perceive the changes. However, lack of adaptive capacity restricts their responses to them through sustainable adaptation strategies. This proves that adaptive capacity of the local communities, if developed, can substantially contribute towards attainment of water security in the rural areas. The 5th and final step is the identification of prioritized actions specified at different spatial scales – from meso scale to micro scale. The prioritized actions, specified at all three levels, are mostly supply side provisions and demonstrate the lack of community engagement. In summary, this research methodology and findings can find wide application in the assessment of rural water security and local level planning initiatives through a framework targeted at attaining water security in rural areas.

CHAPTER 1

INTRODUCTION

"To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science."

Albert Einstein

Chapter 1: Introduction

This chapter presents a brief overview of the doctoral dissertation. The justification behind carrying out the present research has been briefly explained and a first look of the research location is provided. The objectives of the research and questions that work towards achieving the objectives are discussed. Finally, a short introduction to the followed methodologies and structure of the dissertation is provided.

Outline of the chapter

1.1 Overview

Water covers most of the planet but only 3 per cent of it is fresh water and of which 2 per cent is frozen in ice caps and glaciers. A mere 1 per cent in form of lakes, ponds, rivers, streams, swamps, marshes and bogs, is readily accessible and relied on for human consumption. It is this amount that truly matters when sizing up the water challenge. However, increasing climate variability, rapid population growth and contamination from both geogenic and anthropogenic sources are limiting the amount of water available at the end, resulting to severe water related vulnerabilities and risks to human society. While the distribution of global water resources is highly variable, water issues are inherently localized and interdependent, and almost fully reliant on the interaction between social systems and their socio-technical environments. Water Security emerges as an umbrella concept that gives a humane face to water and considers human well-being as the central point of focus. There is growing international consensus for increasing water security in a sustainable manner, and for building more resilient and robust water systems. Securing water for all is emerging as a top human development priority in the post-2015 Development Agenda.

1.2 Problem Statement

The essence of water security is that concern for the resource base itself is coupled with concern about services which exploit the resource base for human survival and well-being, as well as for agriculture and other economic enterprise, should be developed and managed in an equitable, efficient and integrated manner. Achieving water security thus requires cooperation between different kinds of water users, and between those sharing river basins and aquifers, within a framework that allows for the protection of vital eco-systems from pollution and other threats. Water security is also a pre-condition of any effective poverty reduction strategy, and of effective environmental sanitation, wastewater management and flood control. A multitude of threats exert impact in consensus or in isolation to water security which differs spatially from local to national scale. The threats and risks to water security is location specific and is more profound in rural areas than in urban areas as water is an integral part of rural economy and well-being. Still, very few studies exist that have assessed water security at a rural scale.

Continued economic growth that increasingly demands more energy, food, water and other basic inputs, population increases, changing water regimes and climate change are challenging abilities to manage water resources. This increasing demand is resulting in a rapid growth in both surface and groundwater abstraction. In many countries across the world, water withdrawal per capita has been increasing and shows an ongoing upward trend. Many countries, like India, have been extracting water in an unsustainable manner which often exceeds the annual renewable recharge rate of the sources. This incline in water withdrawal is resulting to long-term water scarcity and poor water quality, and low water availability for both agriculture and domestic use. Moreover, with increasing population demand for food increases which results in intensive agricultural practices, thus putting excessive stress on available water resources. Hence, the dependence shifts to groundwater because of the relative ease and flexibility with which it can be tapped and the vagaries of weather on groundwater being not as pronounced. However, excessive withdrawal of groundwater has also become a concern for countries like India, Pakistan, Sri Lanka and Bangladesh where the rate of withdrawal is higher than recharge, resulting to severe groundwater table depletion. Since, groundwater occupies an important part of rural water use, their variability and use needs to be considered and included in the planning process.

There are large uncertainties among the nations vulnerable to climate change impacts over the availability of water resources in the future. In 1955, only seven countries were found to be in water stressed conditions. In 1990 this number rose to 20 and it is expected that by the year 2025, another 10–15 countries shall be added to this list. It is further predicted that by 2050, 2/3rd of the world population may face water stressed conditions (Gosain et al., 2006). Climate change has resulted in increases in globally- averaged mean annual air temperature and variations in regional precipitation and these changes are expected to continue and intensify in the future (Solomon et al., 2007). Rainfall is concentrated in short rainy seasons (3-5 months), with a few intensive rainfall events that are unreliable in temporal distribution and with high deviations from the mean (coefficients of variation as high as 40% in semi-arid regions). Studies show that agriculture yield will likely be severely affected over the next hundred years due to unprecedented rates of changes in the climate system (Thornton et al., 2011). Climate change affects groundwater recharge rates (i.e., the renewable groundwater resources) and depths of groundwater tables. However, knowledge of current recharge and levels in both developed and developing countries is poor; and there has been very little research on the future impact of climate change on groundwater, or groundwater–surface water interactions.

Most hungry and poor people live in regions where water challenges pose a particular constraint to food production. The world’s hotspots for hunger and poverty are concentrated in the arid, semi-arid and dry sub - humid regions of the world. There, water is a key challenge to sustain life due to the extreme variability of rainfall, long dry seasons, and recurrent droughts, floods and dry spells. These regions cover some 40% of the world’s land areas and host roughly 40% of the world’s population. The dry sub-humid category covers 9.9% of Earth’s land surface. Being identified as hotspots, it can be assumed that the rural areas in these regions are extremely exposed to high climate variability and recurrent dry spells. This puts stress on the livelihood, mostly agriculture, as well as daily life of rural people.

In light of the increasing stress on water resources, their availability and accessibility, and increasing uncertainty due to climatic changes, the present research endeavours to understand how water security can be strengthened and attained in rural areas, especially in drought prone dry sub-humid rural area in India, such that domestic and productive use of water is sustained along with the maintenance of water quality as well as the quality of the environment.

1.3 Research Location

The research is conducted in Purulia district, West Bengal, India (**Figure 1.1**). It is the westernmost district of the state which falls under the dry sub – humid climatic zone (Raju et al., 2013) (**Figure 1.2**) and is considered as a highly drought prone area in the country.

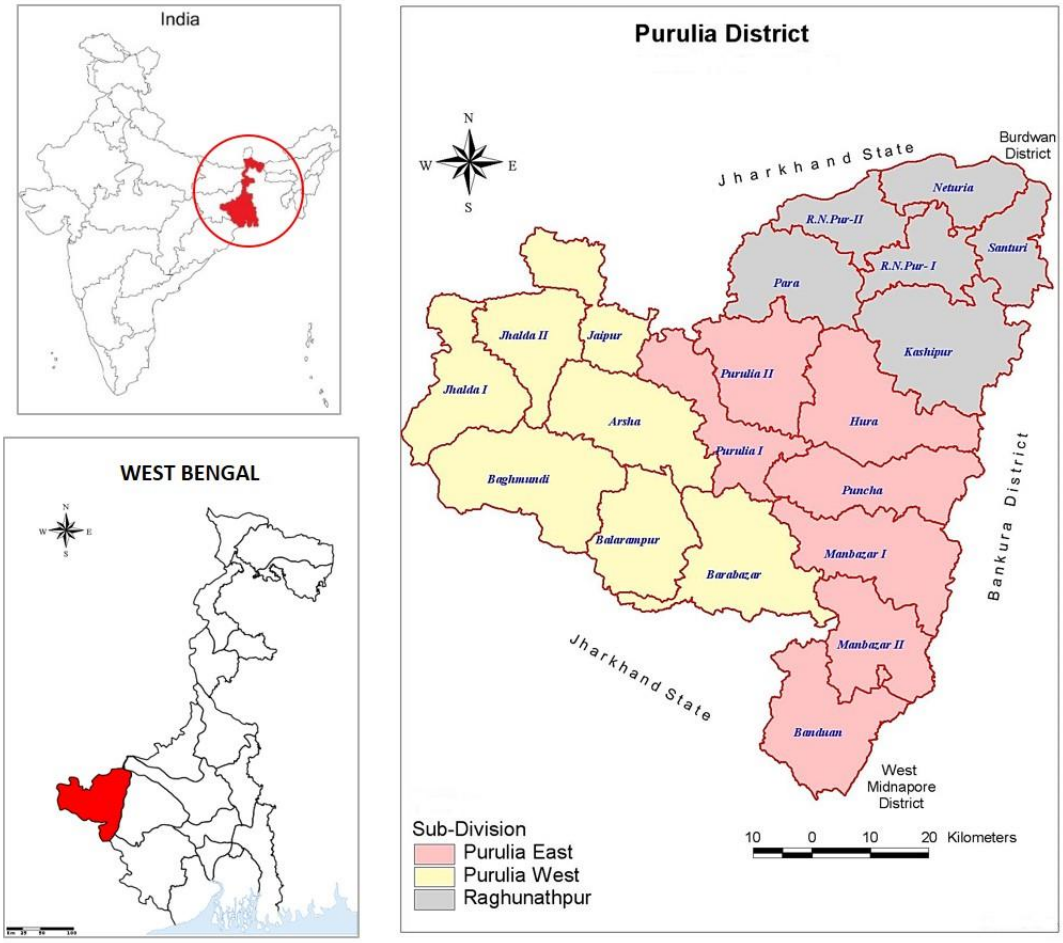

Figure 1.1 Location of Purulia in West Bengal, India

Eastern flank of Chotanagpur plateau, dissected by the valley of river Subarnarekha, is included in the district of Purulia. Undulated plains dotted with numerous residual hills made of old granite and gneiss dominates the morphology. The underlain rocks of this district are mainly made of Precambrian metamorphic. The total geographical area of the district is 6259 sq. km. Out of which urban and rural areas are 79.37 sq. km (1.27%) (Municipalities and Non-Municipalities) and 6179.63 sq. km (98.73%), respectively. The economy of the district is predominantly agrarian and mono-cropping is practiced widely with low cropping intensity.

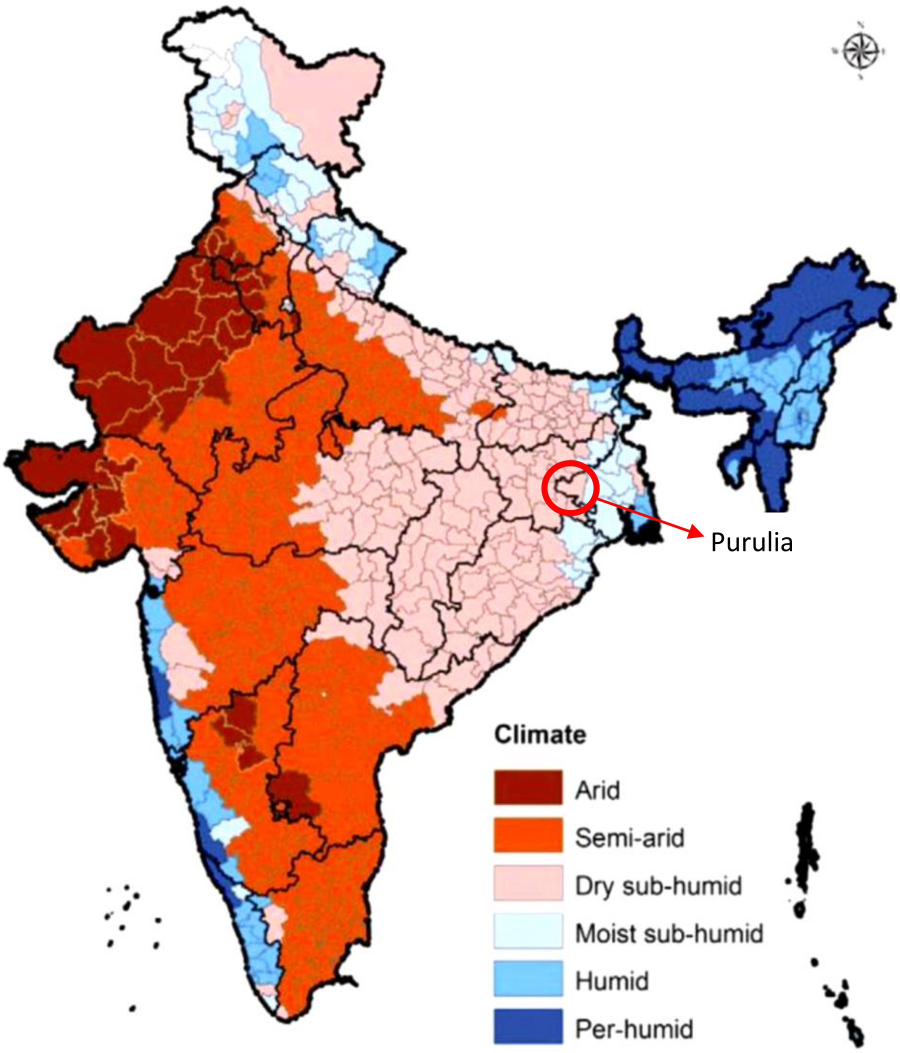

Figure 1.2 Climatic classification at district level (1971-2005) (*Source: Raju et al., 2013*)

1.4 Research Concept, Objectives and Questions

1.4.1 Research Concept

The research focusses on the causes and impacts of prevailing water insecurity in a dry sub-humid rural area. The concept of water security is kept underlain as the principle guideline and is followed vehemently as the research progresses. The qualitative theoretical concept of water security has been transformed into practical tools that fosters the measurement of water insecurity at various levels in rural areas. There are notable benefits of doing this. Firstly, it can encourage clarity and common understanding of the concept. Second, it can help foster discussion and debate on scales and thresholds for evaluating the presence, absence or degree of water security. Third, it can help to assess the extent to which the concept is really being achieved on the ground at different locations. Also, as demanded by the concept of water security, development or welfare of human society has been considered as the central point of focus throughout the research. Apart from evaluation, the research attempts to put the practical learning on water security into a framework that can provide a guideline towards strengthening water security to local policy makers in rural areas. The results of this research can be used at different administrative levels for effective planning towards ensuring water security in rural areas. Also, the outputs can be utilized by researchers across the world to guide them on how to measure rural water security and provide them insights on the existing loopholes in water security planning as well as how to address them. In addition, the methodology followed in the research can be used as a validation process by different monitoring, funding or project/scheme sanctioning authorities. However, the present research agrees that water security is a dynamic process and is bound to change as time progresses. But for the sake of measurement in the present study, it is considered as a static phenomenon.

1.4.2 Research Objectives

The main aim of this research is to assess the extent of rural water security, its causes and impacts and to draw policy implications based on the prevailing water security status. Various assessment tools are applied at different levels of the study. The specific objectives of the study are as follows:

- To develop a tool to assess the prevailing status of water insecurity in a rural area.
- To examine the determinants of household water consumption and the influence of socio-economic conditions on water consumption.
- To analyze the changes in local climate and their plausible impacts on rural livelihood.
- To investigate the strategies practiced by local rural communities to cope with water insecurity and climatic variability.
- To develop Rural Water Security Framework that strengthen and attain water security.

1.4.3 Research Questions

To attain the research objectives, attempts have been made to answer the following research questions:

- How water secure is the rural area under study?
- What are the different determinants that control household water consumption and how does water consumption vary across different socio-economic conditions of the households?
- Is there any changes in the local climate, mainly rainfall, in the rural area? If yes, what are the possible impacts of these changes on local livelihood?
- How does the local communities perceive and respond to the different status of water insecurity and climatic variability?
- How can water security be attained and strengthened in rural areas?

1.5 Research Methodology

To achieve the research objectives, several research tools and methodologies are utilized including review of literature, questionnaire surveys, Participatory rural appraisal tools and semi-structured interviews with key officials.

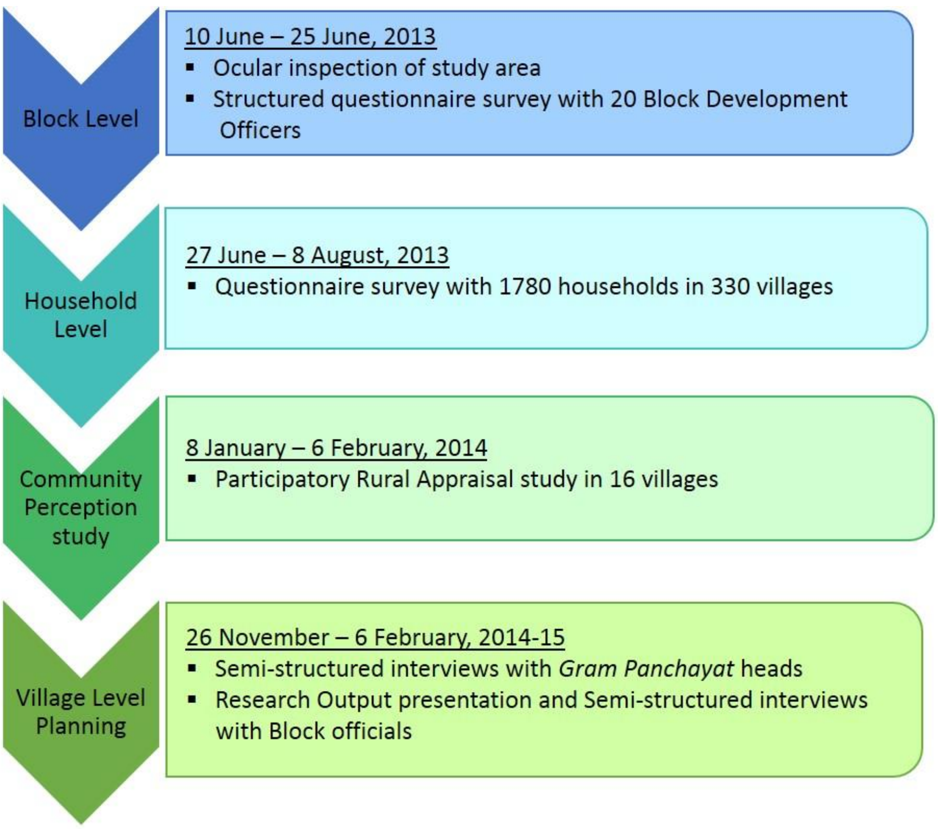

Figure 1.3 Timeline of data collection and research activities

Various statistical analysis has also been carried out, when necessary, to derive the research outputs. A brief explanation of the research methodologies are given underneath with detailed explanation provided in the respective chapters. A timeline of data collection and research activities in the study area is provided in **Figure 1.3**.

1.5.1 Literature Review

An extensive desktop study was carried out during the initial period of the research to understand the concept of water security, drought and community level adaptation, especially for rural areas. Review of relevant literatures about the research location and different research tools and methodologies were carried out as and when required throughout the research period. Various repositories e.g. Kyoto University Libraries, West Bengal Pollution Control Board Library, Central Groundwater Board Library, Kolkata etc. were visited to obtain literature materials on the subject. Published literatures on the study area like District Human Development Report were also obtained from the district administrative office.

The rainfall data for the study area were collected from Regional Centre of Indian Meteorological Department, Kolkata, India from 1950 – 2012. Data for other meteorological parameters like temperature and humidity were obtained from the District Agriculture Department, Purulia.

1.5.2 Questionnaire Survey

Questionnaire survey served as the main tool for primary data collection. Two structured questionnaires were developed, the first targeting the assessment of water insecurity at sub-district or *Block* level and the second focussing on determining the factors that influence household water consumption. In the first survey, *Block Development Officers*, the lowest administrative unit in the rural areas in India, were required to accomplish the questionnaire. There were a total of 20 questionnaire surveys corresponding to the 20 *Community Development Blocks* in Purulia, India. The questionnaire followed the proposed research framework and included 3 dimensions, 17 attributes and 21 variables. Research findings from the analysis of the data obtained from this questionnaire survey were used to construct Rural Water Insecurity Index (RWII).

Households were considered as targets for the second questionnaire survey. The questionnaire was mainly divided into two parts – first part including questions from the household demographic, social, physical and economic characteristics and second part including queries regarding household water source, consumption volume, use, accessibility etc. The survey was conducted across 1780 households from 330 villages from 9 *Blocks* in the district. The collected data from this survey were used to understand the pattern of domestic water consumption and factors that influence household water consumption in rural areas.

1.5.3 Participatory Rural Appraisal tools

Various Participatory Rural Appraisal tools like Focus Group Discussions (FGDs), resource mapping, crop calendar and transect walk were carried out to explore the perception of local village communities on the existing water insecurity and climatic variabilities in the villages in the study area. A total of 16 villages from six *Blocks* were included in the study and 48 FGDs were carried out with the three communities from each village. Research findings demonstrated the perception of the local people about existing water insecurity and climatic variability in their villages, their causes and impacts. The outputs validate and supplement the information obtained from the previous surveys. In addition, the strategies practiced by local communities to overcome the impacts are also delineated in detail. The last part of the FGDs tried to seek communities' opinions on what can be done to improve the water situation in their village which becomes a key input to the Village Water Security Framework.

1.5.4 Semi-Structured Interview

Semi-structured interview with open-ended questions were carried out at three levels, local communities, local leaders and local administrative officials, to obtain their opinions on what can be done to improve the water condition in the studied rural area. Key persons interviewed at local administrative level included *Block Development Officers*, *Block* Agriculture Officer, and Assistant Engineers responsible for water supply from 5 *Blocks*. The participants were required to accomplish the questionnaire together as a group for collective validation. Local leaders selected by the villagers, the *Gram Panchayat* heads, were then approached for semi-structured interview. A total of 29 *Gram Panchayat* heads were interviewed in the process. The inputs from the interviews as well as key research findings were considered to develop the Village Water Security Framework.

1.6 Structure of the Dissertation

The dissertation has been segregated into three parts and ten chapters (**Figure 1.4**). Part I provides an overview of the dissertation. Chapter 1 introduces the problem statement, research location and the research concepts, objectives, questions and methodology. Chapter 2 discusses the origin and concept of water security highlighting the proposed definitions, dimensions of water security and threats to water security. Chapter 3 focusses on water security in rural areas.

The status of water security and interrelated concepts like drought, water scarcity and stress are discussed and selected literatures on rural adaptation to water security and climate are explained lucidly. Considering the role of administration in ensuring water security, administration structure of rural areas in India are discussed with a special emphasis on West Bengal and a detailed discussion on rural water supply in India has been carried out. The chapter concludes by demonstrating the linkage between water security, adaptation and rural administration.

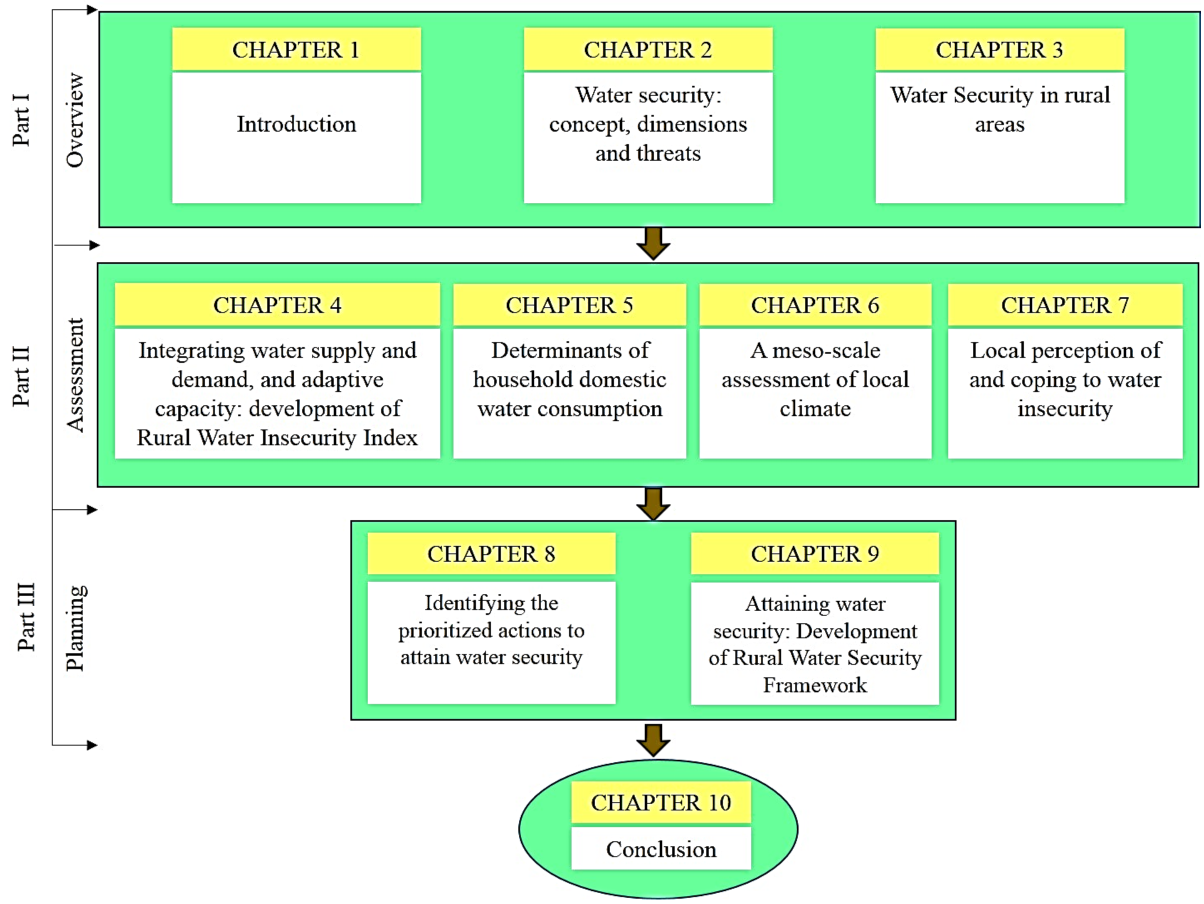

Figure 1.4 Structure of the dissertation

Part II includes the assessment part of the dissertation. In Chapter 4, a detailed account of the study area is undertaken and development of Rural Water Insecurity Index (RWII) has been conducted. The spatial differentiation of the study area into very high, high, medium and low water insecurity has been presented in this chapter. Chapter 5 illustrates the findings of the study on determinants of domestic water consumption at household level and the impacts of season and socio-economic status of households on their water consumption pattern. Chapter 6 describes the variability in the pattern of local climatic variables like rainfall, temperature and humidity. Chapter 7 illustrates the perception of the local communities about water insecurity and local climate, and identifies the adaptation and coping strategies of the local communities in the study area.

Part III describes the planning process undertaken for the development of Water Security Framework in rural areas. Chapter 8 presents detailed findings from the assessment carried out to identify the prioritized actions that can be undertaken to attain water security in the study area. The actions are identified at three different levels along with the main agencies who implement these actions and the expected barriers that may restrict the implementation of these actions. Chapter 9 synthesizes the findings of the research and recommends a local institutional framework, Rural Water Security Framework (RWSF), to attain and strengthen water security in rural areas. Rural Water Security Framework, in the current context, presents a structural frame that specifies the major elements and strategies that can be followed to attain and strengthen water security in a particular rural area. This is not a water security framework for all water users. For example, it does not focus on the needs of environment or the energy sector. Neither is it a comprehensive framework for the water security of a country, which would need to consider all water uses. Instead, it is centred on the provision for basic human needs in a rural area. Chapter 10 puts forward the conclusion of the research.

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CHAPTER 2

WATER SECURITY:
CONCEPT, DIMENSIONS AND THREATS

"Thousands have lived without love, not one without water."

W.H. Auden, Anglo-American Poet

Chapter 2: Water Security: Concept, Dimensions and Threats

This chapter presents a detailed discussion about the concept of water security and its evolution. The significant definitions of water security, developed across the years, demonstrate the shifting of the concept of water security from a physical phenomenon to a more social phenomenon with focus on overall development and welfare of human society. The chapter also provides detailed explanation about the various dimensions of water security suggested by researchers and organizations. Though a more national approach to water security was noticed in all the previous studies and assessments of water security, an increasing shift to regional and local perspectives are found to take shape. An integrative framing of dimensions of water security is stressed upon. Hence, probable threats to water security at both national and local level are discussed in this chapter. The threats are linked to each other and reportedly impact water security in association with each other.

Outline of the Chapter

2.1 Introduction

Water security is rapidly evolving from a vision into a development imperative. The international water community began using the term 'water security' since the 2nd World Water Forum in 2000, where the World Water Council (WWC) introduced its vision for 'A Water Secure World – Vision for Water, Life, and the Environment,' (WWC, 2000) and the Global Water Partnerships (GWP) published 'Towards Water Security: A Framework for Action' (GWP, 2000). Since then, multiple definitions of this concept has been proposed by a range of international organizations like GWP and the World Economic Forum. In 2009, the World Economic Forum (WEF) prioritised water security as a global risk, stating that 'water security is the gossamer that links together the web of food, energy, climate, economic growth, and human security challenges that the world economy faces over the next decades' (WEF, 2009). Other groups identifying the importance of water security include UNESCO's Institute of Water Education which has made water security one of its research themes (UNESCO-IHE, 2009), Water Security Research Centre of University of East Anglia, Asian Development Bank, and the Asia-Pacific Water Forum which held its first summit entitled "Water Security: Leadership and commitment" (Asia Pacific Water Forum, 2007).

Understanding the concept of water security and its applications, including how to quantify water security, is still developing. The water security concept is discussed in relation to concepts such as food security or energy security in that there is need to ensure that the population has access to sufficient water to meet all its needs (productive or consumptive). However, it is not only the absence of water that causes water insecurity, but its excessive presence as well like in the case of floods (Grey and Sadoff, 2007). Due to the close relation between food security and water security concepts, Muller et al. (2009) suggested that they should both be considered in a similar manner. Accordingly, it is argued that, as food security needs to be considered at both household and national level, water security should also be considered in a similar way, particularly in the rural context. Cook and Bakker (2012) argued that while an integrative framing of water security is important, narrowed framing will be a necessary condition to operationalise water security. There are no 'one-size-fits-all' concept to water security, and that appropriate measures will depend on local conditions and available coping capacity.

Despite a broad approach adopted in studies worldwide, it may not be possible to capture fully the complex dimensions of security throughout the hydrological cycle, particularly given the desire to integrate human and ecosystem health concerns. To understand this it becomes necessary to understand the concept and dimensions of water security at a local level, which in turn will contribute to national level policies regarding water security. However, deriving the concept at a local scale needs a clear understanding of the concept and the dimensions that define water security at a national scale.

2.2 Definitions of water security

In general, the definitions of water security used in the 1990s were linked to specific human security issues like military security, food security and (more rarely) environmental security. Then, at the Second World Forum in 2000, the Global Water Partnership introduced an integrative definition of water security that considered access and affordability of water as well as human needs and ecological health (GWP, 2000).

'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.'

Water security has been emphasized to be a complex concept of holistic water management and the balance between resource protection and resource use. GWP (2000) also emphasized on the consideration of water security at local, regional and national levels. Swaminathan (2001) then stated that water security

"involves the availability of water in adequate quantity and quality in perpetuity to meet domestic, agricultural, industrial and ecosystem needs."

This definition was a wholesome definition and clearly stated the productive use of water which was not mentioned in the definition by GWP (2000). Cheng et al. (2004) subsequently defined water security to include access to safe water at an affordable cost to enable healthy living and food production, while ensuring the water environment is protected and water-related disasters such as droughts and floods are prevented. Though this definition seems to be a modification of the definition given by GWP (2000), prevention from water-related disasters is a new aspect that has been included and discussed by Cheng et al. (2004). Cullis and O'Regan (2004) tried to simplify the concept of water security and defined it as the lack of capability to obtain water or as lack of entitlement to water.

The most widely accepted definition was proposed by Grey and Sadoff (2007) as *'the 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.'*

This definition firmly embeds sustainable development that seeks to ensure a triple bottom line of social, environmental, and economic outcomes. Moreover it can be interpreted at different scales and it acknowledges that risks to people, environments, and economies will always persist, whatever is done to improve water security. This definition is more comprehensive, as it indicates the importance of ensuring secure water access for livelihoods and productive uses, not just direct consumptive use. Its weakness, however, is that its application is at the national level and fails to address the requirement at local or household scale for achieving water security for irrigating households (Muller et al., 2009).

While there is growing agreement that water security is a development imperative – not just for water management, but for sustainable development – there is no universal agreement yet on how water security is defined. Until recently, UN-Water's 'working' definition of water security illustrates the difficulty in reaching a unanimously accepted definition (UN-Water, 2013). UN-Water uses this definition to provide a common framework for collaboration across the UN system and is stated as below

'Water security is the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human wellbeing, 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.'

In response to the general definitions proposed across the years, Cook and Bakker (2012) suggested that the framings of water security are not consistent and tend to vary with context and disciplinary perspectives on water use. Hence, researchers across the world framed water security into different contexts, as per their research needs, and tried to define it. International organization like WaterAid proposed a contextual definition of water security (WaterAid, 2012) as

' Reliable access to water of sufficient quantity and quality for basic human needs, small-scale livelihoods and local ecosystem services, coupled with a well-managed risk of water-related disasters.'

This definition can be, compared to other definitions that explain water security at a national scale, applied at a local scale and can be used to formulate indicators and assess water security at a narrow level. At an irrigation scheme level, Muller et al. (2009) highlighted that water security at irrigation scheme level is achieved when the social and productive potential of water has been harnessed adequately to the benefit of all the irrigators, and its destructive potential is sufficiently contained. Water insecurity is thus defined as the perceived difficulty farmer's face in securing adequate and reliable access to water for agricultural production (Rijsberman 2006). From the food security perspective, Sinyolo et al (2014) defined household water security as access by the irrigating households to sufficient and reliable water to meet their agricultural needs and their ability to assert their water rights against other parties. The key aspects of this definition are: access to reliable and adequate water supply, the ability of the household to pay for the water, and their rights or entitlements to the water which they are able to assert against other parties.

Despite some differences, these definitions have several common strands. A first common strand is a focus on access to potable water for basic human needs or domestic use. The second relates to provision of water for productive activities—presumably production of agriculture, food and industrial goods, fishery as specified in some definitions. A third is the focus on environmental conservation or protection. A fourth strand, common at least to the latter two definitions, is prevention of water-related disasters. A final element worth noting relates to Grey and Sadoff's (2007) broader treatment of risk, which strongly suggests inclusion of issues related to water for national security or independence.

2.3 Dimensions of water security

Water security is not only about having enough water. It is about mitigating water-related risks, such as floods and droughts, addressing conflicts that arise from disputes over shared water resources, and resolving tensions among the various stakeholders who compete for a limited resource. It is critical to sustainably managing natural resources and it is embedded in all aspects of development – poverty reduction, food security, and health – and in sustaining economic growth in agriculture, industry, and energy generation. Various studies have focussed on various dimensions of water security. At a national level, Zeitoun (2011) presents a global 'web' to demonstrate the way in which national water security explicitly influences other securities (**Figure 2.1**). Water is placed within the broader definition of security and acts as a central link across the range of securities, including political, health, economic, personal, food, energy, and environmental, among others. As national water security is a function of the interdependencies between the related security areas at multiple levels, it is important to understand both the way and the context within which security and interdependencies relate to each other. The mentioned approach focus on the social and physical processes that occur across many 'security areas' and hence, gets intimately related to water. These include the intimately associated natural "security resources" (water resources, energy, climate, food) as well as the security of the social groups concerned (individual, community, nation). The "web" recognises the interaction occurring at all spatial scales, from the individual through to river basin and global levels. In this sense, an individual's water security may coexist with national water insecurity.

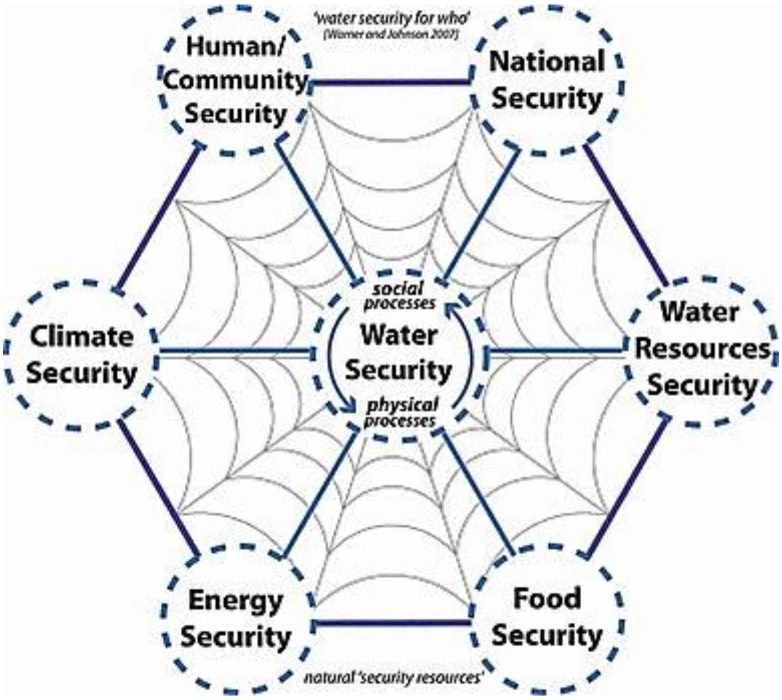

Figure 2.1 The global 'web' of national water security (*Source: Adapted from Zeitoun, 2011*)

GWP (2012) highlighted three dimensions of water security, namely Social dimensions, Environmental dimensions and Economic dimensions. These dimensions of water security are discussed in brief as below:

Social dimensions:

- Ensuring equitable access to water services and resources through robust policies and legal frameworks at all levels.
- Building resilience in communities in the face of extreme water events through hard and soft measures.

Environmental dimensions:

- Managing water more sustainably as part of green economies.

- Restoring ecosystem services in river basins to increase river health.

Economic dimensions:

- Increasing water productivity and conservation in all water using sectors.
- Sharing economic, social and environmental benefits of Transboundary Rivers, lakes and aquifers.

The Overseas Development Institute (ODI) identified five key themes for an inclusive water security framework (Mason and Calow, 2012):

- availability and access: water security goes beyond immediate physical availability
- risk and variability: water security needs to address risks such as floods and droughts
- equity and livelihoods: water security needs a human focus
- ecosystems and biodiversity: water security must meet environmental needs
- institutions and actors: water security should address management, competition, and conflict.

To measure water security at a country level, Asian Water Development Outlook (AWDO) (2013) pointed out five dimensions of water security. These five key dimensions measure national water security of a country by focussing on people's lives and livelihoods, with poverty reduction and governance. These key dimensions of water security can be depicted in a frame as shown in **Figure 2.2**. The dimensions of water security are discussed below:

Household water security: Household water security is the first among the five key dimensions of water security in a country. It includes access to piped water supply and improved sanitation and hygiene at the household level. Providing all people with reliable, safe water and sanitation services should be the top priority of a country. Household water security is vital for a country as it is an essential foundation for efforts to eradicate poverty and support economic development.

Economic water security: The second important dimension of water security for a country is the economic water security. It includes agricultural water security, industrial water security and energy water security. Economic water security measures the productive use of water to sustain economic growth in the food production, industry and energy sectors of the economy. Therefore, the use and supply of water in agriculture, industry and energy sectors of a country must no longer be seen in isolation from each other.

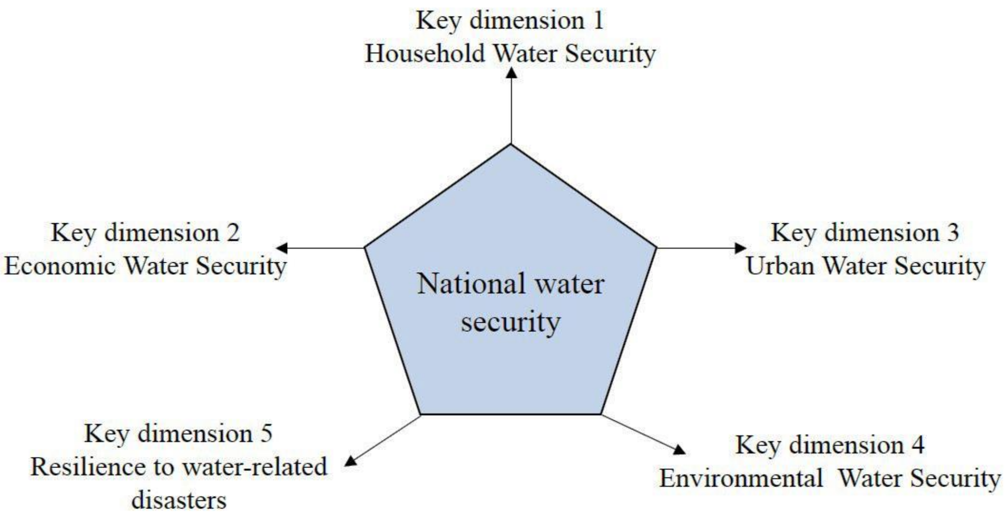

Figure 2.2 Key dimensions of water security (*Source: Adapted from AWDO, 2013*)

Urban water security: Urban water security is another important dimension of water security particularly in Asia and the Pacific. Nearly 43% of the total population in Asia and the Pacific lives in urban areas and the proportion of urban locality have increased by 29% over the past 20 years (UNESCAP, 2011). Moreover, the cities in Asian countries have become important drivers of the economy in recent years. The urban water security indicators measure the creation of better water management and services to support vibrant and liveable cities. It includes adequate water supply, wastewater treatment and drainage services to the urban dwellers.

Environmental water security: Rapid economic growth in Asia region during the last few decades is imposing negative impacts on the environment and precious natural resources. This is because the governments across the region have prioritized economic development over environmental objectives. Therefore, environmental water security is now a great concern in the region. The environmental water security indicator assesses the health of rivers and measures progress on restoring rivers and ecosystems to health on a national and regional scale. The sustainability of economic development and improved lives depends on the natural resources.

Resilience to water-related disasters: The growing socio-economic development in Asia region has resulted in rapid changes in economic activity, urbanization, diets, trade, culture and communication. Consequently, water-related disasters such as flood, cyclone, typhoon and landslides are occurring frequently in the region. Climate variability and change also contribute to water-related disasters. The resilience of communities in Asia and the pacific to these changes and especially to water-related disaster risks is assessed with the indicator of resilience to water-related disasters. The building of resilient communities that can adapt to change and are able to reduce risk from natural disasters related to water must be accelerated to minimize the impact of future disasters.

National water security: The overall national water security of a country is the composite result of the five key dimensions mentioned above. The pentagram of water security (**Figure 2.2**) illustrates that the dimensions of water security are related and interdependent and should not be treated in isolation of each other. This interdependence indicates that increasing water security in one dimension may affect another dimension of water security. However, the simultaneous increase or decrease in all the five dimensions would affect the overall national water security accordingly. Therefore the indicators for each of the five dimensions of water security help governments and civil society assess progress toward national water security.

Both AWDO and ODI have similar approaches and identify a limited number of key dimensions of water security. AWDO assessments focus on outcomes and treat water governance independently as a crosscutting issue and an enabling factor. ODI includes governance within in its five key themes. It is arguable that institutions and actors are a condition for increasing water security and not a key dimension (goal) per se.

WaterAid (2012), based on its definition of water security, outlined the dimensions of water security. The explained dimensions focus on a more community or individual level. Indicators can be derived from these dimensions to measure water security at a local scale.

Reliable access: People are described as having access to water if they can use a functioning facility serving safe water within a reasonable distance of their home, and without exclusion on grounds of race, tribe, religion, disability, gender or other cause (WaterAid, 2011). Conditions can change over time. Water security cannot be achieved if water is only available for part of the year or if water quality is impaired at certain times of the year, for example at the beginning of the rainy season. A water supply must provide reliable access to water of sufficient quantity and quality all year round. An unreliable water supply exposes communities to negative impacts on health and livelihoods.

Quantity: The quantity of water resources available in a particular area will be influenced by rainfall, run-off, recharge of soil and groundwater, hydrogeology, land use, and water demands. Improving proximity to water supply services can increase the quantities available to households, especially where household connections are used. In order to meet basic human needs, sufficient quantities of water must be available to prevent dehydration. There must be enough for cooking, bathing, sanitation and hygiene. There are no universally accepted definitions of what constitutes an acceptable quantity of water. Different countries set different national standards.

Quality: For drinking water security, the quality of water should be such that no significant health risk arises from its use. It should be acceptable to users in appearance, taste and odour. Contaminant levels should not exceed the broadly accepted water quality standards of the region or the country where it is consumed. For poor and marginalized communities, more specifically, the water should be free from microbiological contamination (caused by pathogenic bacteria, viruses and parasites), inorganic contaminants (like Arsenic and Fluoride) and other inorganic contaminants like iron, manganese and salinity that may affect the aesthetic appearance like taste, odour and appearance of water.

Risk of water-related disasters: Just as drought and having too little water causes problems, too much water in its unmanaged state can cause devastation in the form of floods, landslides and disease outbreaks. It is important to consider ongoing risks associated with too much or too little water in water security planning.

A narrowed framing of water security will enhance the ability of a country to harness the productive potential of water and to limit its destructive impact. Water security assessment at the national scale can mask significant variations in security at the local scale (Vörösmarty et al., 2010). A true picture of country water security requires assessment at multitude scales – from the local to the national – for both human and ecosystem needs. Although the nation-state scale of analysis enables important and useful conclusions to be drawn, it precludes a fine-grained analysis of sub-national spatial and social variation of water security. The advantage inherent in narrower framings of water security is that they enable precise identification and assessment of specific issues of concern. When managers try to implement a concept, they necessarily must narrow it, focussing on the primary concerns in the management area (**Table 2.1**). An obvious critique of these narrow framings is the failure to recognise or integrate the multiple stressors that affect water security. Narrow framings would be usefully allied with broader, integrative framings of water security—such that these over-arching issues (such as the political and socio-economic factors) are also taken into account.

In summary, 'narrow' and 'broad' framings of water security are complementary rather than mutually exclusive. Operationalising water security at the management level will likely require specific and sometimes narrow framings of water security; in this context, these will be both useful and may be necessary. However, integrative framing of water security still needs to happen at the policy level, and in governance processes, in which priorities are established and decisions made between competing uses and users.

Table 2.1 Narrow disciplinary framing of water security – selected examples (*Source: Cook and Bakker*, *2012*)

Discipline	**Water security focus or definition**
Agriculture	Input to agricultural production and food security
Engineering	Protection against water-related hazards (floods, droughts, contamination, and terrorism) Supply security (percentage of demand satisfied)
Environmental Science	Access to water functions and services for humans and the environment Water availability in terms of quality and quantity Minimising impacts of hydrological variability
Fisheries, geology/geosciences, hydrology	Hydrologic (groundwater) variability Security of the entire hydrological cycle
Public health	Supply security and access to safe water Prevention and assessment of contamination of water in distribution systems
Anthropology, economics, geography, history, law, management, political science	Drinking water infrastructure security Input to food production and human health/wellbeing Armed/violent conflict (motivator for occupation or barrier to cooperation and/or peace) Minimising (household) vulnerability to hydrological variability
Policy	Interdisciplinary linkages (food, climate, energy, economy, and human security) Sustainable development Protection against water-related hazards Protection of water systems and against floods and droughts; sustainable development of water resources to ensure access to water functions and services
Water resources	Water scarcity Supply security (demand management) ‘‘Green’’ (versus ‘‘blue’’) water security

2.4 Threats to Water Security

Vörösmarty et al. (2010) reported that nearly 80% (4.8 billion) of the world’s population (for 2000) lives in areas where either incident human water security threat exceeds the 75th

percentile. Regions of intensive agriculture and dense settlement show high incident threat (**Figure 2.3**), as found in much of the United States, nearly all of Europe (excluding Scandinavia and northern Russia), and large portions of central Asia, the Middle East, the Indian subcontinent and eastern China. The impact of water scarcity accentuates the threat to drylands, as is apparent in the desert belt transition zones across all continents. Spatial differentiation of water security threat arises from interaction of multiple factors. China's arid western provinces are expected to show high threat due to minimal dilution potential, but sparse population and limited economic activity combine to keep water security low. In contrast, heavily populated and developed eastern provinces show substantially higher threat, despite greater rainfall and dilution capacity. Hence, there are multiple threats to country-, regional-, and local-level water security. The relationships between these different threats are complex and therefore they should not be considered in isolation. Climate change is sometimes singled out as a major driver of water insecurity but there are other significant and immediate challenges that should also be considered. Together, these threats have an impact on access to water supplies of sufficient quantity and quality for basic needs. There are knock-on impacts on health, livelihoods, ecosystem and overall wellbeing. On a local scale, the most serious near-term challenges to water security include meeting the needs of growing populations, weak political will to ensure that the poorest people are served, low institutional capacity to deliver and manage water supply services, environmental degradation, intense seasonality, inadequate management of water resources, inadequate disaster risk reduction planning, and poor siting, design and construction of water sources.

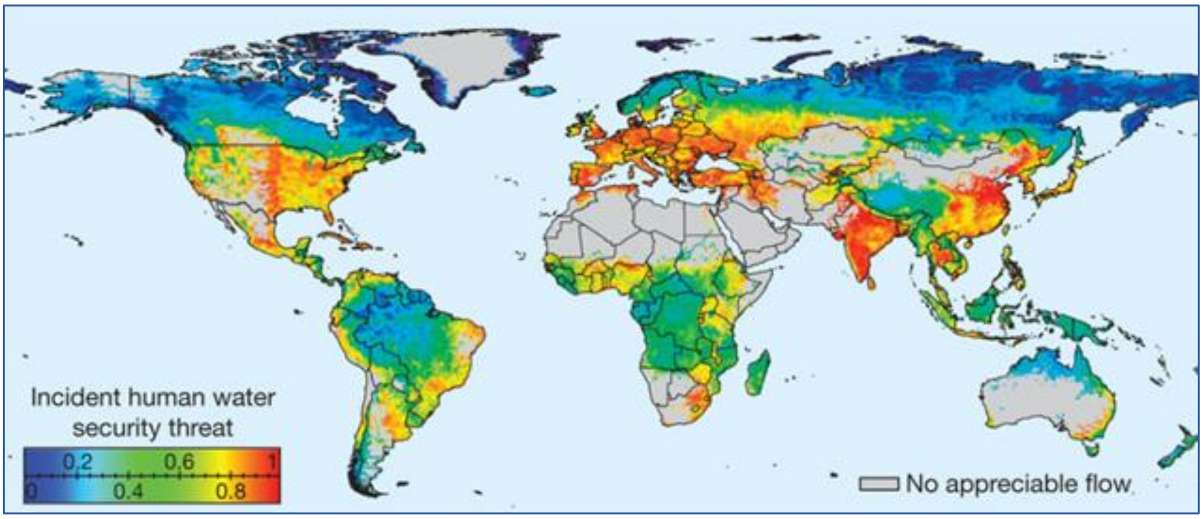

Figure 2.3 Global geography of incident threat to water security
(Source: Adapted from Vörösmarty et al., 2010)

2.4.1 Rapid population growth and urbanization

The global population reached the 7 billion mark in 2011 and is projected to reach 8.5 billion by 2030, 9.7 billion by 2050 and exceed 11 billion in 2100, with India expected to surpass China as the most populous country nearly seven years from now (UN, 2015). Globally, more people live in urban areas than in rural areas, with 54% of the world's population residing in urban areas in 2014 (UN, 2014). By 2050, 66% of the world's population is projected to be urban. With this rapidly changing scenario, domestic water consumption increases and it may be difficult to meet demand using nearby sources as domestic water consumption is higher in urban areas than in rural areas. Many African and South Asian countries already depend upon surface and groundwater conveyed from distant sources (Foster, 2008). Also, growing populations place increased pressure on land, agriculture and water resources to meet food needs. Economic growth increases demand for water resources through changes in diet and lifestyle. As people become wealthier, they typically consume more water-intensive foods and products. Changes to land use have significant knock-on impacts on the quality, quantity and reliability of water resources. Overgrazing is a major cause of environmental degradation, in some situations causing soil compaction and erosion, reducing water infiltration and storage. Clearance of indigenous vegetation to make way for agriculture can increase as well as decrease blue water availability (Amogu et al., 2010). Competition for access to water resources manifesting in localised conflict is a reality in water scarce areas. Growing populations are likely to increase the level of competition and conflict unless competing demands can be managed.

2.4.2 Poverty

The link between water and poverty is well researched theme and is expected to become more prominent in Sub-Saharan Africa and South Asia where the poverty level is noticeably high. Some of the rain-fed agricultural land also belong to most impoverished parts of the world. It is predicted that rainfall variability alone could push over 12 million people into absolute poverty. Also, poverty limits people's affordability to buy water in case of emergency or install and use improved water withdrawing structures. These leaves the poor people dependent on community water sources or unimproved water sources. Water resource availability, or lack of it, is linked to economic and social progress, suggesting that development is likely to be influenced by how water resources are managed. At a national level, it can be seen that countries which have higher levels of income tend to have a higher level of water use (Sullivan, 2002). Fraction of water required for agricultural activities is highest and adequate water availability for crop production determines crop yield which in turns determines the income of the people. Hence, poverty and water are entwined in a vicious cycle. Nobody can be lifted out of extreme poverty without adequate access to water (Sullivan et al., 2003).

2.4.3 Weak political will and low institutional capacity

Poor governance and/or weak political will to commit the necessary financial and human resources to water supply development and water resource management stifles progress. Even where sufficient financial resources are allocated, serious and widespread capacity constraints undermine effective implementation and equitable targeting of services (WaterAid, 2009).

Responsibility for management of rural water services is often delegated to communities. However, all communities cannot manage their water supply services sustainably in the absence of external technical, managerial and financial support from local public or private sector institutions. They often require external support when major repairs are necessary.

Where investment is made in institutions tasked with integrated water resource management (IWRM), communication and enforcement of legislation and regulations can be a slow process, and there can be confusion over responsibilities at the local level. National-level policies can sometimes be developed without consideration of existing informal and traditional institutions tasked with allocation of water resources and resolution of water use disputes, meaning they lack relevance at the local level (Cook and Bakker, 2010).

2.4.4 Social and political exclusion

Many people lack water security because of their political affiliation, disability, race, caste, gender, age or social status. In some situations, communities that do not support ruling political parties are not prioritised for service provision. In some instances, communities may be unaware of their rights to improved service provision and may not demand improved services, contributing to further exclusion.

2.4.5 Poor hygiene and sanitation

The overall effectiveness of water supply interventions aimed at boosting water security is undermined if poor hygiene and inadequate sanitation prevail. Relatively clean water collected from a water source can be heavily contaminated by dirty collection vessels and unwashed hands. Disposal of human faecal material in the open environment increases the risk of human contact with dangerous pathogens. Poorly sited latrines or water sources also have an impact on water quality.

2.4.6 Climate change

Climate change impacts will have direct consequences for water security, which will vary according to geographic location. The Intergovernmental Panel on Climate Change (IPCC) points towards a great vulnerability of freshwater resources as a result of climate change, with severe consequences for economic, social and ecological systems (IPCC, 2012). A majority of impacts from climate change will be on the water cycle, resulting in higher climatic and hydrological variability, with important consequences for societies and their water security. Changes in the hydrological cycle will threaten existing water infrastructure, making societies more vulnerable to extreme water-related events and resulting in increased insecurity. The effect on water security will differ regionally and will depend upon a number of factors, including geographic location and features, conditions of water availability and utilization, demographic changes, existing management and allocation systems, legal frameworks for water management, existing governance structures and institutions, and the resilience of ecosystems.

The variability of the climate presents a major challenge to the water and food security of rural people who make a living from the land and its natural resources. This variability is a major contributor to the continuing poverty of farmers and pastoralists who rely on rainfall for crop production and grazing, and who use the natural vegetation in their immediate environment. Poor and marginalized communities can be even more affected, yet have much less capacity to adequately cope due to underlying factors such as environmental mismanagement, rapid and unplanned urbanization in hazardous areas, and failed governance (IPCC, 2012). Weak local institutions lack the capacity to plan for and respond to water security, which greatly exacerbates their impact, perpetuating poverty and stifling human development in rural areas.

2.4.7 Disasters and conflicts

Disasters and conflicts have an impact on water resources and related ecosystems by reducing their quality, quantity or both. Disasters and conflicts reduce water security by compromising the physical infrastructure needed to access water, sanitation and hygiene services, such as treatment plants, drainage systems, dams, or irrigation channels. Conflicts and disasters may impinge directly or indirectly upon the social capital and human resources needed to run water-related infrastructure, along with the governance, social or political systems that keep water utilities functional and water services accessible (Donnelly et al., 2012).

2.4.8 Low community resilience to cope with stresses

The context of water security is constantly changing. Demand for water may increase as a result of population growth and economic activities. Supplies of water may decrease due to climate change. This constantly changing scenario requires the local communities to cope and respond to increasing insecurity. However, communities with fragile livelihoods, fragile coping strategies, limited financial resources, and limited technical and adaptive capacity are more vulnerable to stresses on their water supplies. They may lack secure water supply infrastructure, services and management capacity.

2.4.9 Complex hydrogeology and challenging terrain

Complex hydrogeology and challenging terrain make development of water resources difficult. Good supplies of groundwater cannot be found everywhere, its occurrence being very much dependent on local hydrogeology. Borehole drilling will not always locate groundwater and drilling success rates vary from place to place. In Sub-Saharan Africa, 50% of the rural population lives on crystalline basement terrain which may or may not have fractures or weathered zones where water is stored (MacDonald and Davies, 2000). This means the siting of wells is not always straightforward and requires investigation. Volcanic rock formations, where the incidence of groundwater is highly variable, underlie some of the poorest and most drought stricken areas of Africa (MacDonald et al., 2011). In mountainous regions it can be difficult to access groundwater using wells and boreholes because the terrain constrains drilling rig access. Instead, water supplies from springs can be piped by gravity to users. The ability of groundwater to meet the demands placed upon it is related to the volume of storage present in the aquifer and the rate at which groundwater can move through the aquifer. Hazardous levels of naturally occurring arsenic are present in groundwater in certain areas such as the alluvial and deltaic aquifers of Bangladesh, north-east India and the Indus Valley of Pakistan. Hazardous levels of naturally occurring fluoride are present in groundwater in parts of India, Ghana and the East African Rift Valley. Hydrogeological and terrain factors combine with hydro-chemical aspects to influence the quantity, quality, reliability, manageability and in some cases where drilling success rates are low, affordability of improved water supplies.

2.5 Concluding Remarks

The term water security captures the dynamic dimensions of water and water-related issues and offers a holistic outlook for addressing water challenges. Achieving water security requires allocation among users to be fair, efficient and transparent; that water to satisfy basic human needs is accessible to all at an affordable cost to the user; that water throughout the water cycle is collected and treated to prevent pollution and disease; and that fair, accessible and effective mechanisms exist to manage or address disputes or conflicts that may arise. From the proposed definitions it can be said that the concept of water security lies on five main pillars – availability of adequate and safe water, accessibility to adequate and safe water, water for productive purposes like agriculture and fishery, protection from uncertainties like in climate and water for protection of the surrounding environment. The concept operates at all levels, from individual, household and community, to local, sub-national, national, regional and international settings, and takes into account the variability of water availability over time. Many factors contribute to water security and range from biophysical to infrastructural, institutional, political, social and financial – many of which lie outside the water realm. As most of the studies on water security has been conducted at international or national levels, the need for more narrowed focus is felt. Though urban water security has been included as a dimension, water security in rural areas has been mostly covered under water security for productive uses like agriculture. However, rural areas are often distinctly different from urban areas with respect to governance, lifestyle of people, landscape, hydrology, hydrogeology etc. Hence a separate outlook of water security is required for rural areas to understand the overall concept and functioning of water security and help in appropriate policy making process. Another important part of water security, groundwater, has been largely ignored in the literatures. Role of groundwater in ensuring water security, especially in rural areas, needs to be explored and included in the policy.

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CHAPTER 3

WATER SECURITY IN RURAL AREAS

"When the well's dry, we know the worth of water."

Benjamin Franklin

CHAPTER 3: Water Security in Rural areas

This chapter presents a detailed review about the status of water security in rural areas. The lack of water security assessment studies and, more specifically, in localized rural areas have been largely observed. Hence, detailed discussion on inter-related concepts like droughts, water scarcity, and water shortage have been conducted in this chapter. The impacts of climate change on water security and rural adaptation to water insecurity has also been discussed. Collectively, billions of dollars have been invested in the provision of rural water supply systems in developing countries like India over the past three decades. Although progress is being made and rates of coverage are increasing, water supply systems are reported to be poorly maintained and eventually break down, leaving them with an unreliable and disrupted water supply. In this chapter, the historical development of rural water supply in India and, various schemes proposed and implemented has been discussed in brief. An attempt has been made to highlight the fund allocation under various Five Year Plans. The chapter concludes by illustrating the relationship between water security, adaptation and rural administration and tries to explain the scope and function of rural administration in ensuring water security.

Outline of the chapter

3.1 Introduction

Nearly half of the world's total population, approximately 3.3 billion people, lives in rural areas. The overwhelming majority of this population (3.1 billion people, or 91.7% of the world's rural population) live in less developed or least developed countries (UN DESA Population Division, 2013) (**Figure 3.1**). Rural dwellers also account for about 70% of the developing country's poor people. IFAD (2010) finds that nearly 1.2 billion poor people (living on $1.25 or less each day) lead out their lives in rural areas – representing some 75% of those in extreme poverty globally (Dasgupta et al., 2014). In developing countries as well as developed countries, the rural is defined as the inverse or the residual of the urban (Lerner and Eakin, 2010). Rural areas in developing countries are characterized by a dependence on agriculture and natural resources; high prevalence of poverty, isolation, and marginality; neglect by policymakers; and lower human development. The rural poor are usually marginalized smallholders who depend partly on subsistence production (mostly not sufficient to sustain their livelihoods) and partly on cash income from selling surplus, from wage labour (mostly not sufficient and not reliable either), and, increasingly, from remittances. They are also the landless people, relying on seasonal jobs as farm workers and on informal non-farm income sources. Despite the diversification of rural livelihoods and increasing urbanization, at least half of the poor people are expected to remain in rural areas by 2035, and a significant number of them will depend on smallholder farming as their main source of livelihood (IFAD, 2001).

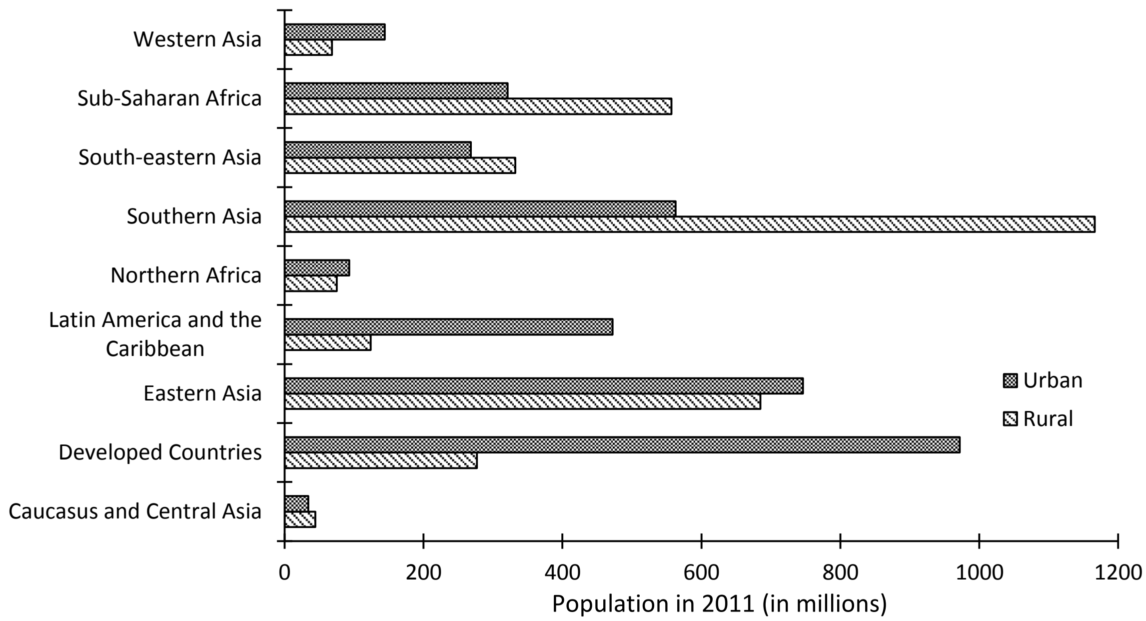

Figure 3.1 Distribution of rural population to urban population across various regions of the world (*Data source: UN DESA Population Division, 2013*)

Water in rural areas “means a fundamental shift beyond considering water as a resource for food production to focusing on people and the role water plays in their livelihood strategies and overall well-being” (WWAP, 2006); and implies a multiple-use perspective (Molden, 2007). Apart from access to sanitation and clean drinking water, the world’s 850 million rural poor also lack access to water for agricultural production, which is usually their primary source of income. Without access to improved agricultural water management, poverty in these regions will persist. Any water intervention needs targeting not only according to farming systems but also according to socio-economic characteristics of the area. Identifying different categories of rural dwellers, their needs, farmers and rural workers according to the level of their integration into the local economies is necessary in order to ensure the effectiveness of interventions. Focusing on women (and the elderly who stay in the village) and taking their specific assets, constraints and coping strategies into account is of paramount importance in ensuring the success of water interventions in rural areas. Although water-scarce areas do not represent a large share of the world’s population in absolute terms, semi-arid areas and dry sub-humid climates such as savannahs and steppe ecosystems are hosts to many malnourishment hotspots in which rainfed agriculture is the primary source of food, and where water scarcity limits crop growth (Molden, 2007).

The plights faced by rural communities have been a part of the development agendas of different international organisations, governments and local communities over the years. Since the 1950s rural issues have oscillated in and out of vogue in development debates (Jerve, 2001). During the 1970s and 1980s development had a strong rural emphasis. However, the last two decades of the 20th century, by contrast, were conspicuous for their limited attention to rural matters (ILO, 2011). Only recently have rural issues resurfaced as priority policy areas. There is a great need to review and understand rural challenges to evaluate what works, where it works, and why. Faced with water scarcity, agricultural and non-agricultural uses of water are increasingly interdependent in rural areas. Hence, there is an urgent need to bridge the gap between the irrigation and domestic water supply sectors to ensure water for food and water for drinking and health in rural areas.

3.2 Status of Water Security in Rural Areas

Water security, as mentioned in Chapter 2, is quite a recent concept. Since water security is mostly a political issue it tends to be viewed from a composite national perspective (Brown et al., 2013). Thus, to date, the concept has been principally applied at the national scale and sometimes even at global or continental scale (Vörösmarty et al., 2010) using parameter indexation to arrive at a 'security score' whose primary objective is to provide an incentive for national governments to invest in water-resource management measures. Let alone rural scale analyses, water security studies have been seldom carried out a local scale. Instead substantial amount of literature focusses on the status and impacts of drought and water scarcity on agriculture and domestic water needs. Drought can result in scarcity of both surface and ground water sources and has devastating effects on crop production and rearing of livestock. Water scarcity can impose a major constraint on agricultural productivity and rural poverty reduction. In South Asia, where millions of small landholders depend on irrigated agriculture, drought drastically impacts river-flow and groundwater, the backbone of irrigation and rural economy (Nellemann et al., 2009). In addition, vulnerability of rural people to water scarcity remains high due to a combination of highly variable and erratic precipitation; poor development of hydraulic infrastructure, management and markets; non-conducive land and water governance; and a lack of access to water for domestic and productive uses.

In 2015, 663 million people still use unimproved drinking water sources like unprotected wells, springs and surface water. Nearly half of these population using unimproved water sources live in sub-Saharan Africa, while one fifth live in Southern Asia. It is estimated that 79% of the people using unimproved water sources and 93% of the people using surface water live in rural areas (UNICEF and WHO, 2015). The use of surface water stands at a surprisingly high 3% of the global population, or 187 million people. Most of these people – 94% – are rural inhabitants. In fact, 19 per cent of rural dwellers in sub-Saharan Africa and 39 per cent of rural residents in Oceania rely on surface water for drinking and cooking (UNICEF and WHO, 2015). For groundwater, the number of people withdrawing it through boreholes (which are usually hand pump-operated) grew from 1 billion in 1990 to 1.3 billion in 2010. Eighty per cent of borehole users, almost a billion people, are in rural areas, demonstrating the importance of groundwater to rural life. While boreholes offer significant advantages over dug wells in terms of water quality, many boreholes with hand pumps still impose a considerable burden on users in terms of the time and effort needed to collect the water (UNICEF and WHO, 2015).

Assessments invariably use physical water scarcity to appraise the hydrological facet of water security, relying on renewable freshwater resources data (defined by measured river discharge and estimated groundwater recharge), which results in the role of groundwater being largely ignored (MacDonald et al., 2012). In principle, the existence of aquifers considerably increases water security, since the large volume of groundwater stored within aquifers can be used to buffer the effect of drought on surface water supplies (Foster et al., 2013). Groundwater plays a significant role in meeting water demand in the rural areas across the world. The development of groundwater has underpinned efforts to reduce poverty and promote sustainable livelihoods. Since groundwater responds slowly to changes in rainfall, the impacts of droughts are often buffered (Calow et al., 1997). Groundwater is generally microbiologically uncontaminated and to a certain extent naturally protected from pollution. The resource is relatively cheap to develop, since large surface reservoirs are not required and water sources can usually be developed close to the demand (UNEP, 1996). These characteristics make groundwater well suited to the more demand responsive and participatory approaches that are being introduced into most rural water and sanitation programmes.

India is a groundwater-dependent nation. Even at conservative estimates, 85% of rural drinking water in India is derived from wells (The World Bank, 2010). With nearly 88% of the total annual groundwater drawn from all the wells in India being used for irrigation (IDFC Foundation, 2013), it is estimated that nearly 700 million Indians who live in Indian villages, almost entirely depend upon groundwater for their daily needs (Kulkarni et al., 2015). However, indicative data drawn from various sources shows that ground-water contamination has emerged as a threat to drinking water security in many parts of India (Krishnan, 2009). Groundwater exploitation and contamination have emerged across a diverse range of agro-climatic and hydrogeological conditions, with nearly 60% of the districts in India showing evidence of either depletion or contamination or both. Localized depletion, resulting in falling groundwater levels in the immediate vicinity of a well or borehole, or group of sources, is a major problem. This is most likely to occur where the demands being placed on a groundwater source are high, and where the transmissivity of the aquifer is low. Increased stress on a groundwater source during drought also makes a failure of the pump more likely. Prolonged pumping throughout the day can put considerable strain on the pump mechanism leading to breakdowns, especially if water levels are falling and pumping lifts increasing. The result may be increased demand on a neighboring source, and thus increased stress (and probability of failure) on that source as well. The problem may be exacerbated by the cessation of maintenance activities as relief drilling programs take priority.

Water security is one of the key challenges under climate change as water resources are highly vulnerable to continuously changing climatic pattern. Water is not only greatly affected by climate change, but is also a core component of climate. The hydrological cycle includes processes such as evaporation and precipitation that are predicted to shift with climate change, and can have important implications for fresh water supply for drinking water, rain-fed agriculture, groundwater supply, forestry, biodiversity, and sea level. Arnell et al. (2004)

observed that climate changes increases water resources stress in some parts of the world where runoff decreases, including around in Mediterranean, in parts of Europe, central and southern America, and southern Africa. In other water stressed parts of the world, particularly in southern and eastern Asia, climate change increases runoff. This increase tend to appear in wet season and extra water may not be available during dry season. For most poor farmers and rural communities in developing countries, especially African and Asian, there are urgent needs to understand the dynamics of local climate and make predictions to respond to climate variability and change. Even a small increase in local temperatures could lead to reduced crop yields for those living at lower latitudes, especially in seasonally dry and tropical regions. More frequent and extreme weather events, such as droughts and floods, are expected to make local crop production even more difficult. The economies of most developing countries depend heavily on climate-sensitive sectors such as water, agriculture, fisheries, energy and tourism, climate change therefore poses a serious challenge to social and economic development in developing countries (Munang et al., 2013). At the continental level in Africa, analysis of existing rainfall and recharge studies suggests that climate change will not lead to widespread catastrophic failure of improved rural groundwater supplies, but it could affect a population of up to 90 million people, as they live in rural areas where annual rainfall is between 200 and 500 mm/yr., and where decreases in annual rainfall, changes in intensity, or seasonal variations may cause problems for groundwater supply (MacDonald et al., 2009). At higher resolution, groundwater resources are threatened (e.g., in South Africa; Knüppe, 2011), and multiple water crises are expected to result from the increasing demand, further affecting people in rural areas (Nkem et al., 2011). Climate change is expected to impact water resources in the Asian region in a major way. Water resources will come under increasing pressure in the Indian subcontinent due to the changing climate. Changes in climatic conditions will affect demand, supply and water quality. The moist sub-humid and dry sub-humid areas are more sensitive to climate change, whereas humid areas are less sensitive. **Table 3.1** demonstrates the climate change impacts on water resources over selected basins and regions in India during the next century.

3.3 Rural Adaptation to Water Insecurity and Climate Change

Several studies have shown the importance of adaptation strategies that rural people can engage in to cope with unseen changes around them including climate change (Adger et al., 2003; Hulme and Shepherd, 2003). Adaptation is a planned approach that deals with adjustment to socio-economic and ecological systems in response to changes around them and its consequences (Gallopin, 2006). Resource dependent communities, historically, have managed weather-dependent natural resources such as forestry, fish stocks, livestock and water resources, experiencing collective adaptation practices (Adger, 2003; Agrawal, 2001; Alexander et al., 2010).

Table 3.1 Climate change impacts on water resources over India during the next century (Mall et al., 2006)

Region/Location	Impacts
Indian Subcontinent	Increase in monsoon and annual runoff in the central plains; no substantial change in winter runoff; and increase in evaporation and soil wetness during monsoon on annual basis.
All India	Increase in potential evaporation across India.
River Basins of India	General reduction in the quantity of runoff
Damodar Basin	Decrease in river flow.
Central India	Basin located in a comparatively drier region is more sensitive.
Kosi Basin	Decrease in runoff by 2-8%.

However, practiced strategies by rural communities are targeted to respond to short term shock events rather than as planned initiatives (Nuorteva et al., 2010), are autonomous and reactive rather than strategic (Bates et al., 2008), and generally applied in socio-economic sectors where capital investment is low (Sohngen and Mendelsohn, 1998). The literature suggests that the local governments and communities often lack capacity to deal with the catastrophic disasters and hence there is a need to enhance their capacity (Ivey et al., 2004). This signifies two aspects. Firstly to improve the capacities of local communities and secondly to improve the capacities of local governments including the states which are chronically drought prone. Bundled approaches are known to facilitate better adaptation than individual adaptation options. Documented examples of rurally managed practices are mostly related to crop diversification, irrigation, water management, disaster risk management and providing insurance (IPCC, 2007). Observed and projected risks are more profound where livelihoods of rural populations are primarily dependent on natural resources (Agrawal and Perrin, 2008; IPCC, 2007). Emerging evidence indicates that adaptation and coping strategies by the poor in developing countries are highly varied and local-level studies are needed for development policies to be effective (IPCC, 2007).

Studies on adaptation to water insecurity are not available at large. On the contrary, substantial amount of studies have been carried out on adaptation to drought and water scarcity. However, agricultural water management has been largely focussed upon under adaptation studies to drought and water scarcity as household income in rural areas are mostly dependent on agricultural activities. Mitigating drought and water scarcity is time consuming, difficult to implement and often requires huge investment. Significant amount of literature has stressed for the greater role of local communities in decision making and in prioritization of adaptation options. Community-based approaches have been suggested to identify adaptation options that address poverty and livelihoods, as these techniques help capture information at the grassroots (Aalst et al., 2008), and help integration of disaster risk reduction, development, and climate change adaptation, connect local communities and outsiders (Aalst et al., 2008), address the location-specific nature of adaptation, help facilitate community learning process, and help design location specific solutions. Various forms of adaptation strategies can be classified, including anticipatory (planned), reactive (autonomous), demand and supply management, structural and non-structural and, hard and soft (IPCC, 2001). Planned adaptation requires government intervention, whereas autonomous adaptation occurs through private agents (Seo, 2011). A planned approach is seen as more efficient and more effective than a reactive approach. In developing countries most adaptation measures are reactive. Most of the literature found the use of new crop varieties and livestock species, crop and livelihood diversification, changing planting dates, planting trees, irrigation, soil and water conservation, and migration are the most common adaptation measures in agriculture for addressing drought and climate change (Hisali et al., 2011; Deressa et al., 2009; Mertz et al., 2009). On the other hand, walking farther, limiting water use, using unimproved water sources and change in food habits are some of the measures that have been adapted at the household level to cope with water scarcity and drought. The published studies demonstrates that there is no single approach to drought adaptation, nor does one solution fit all regions or countries.

Adaptation is location specific and depends on many socio-economic and agro-ecological factors, and climate and weather conditions called determinants of adaptation. However, ascertaining the exact factors that influence adaptation choices, whether environmentally, climatically or socio-economically driven, is extremely difficult (Adger et al., 2005). Dealing with water scarcity requires a complementary approach of supply and demand management as well as on-farm and off-farm measures. Importantly, adaptation strategies can be framed or implemented not only at temporal scales, but can also have a range of spatial scales, from local to regional and to national. Appropriate adaptations foster resilience and decrease vulnerability to multiple threats. Despite a large volume of literature on water scarcity and drought, most studies are at regional and national levels, and from a sectoral perspective, and are not farm or household specific. Although such studies are important to design mitigation strategies, these are ‘less relevant in terms of providing critical insights for effective adaptation strategies at a household level’ (Di Falco et al., 2012).

Different types of barriers are identified to result in the incapability of communities or individuals to adapt to the changing conditions. Barriers are ‘‘obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritisation, and related shifts in resources, land uses, and institutions’’ (Moser and Ekstrom, 2010). As shown in **Figure 3.2**, limits and barriers to adaptation can be mainly divided into three main groups: Human and informational, Social and Natural barriers. Ecological and physical constraints constitute the natural limits to adaptation. These include ecosystems thresholds and resilience, to geographic and geological limitations, and restrictions in resource allocation. The second group is identified as human and informational resource based limits and barriers to adaptation. These limits can consist of, for example, the various spatial and temporal uncertainties associated with forecast modelling, low levels of awareness and information amongst policy makers of the impacts of climate change, as well as a lack of information of how best to facilitate and implement adaptation interventions (Adams et al., 1998). Such barriers may arise due to a combination of knowledge, technological and financial limitations, with obvious implications for monitoring, forecasting and the designing of appropriate adaptation intervention. The third group, social barrier, can be broadly categorised as normative; cognitive, and; institutional structure and governance (Jones and Boyd, 2011). Normative barriers relate to the ways in which cultural ‘norms’ influence how individuals respond to climate stimuli, such as persistence with traditional forms of coping (Jones and Boyd, 2011). Cognitive barriers refer to how psychological and thought processes influence how individuals react to existing or anticipated climate (Jones and Boyd, 2011). They include: denial and apathy, helplessness, uncertainty and acceptance (Stafford-Smith et al., 2011); a lack of trust in and respect for experts and authorities (Gifford, 2011), and lack of knowledge of impacts from changes around them and adaptation responses (Moser and Ekstrom, 2010). Institutional and governance barriers relate to how the organisation and structure of interactions influence how individuals are allowed to adapt to change (Jones and Boyd, 2011).

These barriers and the linkages between them are found to be significantly prominent in rural areas, especially for people living in resource dependent and impoverished regions. When high inequity is observed in the allocation and distribution of resources like water and land in many rural areas across the world, there is a high lack of awareness, knowledge and technology among the rural communities on how to react to the changes around them. Due to the unavailability of resources including financial, social and human, the communities suffer from various psychological blockages that don't let them to think positively and work towards their own upliftment. In addition, there are high rates of corruptions, political unrest and institutional loopholes that often blocks the successful implementation and practice of adaptation in various parts of rural areas, and also fails in establishing the trust among community.

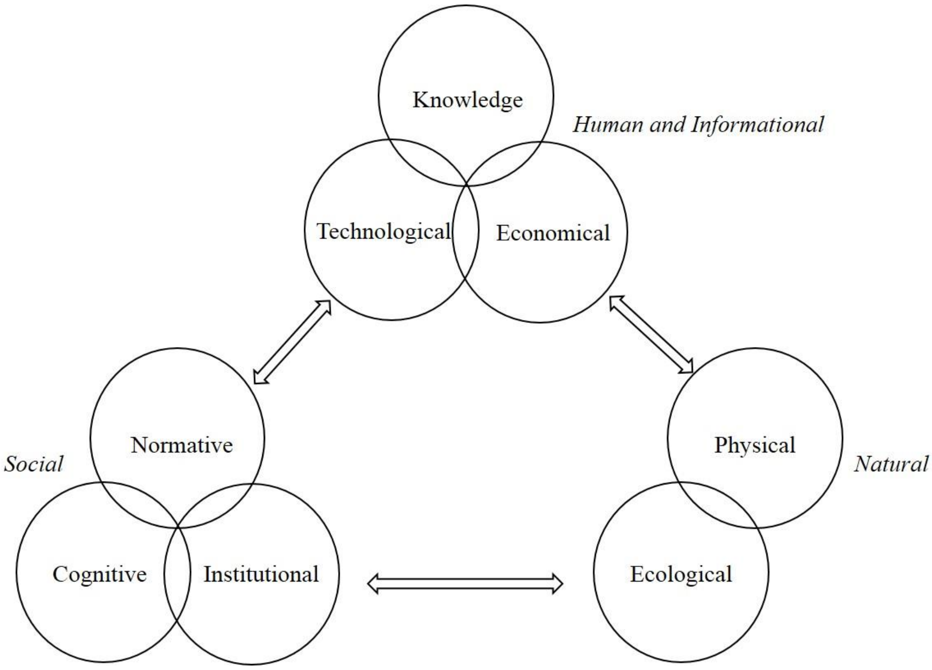

Figure 3.2 Limits and barriers to adaptation and their linkages
(*Adapted from Jones and Boyd, 2011*)

3.4 Rural Administration and Water Supply and Management

Administration constitutes connections, channels, and gates of entry, which influence the outcome of problem definitions, policy options, and concepts embraced by various actors and organizations in the public domain. Role of administrative structures is confined to other policies and social issues rather than the water sector, which for instance has to take account of a political opportunity structure for more equitable distribution of water resources and management in various parts of the world including India. Yet, administrative structures can be seen not only as channels that carry policy options, but also restrictions, or barriers to policy processes. Institutions distribute resources, which may strengthen or weaken the power position of particular actors and organisations. The increasing supply-demand gap intensifies conflicts within regions and economic sectors demonstrate the inherent limitations of the existing administrative organization dealing with resource allocation and management. Allocation and conflict resolution mechanisms have to be either created or strengthened both in the legal and policy spheres.

Local government capacity research has a long history in the public administration field (e.g., Cohen, 1995). Gargan (1981) defines a local government's capacity as "its ability to do what it wants to do". In this way, a local agency can be said to have, or lack, capacity to perform a variety of functions (e.g., encourage economic development, or adapt to drought). Grindle and Hilderbrand (1995) identify five dimensions of public sector capacity: the action environment (social, political, and economic milieu), the institutional context (government policies, procedures, rules and regulations; roles and responsibilities; financial support), the task network (communication and interactions among all organizations involved in a particular task, e.g., water management), organizations (resources, goals, activities, leadership), and human resources (training, recruitment, utilization, retention). In case of rural areas, water being a state subject, combined effort of all these factors play an important role in water supply and management. For impoverished people, with limited economic, physical and social capacity, dependence on local administration is immense and highly significant, mainly for countries like India. With a complex administrative set up, the demands and opinions of local communities often fail to reach higher administrative strata. Here come the functionality of local rural government who channelize the opinions and demands of impoverished, often illiterate and highly resource dependent rural communities to higher administrative level and, implements and monitors the development in a rural area.

3.4.1 Structure of Rural Administration in India

A formal system of local governance, though a very weak one, was introduced in the country during the British period. After independence, the need for having a system of local governance in the rural areas was felt and the same was also accepted as one of the Directive Principles of the Constitution; the Article 40 of which says that "The State shall take steps to organize village Panchayats and endow them with such powers and authority as may be necessary to enable them to function as units of self-government." In view of the need for establishing a system of local governance, i.e., the Panchayats, in the rural areas of the entire country, the Constitution was amended in the year 1993 and that made the Panchayats to be the third stratum of government (along with Municipalities in the urban areas) of the country. The Constitution of India provides for reservation of seats for the Scheduled Castes (SC) and the Scheduled Tribes (ST) in proportion to their share of population in the Panchayat area. In India, there are around 2.4 lakh Panchayats and 2.8 million elected representatives, over 30% of whom are women, 19% are SC and 12% are ST (Alok, 2011). Every State has to pass its own law on composition of Panchayats, representation to those bodies, system of election as well as how those bodies will function. The core functions of the Panchayats include provisions in drinking water supply, construction of roads, culverts, bridges etc., rural electrification, health and sanitation, and maintenance of community assets. To understand the constituents of Panchayats and their function well, the next section discusses the existing Panchayat West Bengal.

3.4.1.1 Panchayat System in West Bengal

A three-tier Panchayat system was envisaged in the West Bengal Panchayat Act 1973. The first general election for the selection of Panchayat system members took place in 1978 and, after that, general election for the selection of Panchayat members' takes place every five years. The members are selected directly for each tier from respective constituencies. The lowest tier or *Gram Panchayat* (GP) is constituted for a cluster of villages; *Panchayat Samiti* (PS) is constituted at Block level and, the highest tier or *Zilla Parishad* (ZP) is constituted at the District level. The GP or village council covers around 10-12 villages and is headed by *Pradhan* (Deputy) and *Upa Pradhan* (Vice Deputy). At the ground level, the GP is a very powerful and influential body, yielding effective control over substantial resources and political power. Each GP have at least 5 and maximum 30 members. Each PS covers, on an average, about 115 villages and an elected *Sabhapati* (President) and *Saha Sabhapati* (Vice President) heads the PS. The Block Development Officer (BDO) is an executive officer to the *Panchayat Samiti*. A *Panchayat Samiti* has standing committees to advise it on themes like Finance and taxation; Agricultural production, animal husbandry and minor irrigation; Education and social welfare; public health and sanitation; and Communications and works (Maheshwari, 2010). This provides a direct linkage of the Panchayats with the administration. It also allows a community-elected body to exercise some control over the administration. The head of the ZP, the *Sabhadhipati* and *Saha Sabhadhipati* enjoys the rank of a minister of the State Government. The ZP functions through a network of standing committees on subjects like Community development; Agriculture, cooperation, irrigation and power, animal husbandry; Industries including cottage, village and small scale industries; Education and social welfare; Finance and taxation; and Public health (Maheshwari, 2010). **Figure 3.3** demonstrates Panchayat system in West Bengal. The Panchayats have become the ubiquitous political institution in rural West Bengal through which all kinds of developmental programmes are now being executed in the state.

Gram Sansad is the assembly of all the voters of a polling station and is the forum for direct accountability of the GP to all the people who have selected the members of the GP and it is not a part of the three tier Panchayat system. Meetings of the *Gram Sansad* are to be held twice a year. Proper functioning of the *Gram Sansad* is very important for effective local governance. The *Gram Sansad* will guide and advise the GP in regard to the schemes to be undertaken and identify or lay down the principles for identification of beneficiaries. Participation of villagers in the meetings are important, which is still quite low and on the decline. The other issue is the ability of the people to raise their voice in such meetings and discuss them freely without any fear. Actual scenario, in many of the rural areas of the State, is far from satisfaction because of extreme political rivalry, corruption and law and order problem.

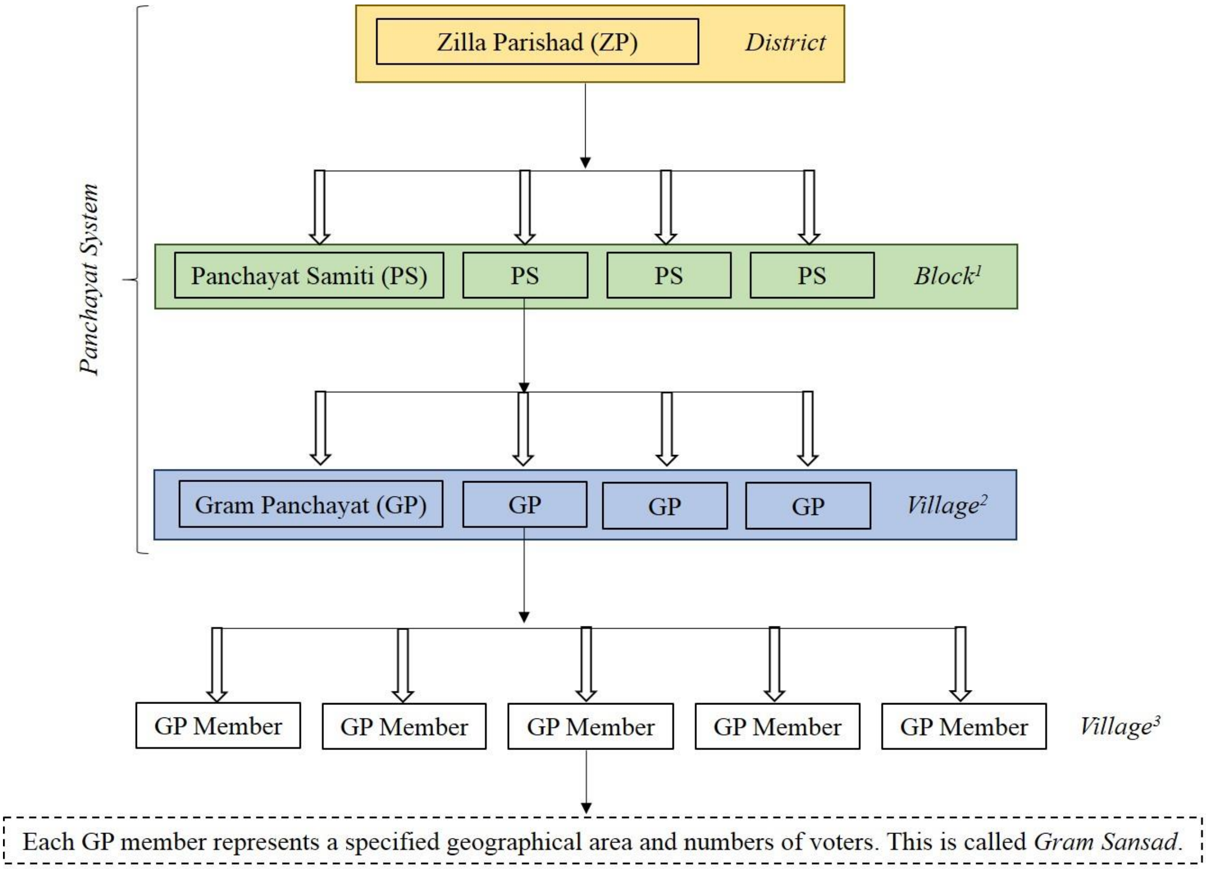

Figure 3.3 Structure of the existing Panchayat System in West Bengal
(*Note.* [1]*: All the PSs within a geographical limit of a district come under ZP;* [2]*: All the GPs within a geographical limit of PS come under it*; [3]: *Each GP member has a specified area and constituency that the member represents, called Gram Sansad.*)

Functioning of the Panchayats. The Act and Rules provide the basic legal framework for function of the Panchayats. Actual functioning of those bodies will depend on the responsibilities assigned to those bodies as well as transferring resources for carrying out those tasks. Such resources not only include fund but also appropriate human resources. Appropriate administrative system including management of finance, capabilities for preparing projects and taking up engineering works etc. should also be in place for the Panchayats to function efficiently. The actual devolution of power and authority to the Panchayats depends on the State concerned and therefore varies from state to state. Depending on the local need for development, the Panchayats can always take up any developmental work which has not been assigned to it by the state government with its own resources. The Panchayats have little scope of earning and much of the fund is received from the State and Central Government as grants and for implementation of schemes.

Supplying drinking water is an important activity of the Panchayats and the Panchayats have been entrusted with installation and maintenance of the spot sources of water. Panchayats also play a very important role in surveillance of water quality. As the funds are available at a block level, the *Panchayat Samiti* and *Gram Panchayats* are informed and asked for proposal of schemes. The *Gram Panchayats*, then decide on the various schemes that need to be done for the development of the villages under it. The GPs need to develop the proposal in consultation with local community participation. The schemes proposal are then submitted to the block office for sanction. The block decides the applicability of the scheme and the amount to be sanctioned based on the usability and priority of the work to the local people. Except this, District Planning Committee (DPC) of each district prepares a development plan annually for the district which consolidate the plans prepared by the Panchayats. In the plan, separate schemes related to water sector are included along with the probable time period required for the completion of the schemes, source and amount of fund required and other logistic requirements. The different roles and responsibilities assigned to different institutions are provided in **Figure 3.4**.

3.4.2 Rural Water Supply in India

Traditionally, rural water supply in India has followed a supply-driven approach with access to safe water being considered a social good. The financial and operational limitations of supply-driven approach led to a fundamental policy shift in the ends of 1990s, towards demand-driven approaches. The demand-responsive approach is based on the principles of community participation and decentralization of powers for implementing and operating drinking water supply schemes with the government playing the role of a facilitator. With a large population and high rate of growth, Government of India is still struggling to provide adequate drinking water supply within limited resources.

The scale of problem called for massive central and state government intervention which was reflected both in term of successive Five-Year Plans' priorities and higher plan outlay for this sector particularly for rural water supply programme. Various initiatives were proposed and taken by Government of India to improve water and sanitation facilities under the different Five Year Plans.

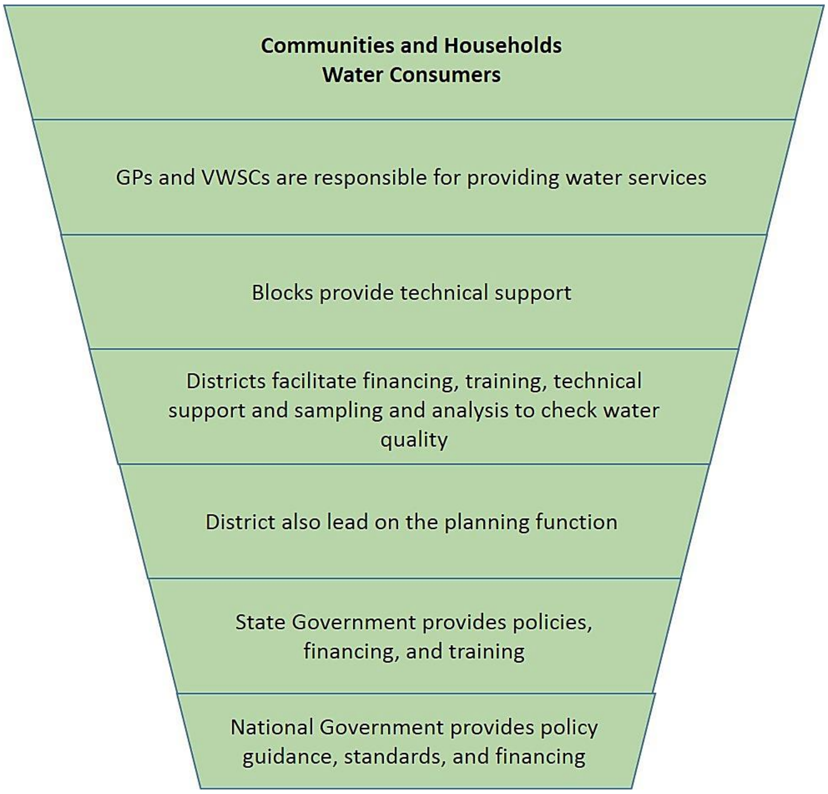

Figure 3.4 Roles and responsibilities of institutions in rural water supply

First Five Year Plan: 1951-56. In the initial stage of the Plan, provision of water supply and sanitation schemes in the States was made from the fund under Community Development works and local government works. The Union Health Ministry announced the national water policy and sanitation programme as part of the health schemes in August-September 1954 under the Plan. The First Plan had made a total provision of Rs. 6 crore for rural schemes to cover the activities during the last 18 months of the Plan period.

The rural works could not make satisfactory progress primarily due to lack of appropriate organisation and trained personnel. Besides, these works had been frequently executed by variety of agencies and had become purely construction projects with little public health education of the villagers in the need for and use of sanitary facilities.

Second Five Year Plan: 1956-61. Rural water supply schemes had been taken up mainly under the programmes for community development, local development, works and welfare of backward classes. These were supplemented by the national water supply and sanitation programme which dealt with the provision of water supply to groups of villages through works requiring a measure of technical skill in design and construction. The programme gave priority to areas of water scarcity and salinity and those in which water borne diseases with endemic were prevalent. A tentative provision of Rs. 28 crore was made for rural water supply.

Third Five Year Plan: 1961-66. Under different programmes, a provision of Rs. 67 crore was available in the Third Plan for rural water supply. This included Rs. 35 crore for the village water supply programmes. The greater part of the amount provided for the village water supply programme intended to be available for backward classes.

In the Annual Plan of 1967-68, states were delegated powers to approve rural water supply schemes with estimates up to Rs. 10 lakh. During the three Annual plans (1966-67, 1967-68 and 1968-69), 478 new schemes at an estimated cost of Rs. 21 crore were taken up.

Fourth Five Year Plan: 1969-74. The ongoing rural water supply schemes were supplemented by the National Water Supply and Sanitation Programme of the Union Ministry of Health. Assistance was given to State governments to establish special monitoring divisions that work with public health engineering departments to prepare technical designs and estimates of rural water supply schemes. In the Annual Plan of 1971-72, rural local bodies had been given powers regarding financing of water supply. The *Zila Parishads* were asked to take up works in all villages where simple measures were to be adopted to solve the problem. For financing the rural water supply during 1972-73, a provision of Rs. 640 lakh was made in the budget. The Accelerated Rural Water Supply Programme (ARWSP) was introduced in 1972-73, to assist States and Union Territories with 100 percent grants-in-aid to implement drinking water supply in villages. The entire programme was given a Mission approach when the Technology Mission on Drinking Water Management, called the National Drinking Water Mission (NDWM) was introduced as one of the five missions in social sector in 1986.

Fifth and Sixth Five Year Plan: 1974-79 and 1980-85. Minimum Needs Programme (MNP) was introduced in the first year of the Fifth Five Year plan. The objective of this programme was to establish a network of basic services and facilities of social consumption in all rural areas within a specified time frame. This plan provided for an expenditure of Rs. 381 crores on rural water supply and sanitation as compared to total of Rs. 289 crores provided in all the previous plans. During the Sixth Five Year Plan the effort was to cover all the problem villages which do not have an assured drinking water source within a reasonable distance, say 1.6 km, and villages endemic with diseases like cholera, Guinea worm etc., and villages where the available water has an excess of salinity, iron, fluoride or other toxic elements. The Sixth plan provided Rs. 128 crores for the improvement or augmentation of existing water supply sources in villages and Rs. 2135 crores for provision of new rural water supply schemes (Alok, 2011).

Seventh Five Year Plan: 1985-90. The rural water supply continued to be a part of the MNP launched in the Sixth Five Year Plan. The Ministry of Water Resources drafted National Water Policy in 1987. Though the Policy has assigned first priority to drinking water, it lacked legislative backing. In the Seventh Plan attempt was proposed to enhance per capita norm for water supply from 40 litres per capita per day (lpcd) to 70 lpcd as recommended by the Estimate Committee. Poor section of the society like Scheduled Caste, Scheduled Tribes and landless agricultural labourers were ensured to have access to this facility. The main objective of the Annual Plan 1990-91 was to provide 40 lpcd water to every individual within the limited resources.

Eighth Five Year Plan: 1992-97. By the end of Eighth Plan, at least one hand pump/spot source for every 250 persons was proposed. Also, ARWSP was renamed Rajiv Gandhi National Drinking Water Mission (RGNDWM) in the existing Plan. The Eighth Plan provided an outlay of Rs. 16711.03 crore of which Rs. 10743.03 crore was under States/UT Plan and Rs. 5968.00 crore under Central Plan for water supply and sanitation programme (Alok, 2011). This works out to 3.85 per cent of the total public sector outlays (Alok, 2011).

Ninth Five Year Plan: 1997-2002. The Ninth Plan envisaged 100 per cent coverage of all habitations with safe water, together with the installation of a quality monitoring and surveillance system all over the country, evolving cost-effective and socially acceptable Operation and Maintenance strategies, re-orienting the structure and functioning of rural water supply planning and implementing agencies and taking measures to ensure sustainability of drinking water. The other priorities tasks were tackling the problems of drying of sources, providing a role for the beneficiaries and Panchayati Raj Institutions (PRIs) in planning and implementing of the water supply facility.

Moreover, the Plan focused on: larger external assistance (higher priority to rural water supply and sanitation) need to be provided to augment State resources; transfer the responsibility of at least operation and maintenance of Rural Water Supply to the PRIs; adoption of improved low cost technology to save cost of construction and maintenance; free supply of water to people in rural areas should be discouraged and some user charges collected through community participation; private sector participation in construction and maintenance of water supply and sanitation; involvement of NGOs and community be encouraged by the State governments; and water supply links with water-shed development programmes should be made more stronger for better sustainability of drinking water sources.

Tenth Five Year Plan: 2002-2007. The new policy initiated in April 1999 has asked the States to implement 'Sector Reform' measures. Emphasizing the need for taking up community based rural water supply programmes and to open up the reform initiatives in the rural drinking water supply sector, Government of India has introduced a programme called Swajaldhara. The strategic elements of Swajaldhara are: (i) demand driven and community participation approach; (ii) Panchayats/communities to plan, implement, operate, maintain and manage all drinking water schemes; (iii) partial capital cost sharing by the communities upfront in cash; (iv) full ownership of drinking water assets with Gram Panchayats; and (v) full operation and maintenance by the users/Panchayats. The unique feature of the scheme is that the rural people should feel as the owners of the Scheme. The 10th Five Year Plan was an initiative to implement the policies in an effective manner.

Eleventh Five Year Plan: 2007-2012. To 'provide clean drinking water for all by 2009 and ensure that there are no slip-backs by the end of the Eleventh Plan' is one of the targets of the Eleventh Five Year Plan. The major issues which are prioritized during this period are the problem of sustainability, water availability and supply, poor water quality, centralized vs. decentralized approaches and financing of Operation and Maintenance cost while ensuring equity in regard to gender, socially and economically weaker sections of the society, school children, socially vulnerable groups such SC, ST, Minority and people residing in LWE districts etc. The rural water supply guidelines have been revised in 2009 and is renamed as National Rural Drinking Water Programme (NRDWP). The Plan coincides with Bharat Nirman Programme under which it is proposed to provide safe drinking water to all habitations. Total allocation during 11th plan is Rs.28190.16 crore and Rs.26105.33 crore expenditure is reported.

Twelfth Five Year Plan: 2012-2017. The Ministry of Drinking Water and Sanitation administers the NRDWP, and the Total Sanitation Campaign through which support is extended to the states for implementing rural domestic water supply and sanitation schemes. One of the important recommendations is to aim to cover at least 55% of the total rural households with piped water supply, with house connection as far as possible. A mix of all the systems, such as piped sources, spot sources, water harvesting systems, protected sources etc.

according to the feasibility should be provided. Piped water supply or improved spot sources within 100 metres radius and within 10 metres elevation in hilly areas from the dwelling unit is proposed. It is recommended that Govt. of India focus its funding on piped water supply with a small percentage for hand pumps in difficult areas so as to provide higher levels of service. States can continue to provide hand pumps out their own resources.

The 12th Five Year Plan emphasize on building capacity of local communities to monitor and measure their water resources, prepare water budgets and self-regulate demand for water from irrigation and industry to ensure drinking water security. It also focussed on Aquifer Management Plans by villages and Panchayats, and sustainability of drinking water sources by convergence with MNREGS, NRDWP and IWMP. Participation of the beneficiaries in water supply schemes should be ensured right from the planning stage. Also, enabling support and environment should be provided to the Village Water and Sanitation Committees (VWSCs), Panchayati Raj Institutions and local communities to manage and carryout operation and maintenance of at least 60% of rural drinking water sources and systems, by devising suitable mechanisms locally adaptable to the community with guidance and assistance from the Block Resource Centres, District Water and Sanitation Missions, State Resource Centre and Regional/District Resource Centres.

Similar to rural drinking water supply, there has been a massive increase in plan expenditure on irrigation over the last 60 years. The Government of India initiated a Centrally Sponsored Command Area Development Programme (CSCADP) in December 1974 to improve irrigation potential utilisation and optimise agricultural production from irrigated land through integrated and coordinated approach of efficient water management. Accelerated Irrigation Benefit Programme (AIBP) was launched in 1996-97 to provide central assistance in the form of loan to State Government to complete those ongoing irrigation projects which were costing Rs.1000 crore or above and were in advanced stage of completion. Minor Irrigation schemes contribute a major share in the growing irrigation across the country accounting for about 65% of the total Irrigation Potential Utilised. Irrigation schemes using either ground water or surface water and having a Culturable Command Area of less than 2000 hectare individually are categorized as Minor Irrigation Schemes. The schemes have been categorized broadly into five major types- dug well, shallow tube well, deep tube well, surface flow schemes and surface lift schemes. The State Governments provide assistance in installation of such schemes which confines mainly to technical guidance, custom service for boring and arrangements for credit facilities at reasonable rates of interest. The subsidies are also made available for installation of these schemes to weaker sections of farmers. The construction, operation and maintenance of these schemes are done by the farmers themselves. Major and Medium Irrigation outlays rose from Rs.376 crore in the First Plan to a projected outlay of more than Rs.165,000 crore in the Eleventh Plan, amounting to a total expenditure of around Rs.351,000 crore over this period. Major irrigation projects normally takes 15–20 years while medium projects should take 5–10 years for completion. Against these norms, a large number of major as well as medium projects are continuing for 30–40 years or even more. This reflects poor project preparation and implementation as well as thin spreading of available resources. Currently, there is a spill over of 337 projects—154 major, 148 medium and 35 Extension, Renovation, Modernisation (ERM) projects into the Twelfth Plan from previous Plan periods.

From the analysis of policy and programmes of rural water supply and sanitation, it is evident that sincere efforts have been made by the government to overcome both the problems. Enhanced funds were earmarked under the Five Year Plans but on the whole, limited success could be obtained at the operational level. No doubt, a variety of programmes were launched to cope with the problems but their implementation could not yield commendable results as the goal of providing safe drinking water and irrigation for all still away and the sanitation problem has not reduced significantly. Supply-driven programs continue to dominate, accounting for over 85 percent of the fund flows. However, serious inadequacies on water supply schemes like less hours of water supply than the designed hours and failed supply during summer has been a major concern across the rural areas in the country. In supply-driven programs, there are large institutional costs, ranging from 15 percent to 50 percent. The funds for expenditure on infrastructure are limited in supply-driven programs, due to large institutional costs and the cost of providing for the operation and maintenance of water schemes. In contrast, most of the funds available under the demand-driven programs are converted into infrastructure, as the cost of institutional arrangement is low. Despite the relatively low institutional cost of demand-driven programs and the advantages of operation and maintenance cost recovery from beneficiaries, a substantial portion of the fund flow continues through supply-driven programs, with ARWSP, MNP, and other such programs. The share of Swajaldhara and the Sector Reform Project (demand-driven programs) is very small, about 6 percent. Much more efforts are required on the part of the Union and State governments, PRIs, NGOs and other community organizations. Special attention on the part of the State government with strong political will is required to get the programmes implemented effectively by devolution of requisite powers to the PRIs. Lack of community involvement in the Panchayat System is also one of the major identified factors that lead to failure of the schemes and projects.

3.5 Linkages among Water Security, Adaptation and Rural Administration

There is a growing interest in the capacity of people, communities, and administration to effectively manage water resources, both now and into the future. The concerns relate not only to the inherent challenges presented by the critical and inherently variable environmental resource like water, but also to the belief that climate may be changing—and along with it, the availability of water. Hydrologic variability introduces risk and uncertainty to the task of balancing competing interests in, and demands for, water. Climate change compounds this challenge and raises the stakes in local water management. At the same time as local water managers struggle to balance supplies and demand for water resources, a second set of changes and uncertainties looms. In many jurisdictions across the world including India, ongoing political and institutional restructuring has resulted in the responsibility and cost of many forms of governance shifting from the state to local people and agencies. Although some local regions have welcomed this redefinition of roles that increased responsibility for both environmental management and development planning, the procurement of resources and expertise needed to undertake these tasks has been more variable. In particular, rural communities may be especially disadvantaged if asked to take on a wider role in water management and planning—especially in the face of changing environmental conditions and institutional arrangements (Krajnc, 2000). As a consequence, "capacity building" has assumed a central place in attempts to assess the prospects for effective water management at many scales, but especially at the local level (de Loë et al., 2002).

To adapt to water insecurity is to make changes that will maintain or improve the ability of a system (e.g., rural water supply) to continue to serve its functions (e.g., domestic water supply) during periods of insufficient supply (Smithers and Smit, 1997). Historically, water users have always had to adapt to climate. In this sector, specific adaptive measures are frequently pursued through planning (e.g., drought contingency planning, watershed planning), demand management (e.g., water conservation, conflict management), supply management (e.g., inter-basin transfers, infrastructure, operations protocols), data management, or public involvement (e.g., education, participatory management). A key criterion for selecting a suitable suite of adaptation strategies is their implementability, i.e. the ability of an organization or community to effectively adopt, or implement, measures. Water management and climate adaptation research contribute knowledge for improving the capacity of local agencies to manage water resources. One practical way forward is through empirical work that identifies adaptation approaches currently used and documents factors that facilitate or impede successes at the local level.

Table 3.2 Factors affecting the capacity of communities to adapt to water insecurity and climate change (*Adopted from Ivey et al., 2004*)

Element of Capacity	Indicator questions
How do administrative arrangements affect capacity?	• Are the roles and responsibilities of higher and local government agencies clear, consistent, and comprehensive? • Are appropriate adaptation activities available to decision-making and implementing agencies as per their roles and responsibilities? • Have higher government agencies demonstrated commitment and support (e.g., financial, political, technical) for local level administration to implement adaptation activities?
How does the nature of the community affect capacity?	• Are community stakeholders aware of the potential impacts of water insecurity and climate change on human and ecological systems? • Are local water management agencies perceived by community stakeholders as legitimate? • Do local water management agencies and related organizations communicate, share information, and coordinate their activities? • Is there an agency providing leadership to local water management organizations? • Are members of the public involved in water management decision-making and implementation of activities?
How do a community's resources affect capacity?	• Are sufficient and secure financial resources available to decide upon and to implement various proposed projects and schemes? • Are adequate staff with appropriate training and technical expertise available to implement activities? • Are information (e.g., about water resources, climate change, and impacts) and technical resources accessible and of appropriate quality?

Indeed, the nature of vulnerability and the prospects and processes for adaptation are likely to be determined in large part by local, place-specific factors (Kelly and Adger, 2000). Locally derived insights hold value for illustrating and understanding better the contested nature of water management in specific locations and can help identify conditions and constraints on effective water management.

The Delft Declaration, proposed in United Nations Development Symposium in 1991, identifies three components of capacity building including an "enabling" set of administrative arrangements, community development (including participation), and development of human resources and organizations (Biswas, 1996). **Table 3.2** illustrates the factors that impact the capacities of communities to adapt to climate change and water insecurity.

Administrative arrangements affect an organization or community's capacity to adapt to hydrologic variability by identifying and defining the roles and responsibilities of core actors in water management. Jurisdiction must be clearly stated and understood in order to avoid overlap and inefficiencies, and to ensure that key management activities are consistently undertaken (Hamdy et al., 1998). Second, in order to prepare for, and adapt to, climatic variability, appropriate tools and adaptive measures must be legally available to decision-making and implementing organizations (Smit and Pilifosova, 2001). In other words, local administrative organizations must have authority to select and implement adaptive measures. Finally, for organizations to effectively implement adaptive measures, they must have political, technical, and financial support from higher government agencies (Chang and Desai, 2001).

Community characteristics relate to the types and intensity of demand for water and to the degree of collaboration or competition for the resource. Key capacity related issues include: public perceptions and attitudes regarding priorities of water use and legitimacy of organizations, communication and coordination among key actors, and the extent of public participation in decision-making and implementation of adaptive measures (Hamdy et al., 1998).

The ability to provide a service, or to implement a program, is constrained or facilitated by *community and organizational resources.* For instance, trained personnel allow organizations to interpret data gathered from external sources and to develop and implement programs and projects. Adequate and secure financial resources also are necessary for development and implementation of adaptive measures. Finally, access to technical resources and current information of appropriate quality is essential for decision-making, planning, and implementation of adaptive measures. In summary, it can be concluded that a sound and functioning local administration along with active participation of water users play a significant role in ensuring water security and minimizing the impacts of climate change on people and communities, especially in rural areas, due to the prevalence of poor and resource dependent people.

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CHAPTER 4

INTEGRATING WATER SUPPLY AND DEMAND, AND ADAPTIVE CAPACITY:

DEVELOPMENT OF RURAL WATER INSECURITY INDEX (RWII)

"The beginning is the most important part of the work."

Plato

Chapter 4: **Development of Rural Water Insecurity Index (RWII)**[1]

This chapter aggregates dimensions that capture multiple aspects of water security in a single or small number of indices that can act as a powerful tool to identify areas susceptible to water insecurity. Proposed Rural Water Insecurity Index is based on water supply and demand dimensions, and adaptive capacity to assess the ability of communities to cope with prevailing water insecurity. The impacts are found to be severe for the poor who live in vulnerable areas including mountains and forests, dependent on natural resource based livelihood and groundwater to meet basic needs, own little land or other physical assets, and have low education and skills. The present study offers valuable guidance to the policymakers providing insights as to where more research or policy interventions should be targeted.

Outline of the Chapter

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4.1 Introduction

Nearly 90% of world's rural population live in developing countries characterized by "a high dependence on agriculture and natural resources, high prevalence of poverty, isolation and marginality, neglect by policy makers, and lower human development" (IPCC, 2014). Due to the strong dependence on agriculture, water is of utmost importance to rural life, and to rural livelihood and income. Physical availability of water, e.g. amount of rainfall, infiltration rate, surface runoff, etc., has been studied across the years. However, measuring and understanding physical factors is a complex method and is, sometimes, beyond the capacity of poor and marginalised population. Secondly, assessing physical availability of water, often, overlooks the economic, managerial, institutional and political inequities which mediate access to the resource (Mason and Calow, 2012). This inequities may lead to water crisis and reduce the ability to manage water related challenges. Hence, there is need for human-focused outlook towards water management that puts an emphasis on livelihoods, especially for the poorest and vulnerable, including women (Mason and Calow, 2012).

As discussed in Chapter 2, water security is an emerging concept. Progress towards water security can be made only if there is a more comprehensive understanding of the interactions among waters' various characteristics and functions. Water is not only a natural resource, but also an economic commodity, *and* a human consumption good or entitlement. Water insecurity originates from a combination of the bio-physical environment, built infrastructure, and institutions or human governance (Zeitoun, 2011; Norman et al., 2010), and can be defined as the lack of capability to obtain water or as lack of entitlement to water (Culis and O'Regan, 2004). Till date, water security has been, mainly, related at national level i.e. the focus is on water availability in a country, transboundary water issues and the investments needed to ensure the availability of safe and sufficient water to the population (Cook and Bakker, 2012). This national level priorities, often, fail to address the requirements at local or household level for achieving water security. While integrative framing of water security is important, as discussed in Chapter 2, Cook and Bakker (2012) argues that narrowed framing is a necessary condition to operationalize water security. Efforts to ensure water security fail because the water policies prevailing in many countries have been narrowly focussing on physical processes and on corrections through infrastructural development to increase water supply provisions (Zeitoun, 2011).

According to Cook and Bakker (2012), the framings of water security are not consistent and tend to vary with context and disciplinary perspectives on water use. This holds true, particularly in a rural context, because water use and its socio-economic relationship with rural communities is completely different from an urban area. Information about how water insecurity varies across space, and the extent to which it relates to various water supply and demand, and socio-economic variables, is imperative to target and prioritize the poor and disadvantaged in various water management and development schemes.

The rural population of India comprises more than 700 million people residing in about 1.42 million habitations spread over 15 diverse ecological regions. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease each year. The resulting economic burden is estimated at $600 million a year (World Bank, 2008). In spite of an expenditure of an estimated amount of Rs.1, 105 billion spent on providing safe drinking water, there is lack of safe and secure drinking water continues to be a major hurdle and a national economic burden. In the context of water supply to rural areas, the conditions on the ground remain far from satisfactory. A significant portion of the water supply infrastructure created does not function or functions much below its design or potential, and has been a cause of slippages experienced by a significant proportion of habitations. In lieu of this, it becomes imperative to assess the existing level of water insecurity in the rural areas, mainly in the less developed and impoverished regions, to identify the gaps that need to be focussed on to improve not only the water scenario but also for the overall development and welfare of the rural communities.

4.2 Research Framework

Water shortages and water quality problems threaten individuals since water is essential for human survival for which there is no substitute. The situation becomes more severe for impoverished people from rural areas who are totally dependent on water not only to meet their daily needs but also their financial status. Most of the studies, carried so far, includes physical aspects of water availability like rainfall, evaporation, soil erodability etc. and does not address the role of groundwater in mitigating growing water demand. However, in most of the rural areas across the world, specifically in developing and least developed countries, data on physical aspects of water availability are difficult to obtain at a local scale. Also, groundwater has been a very important component of water supply considering its vehement use, not only for irrigation but also to meet domestic needs, in rural areas. From the perspective of water management and concept of water security, when the physical system pertain to water supply and demand dimensions, the social system mainly deals with the capacity of communities to cope up, i.e. their adaptive capacity, to the variations in water availability. However, rural water supply schemes are commonly found to be weak in performance in many countries across the world. The quantity of water supply and hours of supply commonly fall short of design, especially in summer. Sizeable sections of households face problems caused by frequent breakdowns, non-availability of daily supply, and insufficient water supply compared to the requirement. Slippages have taken place- habitations once fully covered have later slipped into ‘partially covered’ or ‘not covered’ status for various reasons (water sources going dry or getting quality affected; systems working below capacity due to poor operation and maintenance; increase in population in the habitations resulting in lower per capita availability; and so on). A high proportion of water points are accessed on community-basis, which limits the quantity of water that each beneficiary household can get. In addition, there are problems of seasonal shortage (acute in some regions). A severe decline in groundwater levels has taken place in most states in recent years, adversely affecting sustainability of the drinking water sources.

This chapter is underpinned by the concepts of water security (Chapter 2). Deriving from a thorough literature review and an initial reconnaissance survey, RWII has been developed to analyse the scale of prevailing water insecurity in a rural area (Sullivan, 2011; Sinyolo et al., 2014; Kujinga et al., 2014; Alessa et al., 2008a; Cohen and Sullivan, 2010). The present research framework incorporated Supply Driven Insecurity (SDI) and Demand Driven Insecurity (DDI) along with Adaptive Capacity (AC) to assess the current scale of water insecurity in a rural area (**Figure 4.1)**. In this present context, SDI refers to the level of availability, supply and equitable distribution of both groundwater and surface water to the population under study. DDI intends to measure the current and expected demand of water, through increasing population, sanitation needs, livestock, irrigation etc. Adaptive Capacity has been added to capture the capability of societal systems to respond to the changes in water supply and demand situation and the effects and attributes of locality by the utilization of a range of resources including natural, physical, human and financial. Natural drivers like variation in rainfall, runoff rate or infiltration that control the availability of water has not been included in this study as ensuring water security is considered more to be a managerial issue and, issue and controlling the natural drivers of water supply is beyond the capacity of rural communities. As noted by Zeitoun (2011), water insecurity is primarily social, with water security of some individuals being associated with insecurity of others. The research framework explains both the water supply and demand provisions that exist in a rural area and imparts significant responsibility on the adaptive capacity of local people to overcome the existing gap in water supply and demand scenarios.

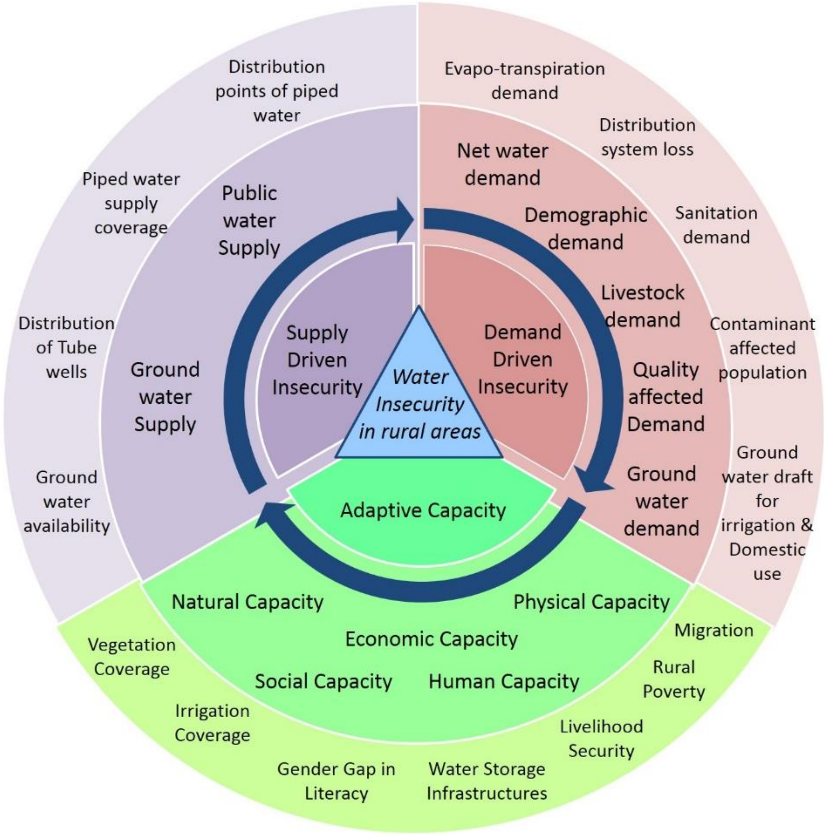

Figure 4.1 Research Framework for measuring water insecurity in rural areas

(The inner circle shows the dimensions that lead to water insecurity. The circle in the middle delineates the attributes that can be used to measure these dimensions and finally, the outer circle denotes the variables under indicators)

4.3 STUDY AREA

Purulia, a district of West Bengal, India, is unique in her coherence of adverse geophysical characteristics, exotic, ethnic and cultural evolutions, abject poverty and deprivations, rapid rebellions and historical turmoil. By regulation XVIIII of 1805, a Jungle Mahals district composed of 23 parganas and mahals including the present Purulia was formed. By regulations XIII of 1833 the Jungle Mahals district was broken up and a new district called Manbhum was constituted with headquarters at Manbazar. Finally, in 1956 Manbhum district was partitioned between Bihar and West Bengal under the States Reorganization Act and the Bihar and West Bengal (Transfer of Territories) Act 1956 and the present district Purulia was born on 1st November, 1956.

The district comprises three subdivisions: Purulia Sadar East, Purulia Sadar West and Raghunathpur. Purulia Sadar East consists of Purulia municipality and seven Community

Development *Blocks* (CDBs, hence after *Blocks*): Manbazar–I, Manbazar–II, Bundwan, Purulia–I, Purulia–II, Hura and Puncha. Purulia Sadar West consists of Jhalda municipality and seven community development *Blocks*: Jhalda–I, Jhalda–II, Joypur, Arsha, Baghmundi, Balarampur and Barabazar. Raghunathpur subdivision consists of Raghunathpur municipality and six community development *Block*s: Para, Raghunathpur–I, Raghunathpur–II, Neturia, Santuri and Kashipur. Purulia town is the district headquarters. There are 20 police stations, 20 development *Blocks*, 3 municipalities, 170 Gram Panchayats, and 2459 inhabited villages in this district.

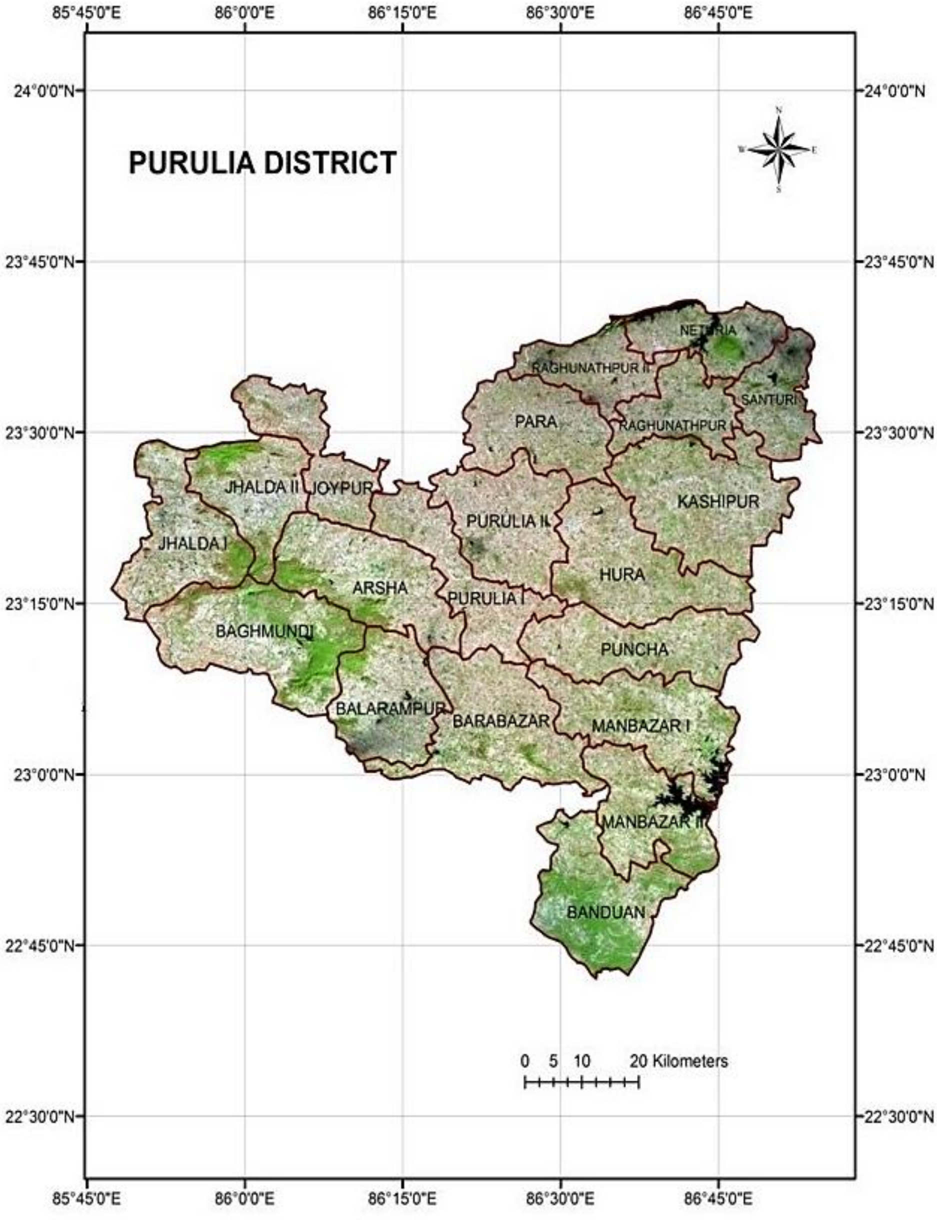

Figure 4.2 Map showing the *Block* boundaries in the study area

4.3.1 Geographical Profile

Purulia, the westernmost district of the Indian state of West Bengal (**Figure 4.2**) and a part of Chotanagpur plateau, is located between 23º 42’ 00’ North and 22º 42’ 35’’South latitude and 86º 54’ 37” East and 85º 49’ 25” West longitude. It is traversed by the Tropic of Cancer. Its physiographic location is also distinguishable as a zone of transition between the young alluvial plains of West Bengal and the ancient plateau of south east Bihar.

Topography. The district is characterized by undulating topography with rugged hilly terrains in the western and southern parts. General elevation of the land surface ranges from 150m to 300m, the master slope being towards the east and south-east. Absolute relief increases towards the west and the south marked by a line of sharply rising. In the eastern and south-eastern part of the district the slope ranges between 10 to 20m/km. In the central part of the district the slope is less than 10m/km and forms a depression. Again in the western part the slope is higher the slope is higher and ranges from 20-80m/km. The district has an undulating topography with occasional hillocks of hard rocks. Some of these isolated hills and the bulging interfluves in the eastern part of the district are forested.

Soils. Gneissic soils predominate followed by Gondwana soils on sedimentary rocks and transition soils with different depths, composition, and fertility status and crop response. The soil is not very supportive to a rich agricultural potential as Gneissic soils are usually sandy loams of low fertility. Soil is acidic throughout the district. The weathering processes are more active and hence the plains are mostly erosion-affected with very thin soil cover. Soil erosion is one of the most prominent phenomenon in this district. Vast areas of land remain as uncultivable wasteland. Nearly 165200 ha of land is affected by soil erosion in the district. Out of this affected land, 135000 ha is in non-forest area.

Hills. Ajodhya Hills forms the main highland region’ of Purulia district. Numerous small streams drain over its western and southern slopes into the Subarnarekha and over the northern and eastern slopes into the Kasai and the Kumari. To the north-east of the district stands the 643.5 m high Panchet hills. The south-east part is also endowed with hilly and forest terrains in the *Blocks* of Banduan.

River Systems. The rivers that flow across the district are few in number and these rivers remain dry during most of the year. These rivers are very turbulent only for a small period during the monsoon and thus provide little scope for fishery. The Kasai is the master-stream of Purulia, draining more than three-fifth of the district, although it is non-perennial for more than three-fourths of its length. A number of non-perennial streams descend down the northern face of the Baghmundi Hills as right - bank tributaries of the Kasai. Rest of the rivers flowing through the district like Dwarekeshwar, Damodar, Kumari and Subarnarekha have a south and south-easterly direction. This rivers run dry for most part of the year and the river beds are mostly sandy. During summer, they become almost or entirely dry.

Forests. About 29.69 percent of the district's total land (6259 sq. km) is under forest cover but these forests are too much fragmented. Randomness of forest patches is greater in the southern and western part of the district than in the north. In the last couple of years, forest cover had actually decreased in Puruliya from 20.95% and 20.19% of the total land area in 2000 and 2004, respectively to approximately 14% in 2012. Canopy density had reduced at the same time. At present only181sq.km is considered as dense forest where canopy density is 40 percent or more. Nearly 112 sq. km of forest area is classified as reserved forest and 729 sq. km as protected forest in the district (Directorate of Forests, 2012). There are numerous small hamlets in the fringe area of the forest lands, inhabited by the indigenous population of the district. The forest resources play a critical role in the lives of this people in the form of livelihood, food, medicine, fuel and host of daily necessities.

4.3.2 Demographic Profile

In 2011, Purulia recorded a population of 2,930,115, roughly equal to the population of Jamaica, out of which male and female were 1,496,996 and 1,433,119 respectively. With respect to population rank, Purulia district is 129th out of 640 districts in India. The district has experienced an increase of 15.52% of total population compared to population in 2001. Population density has increased in Purulia from 355 persons/sq. km in 1991 to 405 persons/sq. km in 2001 and further to 468 persons/sq. km in 2011. The village-wise distribution of population is demonstrated in **Figure 4.3**.

Male and female population has remained nearly constant across the years. Regarding sex ratio, there are 957 female to 1000 male in the district. The average national sex ratio in India was 940 female to every 1000 male in 2011. About 38% of the total population of the district is either scheduled caste (19.38%) or scheduled tribe (18.45%). About 14% of the population belongs to 0-6 year age group compared to 16.12% in 2001. As per Census of India (2011), rural population of the district has declined from 90.56 % in 1991 to 87.26% in 2011.

On the other hand, urban population of the district has increased from 9.44% in 1991 to 12.74% in 2011.

Purulia district has the second highest percentage of tribal population in the State. The tribes of Purulia belong to Proto-Australoid racial stock. The district is the abode of '*Mahato*' community along with different tribal groups like *Lodha-Sabar*, *Birhore*, *Bhumiz*, *Tota*, *Kheria* and mainly *Santhal*. After the *Mahato* community, *Santhals* are the highest in number. They

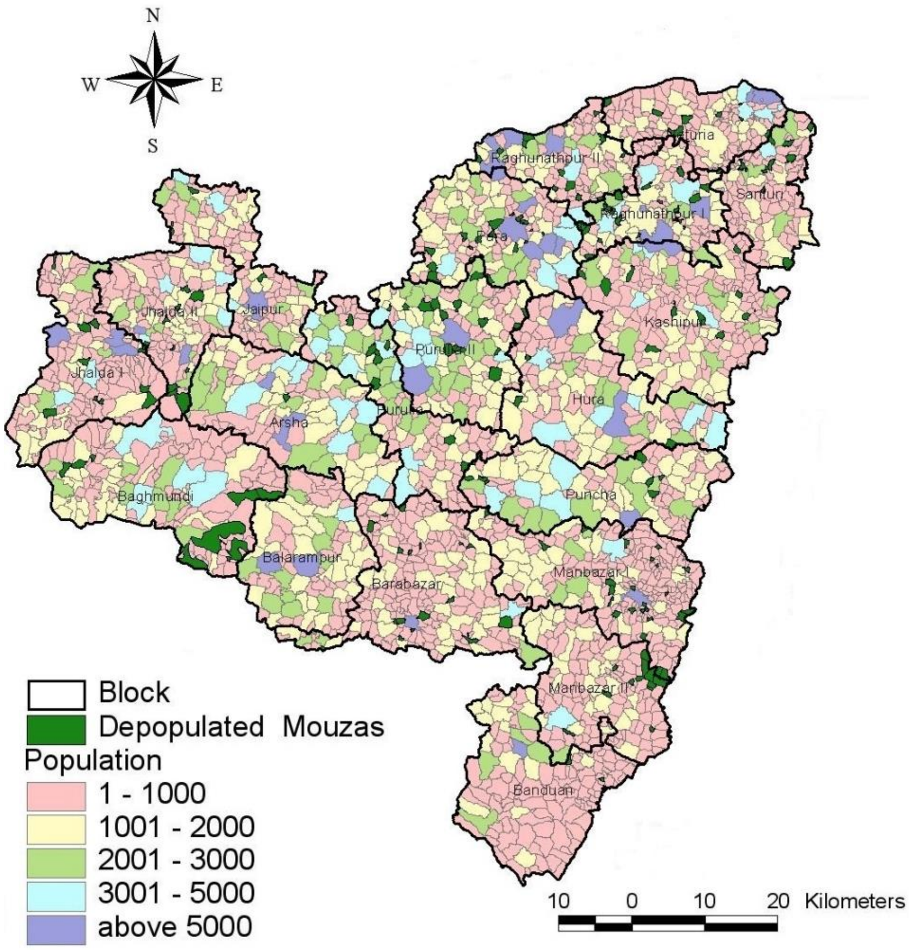

Figure 4.3 Village-wise population distribution in Purulia district (*Source: NRDMS, Purulia*)

account for over 62 per cent (62.66 per cent) of the total Scheduled Tribe population of the district. The tribes are distributed all over the district though they are largely concentrated in the northern, southern and western fringes (**Figure 4.4**). As far as their linguistic affiliation is concerned the languages spoken by the tribes in Purulia district are mostly from Austro-Asiatic family, viz. *Santhali*, *Gondi*, and *Kheria*. However, the relative proportion the tribal population in the district has been continuously declining over the years. The tribal population accounted for 19.23 per cent of the total population in 1991 which declined to 18.27 per cent in 2001 which again inclined to 18.45 per cent in 2011.

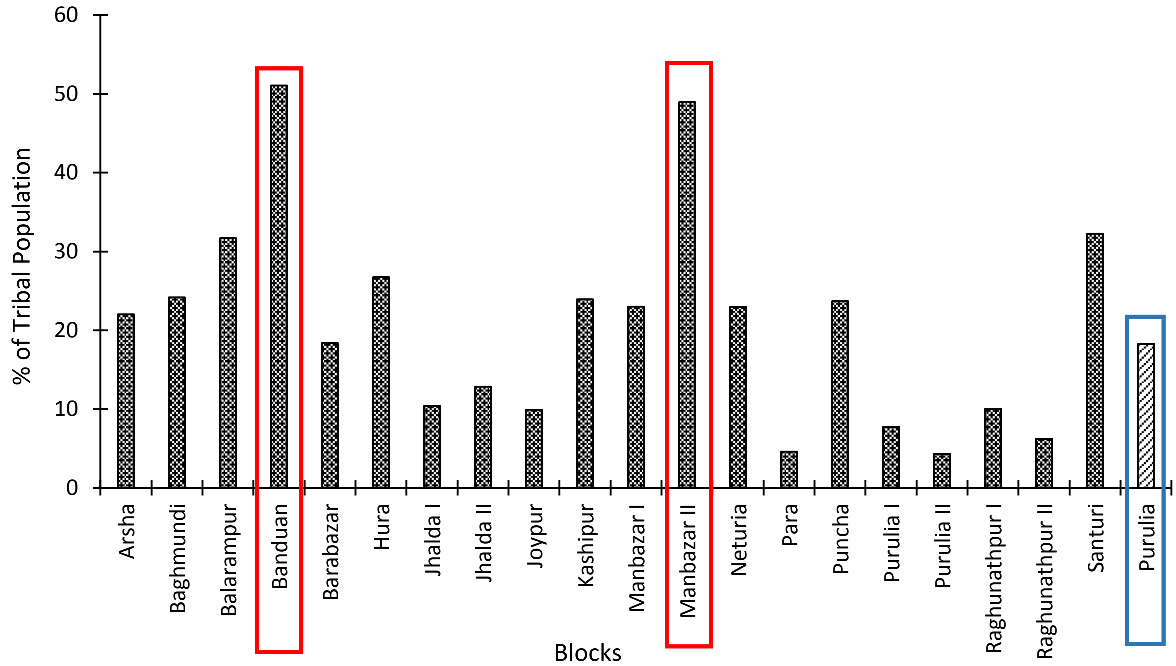

Figure 4.4 Distribution of tribal population in the district

(*Data source: Census of India, 2001*)

4.3.3 Socio-economic Profile

As per Census of India (2001), 994 villages in the district have been identified as 'backward villages' on the basis of two parameters – less than 30% female literacy rate and more than 60% of marginal workers and non-workers. The percent distribution of the backward villages is demonstrated in **Figure 4.5**. The highest number of backward villages are found in the western part while lower number of backward villages are spread across the northern fringes of the district.

Literacy rate has increased from 40.32% in 1991 to 55.57% in 2001 – a 15.25% increase and further to 64.48% in 2011- a further 8.91% increase from 2001. Male and female literacy are 77.86% and 50.52% in 2011, respectively. Increase in female literacy rate is more pronounced than the increase in male literacy rate in the entire period. Female literacy has substantially increased from 19.57% in 1991 to 50.52% in 2011. The gender gap in literacy has been narrowed down from 40.41% in 1991 to 37.22% in 2001 and further to 27.34% in 2011.

Less than fifty percent of the people of Purulia are worker and out of the working population 64.12% are male and only 35.88% are female. In 1991, 55.30% people were workers, which declined to 52.99% in 2001 and finally decreased to 49.59% in 2011. From 1991 to 2011 percentage of male workers has increased from 59.28% in 1991 to 60.22% in 2001 and finally to 64.12% in 2011. Percentage of female worker is found to be decreasing during the same period from 40.72% in 1991 to 39.78% in 2001 and finally to 35.88% in 2011. The census data demonstrates that percentage of working population of Purulia in declining over the census decades and at the same time the working population is becoming more male-centric.

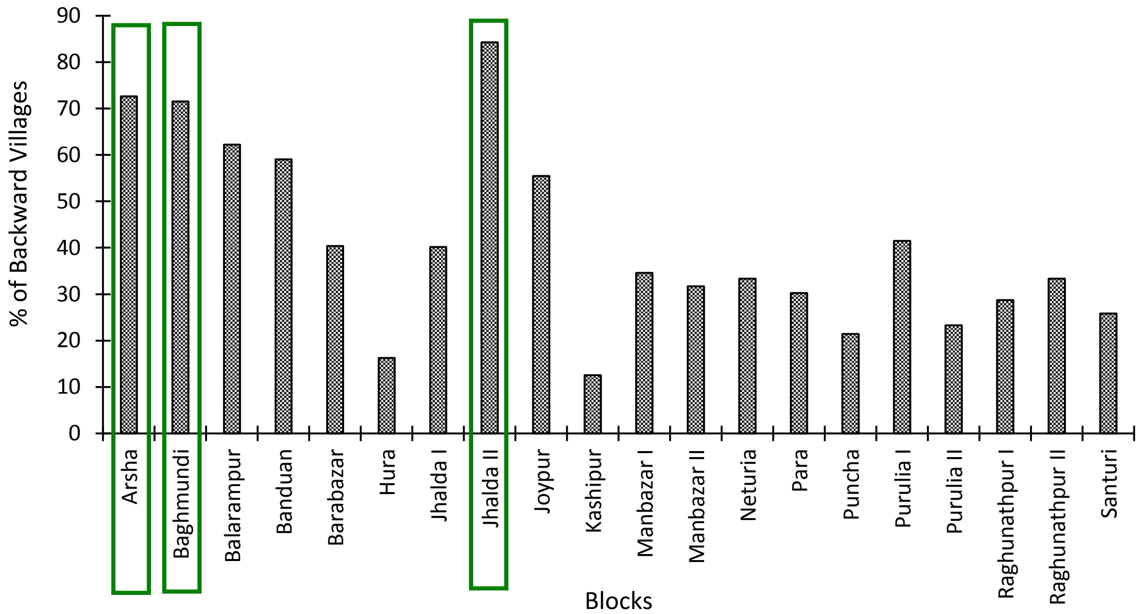

Figure 4.5 Percentage distribution of backward villages in the district
(*Data source: Census of India, 2001*)

Total workers are further subdivided into three broad subgroups namely Main Workers Marginal Workers and Non-Workers. It is quite evident from **Figure 4.6A** that percentage of main workers have declined across the decades and that of marginal workers are increasing over the years. Percentage of male main workers have increased from 70.37% in 1991 to 80.41% in 2011 but percentage of female Main Workers are decreasing consistently from 29.63% in 1991 to 19.59% in 2011. On the other hand, percentage of marginal workers are increasing in general but more prominently for female workers. In 1991, 19% of total workers were marginal workers which increased to 42.75% in 2001 and 50.91% in 2011. Hence, it can be inferred that nature of work opportunities are changing in Purulia and they are becoming more temporary or casual types than the regular ones. It increases the vulnerability of the workers and instability in life of the people in general and marginal workers in particular. The percentage of non-workers has remained almost constant across the three decades.

Cultivator and agricultural labour are two main components of main workers. Together they explained nearly 80% of the main workforce in 1991. But in successive decades, percentage of cultivators has consistently declined from 52.87% in 1991 to 37.65% in 2001 and finally to 27.20% in 2011 (**Figure 4.6B**). Though the percentage of agricultural labours has decreased from 1991 (27.03%) to 2001 (18.80%), it again increased in 2011 (20.94%). Moreover, when the percentage of male agricultural labours has decreased across the decades, percentage of female agricultural labours has increased from 2001 (36.77%) to 2011 (51.29%).

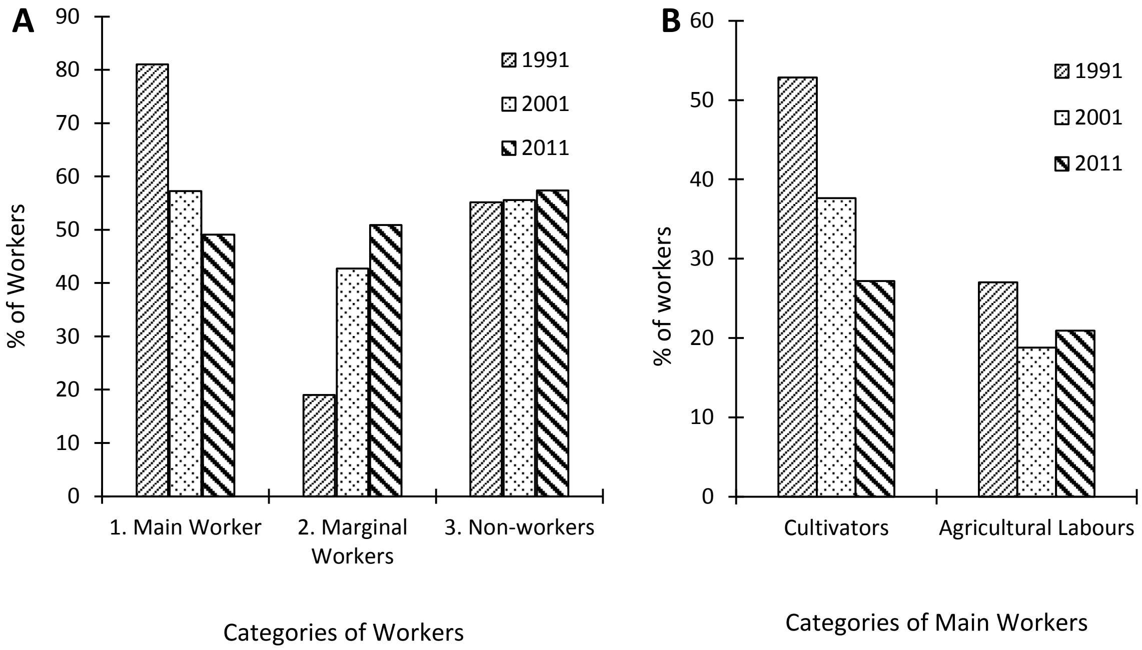

Figure 4.6 (A) Percentage distribution of different categories of total workers in the district; and (B) Percentage distribution of different categories of main workers in the district (*Data source: Census of India 1991, 2001, 2011*)

The composition of district income over different sectors reveals that the economy of Purulia has been shifting towards tertiary sectors like working in transport, storage, hotels and restaurants etc. In 2004-2005, the share of primary sector, i.e. agriculture and allied sectors, has reduced from 44.52% in 1993-94 to 29.13%. This reveals that increasing number of people are leaving agriculture, may be due to unfavorable situations, and are starting to work in other sectors.

A large section of the population is disadvantaged by limited job opportunity, very low per-capita income, low level of GDP, low rate of literacy, especially female literacy, fragile condition of public health and above all the present political crisis leading to least social security and vanished stability. Even after six decades of independence the fulfilment of fundamental demands of food, cloth, shelter, health and education is seemed to be more a fancy than a reality to the people of this area.

4.4 Research Methodology

4.4.1 Research Objectives

The main objective of this study is to develop a tool that assess the scale of prevailing water insecurity in the study area and also investigate how it varies across different *Blocks*. The novelty of this study lies in the development of Water Insecurity Index, specially designed for rural areas and applicable at a local administrative scale. Results from this study can be used as an informative base to implement water security policies in rural areas characterized by socio-economic disparities, as their priorities are, often, overlooked or ignored (Wilk and Jonsson, 2013). It could also assist in identifying the factors that need improvements when planning the revitalization of existing water supply and developmental schemes and suggest the areas that need prioritized actions. Also, because of the choice of easily available variables and Principal Component Analysis (PCA) based statistically robust methodology, this index may emerge as a potential tool for assessing water insecurity in rural areas.

4.4.2 Selection of attributes and data collection

To examine rural water insecurity of the study area, as per the framework (**Figure 4.1**), attributes are selected under each dimension. The criteria for selecting the attributes are relevance to the water management issues at a local scale, interest to rural communities, quantifiable and easy availability of data, relatively simple to understand and implement, amenability to existing data or future inventory and independent of other attributes to minimize redundancy. The initial set of attributes and variables were developed after extensive literature review of various indices like Rural Water Livelihood Index (Sullivan et al., 2009), Water Poverty Index (Sullivan, 2002), Water Vulnerability Index (Sullivan, 2011), Basic Human Needs Index (Moglia et al., 2012) and Arctic Water Resources Vulnerability Index (Alessa et al., 2008a) and then modified in an iterative process via consultation with field experts resulting in the final suite of attributes and variables used in this study. A total of seventeen attributes (**Table 4.1**), divided into three dimensions, namely SDI, DDI and AC, have been aggregated to form the Rural Water Insecurity Index. The index itself is not specific to the study area, but sufficiently generic to have a widespread application in rural areas in the world.

Table 4.1: Major dimensions, attributes and variables comprising the Rural Water Insecurity Index (RWII)

Dimensions of Water Security	**Attribute**	**Variables**	**Additional Remarks**
Supply Driven Insecurity (SDI)	Ground Water Availability (-)	Net groundwater availability	*Block*-wise ground water available for extraction in an area after deducting natural discharge during non-monsoon season from Annual Replenishable Ground Water Resource, measured in hectare meter.
	Ground Water Distribution (-)	Number of consumer points supplying groundwater	Number of existing and functional hand pumps per 100 persons for groundwater withdrawal in a particular area.
	Access to improved water sources (-)	Percent population with piped water access	Percentage of population with access to piped water supply systems. Piped water supply confirms consistency and reliability in water supply.
	Piped Water Supply Distribution (-)	Number of piped water supply delivery points	Number of outlets or Public taps/Stand posts per 100 persons for piped water supply.
	Sub Surface Water Supply (+)	Percent of River Bed Tube Wells	Percentage of functioning River Bed Tube Wells, extracting sub surface water, for irrigation purpose in a *Block*.
Demand Driven Insecurity (DDI)	Demographic Demand (+)	Population Density	Number of people living per square kilometre of *Block* area.
	Groundwater draft for Irrigation (+)	Percent groundwater use for irrigation	Percentage annual groundwater draft from all abstraction structures for irrigation uses to total annual groundwater draft.
	Groundwater draft for Household Demand (+)	Percent groundwater withdrawal for domestic use	Percentage existing gross groundwater withdrawal to meet domestic needs to total annual groundwater draft.

	Livestock Demand (+)	Livestock holding size	Livestock holdings per 1000 persons have been used as a proxy indicator in absence of concrete data of total number of livestock in the *Block*s.
	Sanitation and Hygiene Demand (-)	Percent population with no access to improved sanitation facilities.	The ratio of population without access to improved sanitary facilities, like connection to public sewer, a septic system, pour-flush latrine, Simple pit latrine, or a ventilated improved pit latrine.
	Net Water Demand (+)	Percent water demand from irrecoverable losses	Percentage of evapotranspiration of applied water in an area, the irrecoverable losses from the distribution system, and the outflow leaving the area.
	Quality Affected Demand (+)	Percent of households with low quality groundwater supply	Percentage of households using contaminated groundwater (Fluoride, > 1.5 mg/l and Iron). The demand for safe water supply increases with increasing quality affected households.
Adaptive Capacity (AC)	Natural Capacity (-)	Percent forest area to total *Blocks* area	Vegetation cover (percentage of forest cover) is used as an indicator of the state of ecosystem. Removal of vegetation cover change hydrological properties of the land surface, increasing vulnerability of freshwater resources.
	Physical Capacity (-)	Percent cultivated area with irrigation facility	Percentage of cultivated area that has irrigation facility. Higher value indicates higher availability of water for irrigation and reduced possibility of exploitation of available water resources.
		Water storage capacity	Percentage of *Block*-wise water storage infrastructures including ponds, wells, check dams, hapas (small and deep ponds excavated in agricultural fields) and other water harvesting structures.
	Human Capacity (-)	Gender gap in literacy	Ratio of female literacy to male literacy in a *Block*. Proxy indicator of the decision making power of women regarding water use and distribution.

Economic Capacity (-)	Dependence on agriculture based livelihood	Percentage of population that report agriculture as the only source of income. Any variation, in any form, in the water scenario influences agricultural production and income, and the adaptive capacity to current and future stresses.
	Workforce Participation Rate	Percentage of total workers (main and marginal) to total *Block* population. More work force ensures more livelihood security, and water and food security.
	Asset ownership	Percentage of population with ownership of any of the assets including television, motorbike, car, jeep, van, radio, bicycle etc. Ownership of assets is directly proportional to steadier livelihood base and capacity to combat risks.
Social Capacity (-)	Percent of migrants working outside the *Blocks*	Percentage of migrants in a *Block* for temporary employment, seasonal migration, and migration for other means of livelihood.
	Percent of population borrowing credit	Percentage of population borrowing credit to meet daily needs from government or non - government organizations. Higher the proportion of vulnerable population borrowing credit, lower is the adaptive capacity.

(Note: '+' denotes the directly proportional hypothesized relation between the attribute and water insecurity; '-' denotes the inversely proportional hypothesized relation between the attribute and water insecurity)

The application of RWII is demonstrated using the study area-specific datasets. There may be variations in the availability and suitability of datasets from country to country and proper testing is required before the implementation of RWII under different circumstances.

Structured interviews were carried out with *Block Development Officers* (BDOs), immediate administrative head of clusters of villages under one *Block*, as discussed in Chapter 3. Data was collected from all the twenty *Blocks* (N=20) through face-to-face interview with a pre-set questionnaire (**Appendix I**) in June-July, 2013. The empirical data collected during questionnaire surveys can be regarded un- biased and accurate as they are referred from various official documents and not based on opinion of interviewed officials. A prior appointment was taken from each BDO and a sample of questionnaire was send to him beforehand so that the BDOs can collect all the recent data from the concerned administrative departments. On the day of interview, the BDOs answered the questions as per the collected datasets. The interviews also helped in complementing the information by providing explanations and issues behind quantitative data. The feedbacks from the BDOs facilitated a better understanding of the data and helps in clear understanding of the current water situation.

4.4.3 Construction of RWII

Construction of RWII followed the methodology used by Cutter et al. (2003), Schmidtlein et al. (2008) and Wood et al. (2010), for measuring Social Vulnerability Index (SoVI). The methodology has been replicated in a number of studies in various geographical settings (Boruff and Cutter, 2007), at various spatial scales (Borden et al., 2007) and in response to hazards like hurricane storm surges and tsunamis (Cutter and Finch, 2008; Wood et al., 2010). The original SoVI was used to represent vulnerability for populations within particular areas (Cutter et al., 2003), which is quite similar to the objective of this paper, except that relative scale of water insecurity will be measured for a rural area instead of social vulnerability.

The collected data were standardized to “z-scores” with zero means and unit variances (Eq. 1).

$$z = (X_i - X_{mean})/X_{SD} \qquad (1)$$

Where, X_i denotes the actual scores of the variable for a particular *Block*, X_{mean} denotes the mean of the variable scores and X_{SD} denotes the standard deviation of the variable scores across the *Block*s. The use of standardized z-scores avoids potential errors resulting from the aggregation of variables with different units (Jones and Audrey, 2007). The approach to quantify the multivariate nature of water security and also overcome the issue of incommensurability represented by the values of the variables is the use of statistical exploratory analysis like Principal Component Analysis (PCA). After standardization, Barlett's sphericity test and Keiser-Meyer-Olkin Measure of Sample Adequacy (MSA) test was carried out to check the appropriateness of PCA. Both the tests indicated significant results (at 0.01 level for Barlett's sphericity test and >0.05 for MSA test) for the available dataset. Varimax rotation and Kaiser Criterion (eigenvalues greater than 1) were used to extract a parsimonious subset of components that explains the underlying features in the data as closely as possible. A detailed methodology of PCA has been explained by Khatun (2009) and Vyas and Kumaranayake (2006). For the present study, SPSS 22.0 was used to conduct PCA of the database, separately with the variables for each of the three dimensions under study, namely, SDI and DDI and AC. For example, let $X_1, X_2, X_3 \ldots X_n$ be the n number of variables denoting SDI in the present study. Each of the X_i's are observed for each of the twenty *Blocks* under study. PCA extracted two components, PC_1 and PC_2, from the SDI dataset with eigenvalue more than 1. Theoretically, component loadings of each variable represent the weights used to compute component scores and tell the contribution of each variable to the component score. This calculation was carried out using SPSS procedure and the component scores are saved as new variables in the SPSS data file and saved for further analysis. The component loadings for an individual variable were considered as significant at 0.5 and higher or -0.5 and lower.

One of the most challenging parts of composite index development is the selection of appropriate weighting method. In the original SoVI, component scores were equally weighted which can be justified by the large populations and high demographic variability of the counties making it difficult to formulate explicit weights. However, scale dependent deficiencies may exist at the smaller *Block* level where the PCA based index may inappropriately focus on isolated anomalies or outliers within individual *Block*. In an effort to minimize this potential difficulty and more accurately represent the components that contribute the most to variability in water insecurity, each component score was weighted by its percentage variance explained (Eq.2), thereby compelling components with higher variance to contribute more to the overall RWII score (Schmidtlein et al., 2008; Wood et al., 2010). Weighted components under each dimensions were put in an additive model to calculate the scores of each dimension. For example, in case of SDI

$$SDI = (Component\ score\ of\ PC_1 \times \%\ variance\ explained\ by\ PC_1) + (Component\ score\ of\ PC_2 \times \%\ variance\ explained\ by\ PC_2) \qquad (2)$$

Next, SDI and DDI, are combined to generate an overall assessment of water insecurity for a particular area. For quantitative vulnerability studies, Adaptive Capacity (AC) is subtracted from other components of vulnerability to obtain the index (Hahn et al., 2009; Luers et al., 2003). As adaptive capacity and its role is clearly defined in the context of water insecurity assessment, the present study uses the similar approach and AC is deducted from the sum of SDI and DDI to compute RWII. This implies that higher supply and demand driven insecurity reflect higher water insecurity that could be reduced by enhanced adaptive capacity. Once scores for each of the dimensions for a *Block* were calculated, *Block* – level Rural Water Insecurity Index (RWII) is calculated using Eq.3.

$$Rural\ \ Water\ Insecurity\ Index\ =\ (SDI + DDI) - AC \qquad (3)$$

Each of the dimension scores and the value of overall index were standardized to a z-score with mean 0 and variance 1 in order to map the values over space using ArcGIS® 10.3.

Finally, the *Blocks* were classified according to their relative water security for the ease of decision making. The present study applied standard deviation classification method to segregate the *Blocks*. The major advantage of this classification method is that by using the mean as dividing point, a contrast values above and below the mean is readily seen. Also, an aggregation of SDI and DDI had been plotted against AC for a better understanding about the relationship between different dimensions in a water insecurity.

4.5 Results and Discussion

4.5.1 Water Insecurity Indicators

Two components are retained by PCA from five original SDI variables. These components have an eigenvalue of more than 1 and cumulatively explains 70.9% of the total variation in the data. Component 1, the proximate determinant, captures 47.7% of SDI variance and is heavily loaded on three variables namely percent population with piped water access, number of piped water supply delivery points and percentage of River Bed Tube Wells (RBTWs) (**Table 4.2**). When the first two variables demonstrates a high positive loading, and percentage of River Bed Tube Wells (RBTWs) loads negatively on Component 1. Sub-surface water is mainly used for irrigation during dry season in few scattered pockets of the district. Excessive withdrawal of sub-surface water using RBTWs results to altered river flow and reduced volume of water flow in the rivers. A high negative loading implies that higher number of RBTWs increases SDI of the area. Access to piped water supply system and distribution of water supply delivery points are highly varied in the district. *Block* population coverage by piped water supply varies from as little as 4% in Baghmundi to 57% in Raghunathpur I. As surface water supply through pipeline system is considered to be a safe source of water and is also easily accessible, their importance to local rural people is highly recognised. But due to the non-perennial characteristics of the river and undulating terrain, surface water supply through pipeline system is limited only to the northern part of the district. As a result groundwater extraction is mostly stressed upon by both the administrative water managers and local people. Component 2 demonstrates 23.2% of SDI variance, and is noted to be heavily loaded on two variables – net groundwater availability and number of consumer points supplying groundwater. Component loadings of the variables illustrate that higher net groundwater availability and distribution of groundwater consumer points increases water security of the particular area. A study by Kujinga et al. (2014) also demonstrated similar results where water supply and distribution infrastructure, irrespective of surface water and groundwater, play a major role in ensuring water security. However, higher availability of groundwater is associated with higher number of hand pumps installed for extracting them. This, in a long run, may prove detrimental for the rural communities due to the rapid decline in groundwater table.

For DDI, two components are retained that account for 62.8% of variation in the original seven variables included in the analysis. The first component captures 34.2% of the DDI variance and is heavily loaded on percent water demand from irrecoverable losses and percent withdrawal of groundwater from various sources for domestic use (**Figure 4.7**). Percent groundwater use for irrigation and percent of household with contaminated groundwater supply load moderately on Component 1 (**Table 4.2**). Net water demand refers to the sum of evapotranspiration of applied water in an area, the irrecoverable losses from the distribution system and the outflow leaving the service area. High positive loading of net water demand suggest a strong direct relationship between the variable and Component 1 of DDI and denotes its high variability across the district. Increased losses due to evapotranspiration, water distribution systems and outflow curtails agricultural production as well as domestic water requirement. This, in turn, contributes to increasing water insecurity. Groundwater is the principal source for domestic use in rural areas in India including the present study area. The high positive loading of the variable on Component 1 illustrates the role of groundwater withdrawal for domestic use to demand driven water insecurity. Except for domestic use, groundwater is also withdrawn for irrigation during the dry season. However, the scale of groundwater use for irrigation is significantly low in the district and is mainly for small-scale cultivation.

Table 4.2: PCA results showing principal components extracted, eigenvalues, percentage variance explained and component loadings of the variables

Component	Eigen value	% of variance	Variables and component loadings
		Supply Driven Insecurity	
1. Piped surface water supply and distribution	2.383	47.65	Percent population with piped water access (0.870) Number of piped water supply delivery points (0.818) Percent of River Bed Tube Wells (-0.777)
2. Groundwater availability and distribution	1.161	23.23	Net groundwater availability (0.772) Number of consumer points supplying groundwater (0.749)
		Demand Driven Insecurity	
1. Evaporative demand and groundwater withdrawal	2.395	34.22	Percent water demand from irrecoverable losses (0.880) Percent groundwater withdrawal for domestic use (0.872) Percent groundwater use for irrigation (0.620) Percent of households with low quality groundwater supply (0.543)
2. Livestock and sanitation demand	2.000	28.58	Livestock holding size (0.864) Percent population with no access to improved sanitation facilities (0.742) Population density (-0.791)
		Adaptive Capacity	
1. Work participation rate, gender and vegetation coverage	2.991	33.24	Work Participation Rate (0.884) Gender gap in literacy (0.712) Percent forest area to total *Block* area (0.700) Asset ownership (-0.875)
2. Social capacity and agro-based livelihood	2.221	24.68	Percent of population borrowing credit (0.887) Percent of migrants working outside the *Block* (0.835) Dependence on agriculture based livelihood (0.699)
3. Irrigation coverage and water storage	1.189	13.20	Percent cultivated area with irrigation facility (0.785) Water storage capacity (0.598)

Due to over extraction, groundwater level has declined, aggravating DDI in the study area. With decrease in groundwater table and long spells of drought, fluoride from the mineral bearing rocks leaches into the circulating water (Bhattacharya and Chakrabarti, 2011; Chakrabarti and Ray, 2013). A moderate positive loading of percent households with contaminated groundwater supply reinforces the increase in demand for safe water. Component 2 accounts for 28.6% of the DDI variance and, loads positively on livestock holding size and percentage of population with no access to improved sanitation facilities. Component 2 explains that *Block*s with larger livestock holdings are also associated with higher percentage of population without access to improved sanitation facility. Though high population is considered as one of the major factors behind increasing water demand, DDI is not directly proportional to population density in the study area. This can be attributed to high poverty and water scarce periods in the district that results to loss of livelihood and income. This scale of stagnation leads to migration of people to other areas, thus, decreasing the population. Hence, for the present study area, highly dense populated areas are more water secure than lesser dense populated area.

Figure 4.7 Use of different sources of groundwater in the study area
(*Photographed by Author*)

For Adaptive Capacity, PCA extracted three components with eigenvalue more than 1 (**Table 4.2**). Together this components explains 71.1% of the variation in the nine variables included in the study. Component 1 captures 33.2% of adaptive capacity variance, and is heavily loaded on four variables. Assets ownership shows high negative loading, thus negating its hypothesized relationship with water insecurity. This implies, all things being equal, that a household with any asset will be ranked lower in terms of adaptive capacity than a household that does not own any asset. Ownership of an asset, mostly bicycle for this study area, is more strongly correlated with variables that are expected to be associated with lower adaptive capacity, for instance sanitation conditions and lower livelihood security. On the other hand, *Block*s with large forest area and higher female literacy rate is expected to exhibit higher workforce participation rate. Past research on gender indicates that women show higher preparedness planning and are more likely to be single parents or primary care givers and have lower incomes, fewer financial resources, and have less decision making power than men (Laska and Morrow, 2007). A high loading of gender gap in literacy is a significant issue in the study area, emphasizing the role of women in increasing adaptive capacity. Component 2 accounts for 24.7% of the total variance, and is heavily loaded on social capacity variables and moderately loaded on percentage of population dependent on agriculture based livelihood. The findings match well with the argument by Adger (2000) that places where natural resource dependent rural livelihood are predominant, high rate of rural-urban migration can be a sign of lack of adaptive capacity and narrow coping ranges of the rural population. Any alteration in livelihood, mainly based on natural resources, compel the rural communities to borrow money to meet their daily needs. When the communities are unable to revert back with the existing resources, they migrate to other places in search of alternative livelihood. Component 3 explains 13.2% of the total variance and is significantly loaded on physical capacity of the *Block*s (**Table 4.2**). The component is heavily loaded on percent cultivated area with irrigation facility and moderately loaded on number of existing water storage infrastructures in the *Blocks*. The higher the number of water harvesting structures in a *Block*, higher is the irrigation coverage that ensures agricultural as well as income stability. On the other hand, inadequate, under-funded or poorly maintained water infrastructure is often a critical factor leading to uncertain availability of water (Sullivan, 2011).

4.5.2 Spatial distribution of the dimensions and RWII

The z-scores of each dimensions and the overall score of RWII for twenty *Blocks* is given in **Table 4.3**. It should be noted here that these distribution do not represent precise groups; they show the relative comparison among the *Blocks* as per their relative water insecurity. Since, PCA is a data reduction technique, dimensional and RWII scores are dependent on selected input variables and relevant only to the database from which the PCA was conducted (Burton and Cutter, 2008). The spatial distribution of *Blocks* based on dimensions and overall RWII scores are illustrated in **Figure 4.8a** to **4.8d**. **Figure 4.8a** to **4.8c** indicates strong spatial differences in the sources of water insecurity across the district.

4.5.2.1 Supply Driven Insecurity Index

Higher SDI, denoted by higher negative deviation from mean (< -1.5 Std. Dev. and -1.5 to -0.5 Std. Dev.), in the western and eastern *Blocks* of the district can be attributed to localised depletion of water, resulting in declining groundwater levels in the immediate vicinity of a well or borehole, or group of sources (**Figure 4.8a**).

Table 4.3: z-Scores of each dimension and RWII for 20 *Blocks* in the study area

Blocks	Supply Driven Insecurity (SDI)[1]	Demand Driven Insecurity (DDI)[2]	Adaptive Capacity (AC)[3]	Rural Water Insecurity Index (RWII)[4]
Arsha	-0.83	-0.63	1.11	-2.16
Baghmundi	-1.77	0.39	0.38	-1.66
Balarampur	0.02	-0.32	0.31	-0.48
Banduan	1.11	0.21	1.16	0.32
Barabazar	-0.18	1.45	1.05	0.17
Hura	-0.26	0.62	0.43	-0.08
Jhalda I	-0.88	0.83	0.32	-0.42
Jhalda II	-0.23	-0.10	-0.70	0.25
Joypur	-1.05	0.05	0.76	-1.55
Kashipur	0.57	0.42	-0.23	1.05
Manbazar I	-0.48	0.86	1.17	-0.68
Manbazar II	1.05	0.09	1.23	0.11
Neturia	1.64	-1.94	-2.12	1.66
Para	-0.67	0.64	-1.12	0.75
Puncha	-0.54	0.41	0.24	-0.37
Purulia I	-0.49	0.73	-0.67	0.64
Purulia II	-0.98	1.14	-0.73	0.54
Raghunathpur I	1.79	-2.04	-1.91	1.57
Raghunathpur II	1.29	-1.41	-0.59	0.55
Santuri	0.87	-1.38	-0.08	-0.21

([1] A negative value indicates higher Supply Driven Insecurity (SDI); [2] A positive value indicates higher Demand Driven Insecurity (DDI); [3] A positive value indicates lower Adaptive Capacity (AC); [4] A negative value indicates higher Rural Water Insecurity)

Groundwater availability is also low due to the hydrogeology of the area and get further lowered with the onset of dry period. Population with access to piped water system is significantly low in these *Blocks*, e.g. 6.4% in Baghmundi and 8.3% in Jhalda I. Baghmundi and Arsha are mountainous *Blocks* with various hills and hillocks and are forested. Many of the tribal dominated villages are located on the hill tops where neither piped water supply nor groundwater provisions exist. Villagers still rely on springs or rivers for their sustenance. On the other hand, more than half of the total population in northern *Blocks* of the district like Neturia and Raghunathpur I receive water through pipeline system which is more consistent and reliable.

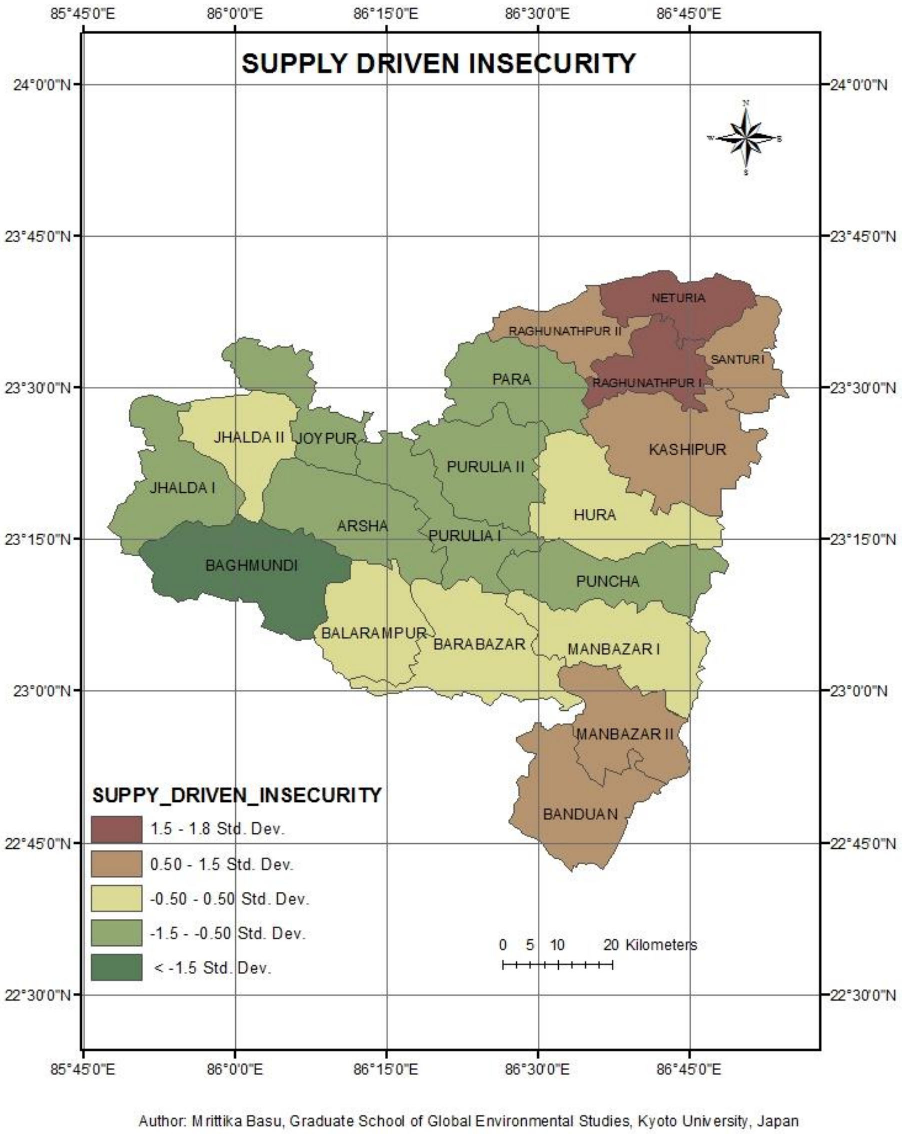

Figure 4.8a Map illustrating the spatial distribution of SDI in the study area

The SDI scores of these two *Blocks* are found to be much above average score (1.5 - 1.8 Std. Dev.), hence demonstrating lower SDI. Distribution of both groundwater and surface water source is highly varied in the district. The local government and Public Works Department (PWD) has stopped giving household connections in the district since 1970s owing to the increasing water shortage in the area. Since then, community taps or hand pumps are installed by local government for rural communities' use. The distribution of water sources is relatively better in the northern *Blocks* of the district like Raghunathpur I, Raghunathpur II and Neturia. Banduan and Manbazar II, located in the eastern part of the district, score relatively low in SDI due to the better distribution of water supply points, established recently by the authorities under various projects and schemes for the upliftment of the area (**Figure 4.8a**). For rest of the *Blocks* in the district, water distribution system is unsatisfactory with most of the villages having very few or no improved water sources.

4.5.2.2 Demand Driven Insecurity Index

Spatial variation of DDI follows a different pattern than SDI with the eastern belt of the district experiencing more demand driven water insecurity than other parts of the district (**Figure 4.8b**). DDI is found to be lowest in the northern *Blocks* of the district (< -1.5 Std. Dev. and -1.5 to -0.5 Std. Dev.). Though the *Blocks* rank high in population density, presence of consistent water supply through piped system makes the *Blocks* relatively water secure. There is a large reservoir (Panchet reservoir) and a perennial river flowing along the border of Neturia due to which the adjoining *Blocks* gets piped water supply. This puts less stress upon groundwater and net water demand is also noticeably less. Groundwater withdrawal for both domestic and irrigation purpose is one of the major factors behind the prevailing DDI in *Blocks* like Para, Purulia I, Purulia II, Manbazar I, Hura, Barabazar and Jhalda I. Also, transmissivity of the aquifer is low in numerous areas of the district that magnifies water insecurity in those areas. More than 90% of the district population depends on groundwater for their daily life which significantly contributes to increasing demand driven water insecurity. Increased stress on groundwater sources results in failure of the pump as prolonged pumping put considerable strain on the pump mechanism leading to breakdowns, especially if water levels are declining. The problem gets exacerbated by the cessation of maintenance activities, thus increasing the DDI of the area. Purulia I and Purulia II have the highest quality affected population, mostly through fluoride and iron contamination of the groundwater (NRDWP, 2013).

4.5.2.3 Adaptive Capacity Index

The ability to perceive and understand changes in water supply and demand are the key features of successful community responses and depend on a variety of factors reflected by adaptive capacity of local communities (Alessa et al., 2008b). **Figure 4.8c** shows an alarming picture of adaptive capacity in the district with nearly thirteen of the total number of blocks demonstrating low and medium adaptive capacity (0.50 – 1.3 Std. Dev. and -0.50 to 0.50 Std. Dev.). Only two *Blocks* in the northern part of the district, Neturia and Raghunathpur I demonstrates very high adaptive capacity (< -1.5 Std. Dev.) which can be attributed to lowered rate of borrowing money, higher physical capacity like access to irrigation facility and higher number of water storage infrastructures, and lower gender gaps in literacy. Less dependence on agriculture-based livelihood make them less reliant on the availability of water for sustaining livelihoods and a well off community can potentially buy themselves out of various problems, relative to poorer communities (Alessa et al., 2008a).

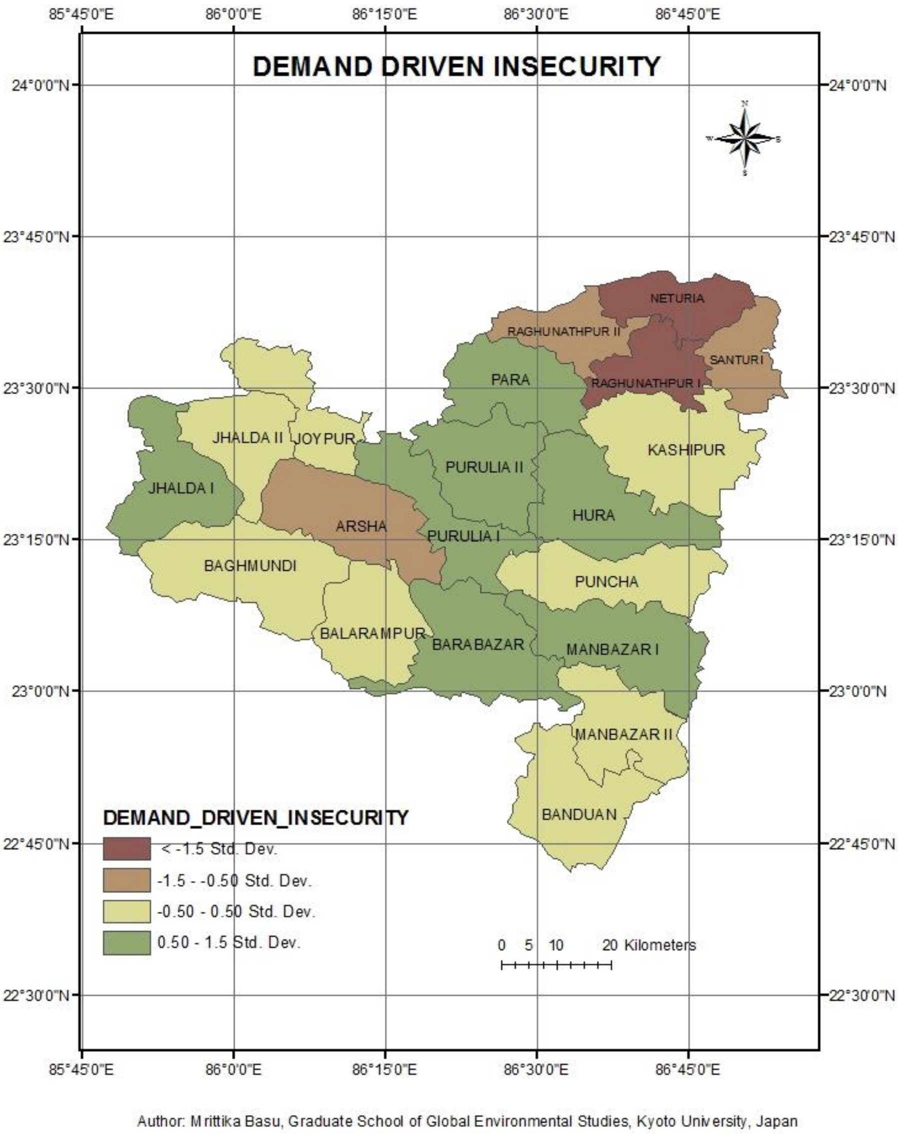

Figure 4.8b Map illustrating the spatial distribution of DDI in the study area

Blocks like Manbazar II and Banduan, in spite of having high water supply provisions, exemplifies low adaptive capacity. This two *Blocks* have been the target of various government initiatives to ensure effective water supply due to the high scale of underdevelopment - led extremist movement. However, the present study demonstrates that the demand side provisions as well as initiatives to improve adaptive capacity has been largely ignored in these two *Blocks*. In addition, western and eastern halves of the district shows comparatively low adaptive capacity which can be attributed high gender gap in literacy, low irrigation coverage and high dependence on agriculture for livelihood. Social capacity denoted by percentage of households borrowing credit and percentage of migrants are also very high in these *Blocks*. The population usually move to work as daily labours in various construction sites, brick making factories or as agricultural labours. The family left in the village becomes more distressed and have to meet their daily needs by borrowing credit from people around them.

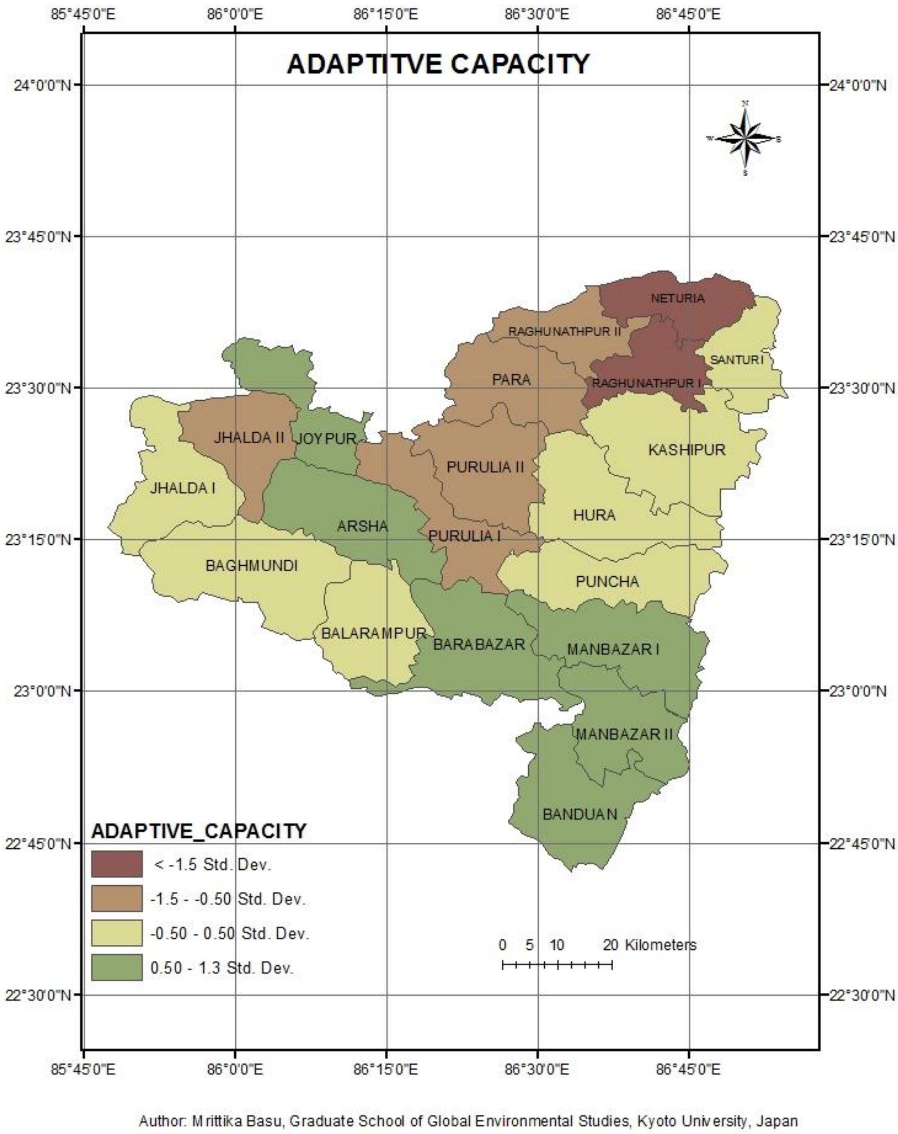

Figure 4.8c Map illustrating the spatial distribution of Adaptive Capacity in the study area

When the family reaches the point of 'no return', the whole family migrates to work outside their villages. Workforce participation is found to be higher in the western and eastern *Blocks* than in the norther part of the district. More workforce participation implies more household income and stability, and capability to react to the unforeseen. However, most of the eastern and western *Blocks* of the district exhibit low and medium capacity. High workforce participation in the most deprived parts of the district can be attributed to the fact that most poor people, from low-income areas, cannot afford to be unemployed and, sometimes, it is just for survival (Cramer, 2010).

4.5.2.4 Rural Water Insecurity Index

Although spatial mapping of the individual dimensions can be useful, it is better to assess the overall vulnerability throughout a region if the multidimensional components can be

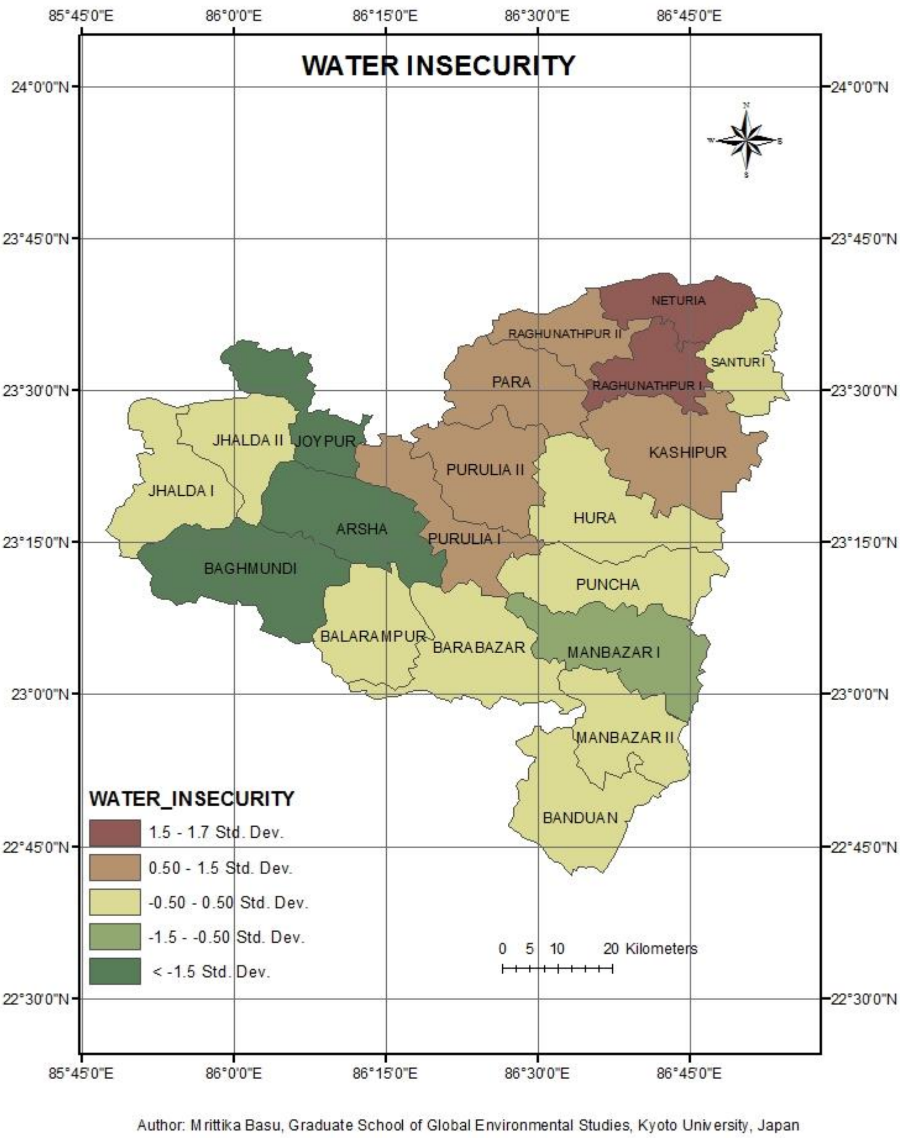

Figure 4.8d Map illustrating the spatial distribution of RWII in the study area

combined into a single measure. **Figure 4.8d** depicts the spatial distribution of RWII among the 20 *Blocks* in the study area.

Mapping with RWII scores allows to determine the potential hotspots of water insecurity within a district, and determine the components that should be prioritized to ensure water security in a particular area. The very high water insecure *Blocks,* showing higher negative deviation from mean (< -1.5 Std. Dev. and -1.5 to -0.50 Std. Dev.), occupy some of the most intensely under developed *Blocks* like Arsha and Baghmundi which can be attributed to the high variation in piped water supply in this blocks along with low work participation rate, lower female literacy rate, less number of water harvesting structures and higher dependence on agriculture based livelihood. Most of the *Blocks* that displays high water insecurity are also reported to score low in Livelihood and Vulnerability Index, as explained by DHDR (2012). Out of twenty *Blocks*, only 10% fared well and are comparatively water secure (Neturia and Raghunathpur I). Finally, it can be concluded that *Blocks* like Arsha, Baghmundi and Joypur needs immediate intervention for improving water insecurity followed by *Blocks* like Manbazar I, Jhalda I, Jhalda II, Balarampur, Barabazar, Manbazar II, Banduan, Hura, Puncha, and Santuri.

Resource availability, whether in terms of social, natural, economic, human or institutional, is fundamental to attain adaptive capacity (Wall and Marzall, 2006). Generally, inadequate access to water as well as poor water quality have been attributed to ineffective water management systems (Dinar, 2003; Fonjong et al., 2004; Garande and Dagg, 2005). It has also been recognized that water resources cannot be considered separately from the surrounding ecosystem and people. Effective adaptive capacity of local people ensures effective maintenance of water resources. For example, lesser gap in gender literacy will empower women in making functional decisions of managing water at the local level. In the present study, when adaptive capacity is plotted against the combination of SDI and DDI (**Figure 4.9**), a more detailed insight into water insecurity is observed. When adaptive capacity of *Blocks* like Joypur and Arsha is plotted against the sum of SDI and DDI, the *Blocks* are found to be highly water insecure. Adaptive capacity of these *Blocks* are not high enough to negate the impacts of SDI and DDI and results to high water insecurity in these *Blocks*. For Raghunathpur I and Neturia, when their comparatively lower SDI and DDI is plotted against their high adaptive capacity, water insecurity was found to be highly reduced. Plotting of low insecurity from supply and demand driven variables against lower adaptive capacity increases water insecurity of *Blocks* like Banduan, Manbazar II and Barabazar. Inclusion of adaptive capacity in RWII reinstated the human faced approach of water security and a better adaptive capacity can negate the worsening impacts of supply or demand driven insecurity.

It is unlikely that all the factors, identified in this study, would perform unsatisfactory every time, thereby achieving the level of water insecurity depicted here. The scores of the variables will keep changing in a temporal scale, shifting the scale of water insecurity in an either positive or negative direction. However, knowledge about the spatial distribution of water insecurity coupled with geographic understanding of lifelines, can help *Blocks* to better prepare for the unforeseen and develop mitigation strategies to reduce future losses.

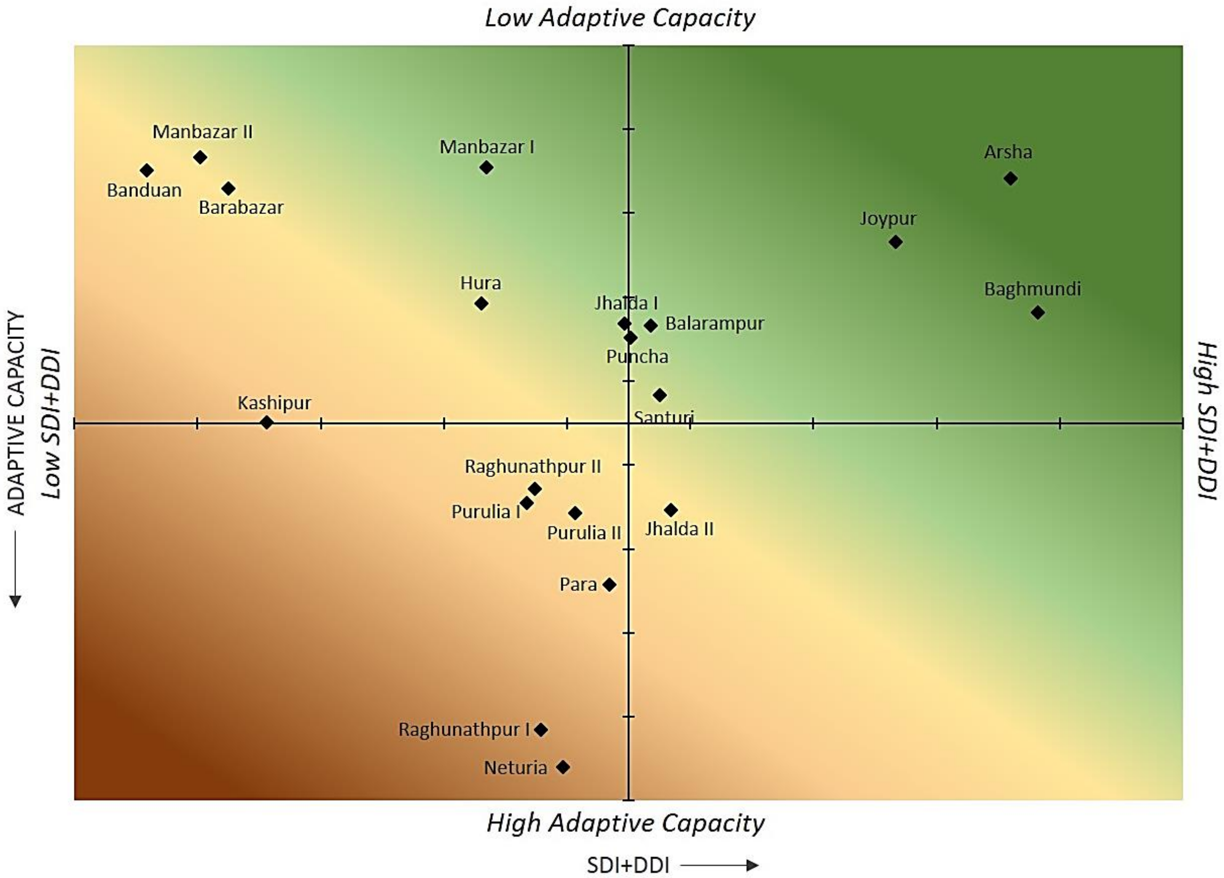

Figure 4.9 Water insecurity matrix demonstrating distribution of *Blocks* with respect to SDI, DDI and AC

4.6 Implications to Rural Water Security Framework

Rural Water Insecurity Index provides a powerful tool for supporting decisions about project planning, monitoring and evaluation and prioritization of water management at a rural scale. This index simplifies a complex reality of rural water management to a more tangible and flexible form so that policymakers, planners, donors, government officials and stakeholders alike can quickly identify which areas and dimensions may be most in need of assistance.

Water security is a dynamic concept and this study investigates it at a particular point in a particular time. The presence of this site-specific institutional framework means that locally-generated decisions can be implemented, with results delivered more quickly (Sullivan, 2011). Considering water security challenges in many rural areas, speeding up service delivery would be a significant advantage. However, as the supply-demand scenario and socio-ecological conditions change, new water security maps need to be prepared to reflect the changes. Hence, precautions must be taken when interpreting the results here and when comparing these results to others created using different data and methods.

The spatial variability of overall water insecurity and its dimensions showed distinct differences. Supply driven insecurity was found to be very high in the western part of the district, whereas demand driven security fared poorly in the eastern part. Understanding the detailed reasons behind high supply driven insecurity can be attributed to localised depletion, resulting in falling groundwater levels in the immediate vicinity of a well or borehole, or group of sources. This is most likely to occur where the demands being placed on a groundwater source are high, and where the transmissivity of the aquifer is low, as in the case of this rural area where more than 90% of the population depends on groundwater for their daily life. In these circumstances, insufficient groundwater is transported to the well or borehole to replenish the water being withdrawn, and a dewatered zone may form around the source. The most likely time for this to occur is at the end of the dry season when demand for groundwater reaches a peak. Increased stress on a groundwater source also makes a failure of the pump more likely. Prolonged pumping throughout the day put considerable strain on the pump mechanism leading to breakdowns, especially if water levels are falling and pumping lifts increasing. The result may be increased demand on a neighbouring source, and thus increased stress (and probability of failure) on that source as well. The problem may be exacerbated by the cessation of maintenance activities as relief drilling programmes take priority.

The influence of adaptive capacity on the dimensions reinstated the human faced approach of water security and stressed that a better adaptive capacity of the local people can negate the worsening impacts of supply or demand driven insecurity. The results presented here do suggest that the use of PCA to derive water security from a suite of indicators of supply and demand driven security and adaptive capacity will be of use in the local scale mapping of water security. Such results not only provide a useful means of assessing relative water security among rural areas, but also indicate the drivers and the relationship among them that results in the water security in the area. The methodology followed confirms “zero loss” of information by integrating the variance of all the extracted components to derive weights instead of using only the first component.

Integrated assessments at a local scale offers pathways to constructive policy solutions by creating options and opportunities. Policy options capable of reducing the exposure of local people to water insecurity is very limited and in many cases, absent. Disintegrating the water supply and demand components into indicators highlights policy opportunities for building it. For example, supply driven insecurity, for this study, can be decreased by investments in developing surface water supply systems and by well-planned distribution of consumer end points or the demand driven insecurity can be reduced by treating contaminated water before supply and policy interventions to develop sanitation system. This helps in the development of micro-level water security framework by highlighting the measures that needs to be improved and the priority areas that need immediate intervention. In spite of the debate on the relevance of indicators and composite index towards policy development, considering the ignorance and negligence faced by most of the rural people in many countries, this study with simple easily available data, contributes towards quick and data driven policy decisions for the local water managers. As the local administrative authority is in charge of sanctioning funds and installation of various water extraction structures and other development provisions in the villages under its boundary, the present study is useful to access the different fund opportunities available for regional or local scale development. Hence, the assessment at a local administrative scale is a significant contributor to the proposed water security framework as it will be functional with the support from local government officials.

4.7 Concluding Remarks

Basic water management issues, supply and demand, emerged as a significant contributor, along with adaptive capacity, in safeguarding water security at a rural administrative scale. The present study enforces the need for shifting the focus from physical factors of water availability to more community based priorities when considering water security for rural areas. The PCA based assessments demonstrated the variability in a spatial scale with different rural areas (*Blocks*) characterised by different scale of water insecurity. The impacts are found to be severe for the poor who lived in vulnerable areas including mountains and forests, depended on rain-fed agriculture and groundwater to meet basic needs, own little land or other physical assets, and have low education and skills. The difference in the distribution of supply and demand driven insecurity among the *Blocks* leads to the fact that except for reduced supply, other factors also play a noteworthy role in increasing the demand like contamination of source water, excessive groundwater withdrawal or higher rate of evapo-transpiration. The factors identified illustrate how the rural communities appear to be struggling to adapt to their changing environment with their low adaptive capacity demonstrated by their limited knowledge, poor assets, high livelihood insecurity and inadequate external support. Limitations of the study include the data sensitivity and influence of various factors (e.g., sample size, sampling strategy and biasness in response) on the assessment results. However, it is important to outline that the results are based on quantitative data that can be easily measured and validated. Flexibility in inclusion or exclusion of relevant and location-specific indicators makes the index more versatile in its applicability in new areas.

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CHAPTER 5

DETERMINANTS OF HOUSEHOLD DOMESTIC WATER CONSUMPTION

"The waste of plenty is the resource of scarcity."

Thomas Love Peacock

CHAPTER 5: Determinants of household domestic water consumption

This chapter investigates the determinants of water consumption at household scale and assesses how different seasons and socio-economic conditions of household impacts their per capita water consumption. Out of the different variables included, Ordinary Least Square regression selected 11 variables that influence household water consumption significantly. The variables found to influence household water consumption not only included household demographic and economic characteristics but also social characteristics like household participation in village meetings and household demands being addressed in local decision making process. Households have been segregated into different groups based on their ownership of assets and the study found that there is a strong relationship between household consumption of water for domestic use and socio-economic conditions. Seasonal impacts on household water consumption are also found to be profound, mainly during the dry season. The present study helps in streamlining the issues that need attention at a household scale to ensure water security at a larger scale.

Outline of the chapter

5.1 Introduction

Rural areas in developing countries are often neglected in the provision of water facilities. Where such facilities exist, they are seldom fully utilized (Sharma et al., 1996). This can be attributed to their design and implementation engineering which is mainly guided by technical considerations. Rathgeber (1996) argues that water planners in developing countries usually assume that households and other social groups in rural communities will change their water use habits to accommodate to the changes around them. They fail to recognize that improving water supply provisions cannot solve the household water security alone. The demand side provisions, cultural and social inclinations of the households are seldom considered before developing any water supply plan. Before providing new rural water facilities, it is expedient that water planners should understand the existing water use habits of the local population, and how they may adapt their use in changing conditions.

Several studies have been conducted to understand residential water consumption (Tucker et al., 2014; Lee et al., 2012; Sivakumaran and Aramaki, 2010). These studies have shown that patterns of water consumption not only vary with nations and communities but also significantly across households depending on multitude of factors like social, economic, cultural, and climatic, water availability and accessibility as well (Corbella and Pujol, 2009; Jorgensen et al., 2009; Rathnayaka et al., 2014). These factors are highly characterized with distinct spatial and temporal traits and the spatial variability of household water use reflects the structure of the household, economic status and local water use culture. However, little is known about how much water people actually use, from what sources, and how this varies over time and among communities and households. These questions matter because of the vital health and livelihood benefits of water access (Howard and Bartram, 2003; Tucker et al., 2013). Few studies capture information on actual water use and the factors which shape it. Reviews of empirical literature on water consumption show the dominance of residential (urban) over that of rural water consumption studies in spite of a large difference urban and rural household water consumption pattern.

Considering the importance of domestic water consumption to household well-being and livelihood, various minimum volumetric standards have been proposed for daily per capita water needs for domestic purposes, comprising water for drinking, cooking, personal hygiene and laundry/cleaning. The Sphere Project (2011) sets standards designed for use in emergency situations, specifying a minimal requirement of 7.5-15 lpcd. For non-emergency situations, others have suggested higher minimum volumes ranging from 20-50 lpcd (Gleick, 1996; Carter et al., 1999; Howard and Bartram, 2003). The World Health Organization (WHO) classifies the supply and access to water in four service categories. These categories are: (i) no access (water available below 5 lpcd); (ii) basic access (average approximately 20 lpcd); (iii) intermediate access (Average approximately 50 lpcd); and (iv) optimal access (average 100-200 lpcd) (WHO, 2003; Howard and Bartram, 2003). The Ninth Five Year Plan (1997-2002) of government of India had advocated the requirement of water for those collecting from public posts as 40 lpcd.

It is often argued that efficient management of water resources in rural areas requires a full understanding of existing patterns of water use (Nyong and Kanaroglou, 1999). In rural and impoverished areas, similar to the present study area, inadequate access to convenient water resources force households to travel long distances and often means that children are employed to collect water, adversely affecting productive activities of adults and education of children (Mehta et al., 2014). In addition, poorer households may use water from open sources, often contaminated, which increases vulnerability to water-borne diseases. When households do gain access to a water system, their well-being can increase dramatically. Hence, capturing variability of household water consumption for the prediction of water demand is essential to perform efficient and effective supply and demand balance assessment at any spatial scale, particularly at household and precinct scales. Domestic water demand management may help to reduce water deficits and improve the reliability of supplies, and may lessen existing pressures on the natural environment. In addition, it could improve utility management band decrease economic costs. Though various studies have been carried out that assess the links to poverty and residential water demand, few studies has made an attempt to link household water consumption with household socio-economic an demographic characteristics in a rural area.

5.2 Research Framework

This chapter mainly focusses on the concept of water security (Chapter 2) and hypothesizes that, even at a narrow scale like household, determinants other than related to water like household income, social relationships, education level, source of income etc. play a major role in domestic water consumption pattern. It also hypothesizes that understanding the factors that influence household water consumption helps in identifying the provisions that need to be improved to ensure household water security. A few attempts have been made to define household water security like Ariyabandu and Dharmalingam (1997) defined household water security as “having adequate domestic water supply, so that the productive life of peasants can be sustained”. What determines water security, according to Ratnaweera (1999), is the ability of households to obtain the required quantity of suitable quality water for drinking water, personal hygiene, other domestic purposes and other economic activities. A definition by Ariyabandu (2001) expresses household water security as “accessibility, reliability and timely availability of adequate safe water to satisfy basic human needs”. Deriving from the previous definitions and in lieu of the present study, household water security in rural areas can be defined as a constant and reliable availability and accessibility to safe and adequate volume of water that maintains health and hygiene at a household level and meets all the domestic water demand, including for livestock. Hence, it becomes imperative to assess the household water consumption pattern and the determinants to understand if the household is water secure or not.

Household water consumption, in the current pretext, refers to the volume of water withdrawn and conveyed for use. The households, without personal water source, withdraw and fetch water from improved sources like community hand pumps, tap water or borehole, mainly for cooking and drinking purposes. As the improved sources are few and the demand are high, in rural areas in developing countries, similar to the present study area, bathing, washing clothes and utensils are usually carried out in open sources like ponds and river or in open community wells. If a household own a toilet facility, water for sanitation is usually carried from the unimproved water sources available. Though in a developing country like India, more than half a billion people still practice open defecation. The household livestock usually consume the surface water available in the ponds and rivers. With the onset of dry season the surface water sources usually dries up in arid and semiarid areas across the world and the households, in such cases, have to withdraw water and convey for livestock use also.

Drawing from the concept of water security, the present research framework (**Figure 5.1**) includes household demographic determinants, economic determinants and social determinants to analyse their relationship, if any, with household water consumption (**Table 5.1**). Household productive characteristics has been included in these framework to assess the household if household water use for productive uses like crop production or livestock rearing has any influence over household water consumption. In addition, household water consumption revolves round issues of water availability, accessibility, usage and quality (**Figure 5.1**). Traditionally, availability has been at the central focus (Ariyabandu, 2001) although availability alone does not ensure household water security at a given point in time. Water availability is affected to a larger extent by environmental factors that may result from hydrological changes and may have short-term variations. In this case, water is viewed as a natural resource that has to be managed and sustainably used. Hence, the unsustainable consumption of water may have long-term impacts by reducing available water to communities concerned. Human factors also influence water availability in that available water would have to be harnessed and distributed to ensure adequate and reliable flow.

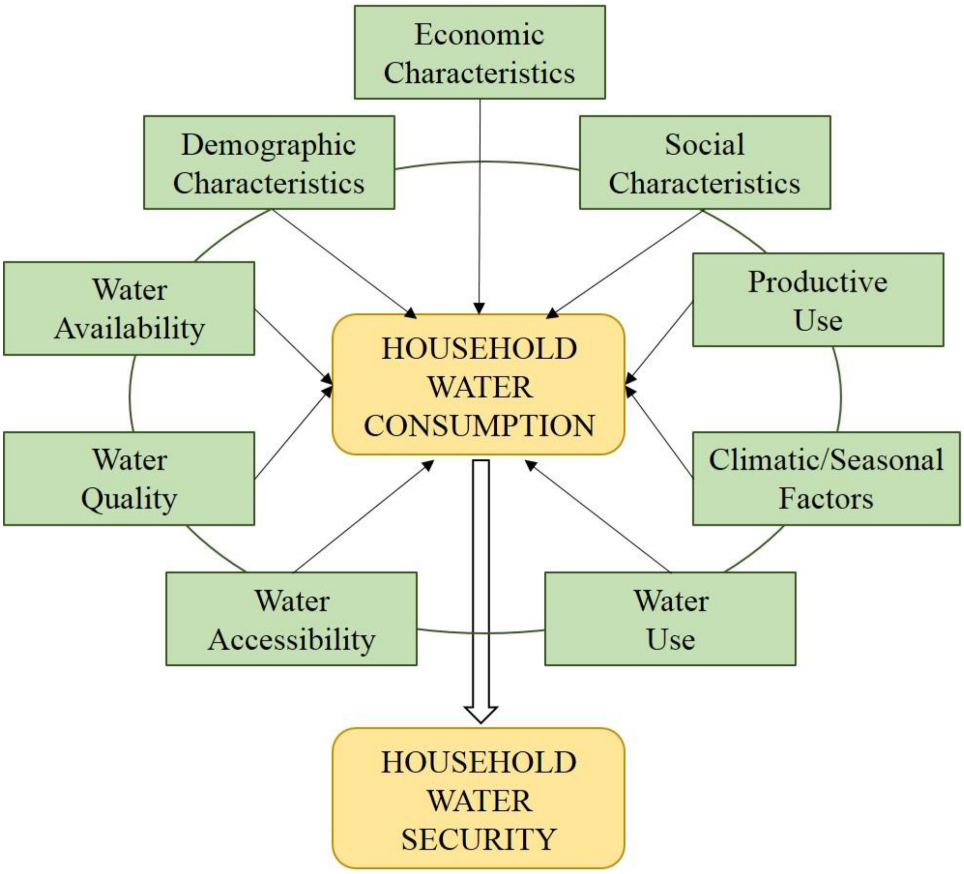

Figure 5.1 Research framework demonstrating determinants of household water consumption in rural areas

Water accessibility considers water as a commodity and ensures that households have full or firm control of the available water. Access to this commodity therefore depends on its physical location and timely availability. Water usage relates to "entitlement rights" of households, required for basic needs (i.e., for drinking, cooking, hygiene and sanitation) and other purposes such as watering livestock and backyard gardens. The availability and location of natural water sources and the siting of water supply points in communities determine the ease of accessibility, which may influence quantities consumed and for that matter, usage patterns. In addition to these, the quality of water is important because households cannot be secure from water-borne and water-related diseases when its quality is questionable. Seasonal variation also plays a significant role in household water consumption particularly for areas which are dependent on different seasons for water availability.

Table 5.1: List of major dimensions and variables used in the present study

Major Dimensions	Variables	Major Dimensions	Variables
Demographic Characteristics	Household size	Water Availability	Primary source of domestic water
	Age and gender of household head		Availability of water from primary source
	Age dependency ratio		Water collected by household (season wise)
	Male : Female ratio	Water Quality	Quality of water used for domestic use
	Education level of household head		Household water treatment
	Literate members of household		Household water treatment method
Economic Characteristics	Households below poverty line	Water Accessibility	Access to personal water source
	Primary source of household income		Time spent on collection of water (season wise)
	Household income per day		Water collection distance (season wise)
	Access to sufficient food		Number of trips to collect water per day (season wise)
Social Characteristics	Participation in village meetings	Hygiene and sanitation	Household access to toilet facility
	Priorities or demands addressed in local decision making process	Conflicts	Intra-community conflicts over water availability and accessibility
	Help/assistance from community members		Inter-community conflicts over water availability and accessibility
Productive Characteristics	Agricultural land holding size (ha)		
	Water available for crop cultivation (months)		
	Livestock holding size		

For example, in rural areas where no stable water supply system exists, rainfall is the principal source of water not only for agriculture but also for domestic water use as rainfall helps in recharging groundwater as well as filling up surface water sources like ponds. At this point, it is important to note that this determinants may influence household water consumption individually and/or in a concerted action with other determinants.

5.3 Survey Approach and Methodology

5.3.1 Research Objectives

Rural household water consumption is under-researched compared to urban water demand studies. Understanding of the dynamics of local water use in time and space is a necessary task with several important applications. First, it helps in strengthening the design and planning of services: enabling providers to better target those most in need, increasing scheme reliability, and thus maximizing the benefits derived from the investments. Secondly, characterization of how water access and use respond to existing levels of rainfall and temperature variability can inform programmes and investments aimed at increasing resilience to longer term climate change. Thirdly, in impoverished areas, beset with chronic food security and repeated food crises, there is an urgent need to understand the drivers of food security and to identify the preparedness measures that would protect livelihoods from water scarce periods.

Although domestic water use (cooking and drinking, in this case) accounts for only a small percentage of total water consumption of a household, the benefits associated with an adequate supply, such as the effects on health, savings of time, and greater productivity, are immense. In this context, analysis of household level determinants of water consumption is an important tool for gaining a comprehensive understanding of the behaviour that shapes a household's use of water and ensures water security at household scale.

5.3.2 Selection of study area

To carry out the survey, villages were selected from various *Blocks* in the district under study. The *Blocks* are selected based on their water insecurity status, as analyzed in Chapter 4. Villages from Arsha and Baghmundi are selected as the districts are found to be highly affected by water insecurity. Similarly, Puncha and Manbazar I are observed to experience high water security. Villages from three *Blocks*, namely Jhalda II, Purulia I and Purulia II, have been chosen to represent household water consumption in moderately water insecure *Blocks*, whereas Neturia and Raghunathpur I are chosen to represent low water insecure *Blocks*. A total of 330 villages were selected from the nine *Blocks* for household survey (**Figure 5.2**).

Prior to the survey, five villages from each *Gram Panchayat* (GP) in a particular *Block* was selected based on their location, water sources and feasibility to carry out the study. For instance, five villages (highlighted) spread across the nine GPs have been selected in Purulia II *Block* to demonstrate the rural household water consumption. The villages are selected in a way so that they are, as much as possible, uniformly spread across the GP and the *Block*. Less or more than five villages were considered for survey depending on the dimension of the GP, lesser or higher number of villages in the GP or non-feasibility to carry out the survey. With the selected list of villages, discussions were conducted with local government officials and a prior reconnaissance survey was done before the final list of villages to be surveyed were made.

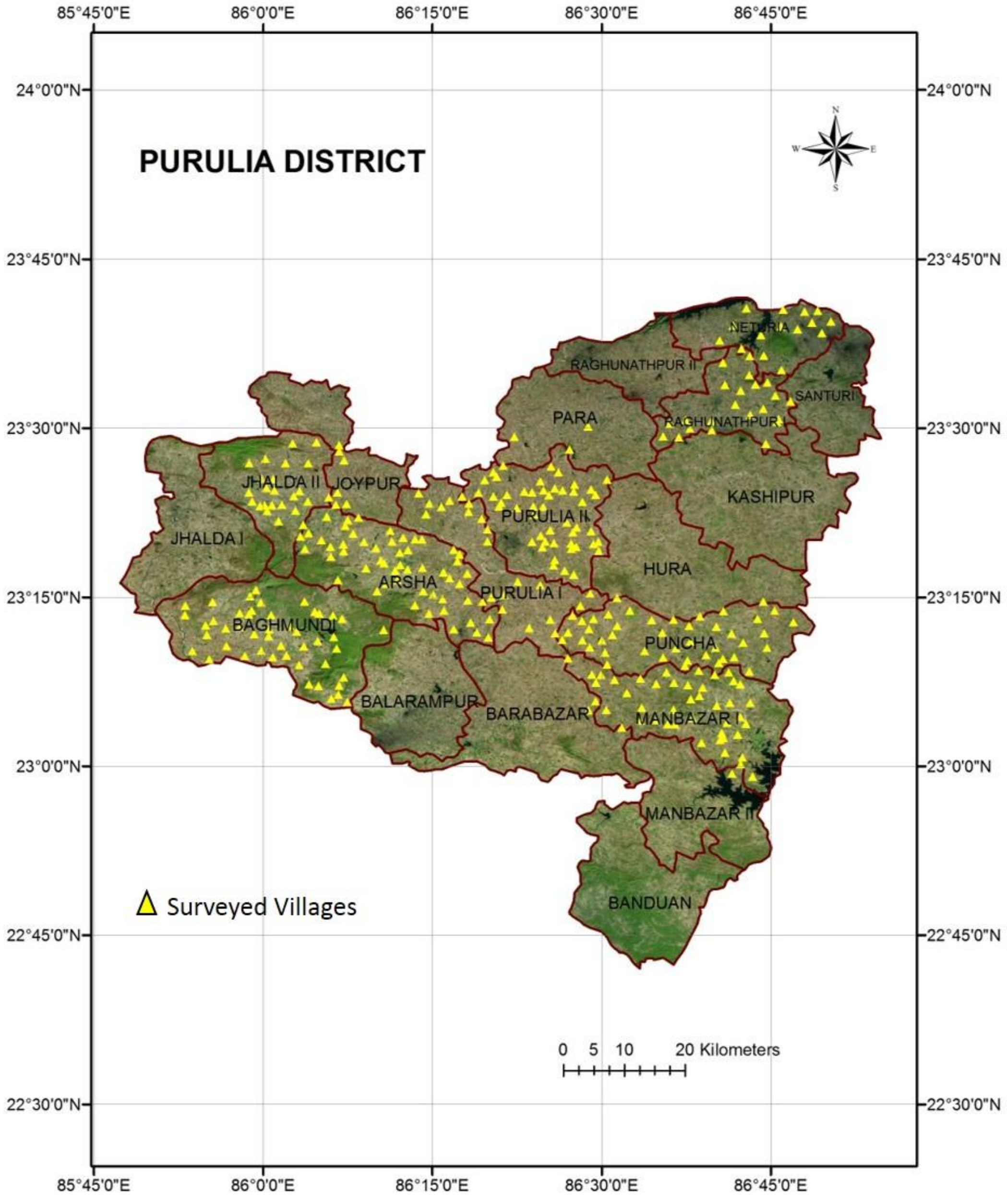

Figure 5.2 Map showing the location of the villages under survey

5.3.3 Selection of households and data collection

Primary data was collected using structured questionnaire survey. The questionnaire was mainly divided into two sections (**Appendix II**). The first part consisted of information on basic household demographic characteristics, measures of household wealth (such as household assets, type of construction, and livestock), food security, social networks, and household income sources and levels. The second part of the questionnaire included information of household water sources, time and distance to collect water, volume of household water use, water treatment, accessibility to toilet facility and other related factors. Data were collected over a two and half month period in May – July 2013.

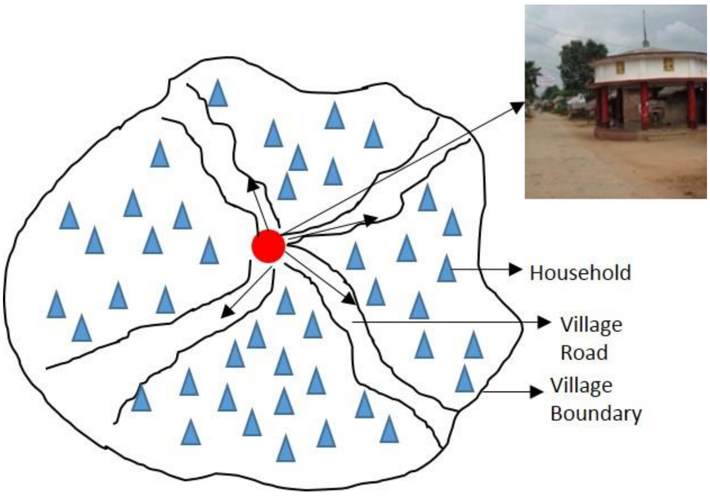

Figure 5.3 Sampling plan followed to select households in the present study

The study used household as a unit of analysis as households appear to be the key unit to analyze the relationships between population and domestic water consumption. Household dynamics are considered basic to understand resource use and environmental impacts (Liu, 2003). Simple random sampling technique was followed to select households such that each and every household has an equal probability of being included in the sample. As shown in **Figure 5.3**, the centre of the village was taken as the starting point. Each village road intersecting the village centre was followed and five households were randomly sampled based on their location – one each at the beginning and end of the road, and three households located along the middle section of the road. If a household on the path was empty or the owner did not agree to participate, the next closest household was approached. Twenty to twenty five households were interviewed in each village. Ten volunteers, mostly college students, were appointed to assist in carrying out the questionnaire survey. The volunteers were given prior training before carrying out the survey. A total of 1780 households were surveyed (*N = 1780*) and verbal consent was obtained from the head of household before conducting the survey. Generally the head of the household was interviewed, but if s/he was not available, the spouse was interviewed. As the questionnaire focussed on detailed information about household water collection and use which are mostly carried out by women of the household, the surveys were actively participated by household female members along with the male members (**Figure 5.4**). Though greater time and effort were expended in the survey, the questionnaire was administered personally via face-to-face interviews to reduce inaccuracies of inconclusive responses and difficulties encountered in survey item interpretations. Identifying information recorded was limited to the name of the village and the questionnaire number. Each interview lasted on average 30 – 40 minutes and were carried out in local language i.e. Bengali.

Figure 5.4 Questionnaire survey in different households in the study area

5.3.4 Data analysis

Various statistical techniques were applied to analyze and present the data. The statistical package SPSS 22.0 was used for data entry and analysis. Simple descriptive measures, analysis for variance, Post hoc tests, and multivariate regression analysis were applied. Principal component analysis was used to assess the socio-economic status of households on the basis of assets they hold. Prior to any parametric statistical analysis, data was assessed for normality.

Multiple regression analysis

A stepwise multiple regression analysis has been carried out to create a model of household water consumption (lpcd) (excluding the volume of water required for bathing, washing utensils and clothes) as the dependent variable. Household demographic, economic, and social characteristics, and water accessibility, availability, treatment, local conflict etc. as independent variables (**Table 5.1**). The Ordinary Least Squares regression method (OLS) (Freund et al., 2006) was used that determines the significance of correlation between the independent and dependent variable. The OLS model utilizes all variables at all locations to estimate the value of the dependent variable (Eq. 1).

$$y_i = \beta_0 + \beta_1 X_{1i} + \cdots + \beta_k X_{ki} + \varepsilon_i \qquad (1)$$

The OLS is defined by the dependent variable, y_i on the left side of the equation, the independent variables, X_{ki} ($k = 1, 2 \ldots$K) and ε_i, the error or disturbance term which is a random variable with zero mean. The β_s or regression coefficients are unknown and usually assumed to have fixed values. β_0 represents the intercept coefficient and β_k (k = 1… K) are the slope coefficients. In a linear model, β_1 is the impact of a one unit increase in X_1 on y, holding the other independent variables constant.

Computation of Asset Index: Principal component analysis

Information on expenditure and income are the most widely used tools for differentiating economic status of households. However, in many surveys it's hard to obtain data on expenditure and income, particularly for rural areas where the people does not have a fixed monthly income as they either work as daily wage labours or practice agriculture. In such cases questioning the availability of household assets would serve as a tool for constructing an asset index and thus differentiating the economic status of households. A household whose income is higher is expected to spend more and possess more of the durables and would be expected to have better housing conditions. Though the survey carried out in the present study included household income per day, household assets are considered as a more reliable way to measure the economic status of the households.

In the present study dummy variables were created for 17 assets. All variables were first dichotomized to indicate the ownership of each household asset (Vyas and Kumaranayake, 2006). The asset variables are grouped into three types. First category is household ownership of monetary assets like possession of bank account, monetary savings in bank and/or post office and health insurance, ownership of agricultural machinery like tractors and water pump and, ownership of consumer durables like bicycle, refrigerator, television, motorbike, car and ceiling fan. Second category is characteristics of household dwelling with three variables about toilet facility (no-, unimproved- or improved-toilet), one about construction material and one each about source of energy for cooking and lighting. The third category of household assets mainly includes land ownership and possession of livestock.

One of the major issues in using assets to measure household socio-economic status is about the weights to assign to each asset variable. Filmer and Pritchett (2001) proposed the use of Principal Component Analysis (PCA) for estimating wealth levels using asset variables to replace income or consumption data. The first principal component explains the largest proportion of the total variance and is considered to represent household's socio-economic status (Houweling et al., 2003). The weights for each variable from this first principal component is used to generate scores for each asset. Assets that are more unequally distributed have a higher weight in the first principal component. Variables with low standard deviations would carry a low weight from the PCA; for example, an asset which all households own or which no households own would exhibit no variation between households and would be zero weighted, and so, of little use in differentiating Socio-Economic Status (SES). Finally, all the asset scores for each household are put in an additive model to generate asset index (Eq. 2).

$$y_i = \alpha_1 \left(\frac{x_1 - \bar{x}_1}{s_1}\right) + \alpha_2 \left(\frac{x_2 - \bar{x}_2}{s_2}\right) + \cdots + \alpha_k \left(\frac{x_k - \bar{x}_k}{s_k}\right) \tag{2}$$

Where, $\bar{x}_k$ and s_k are the mean and standard deviation of asset x_k, and α represents the weight for each variable x_k for the first principal component.

The households has been classified according to their asset index into quintiles (5-quantiles) to segregate them into different socio-economic groups.

Analysis of Variance (ANOVA) and Post Hoc test

To better understand the relation between household economic status segregated into five groups and water consumption patterns and other independent variables related to water, one-way ANOVA was used. A significant F-test value in one-way ANOVA determines that there are significant differences between the means of independent groups of households according to their water consumption patterns and other water related dependent variables. However, it is important to realize that one-way ANOVA is an *omnibus* test statistic and cannot tell which specific groups were significantly different from each other; it only tells that at least two groups were different. Since, there are five groups in this study design, determining which of these groups differ from each other, in relation to water consumption patterns and other water related variables, is important. Hence, Tukey HSD post-hoc test was conducted to find out which pairs of household economic groups are significantly different from each other.

5.4 Results and Discussion

5.4.1 Demographic and socio-economic characteristics of households

The total sample size was 1780. Due to large number missing information, 143 samples were discarded from the final sample for analysis. Descriptive analysis of the variables were made and the results are presented in **Table 5.2** and **Table 5.3** for continuous and categorical variables, respectively.

The key points to be highlighted from **Table 5.2** are that the households have low levels of schooling and hold very small agricultural land. The age statistic indicates that households exhibit an ageing trend with the dominance of older households than younger ones in the study area. Average number of household literate members are approximately half of the average household size. This indicates a higher illiteracy level that characterizes the district.

Table 5.2: Description of household characteristics using continuous variables

Variable	Mean	Std. Dev	Min	Max
Household head age (years)	49.40	11.80	18	93
Household size (adult equivalents)	6.43	3.00	1	25
Age dependency ratio (%)[1]	60.512	52.84	0	600
Household literate members	2.98	2.04	0	20
Male: Female ratio	1.32	0.82	0	6
Access to food (months)	10.28	1.93	4	12
Agricultural land size (hectares)	1.12	1.74	0	26.4

Average male to female ratio is observed to be more than 1 which suggests the predominance of male members than the female members in a household. The proportion of age dependency ratio demonstrates that, on an average, 60 of the household members are dependents per 100 working age population. Average duration of household's access to food is found to be less

[1] Age dependency ratio is the ratio of dependents – people younger than 15 or older than 64 years- to the working age population (15-64 years).

than 12 months with some households having access to sufficient food for as low as four months. This indicates the deprived condition of local people in the study area.

Table 5.3 indicates that majority of the households are male-headed. Only 28.56% of the household head have an education up to primary level and out of 50% of the sampled household heads, 26% are found to be able to non-formally educated i.e. they did not attend any school and have very preliminary level of education like signing their names. This confirms the low level of education in the study area. Out of the sampled households, more than half of the proportion are found to lie Below Poverty Line (BPL) (Rs. 32/capita/day or $0.49 per day for rural areas) that identifies them as belonging to the deprived group and entitles them to receive various subsidies and reliefs from the government. However, many households reported high level of political intervention, corruption and lack of transparency in the entitlement under BPL list due to which the real poverty stricken households are often not included in the BPL list. The physical characteristics of households like construction material, lighting source and cooking fuel source are also included in **Table 5.3**. Majority of the studied households (69.76%) are observed to have 'Kachha' house i.e. made of mud and bamboo with thatched or mud tiled roofs. Only 30% of the households have 'Pukka' or concrete house made with bricks and a concrete ceiling. Electricity supply for lighting has developed a lot in the study area with more than 70% of the households reported to have electricity supply. However, lack of consistency and reliability in supply is yet to achieve. More than 80% of the households are found to use 'traditional' sources like fuelwood, cow dung and leafs and hatches as cooking fuel followed by 'intermediate' fuel sources like coal, charcoal and kerosene. This demonstrates the inability of the households in using improved and modern cooking fuel like LPG (Liquid Petroleum Gas). All the findings cited above demonstrate the deprived conditions of the households and indirectly relates to the existing poverty and lack of development in the study area.

As mentioned in Chapter 4 (section 4.3), a majority of the population in the district is dependent on agriculture for their income. Out of 65.49% of the surveyed households depending on agriculture, 23.22% are found to be solely dependent on agriculture to run their family and does not derive income from anywhere else. This group includes only the main cultivators. Agricultural labours are included in the group dependent on both agriculture as well as part-time off-farm work to run their family. As crop cultivation takes place only during a certain period of the year, the agriculture labours have to engage themselves in off-farm activities to earn money. A relatively higher percent of household (29.29%) deriving family income from both agricultural activities and part time off farm work demonstrates the lack of

Table 5.3: Description of household characteristics using categorical variables

Variable definition	Categories	% distribution
Household head gender	0 = male 1 = female	94.94 5.06
Household head education	1 = Illiterate 2 = Literate (non-formal) 3 = Primary education 4 = Secondary education 5 = Higher secondary education 6 = College 7 = University 8 = Others (vocational)	23.72 26.53 28.56 17.20 2.64 0.96 0.34 0.06
Households below poverty line	0 = No 1 = Yes	45.92 54.02
Household with migrated members	0 = No 1 = Yes	86.51 13.49
Primary construction	0 = 'Kachha' 1 = 'Pukka'	69.76 30.24
Primary light source	0 = No electricity supply 1 = Electricity supply	25.91 73.97
Primary cooking fuel source	1 = Traditional 2 = Intermediate 3 = Modern	83.02 15.40 1.57
Source of household income	0 = Only agriculture 1 = Only part-time off-farm work 2 = Only full-time off-farm work 3 = Both '0' and '1' 4 = Both '0' and '2' 5 = Both '1' and '2' 6 = All of '0', '1' and '2'	23.22 25.91 7.03 29.29 12.98 1.57 0.00
Agricultural land holding size	0 = None 1 = Marginal (< 0.01 km^2) 2 = Small (0.01 – 0.02 km^2) 3=Semi-medium (0.02 – 0.04 km^2) 4 = Medium (0.0.4 – 0.1 km^2) 5 = Large (≥ 0.1 km^2)	26.87 41.99 17.93 9.05 3.71 0.45
Livestock holding	0 = No 1 = Yes	34.35 65.60
Household toilet facility	0 = No toilet facility 1 = Unimproved toilet facility 2 = Improved toilet facility	88.76 8.09 3.49

reliability of local villagers on agriculture alone. Also, lack of agricultural land, monetary asset or lack of proper irrigation facility compel many of the studied households (25.91%) to earn money through part time off-farm activities only like working as daily wage labours in construction sites, brick factories etc. The lower percent of households (7.03%) dependent only on full time off-farm activities like working in offices or factories with a fixed monthly income can be attributed to the lack of education level and livelihood skills in the study area. Except for 26.87% of the surveyed households who do not possess any agricultural land, more than 40% of the sampled households reported to own marginal land holding size (less than 1 ha). Thus it can be inferred that most of the farmers in the study area are marginal farmers. Out of total 1780 households, only eight households are found to possess more than 10 ha of agricultural land and can be considered as large-scale farmers. Another notable finding from **Table 5.3** is the absence of any toilet facility in nearly 88% of the studied households. Open defecation is found to be a common practice in the study area and can be extremely harmful for the health and hygiene of the local people.

5.4.2 Daily domestic water consumption

Domestic water use refers to drinking, cooking, personal hygiene and laundry (Tucker et al. 2014). Various international standards exist for minimum volumes of domestic water required to sustain life and health, and are expressed in litres per capita per day (lpcd) (mentioned in section 5.1). In case of the present study, as mentioned in section 5.2, the households collect water mainly for drinking and cooking purpose and water demand for rest of the domestic work like laundry and utensil washing are usually carried out outside the house in open water sources. Very few households have toilet facility, hence water is not fetched in the study area. For the households with toilet facility, water is carried, when in need, from nearby open sources like ponds and is difficult to quantify.

To quantify the volume of water consumed by household for domestic use, jerry cans, pitchers and/or other containers used by the household were viewed at the start of the survey. The volume of the used container were measured by the interviewer to convert reports given in numbers of containers and number of fetching times into volumes of water consumed (**Figure 5.5**). Household women were mostly consulted to quantify the volume of water consumption as they are the principal carriers and users of water in the study area. The average household water consumption for domestic use is found to be 9.66 lpcd in the surveyed households with a minimum consumption of 4.17 lpcd to a maximum consumption of 22.5 lpcd.

Water consumption of only 1.52 % of the sampled households are found to exceed the basic water requirements recommended by the Sphere Project for humanitarian emergency situations (7.5-15 lpcd) (The Sphere Project, 2011). Out of this 1.52%, only 4 households (0.22%) are reported to consume domestic water above 20 lpcd i.e. the recommended basic water requirement for non-emergency conditions (The Sphere Project, 2011) and the maximum amount of water used by a household is found to be 22.50 lpcd. Gleick (1996) recommended a minimum volume of 10 lpcd for cooking and 5 lpcd for drinking irrespective of climate, technology and culture of the region. Out of the surveyed households, 98.48% households consume less than 15 lpcd (for both cooking and drinking). Out of this 98.48% of households, 11.69% are observed to use even below the basic water requirement recommended for emergency situation (7.5-15 lpcd).

Figure 5.5 (A) Village woman showing her water collecting container during the survey; (B) Village women collecting water for cooking and drinking use from hand pump

The results indicate that the volume of water consumed by the households to meet domestic needs is much below the international as well as national (40 lpcd) recommendation level of basic water requirements for human needs. This may compromise with the health of the household especially the children. As the households are found to consume lower volume of water to meet domestic needs, it becomes imperative to understand the factors that hinder or limit the household domestic water consumption.

5.4.3 Determinants of household domestic water consumption

The Ordinary Least Square regression analysis was used to identify the determinants that affect the variability in household water consumption per capita per day (dependent variable). **Table 5.4** summarizes the result. Stepwise regression method has kept the determinants showing *p* value smaller than 0.05 and *F* value greater than 1.84 (critical value) as significant at 0.05 level. Hence, out of the 29 variables included in the study, multiple regression model retained only 11 variables that explain household water consumption significantly. The model fits the data very well, as indicated by a highly significant *F* value. The determinants statistically significantly predicted household domestic water consumption, F (11, 1767) = 145.65, $p <$ 0.0005, $R^2 = 0.476$. An R^2 value of 0.48 is considered acceptable for cross-section data in light of the argument of Studenmund and Cassidy (1987) that an R^2 of 0.35 is a good result for cross-section data. The R^2 in cross-sectional models is usually much lower than those obtained in time series models, since each case in the cross section will have a number of specific characteristics that cannot be adequately modeled.

Heteroskedasticity is remedied by using robust standard errors. The model had no problem of multicollinearity which is evident from the Variation Inflation Factor (VIF) and tolerance values. The suggested model has a low average variance inflation factor (VIF) of 1.91, with the highest VIF of 3.17. A value of 10 has been recommended as the maximum level of VIF (Hair et al., 1995; Kennedy, 1992). Tolerance values of all the determinants in the model are higher than 0.20. A value of .10 is recommended as the minimum level of tolerance (Tabachnick and Fidell, 2001). However, a recommended minimum value as high as .20 has also been suggested (Menard, 1995). Therefore, it can be concluded that the OLS model's estimated coefficients are unbiased, consistent and efficient. Detailed analysis of each determinant is described below:

5.4.3.1 Household size

In principle, the higher the number of people living in a household is, the larger the aggregate demand is supposed to be. In the literature, household size is the most widely claimed determinant affect household water use (Keshavarzi et al., 2006; Dungumaro, 2007; Rathnayaka et al., 2014). The coefficients of this model also show that household size is the most significant determinant of household domestic water consumption per capita per day (**Table 5.4**). However, household size is found to be inversely related to the dependent variable i.e. in households with larger families, water consumption per capita per day is reduced. A plausible explanation can be that for households with more members, it becomes difficult for the collector to meet the demand of every member and this becomes truer if there is not enough water available nearby for the household. Also, household with more members has higher probability of experiencing poverty than those with fewer poverty. It can be fairly argued that households with large size are less likely to obtain water from a safe source.

5.4.3.2 Participation in Gram Sansad meetings

Water governance essentially concerns the highest level of participation (Singh, 2008). In the local governance context, this implies interaction among different stakeholders in determining their agenda and in managing resources to implement development priorities. In India, water governance is being progressively institutionalized at local levels. The subject of rural water supply is vested with the local government (discussed in Chapter 3) that is functional at three levels, namely, district, *Block* and village. Ideally, *Gram Sansad* meetings handle decisions on selecting the location of new water sources (generally hand pumps), and in operation and maintenance of the sources (MoRD, 2002). Hence, participation in these meetings demonstrates the active involvement of the local community in the decision making process.

Table 5.4: Ordinary least squares results estimating the determinants of household water consumption

Variable	Coefficients	Std. Error
Household Size	-0.732*	0.018
Participation in *Gram Sansad* meetings	0.247*	0.063
Time spent on water collection (min.)	-0.114*	0.003
Access to personal source of water	0.144*	0.158
Household income per day	0.135*	0.029
Priorities addressed in decision making process	0.111*	0.073
Number of trips to collect water per day	0.087*	0.022
Households under national poverty line	-0.062*	0.081
Area of agricultural land (ha)	-0.054*	0.025
Intra-community conflicts over water availability and accessibility	0.062*	0.047
Water collection distance (m)	-0.065*	0.137
F (11, 1780)	145.65*	
R^2	0.476	
N	1780	

(*Note:* * significant at 0.05 level; Dependent variable: Water Consumption in lpcd)

Only 3.15% of the surveyed households responded that they 'always' participate in the *Gram Sansad* meetings whereas majority of the households (39.57%) responded that they 'never' attend the meetings. However, the difference in average volume of water consumption is just 1.40 lpcd between the households that 'never' attend meetings and household that 'always' attend meetings. From the above findings it can be derived that participation in *Gram Sansad* meetings may have a meagre influence on household water consumption. The proposed model also showed that household's water consumption for domestic use is moderately influenced by household's participation in *Gram Sansad* meetings. It is also to be noted that there is a high positive correlation between household income per day and participation in *Gram Sansad* meetings which implies that relatively well-off households, with better availability and accessibility to water, attend the meetings.

5.4.3.3 Time spent on water collection

Time spent on water collection is one of the significant determinants of household water consumption, especially in rural areas. A study by Cairncross and Cliff (1987) found that, in rural Mozambique, when water collection time dropped from 5 hours to 10 minutes, usage increased from 4.1 to 11.1 lpcd. It has been reported that beyond 30 minutes, the amount of water collected decreases dramatically with increasing collection time (WHO/UNICEF, 2005). In the present study, time spent on water collection (return trip) is found to be negatively linked to household water consumption (lpcd) (**Table 5.4**) i.e. with increasing time spent on water collection, the volume of water consumed by households becomes less. There is an average increase of nearly 5 lpcd in household water consumption as the collection time decreases from more than one hour to less than 10 minutes.

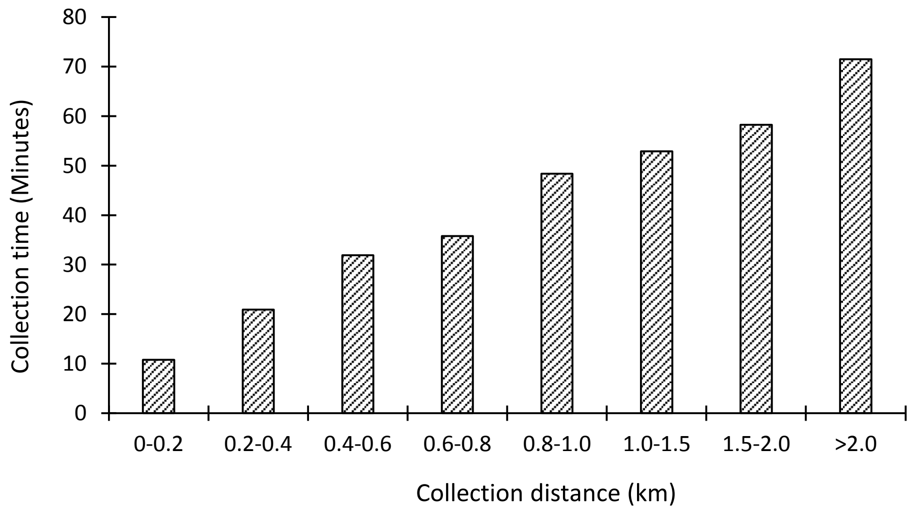

Figure 5.6 Mean reported collection time for different collection distances.

High collection times might be expected to limit the volume of water used by limiting the number of trips that households are willing or able to make to water sources. Also, with increasing distance to water source, the collection time increases (**Figure 5.6**). On an average, the collection time increased 7 times when the collection distance increased from less than 200 m to more than 2000 m.

5.4.3.4 Access to personal source of water

Only 5% of the surveyed households are found to have access to personal water sources in the form of dug wells and/or hand pumps. However, total volume of water consumption (lpcd) of these 92 households accounts for nearly 11% of the total volume of water consumption (lpcd) by 1780 surveyed households. OLS regression model also revealed a statistically significant directly proportional relationship between household domestic water consumption (lpcd) and household's access to personal water source. Water sources in the household premises save water collection time which the household can convert into productive purposes.

5.4.3.5 Household income per day

It is widely accepted and empirically demonstrates, that domestic water consumption is positively correlated with income (Hoffman et al., 2006; Dungumaro, 2007; Rahut et al., 2015). Being a proxy of affluence, income affects water consumption in different ways, e.g. choice of water (Rahut et al., 2015) and access to water and poverty alleviation. On the other hand, higher levels of income may suppose an increase in living standards, which could imply higher quantity of water consuming behaviours. In the present study, a directly proportional relationship was found between household water consumption and household income per day. This can be attributed to the fact that wealthy families have better access to water sources, sometimes personal water sources, which the poor households cannot afford. With personal water sources, the wealthier households do not have to limit their water use and do not need to share water with anyone else, thus increasing their volume of water consumption. The poor households, on the other hand, have to carry water from community sources which limits their volume of water collection, sometimes even from unimproved sources. Also, poorer household have less water storage capacity and don't have sufficient number of containers to carry water due to economic limitations. Impoverished households also lack awareness and often compromise with their health and hygiene by limiting water use during the water scarce periods.

5.4.3.6 Priorities addressed in decision making process

Studies have suggested that households are more likely to be satisfied when they have participated in the decision making process and when the community makes the final decision about water supply service type. In case of the present study, only 1% of the studied households responded that their opinions and demands are 'always' addressed properly, whereas nearly 55% of the households responded that their priorities or demands are 'never' addressed in the decision making process. However, average per capita water consumption is 17.29% higher for households whose demands are addressed 'always' than whose are addressed 'never' (**Figure 5.7**).

The suggested OLS model also reinforced the fact that household's whose priorities or demands are addressed properly in the decision making process consume more volume of water for domestic use. It is also to be noted here that 94% of the studied households who responded that they 'never' attend Gram Sansad meetings (discussed in section 5.4.3.2), also responded that their problems and demands are 'never' addressed in the local decision making process. This implies that participation in *Gram Sansad* meetings, if not necessarily, helps the households in putting up their problems and demands, and can also get them addressed in the local decision making process.

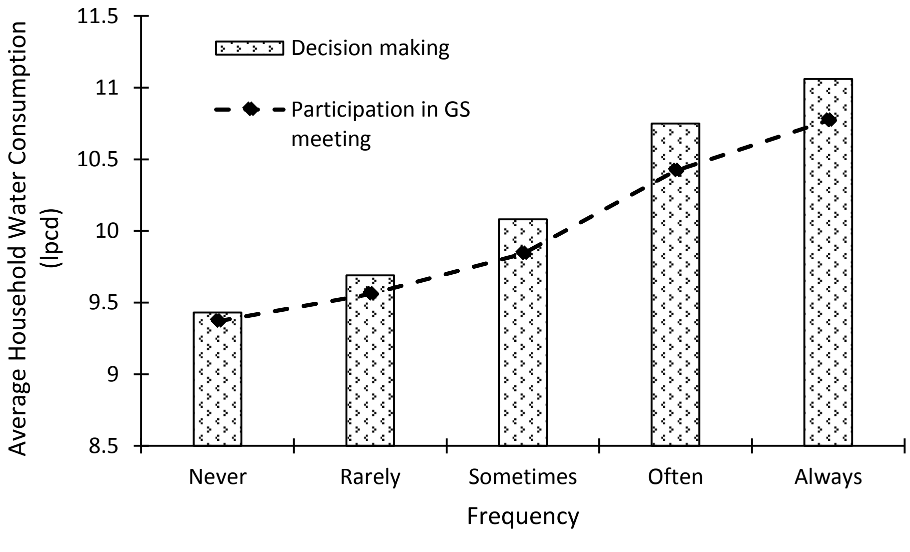

Figure 5.7 Impacts of frequency in participation in *Gram Sansad* meetings and issues addressed in the local decision making process on average household water consumption (lpcd)

5.4.3.7 Number of trips to collect water per day

Number of round trips made by a household often influence the per capita water consumption of a household. A study by Singh and Turkiya (2013) in a rural semi-arid village in India found that more than half of the studied households make up less than 4 trips to collect water whereas 6% of the households collect water more than 20 times to fulfil their water consumption demand. Households make multiple water collection trips, and each trip is affected by unobserved factors, including the weather, which household member is collecting water, the expected queue, other errands the water collector needs to undertake, or their mood that day (Kremer et al., 2011). The OLS model suggested in the present study revealed a statistically significant impact of the number of trips for collection of water to household water consumption (**Table 5.4**). Nearly 62% of the studied households responded that they have to make 4-8 trips a day to collect sufficient water that meets their household demand. A relatively higher quantity of water is found to be consumed by households that make less than 4 trips and/or more than 8 trips.

5.4.3.8 Households below poverty line

Nearly half of the surveyed population has been designated to belong under the nationally recommended poverty line i.e. Rs. 32 per day ($ 0.49) (discussed in section 5.4.1). These households are found to be negatively proportional to household domestic water consumption. As discussed earlier and in various literatures, income is a strong predictor of household water consumption. Below poverty level can be considered as a proxy indicator to household income level and, hence, below poverty level household is found to consume less volume of water for domestic use compared to well-off households.

5.4.3.9 Area of agricultural land

Ownership of agricultural land is found to have a lesser yet significant influence on household water consumption in the proposed model. Though ownership of land can be related to household income, the model suggests that the larger the land a household own, lesser is the volume of water consumed for domestic use. This can be attributed to the fact that larger agricultural land needs more labour. In most of the households in the study area, family members work together in the land for most part of the day. Hence, very few members are left at home, thus decreasing the household water consumption. The household members, working in the land, consume water from nearby water sources.

5.4.3.10 Intra-community conflicts over water availability and accessibility

Occurrence of conflicts in water distribution have negative and significant influence on the perceived water security level (Sinyolo et al., 2014). In the present study area, intra-community conflicts over water accessibility and availability is a dominant phenomenon. Approximately 18% of the sampled households responded that they 'often' have intra-community conflicts, whereas 5% reported that they 'always' have conflicts over water collection. Only 13% of the respondents reported that they 'never' have conflicts over water collection. The conflicts are usually over collection of water as the number of improved water sources are often not sufficient to meet the needs of the whole community and there are long queues to collect water. As the waiting time becomes more with long queues, people hurry to collect water that often results in fights and conflicts. A positive relation was found between intra-community conflicts and household domestic water consumption i.e., households which have fight over water collection with other households are able to collect more for domestic consumption. This can be attributed to the fact that those who engage in conflicts, may be regarded as the trouble-makers or powerful person in the community and, hence, are successful in collecting water from community sources.

5.4.3.11 Water collection distance

Sandiford et al. (1990) investigated the effect of distance from the source of water supply on domestic water consumption in rural areas of developing countries and revealed that a decrease in the distance to the water source from 1000 to 10 m is associated with an increase in per capita water consumption of 20%. For the present study, a decline in the collection distance (one-way trip) from more than 1000 m to less than 100 m is found to result in a 13% increase in per capita household water consumption.

Figure 5.8 Village women carrying water from distant sources away from houses

The OLS regression model also suggests a statistically significant inverse relationship between household water consumption and water collection distance (**Table 5.4**), identifying distance to water source as one of the determinants that influence per person household water consumption per day. **Figure 5.8** shows village women collecting water from water sources located far from the households.

It is important to note that the ability of the variables considered in this study to explain the variability in per capita household water consumption for domestic use is moderate as expressed by the R^2 value (discussed in section 5.4.4). This explanatory capacity can be considered reasonable and is still valuable in investigating household water consumption prediction since these variables are tangible and thus available to use for water consumption prediction. The moderate R^2 value also reveal the limited capacity of the variables considered in this study to represent the variability of household water consumption that are generally influenced by behavioural variables. However, it is important to note that the focus is not creating a prediction tool but principally to identify the factors that determine per capita household water consumption for domestic use in a dry sub-humid rural area.

5.4.4 Seasonal impacts on household water consumption

Climate is one of the most explicative drivers of domestic water consumption. In other words, domestic water consumption is supposed to vary depending on different seasons (Gato et al., 2007). In the present study, average quantity of per capita household water consumption for domestic use was found to be highest during summer season (12.78 lpcd). The hotter days results in drying up of surface water sources like ponds and rivers. Hence, the quantity of water used for household consumption not only include the drinking and cooking demands but also the livestock demands. Household water consumption is found to be less in monsoon (7.04 lpcd) because most of the household members including women are busy with agricultural activities and spend most of their time in agricultural lands. Except for cooking demand, drinking water demand during monsoon becomes very less as the workers in the field usually consume water from the nearby sources.

Out of the 1780 households, highest percent of households (64.40%) are found to depend on single improved water source like hand pumps to meet their daily domestic needs. Nearly 16.76% of households depends on both improved and unimproved water sources to meet their domestic needs which increases to 28.12% during summer season. However, the percent of household depending on single improved water sources (64.40%) decreases to 34.61%, thus highlighting the failure of improved water sources to supply during the dry season.

The percent of households depending on single unimproved water sources likes ponds or rivers are also found to decrease from 12.15% to 9.73% in summer and the percent of households dependent on two or more unimproved water sources are found to increase in summer by 3.22%. This demonstrates that when one source fails to supply water, mostly during dry season, people resort to other sources of water in the study area. For rest of the year, water sources mostly remain same except in monsoon season when the use of surface water decreases from 12.15% to 11.02% of households as local people avoid using open surface water due to their contamination.

Time spent on water collection was also found to be different for the dry season and rest of the year. There is an increase in collection times experienced by users of improved water sources during dry season, with round trip collection times increasing to an average of 2-3 hours for nearly 39.23% of the studied households. Collection time from unimproved water sources also increased for approximately 8.55% of households. In the dry season, most of the water sources dry up in the study area and more households are forced to use those remaining, leading to longer queues and for many people (78.68%), greater travel distances. Collection time from excavated riverbed pits increase substantially from about 30-60 minutes in wet season to 2.5-3 hours in long dry season, as the water table drops and much deeper pits must be dug to access water. Reports are given of high hand pump failure year round, and particularly in the dry season when rising demand (as other sources fail) can precipitate mechanical failure, or the water table may fall below the intake depth.

5.4.5 Socio-economic influence on household water consumption

As discussed in section 5.3.4, household asset index is used to demonstrate the Socio-Economic Status (SES) of household based on their ownership of various assets. Asset index has been considered, instead of household income per day, to represent household SES as it is internally

Table 5.5: Descriptive statistics of the asset index scores

SES groups	Mean	Std. Dev	Min.	Max.
A. Poorest	-2.30	0.14	-2.67	-2.20
B. Second	-1.72	0.46	-2.19	-1.14
C. Middle	-0.90	0.21	-1.13	-0.24
D. Fourth	0.52	0.47	-0.23	1.57
E. Richest	4.18	2.54	1.58	15.36

coherent because average asset ownership differs markedly across the different levels of SESs and is robust to the assets included (Filmer and Pritchett, 2001). Asset based measures depict an individual or household's long-run economic status and therefore do not necessarily account for short-term fluctuations in economic well-being or economic shocks (Filmer and Pritchett, 2001). In the present study, SES of households are divided into five groups – poorest (SES A), second (SES B), middle (SES C), fourth (SES D) and richest (SES E). Mean asset index score of the five SES groups are provided in **Table 5.5**. One-way ANOVA statistics was used to better understand the relation between household socio-economic condition and per capita household water consumption and other variables that denotes the characteristic of household water condition.

Table 5.6: Comparison of mean scores of characteristics among five groups of households with different socio-economic status

Variables	Household groups with varying socio-economic status					F	*p*
	SES A	SES B	SES C	SES D	SES E		
Water Consumption (lpcd)	9.58	9.35	9.28	9.42	10.67	23.57	0.00
Collection Time (minutes)	28.55	30.65	31.75	29.81	22.60	9.96	0.00
Collection Distance (km)	0.44	0.47	0.52	0.49	0.37	6.87	0.00
Primary source of water	1.29	1.27	1.44	1.64	1.82	12.72	0.00
Access to personal source of water	0.05	0.05	0.06	0.08	0.22	23.45	0.00
Number of trips per day	3.84	3.84	4.16	4.37	5.00	29.56	0.00
Access to toilet facility	0.36	0.44	0.30	0.57	0.70	13.07	0.00
Intra-community conflicts	2.58	2.69	2.81	2.88	2.71	4.11	0.00
Inter-community conflicts	2.19	2.21	2.35	2.48	2.40	6.01	0.00
Water Treatment	1.45	1.62	1.63	1.74	2.05	29.90	0.00
Conservation of water	0.46	0.48	0.45	0.47	0.47	0.21	0.93*

(*_Note_: Mean scores of conservation of water is not significantly different at $p<0.05$ level)

The results, shown in **Table 5.6**, reveal that per capita water consumption significantly differs for households with different socio-economic conditions (p<0.05).

Table 5.7: Comparison of asset variable scores under different socio-economic groups

Water Consumption (lpcd)					Collection Time (minutes)				
	SES A	SES B	SES C	SES D		SES A	SES B	SES C	SES D
SES A					SES A				
SES B	0.65				SES B	0.69			
SES C	0.39	0.99			SES C	0.27	0.96		
SES D	0.88	0.99	0.92		SES D	0.94	0.99	0.75	
SES E	0.00*	0.00*	0.00*	0.00*	SES E	0.00*	0.00*	0.00*	0.00*
Collection Distance (km)					Primary source of water				
	SES A	SES B	SES C	SES D		SES A	SES B	SES C	SES D
SES A					SES A				
SES B	0.93				SES B	0.99			
SES C	0.14	0.56			SES C	0.49	0.32		
SES D	0.62	0.98	0.9		SES D	0.00*	0.00*	0.21	
SES E	0.08	0.01*	0.00*	0.00*	SES E	0.00*	0.00*	0.00*	0.32
Access to personal source of water					Number of trips per day				
	SES A	SES B	SES C	SES D		SES A	SES B	SES C	SES D
SES A					SES A				
SES B	1				SES B	1			
SES C	0.9	0.94			SES C	0.07	0.07		
SES D	0.34	0.41	0.87		SES D	0.00*	0.00*	0.45	
SES E	0.00*	0.00*	0.00*	0.00*	SES E	0.00*	0.00*	0.00*	0.00*
Access to toilet facility					Choice of water treatment				
	SES A	SES B	SES C	SES D		SES A	SES B	SES C	SES D
SES A					SES A				
SES B	0.71				SES B	0.02*			
SES C	0.89	0.17			SES C	0.02*	1		
SES D	0.01*	0.29	0.00*		SES D	0.00*	0.19	0.26	
SES E	0.00*	0.00*	0.00*	0.19	SES E	0.00*	0.00*	0.00*	0.00*
Intra-community conflicts					Inter-community conflicts				
	SES A	SES B	SES C	SES D		SES A	SES B	SES C	SES D
SES A					SES A				
SES B	0.67				SES B	1			
SES C	0.04*	0.56			SES C	0.16	0.32		
SES D	0.00*	0.12	0.9		SES D	0.00*	0.00*	0.34	
SES E	0.52	0.99	0.7	0.2	SES E	0.03*	0.08	0.97	0.75

(**Note:* The highlighted cells shows the statistically significant p (<0.05 level) value on Tukey HSD post hoc test)

In other words, households with higher per capita water consumption are those with relatively better socio-economic status. Similarly, except for conservation of water, all the other variables displayed significant variability in their mean scores between the different socio-economic groups. One-way ANOVA does show that there are significant difference among at least two groups but to specify the groups that are significantly different from each other, Tukey HSD post hoc test was carried out. The post hoc test results demonstrated some interesting findings (**Table 5.7**). Time spent on collection of water and access to personal water source displayed that the richest group spends shortest time in collecting water and have higher number of personal water sources. The difference in mean scores for both these variables are found to be significantly different ($p<0.05$) between the richest group of households (SES E) and other household groups. Hence, household socio-economic status is found to influence household's accessibility to water sources. This is also reinforced by the higher number of round trips made by well-off household groups (SES D and SES E) to collect water (**Table 5.7**). As, distance to water sources is found to be less for well-off households, making more trips to collect water is relatively easier for them compared to the relatively weaker households who are far from the water source. All these variables along with household water use pattern and lifestyle may have a cumulative influence on per capita household water consumption. Mean score of per capita household water consumption (lpcd) was found to be significantly different (at $p<0.0.5$ level) between the richest (SES E) and all the other household groups i.e. SES A, SES B, SES C and SES D.

However, no significant difference in water consumption was found between the rests of the four household groups (**Table 5.7**). Hence, it can be said there exists an inequality and volume of water consumption by the relatively richer households are much higher than all the other households in the study area. As shown in **Table 5.7**, the mean score of primary domestic water source for poor household groups (SES A and SES B) is significantly different from SES D and SES E household groups. This implies that the more well-off households have access to higher number of water sources for domestic use than the socio-economically weaker households. The percent of well-off households using single unimproved sources like ponds or springs is lowest (8.68%) compared to other household groups whereas access to two or more improved sources of water for domestic use like hand pumps and piped water supply is highest for the richer households under SES D (6.50%) and SES E (9.80%) compared to the weaker households like SES B (1.40%).This implies that socio-economically well-off households have a better access to improved water sources for domestic needs when compared to the socio-economically weaker household in the study area. No significant difference in mean scores were observed between the richest group of households (SES E) and other household groups in case of intra-community conflicts enforcing the fact that well-off households have to face less issues regarding water availability and accessibility and may be local people does not engage in conflict with them because they are quite powerful and influential people in the society. Interestingly, in case of inter-community conflicts significant difference in mean scores were found between SES A and both the groups of SES D and SES E. This denotes that households who go to collect water from other communities or villages usually belong to the poorer section. As this puts extra pressure on the existing water sources, they are not allowed to collect sufficient water by the well-off households, who are also the powerful in the community, because this increases the crowd and might limit their own water availability. As the mean score of household action on conservation of water was not found to be statistically significant in one-way ANOVA, it has not been included in the post hoc test.

5.5 Implications to Rural Water Security Framework

Understanding household water consumption is an important part of developing rural water security framework. Water consumption behaviour is different for urban and rural households as their needs are different. Hence, a policy or scheme that is effective in urban areas may mask the reality of problems faced at local level in rural areas. Moreover, the increased dependence of rural people on water makes it imperative to study the determinants that influence household water use and consumption. In most cases research tend to focus on factors attributing to inadequate supply of water and not exploring factors which hinder people to access water. Understanding household demographic and socio-economic characteristics offers a way of linking availability of water and ability of households to obtain water from a safe source. A better understanding of socio-economic and demographic variables and linking them to water availability will not only enable to rank communities according to their needs and poverty levels but also decide on more practical, affordable and sustainable interventions.

In order to ensure and enhance water security in rural areas, it is important for policy makers and planners to take into consideration the influence of different determinants on household water consumption. Determinants such as household income, household size, and distance of water sources from the household, time spent on collecting water, number of trips, active participation in local decision making process and intra-community conflicts on water issues need to be given an important priority in legal and policy formulation in rural areas with similar characteristics like the present study area.

Location of water sources and time spent on fetching water is major problem in rural areas in many parts across the world. The time it takes to collect water includes not only the travel time from water source to home, but also the time a person lines up at a water source. This water fetching activities often lead to missing school days for children mostly girls and health problems to the water carriers. The problem becomes more serious during the dry season due to failure of multiple water sources near the households that compel the villagers to collect water from far away sources. Hence, installation of any communal water harvesting structure needs a prior survey of the area and proper planning, and needs to calculate the optimum time and distance of water sources from local households. To improve quality of life, every effort should be made by all stakeholders to decrease collection efforts and times, including waiting times, in rural communities throughout the developing world.

Any plan for enhancing water security has to critically take into consideration issues of effective community participation in local governance. The emergence of participatory approaches demonstrates the importance of local communities consent in taking part in public decision-making processes, especially on issues that directly affect their welfare. In this context, the local community participation could provide an important database, experience and ideas that could lead to practical, relevant, achievable and acceptable solutions to water related problems. In the present rural area, household participation in village meeting is found to be negligible and, as responded, the demands of the households are seldom addressed during the local decision making process. Since households, mainly women, are the primary users of water at the domestic front, it is important to come up with a holistic and integrated water security framework that provides equal opportunity to every stakeholders to put up their demands and get is addressed, if found relevant.

Equitable access to safe and adequate amount of water is a pre-requisite to household water security. However, the concept is lost when it comes to socio-economically weaker households. The present study delineated that a socio-economically privileged household has much better access to water. A majority of them have their personal water source as they can afford it and need not depend on community water source to meet their demands. Even if they have to depend on community water sources, the study reveals that they spend less time and travel shorter distance to fetch water compared to relatively weaker households. Moreover, well-off households are found to use higher number of water sources, both improved and unimproved.

The full adoption and implementation of rural water security framework will only be successful when the demands and priorities at micro-level i.e. household level are properly considered. When the ultimate aim of any policy is the welfare of local communities, it is important to include their demands and priorities into decision making. The identified determinants when included in micro-level water security framework, helps in focussing on the needs of household, the lowest level users, and linking them to broader policy frameworks.

5.6 Concluding Remarks

The micro-level analysis for the rural study area attempted to address two main questions. First, what are the key determinants influencing a rural household's water consumption for domestic use? Second, how does the water consumption change in response to household socio-economic conditions? Average per capita water consumption for domestic use is found to be quite low in the study area and lies in the range on basic water requirement for emergency conditions. Multiple regression model identified determinants like ownership of agricultural land, participation in village meetings, frequency of addressed household demands in local decision making process, local conflicts, collection distance and collection time to impact rural household water consumption. These factors are found to be quite unique compared to the various factors that have been observed to impact residential water demand in various literatures and are characteristic of rural areas in developing countries. The collection time is also found to be high in the study area and reducing collection time and effort will allow communities, and particularly women and children, to spend their time doing more productive things to improve their lives in numerous other ways. From a seasonal aspect, water consumption is found to be profoundly affected in dry season compared to the wet season. In addition to domestic water demand for cooking and drinking, livestock demand also increases during dry season. Finally, the study emphasizes on the fact that there exists an inequity in availability and accessibility of water in the rural communities as per their socio-economic conditions. In conclusion, household water security is found to be largely compromised in the study area. Micro-level issues that hinder access to safe and adequate amount of water like increasing distance to water source, seasonal uncertainty, reluctance in participating in local decision making process, low socio-economic status needs to be included and properly addressed in different water supply and management schemes and projects implemented in the rural areas.

Finally the data collected focuses only on what happens in a normal year. Water access deteriorates markedly during drought and that collection times can rise substantially, and collecting data on how water use volumes change, particularly for the poorest, and its impact on health and livelihoods, would add to our understanding of suitable mitigation and response strategies. Nonetheless, understanding the dynamics of water use in a normal year reveals where some critical sensitivities lie, and therefore how catastrophic impacts during drought years might be prevented.

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CHAPTER 6

A MESO-SCALE ASSESSMENT OF LOCAL CLIMATE

"On climate change, we often don't fully appreciate that it is a problem. We think it is a problem waiting to happen."

Kofi Annan

CHAPTER 6: A meso-scale assessment of local climate[1]

This chapter investigates the characteristics of various climate variables like rainfall, temperature and relative humidity of Purulia district. Considering the agriculture dependent communities, detailed analysis of long period rainfall data, from 1950-2012, was conducted by analysis of anomalies and application of both parametric and non-parametric statistical tests. The chapter also provides an overview on how changing rainfall pattern impacts crop growing in the study area. In conclusion, the chapter argues for district level climate studies which will provide local stakeholders with the necessary information for better planning and management of rainfall dependent development sectors, thus resulting in reduced overall socio-economic upheaval of rural communities.

Outline of the Chapter

[1] A part of this chapter has been published in *International Journal of Environmental Studies*.

6.1 Introduction

Climate variability is a pervasive stress for individuals and communities. Change in climate variables such as temperature, rainfall, humidity, wind velocity etc. have positive and/or negative impact on agricultural productivity and food security in an economy (Greg et al., 2011). The extent of the variation in climatic factors differs in both spatial and temporal scales and the impacts are also felt in a different way by people living in different socio-economic conditions. Rural communities are identified to be affected more because of their extensive dependence on climate sensitive livelihood options, and limited adaptive capacity. Any climate-related changes push the rural, marginalized and deprived population towards more vulnerable future risks.

Among the various climate variables, rainfall is extremely important as any alteration in it, higher or lower, and/or changes in its distribution would influence evaporation rates, distribution of runoff, soil moisture, and groundwater reserves and would alter the frequency of droughts and floods. Factors like radiation, temperature and rainfall affect crop yield in different ways. Rainfall, especially, affects the growth and production of the plant as it controls the availability of soil moisture to crop plants (Olesen and Bindi, 2002). Variability in rainfall from year to year is closely related to crop yield. Farmers mainly feel the impact of climate change through changes in timing, frequency and intensity of rainfall events, and in the distribution of these events in the crop growing season. The randomness and deficiency in rainfall impacted heavily on the availability and quality of water resources, expansion of saline soils and degradation of plant cover in a rural area of Senegal (Ndour et al., 2012). Similarly in rural Bangladesh, the effects of local rainfall variability were found to impact occupational choice and welfare of the local rural people. It was concluded that higher local rainfall variability pushes rural households to maintain diverse occupational and employment options as adaptation strategy and to lower household consumption significantly (Bandopadhyay and Skoufias, 2013). Negative rainfall trends often signify higher probabilities of droughts that have historically affected ‘millions of rural poor farmers, pastoralists, domestic and wild animals,’ and have grave consequences for the environment and social instruments such as drought monitoring programmes (Seleshi and Zanke, 2004). Given the heavy dependence on rainfall, it becomes imperative to study the historical variation in rainfall in rural areas along with the vulnerability and climate change studies based on indicators or perceptions of local people.

Similar to changing rainfall pattern, surface temperatures over a given region vary seasonally and annually depending upon latitude, altitude and location with respect to geographical features such as a water body (river, lake or sea), mountains etc. Since the hydrologic cycle is a thermally driven system, rise in temperature is likely to impact this cycle. Temperature and it changes impact a number of hydrological processes including rainfall and relative humidity and these processes, in turn, also impact temperature (e.g., cooling due to rain/snow).

The Planning Commission of India had emphasized the need for district-level plans and the district is the focal unit for several developmental schemes in the XII Five Year Plan. At macro-level (country), rising temperature along with no significant trend in monsoon rainfall may cause aridity to rise. However, if assessment is done at smaller geographical scale such as district, there may be different trends. Hence, this chapter gives an exhaustive coverage of the local climate variability, of the district under study, dealing with three variables which are critical in hydrological processes: rainfall, temperature and relative humidity.

6.2 Signatures of climate change over India

Studies carried out by several researchers have demonstrated that the trend and magnitude of warming over India/the Indian sub-continent over the last century is broadly consistent with the global trend and magnitude (Arora et al., 2005; Dash et al., 2007). The analysis of seasonal and annual air temperature from 1881 – 1997 have shown an increasing trend of mean annual temperature, at the rate of 0.57˚C per 100 years (Pant and Kumar, 1997). Singh et al. (2008) also found a warming trend in seven of the nine river basins in northwest and central India. Kothyari and Singh (1996) found increasing annual maximum temperature over the Ganga basin and increasing average annual temperature for India.

Though no trend in the monsoon rainfall in India is found over a long period of time, particularly on the all-India scale, pockets of significant long-term rainfall changes have been identified (Dash et al., 2007; Kumar and Jain, 2010). Most of the rainfall studies investigate the trend either on country and/or regional (state) scales. Studies by Rajeevan et al. (2006) and Guhathakurta and Rajeevan (2008) on a network on 1476 rain gauge stations, irrespective of urban and rural areas, for the period 1901-2003 reveal a significant decreasing trend in the monsoon season for three sub-divisions (Jharkhand, Chhattisgarh and Kerala) and significant increasing trend over eight sub-divisions (Gangetic West Bengal, Western Uttar Pradesh, Jammu and Kashmir, Konkan and Goa, Central Maharashtra, coastal Andhra Pradesh and north interior Karnataka). Srivastava et al. (1998) supported the existence of a definite trend in rainfall over smaller spatial scale. Another study on seasonal rainfall from 1871-2002 indicated a decreasing trend in monsoon rainfall and an increasing trend in the pre-monsoon and post-monsoon seasons (Dash et al., 2007). Mall et al. (2006) inferred that there has been a westward shift in rainfall activity over the Indo-Gangetic Plain region. An increase in intense rainfall events leads to more severe floods and landslides. The number of cyclones originating from the Bay of Bengal and the Arabia Sea has decreased since 1970, but their intensity has increased (Lal, 2001).

Major parts of rainfed areas of India is having the probability of three to four year drought in every ten year period in which, there is again a probability of getting one to two years moderate and half year to one year severe droughts. Due to the variability of climate in the recent past, more intense and longer droughts have been observed over wider areas since 1970, particularly in the tropics and subtropics. On a whole, India is experiencing varied climatic conditions that differs with every region in the country.

6.3 Research Methodology

6.3.1 Research Objectives

The main objective of this study is to analyze the temporal variability in local climate variables like rainfall, temperature and relative humidity in the rural sub-humid district under study. Since, rainfall is the principal supplier of water for both agricultural and other purposes in the district and water availability is crucial to socio-economic development, special emphasis has been put on assessing the changing trends in rainfall. The trends are assessed on monthly, seasonal and annual timescale, and the probable impacts on crop cultivation are discussed, when appropriate. Erratic rainfall coupled with low moisture retention capacity of soil and faulty agricultural practices produced a gap between demand and supply of water, widening day by day. In spite of its long history of water scarcity and declaration as a drought prone district, so far there has been no comparable study on district climatology, its variability and the changing pattern using long period data, as with many other regions across the world.

6.3.2 Study area and data collection

The district falls within the semi-arid region of the state of West Bengal. This region has a dry sub-tropical climate with variation of temperature over a wide range during the year. As per the District Gazetteer (1985), the district exhibits an all-India significance because of its tropical location, its shape as well as its function like a funnel. It funnels not only the tropical monsoon current from Bay of Bengal to the sub-tropical parts of north-west India, but also acts as a gateway between the developed industrial belts of West Bengal and their less developed hinterlands in Orissa, Bihar, Madhya Pradesh and Uttar Pradesh. The district suffers from recurrent drought, with the latest occurring in 2010 when the district has been declared as worst hit in the state (GoWB 2012b). Years like 1976, 1979, 1980, 1982, 1983, 1985, 2001 and 2003 were the worst years with nearly total area under extreme drought (Palchaudhuri and Biswas 2013). Mild and moderate droughts are recorded from the central part of the district, whereas northeast part is prone to severe and northwest and southwest part are prone to extreme drought situations.

Monthly rainfall data from 1950 – 2012, obtained from seven rain gauge stations in the district (**Figure 6.1**) by the Regional Centre of Indian Meteorological Department (IMD) in Kolkata, India, have been used in this study. The altitude of the rain gauge stations ranges from 219 m to 318 m above mean sea level. Rainy day data (days having rainfall more than 2.4 mm) from IMD were used to analyse the trend in rainy days across the years and to calculate the rainfall intensity. Data from 1950-1999 (50 years) have been used for this analysis as many data for the remaining years were missing. Meso-scale agricultural data (1966-2011) for the district have been derived from VDSA-ICRISAT (Village Dynamics in South Asia-International Crops Research Institute for the Semi-Arid Tropics) database for drawing references with respect to rainfall variability.

As the temperature and relative humidity data collected from Regional Centre of IMD, Kolkata, India contained numerous missing values, the data provided by District Agriculture Department, Purulia has been used in the present research. Temperature data was available for last 25 years (1990 – 2014) and relative humidity was available for only last 10 years (2005 – 2014).

6.3.3 Exploratory Analysis

From the basic rainfall and temperature data, mean, Standard Deviation (SD) and Coefficient of Variation (CV) were computed on a monthly and seasonal timescale viz. Pre-monsoon (March – May), Monsoon (June – September), Post-monsoon (October – December) and Winter (January – February), as defined by IMD. Mean, SD and CV were also calculated for the rainy day data on monthly, seasonal and annual timescale. Annual and seasonal rainfall intensity was calculated by dividing the number of rainy days from the yearly annual and seasonal rainfall data.

To draw the multi-decadal comparison, the reference period 1950-2012 was segregated into six decades, namely 1950 – 1959, 1960 – 1969, 1970 – 1979, 1980 – 1989, 1990 – 1999 and 2000 – 2009 and decadal departure from mean along with number of excess and deficit rainfall years per decade were calculated. Season-wise percentage departure from mean was also estimated separately for the overall period. Three years, namely 2010, 2011 and 2012, were kept out of the decadal analysis to include an even number of years in each time period.

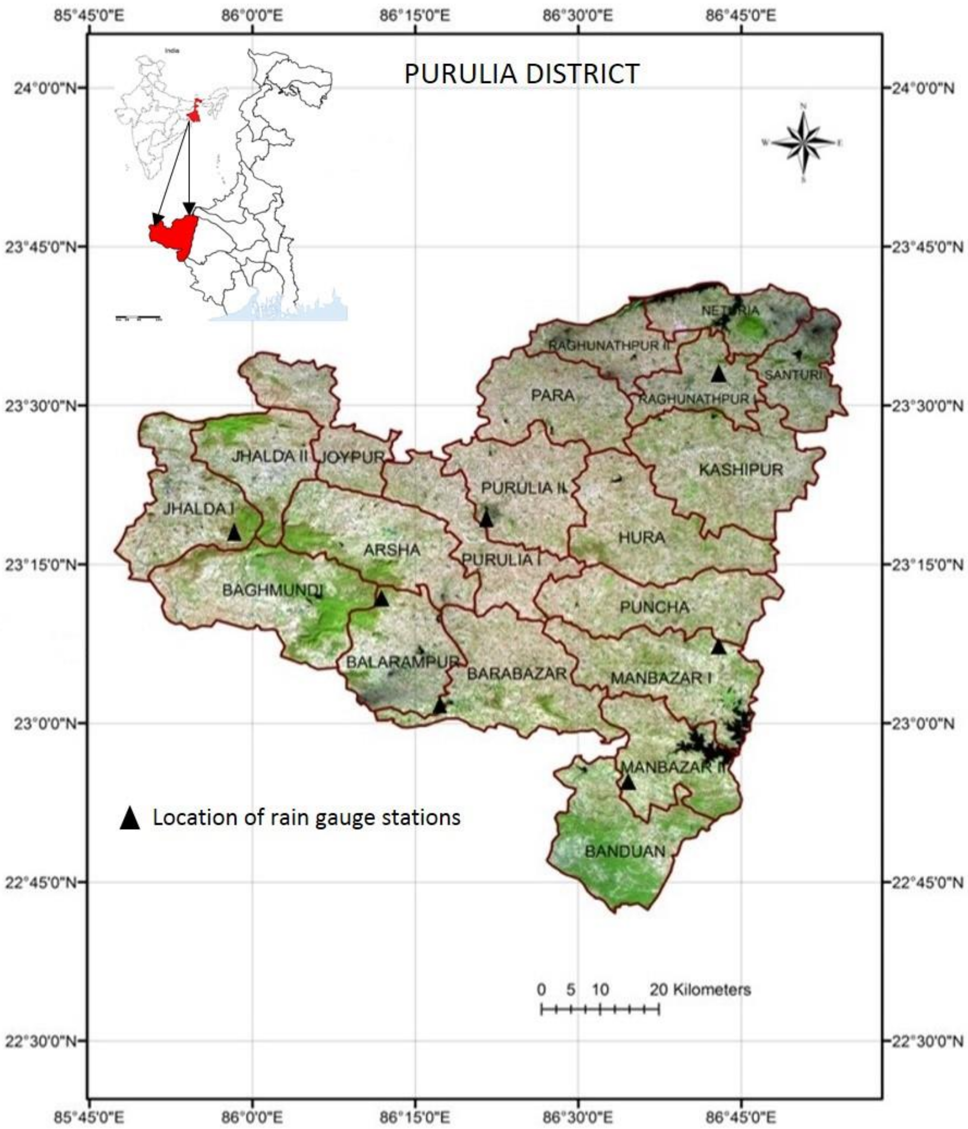

Figure 6.1 Location of the rain gauge stations in the study area

6.3.4 Trend Analysis

Trend analysis of a data set can be done with both parametric and nonparametric methods. Parametric test are more powerful when the data are normally distributed (Onoz and Bayazit, 2003). Non-parametric tests are usually much less affected by the presence of outliers and other forms of non-normality and represent a measure of monotonic linear dependence. To compare the results, both parametric and non-parametric methods were employed in this study.

6.3.4.1 Parametric analysis of trends: Linear Regression Analysis

A straight line regression model is hypothesized to describe the relationship between the amount of rainfall and time, hence to characterize the prediction of any amount of rainfall y (mm), at any time t (year). The relationship between the amounts of rainfall with time can be expressed as:

$$y = \gamma_0 + \gamma_1 t + \varepsilon \qquad (1)$$

where, *y* is the dependent variable representing the amount of rainfall (mm), *t* is the independent or explanatory variable representing time, and ε is the unobserved error or disturbance. The point of interest in Eq. 1 is γ_1, which in the present context, is interpreted as the average rate of change of rainfall through every one year time period. Significant γ_1 ($p<0.05$) is interpreted as indicating a trend in the amount of rainfall and is equal to the magnitude of γ_1. Insignificant γ_1 signifies absence of trend in the amount of rainfall over time. On the other hand, the direction (increasing or decreasing) is represented by the sign of the slope parameter γ_1 in which a negative sign indicates a decreasing trend while a positive sign implies an increasing trend.

6.3.4.2 Non-parametric analysis of trends: Mann-Kendall test and Sen's slope estimator

The statistical significance of the trend in monthly, seasonal and annual series is analysed using the non-parametric Mann-Kendall (MK) test. The MK test checks the null hypothesis (H_0) of no trend and the alternative hypothesis (H_a) denotes either increasing or decreasing trend. No pre-whitening of the rainfall data series was carried out, as the sample size is large ($n \geq 50$). For the present study, both rainfall and rainy day trends are measured by carrying out the MK test and Sen's slope estimator test using XLStat, a software that works as an add-in function with Microsoft excel.

Mann-Kendall test statistic. The Mann-Kendall statistics *S* is given as

$$S = \sum_{i=1}^{n=1} \sum_{j=i+1}^{n} Sgn\,(x_j - x_i)$$

The application of trend test is done to a time series x_i that is ranked from $i = 1, 2, \ldots n - 1$ and x_j, which is ranked from $j = i + 1, 2, \ldots n$. Each of the data point x_i is taken as a reference point which is compared with the rest of the points x_j so that,

$$Sgn\left(x_j - x_i\right) = \begin{Bmatrix} +1, (x_j - x_i) > 0 \\ 0, \left(x_j - x_i\right) = 0 \\ -1, \left(x_j - x_i\right) < 0 \end{Bmatrix}$$

The variance statistic is given as

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i(i)(i-1)(2i+5)}{18}$$

where t_i is considered as the number of ties up to sample *i*. The test statistic Z_c is compared as

$$Z_c = \begin{Bmatrix} \frac{S-1}{\sqrt{Var\ (S)}}, S > 0 \\ 0, S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, S < 0 \end{Bmatrix}$$

Z_c here follows a standard normal distribution. A positive (negative) value of Z_c signifies an increasing (decreasing) trend. A significance level α is also utilized for testing either an increasing or decreasing trend. If Z_c appears greater than $Z_{\alpha/2}$ where α depicts the significance level, then the trend is considered as significant.

Sen's Slope estimator. The Sen's Slope estimator test is a nonparametric, linear slope estimator that works most effectively on monotonic data (Sen, 1968). Unlike linear regression, it is not greatly affected by gross data errors, outliers or missing data. The approach involves computing slopes for all the pairs of ordinal time points using the median of these slopes as an estimate of the overall slope. When Mann-Kendall test demonstrates a trend (positive value of test statistic indicates the increasing trend and negative value indicates the decreasing trend), the Sen's Slope is used to quantify the trend.

6.4 Results and Discussion

6.4.1 Rainfall Characteristics

Table 6.1 presents the descriptive statistics of monthly, seasonal and annual rainfall. On a monthly timescale, CV is found to be higher than 30% for all the months, highest in December (209.97%) and lowest in August (31.98%). As dependability and reliability of rainfall is demonstrated by CV which, when higher than 30%, indicates significantly variable and non-dependable rainfall, it is noticed that none of the monthly rainfall meets the criterion. Considering the percentage contribution to annual rainfall, southwest monsoon (June-

September) contributes to nearly 81% of the annual rainfall and is found to be dependable as the cumulative seasonal CV is less than 30%. The annual long period mean rainfall in the study area is 1325.8 mm, with the highest annual rainfall in 1978 (2138.8 mm) and lowest annual rainfall in 2010 (835.6 mm).

Table 6.1 Descriptive statistics of monthly, annual and seasonal rainfall

Months & Seasons	Minimum rainfall (mm)	Maximum Rainfall (mm)	Mean (mm)	SD (mm)	CV (%)	Percentage contribution to annual rainfall
January	0	91.5	12.8	16.3	127.4	1.0
February	0	106.4	18.2	19.6	107.8	1.4
March	0	85.0	21.9	21.5	98.1	1.6
April	0	209.8	33.4	32.9	98.5	2.5
May	4.3	169.0	60.5	39.1	64.6	4.6
June	43.4	842.0	221.3	128.9	58.3	16.7
July	33.7	573.6	295.9	108.1	36.5	22.3
August	21.6	520.0	299.2	95.7	32.0	22.6
September	52.4	773.6	257.8	136.5	52.9	19.4
October	0	233.1	82.0	64.4	78.5	6.2
November	0	135.0	15.5	24.2	155.6	1.7
December	0	88.0	7.8	16.3	210.0	0.6
Annual	835.6	2138.8	1325.8	244.4	18.4	100
Pre-monsoon	11.9	269.6	115.9	54.3	46.9	8.7
Monsoon	623.4	1740.6	1074.3	225.3	21.0	81.0
Post-monsoon	21.0	244.0	105.3	64.7	61.4	8.0
Winter	0	134.2	31.0	27.8	89.8	2.3

6.4.1.1 Trend analysis at monthly, seasonal and annual timescale

Table 6.2 illustrates the results of both parametric and non-parametric test for the rainfall trend at monthly, seasonal and annual timescale. The significance value of the Shapiro-Wilk Test is found to be greater than 0.05 for all the months, confirming the use of parametric test for analysing rainfall trend. A negative slope parameter, γ_1, from linear regression analysis suggests a declining trend in rainfall. Both the parametric and non-parametric test (MK test) are not always statistically significant ($p>0.05$). Yet, a statistically significant trend may not be practically significant and vice versa (Daniel, 1978).

Monthly rainfall trends

The trend in rainfall is associated with crop growing season and crop growing stages. Mono crop cultivation, mainly paddy, is the primary livelihood of rural people of the district and the wellbeing of the local communities depends on the agricultural output. *Aman*[2] paddy is the principal crop grown in the study area in rain-fed condition. Crop cultivation usually takes place in the monsoon months and harvesting is mainly done in the post-monsoon season. The other crops are grown subject to availability of adequate soil water from rainfall as there are no irrigation facilities available in the study area. Because crop cultivation depends on rainfall, any significant alteration in the rainfall, in terms of amount and timing, impacts crop yield, thus affecting the principal income of the rural communities (GoWB, 2012a). As paddy cultivation involves a number of critical stages of water requirement like active tillering, panicle initiation and booting, it would be interesting to know how monthly rainfall pattern in the study area may impact on the different stages of paddy growth.

Table 6.2 presents the trend of monthly rainfall, as obtained from both parametric and non-parametric tests. It is interesting to note that rainfall in May shows an increasing trend significant at 0.05 level. There has been 43 mm increase in May rainfall at a rate of approximately 0.68 mm $year^{-1}$. June rainfall also demonstrates an insignificant but increasing trend. This increasing trend in the months of May and June plays a significant role in the sowing of paddy in the study area. In the conventional wetland rice production systems, the crop is usually transplanted in the paddy field 25-30 days after sowing in the nursery. Ten to fifteen days prior to transplanting the seedlings, the rice field needs to be prepared and there should be 2-5 cm standing water in case of short duration paddy variety. But, when there is delay in the onset of monsoon or receipt of an adequate amount of rainfall, the transplanting time has to be delayed in the study area. The State Action Plan on Climate Change of the state (GoWB, 2012b) makes clear that the monsoon has got significantly delayed in the state, especially in South Bengal where the present study area is located. Sowing of over matured seedlings is known to reduce the yield drastically. Following transplantation, a shallow depth of land submergence with water facilitates tiller production and firm root anchorage in the soil. In the conventional wetland production system, it is considered ideal to maintain 2-5 cm water

[2] *Aman* paddy is the locally used term used for lowland rice grown in the wet season during June to November.

throughout the growing season but where there is good water control, it is more productive to maintain the soil moisture at field capacity as is the case with the System of Rice Intensification (SRI) (Kassam et al., 2011). Moisture stress due to inadequate water at rooting and tillering stage causes poor root growth leading to reduction in tillering, poor stand and low yield.

For paddy growth, the highest percentage of water is required in the planting to panicle initiation phase and panicle initiation to flowering phase (Adhikari et al., 2010). The first phase mainly takes place from July to September. In the present study area, there have been 12.5, 48.3 and 13.1 mm reduction in rainfall at a rate of 0.2, 0.8 and 0.2 mm year^{-1} for the months of July, August and September, respectively. This reduction may become detrimental to crop growth as adequate soil moisture supply is necessary for active tillering and root development that will prevent damage to seedlings from high winds.

Panicle initiation to flowering is the next critical phase of paddy growth where irrigation plays a major role. In the conventional wetland production system, there has to be at least 2.5-5 cm standing water during this phase for successful crop yield. **Table 6.2** shows, however, that rainfall in the month of October displays an insignificant but slightly decreasing trend. Rainfall in October also shows high variability with higher number of epochs below mean indicating the receipt of lesser amount of rainfall compared to the long period mean (82.0 mm). This variability and reduction can have a heavy influence on the flowering and ripening phase of crop growth, which can subsequently reduce the crop yield. November and December showed an insignificant but increasing rainfall trend, which is favourable for the sowing of mustard or wheat, as a *Rabi*[3] crop. But this increase in November rainfall can lead to heavy negative effect on the matured grains of paddy and can damage the crop. From January to April, rainfall trends are nearly constant or show an insignificant rising trend.

Seasonal rainfall trends

An increasing and significant trend (0.05 level of significance) is noticed for pre-monsoon rainfall. There has been 48.4 mm of increase in pre-monsoon rainfall against the long period mean (115.9 mm) (**Table 6.1**). Southwest monsoon rainfall indicates an insignificant but declining trend, as denoted by MK test statistics (-0.028), over 1950-2012 with a lowering of 20.2 mm at the rate of about 0.32 mm year^{-1}. The distribution of rainfall during this season is also poor and, owing to the hydrogeology and topography of the area, more than 80% of rainfall flows as runoff.

[3] *Rabi* crops are crops sown around mid-November and harvesting begins in April/May.

Post-monsoon season reflects highly variable rainfall pattern all through the time period under study (1950-2012) with as high as 244 mm in 1973 to 21 mm in 2008. The variability in rainfall is more prominent 1973 onwards. MK test indicates that the seasonal rainfall during post-monsoon is following an increasing trend (**Table 6.2**) at the rate of about 0.15 mm $year^{-1}$. Increased quantum of post-monsoon rainfall has affected sowing of *Rabi* pulses and oil-seeds and planting of potato. Linear regression equation shows a decrease of 0.25 mm of winter rainfall over the last 63 years. Similar findings were also reported in the State Action Plan on Climate Change (GoWB, 2012b) citing a decrease in winter rainfall in South Bengal. Studies by Dash et al. (2007) and Rupa Kumar et al. (1992) on seasonal rainfall also reported a decreasing trend in monsoon rainfall and an increasing trend in pre-monsoon and post-monsoon rainfall in the northeast peninsula, northeast India and northwest peninsula. On the contrary, a study by Sinha Ray and Srivastava (1997) illustrated an increasing trend in monsoon rainfall over certain parts of the country, but a decreasing trend in winter, pre-monsoon and post-monsoon season.

Annual rainfall trends

Both the parametric and non-parametric tests illustrate an insignificant but increasing trend in the mean annual rainfall for the district of Purulia over the period from 1950-2012 (**Table 6.2**). An increase of 35.6 mm of annual rainfall is noticed during the study period as against the long period mean rainfall of 1325.8 mm. The annual amount received by the district is highly variable over the years. A relatively wet period (excess rainfall) was seen in earlier decades from 1970-1999 (**Figure 6.2**).

Beyond 1999, there has been a lesser amount of rainfall received by the district with a higher number of below mean epochs. The annual amount of rainfall received is projected in parallel to annual rice production in the district from 1966-2011 to understand the relation between annual rainfall and annual rice production, if any. An insignificant yet increasing relationship between rainfall and rice production was noticed during this period of time. This can be attributed to the introduction of short duration rice varieties by the farmers in response to irrigation water stress in the study area. It can also be seen from **Figure 6.2** that 1997 onwards rice production was highly variable and the epochs of rice production and rainfall match each other. The yield was found to be more or less constant from 1966 – 1978 and 1983-1996 in spite of the visible variation in rainfall in the said periods (**Figure 6.2**). The pattern and variation of other factors impacting rice growth might have been favourable in this period which could have negated the impacts of rainfall variability. The lowest amount of rice production (166040 tons) was recorded in 2010 which was also a drought year in the district. While *Aman* paddy (*Kharif*[4] or winter rice) yield shows an increasing trend, area instability for *Aus*[5] (pre-*Kharif* or autumn rice) has been recorded maximum in Purulia (65.5%) across last three decades (1980-81 to 1990-91, 1990-91 to 2000-01 and 2000-01 to 2011-12) (Chatterjee and Ray, 2013). Hence, cultivation of *Aus* paddy has been totally stopped in the district, leaving only mono crop cultivation of *Aman* paddy during the monsoon period.

Table 6.2 Rainfall trend in Purulia from 1950-2012

Month	Parametric	Non-parametric		
	Slope	MK	p-value*	Sen's Slope
January	0.05	-0.01	0.88	0.01
February	-0.06	-0.03	0.76	0.00
March	0.05	0.04	0.61	0.03
April	0.04	0.01	0.93	0.01
May	0.68	0.23	0.01*	0.63
June	0.85	0.06	0.48	0.41
July	-0.20	-0.07	0.45	-0.52
August	-0.77	-0.07	0.42	-0.46
September	-0.21	-0.01	0.88	-0.17
October	-0.10	-0.05	0.61	-0.16
November	0.04	0.02	0.79	0.02
December	0.20	0.13	0.17	0.01
Annual	0.57	0.04	0.69	0.71
Pre-monsoon	0.78	0.17	0.05*	0.67
Monsoon	-0.32	-0.03	0.75	-0.63
Post-monsoon	0.14	0.01	0.93	0.03
Winter	-0.01	-0.04	0.62	-0.08

*Significant at $\alpha = 0.05$

6.4.1.2 Departure from mean and decadal shifts

To learn the changing behaviour of seasonal rainfall over the study period, rainfall departure from mean has been analysed and is demonstrated in **Figure 6.3a to 6.3d**. Post-

[4] *Kharif* crops are usually sown in monsoon season and harvested in post-monsoon season.
[5] *Aus* paddy is the locally used term for paddy grown from April to August.

monsoon and winter season rainfall exhibited the highest number of negative departures from long period mean compared to pre-monsoon and monsoon season rainfall (**Figure 6.3b** and **6.3c**) in the study area. For post-monsoon (**Figure 6.3d**), nineteen years have been found to experience more than 50% of negative rainfall departure from the long term mean (1950-2012), the highest being in 2008 (> 80%).

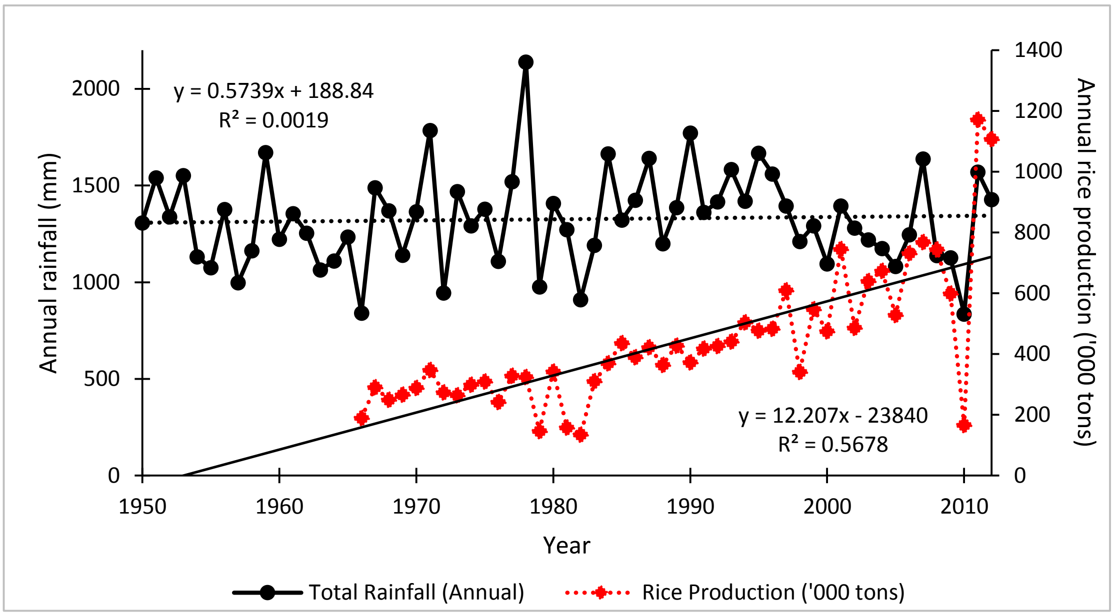

Figure 6.2 Annual rainfall and rice production trends over study area

Rupa Kumar et al. (1992) reported that Indian summer monsoon demonstrates multi-decadal variations in which there is clustering of dry or wet anomalies. Hence, decade-wise percentage departure of seasonal rainfall, frequencies of excess and deficit rainfall years has been analysed and the results are presented in **Table 6.3**. The deficit or excess rainfall years are defined as those years when rainfall is less or more than the standard deviation (Krishnakumar et al., 2009). Decade-wise winter rainfall shows a significant decrease with just 19.2 mm decadal mean in 2000-2009 compared to the previous decades. The decadal mean of pre-monsoon rainfall in 2000-2009 (120.4mm) and 2010-2012 (106.0mm) has been reduced drastically compared to previous decades namely, from 1990-1999 (141.7mm), 1980-1989 (138.1) and 1970-1979 (126.1mm) (**Figure 6.3b**). Usually, wheat and mustard are grown in *Rabi* season (generally, sown in post-monsoon and harvested in next winter or pre-monsoon) in the study area subject to availability of water at the sowing period. Percent change in wheat yield was found to increase by 18.7% in the period from 1980-81 to 1990-91 (1st decade) and 1990-91 to 2000-01 (2nd decade). The percent change declined to 5.2% in 1990-91 to 2000-01 (2nd decade) and 2001-01 to 2011-12 (3rd decade). Percent change in mean yield of rape mustard also shows a declining trend between the decades. Although the seasonal rainfall trend is suitable for cultivation of mustard, variable rainfall in post-monsoon can hinder the mustard yield; the crop is sensitive to either water logging or drought conditions (Chatterjee and Ray, 2013). On the other hand, compared to eight excess rainfall years in monsoon, there are ten deficit rainfall years during 1950-2012. Monsoon rainfall, greatly needed for the rain-fed agriculture in Purulia, also showed a decline when the decadal mean was taken into account (**Table 6.3**). It was lowest in the last decade (2000-2009) compared to the previous four decades (1970-1979, 1980-1989 and 1990-1999). The lowest mean monsoon rainfall was found in 1960-1969 (991.98mm) and the decade witnessed below mean rainfall for eight years (**Figure 6.3c**). An inter-annual and decadal variability in summer monsoon rainfall over India also demonstrated random fluctuations in annual rainfall and an alternating epoch of above- and below-mean rainfall for decadal rainfall (Kripalani et al., 2003).

Decade wise, there were more negative departures in 1970-1979 (6 years), 1990-1999 (6 years) and again in 2000-2009 (7 years). The overall study period has been divided into two separate periods of 30 years (1950-1979) and 33 years (1980-2012) (**Figure 6.4**). Negative departures in annual rainfall were noticed in 15 years in the first 30 years with lowest departure of 35% in 1966. For the next 33 years, negative departure from mean was observed in 16 years with more than 30 % departure for 1982 and 2010. Figure 5b shows that from 1998 onwards there has been a higher number of negative departures from the long period mean with a record below mean departure (37.78%) in 2010, when the State Authority declared the district to be drought stricken. In addition, it was observed that there had been five excess rainfall years for the first 30 years under study (1950-1979), which fell to three excess rainfall years for the next 30 years period from 1980-2009 (**Table 6.3**), thus signifying that the number of excess rainfall years has reduced in recent years.

Table 6.3 Percentage departure from normal, frequency of excess and deficit rainfall years over Purulia

Decade	Pre-monsoon			Monsoon			Post-monsoon			Winter		
	% departure from normal	Excess	Deficit	% departure from normal	Excess	Deficit	% departure from normal	Excess	Deficit	% departure from normal	Excess	Deficit
1950-1959	-29.52	2	1	3.70	2	2	-8.66	2	3	-25.17	2	1
1960-1969	-22.13	2	2	-7.66	2	1	-9.97	2	1	-0.55	2	2
1970-1979	8.85	2	2	4.70	1	2	-0.33	2	0	34.56	2	1
1980-1989	19.16	2	1	-1.27	1	1	6.70	2	2	-0.87	1	0
1990-1999	22.27	1	2	7.55	1	2	27.23	1	2	31.62	2	1
2000-2009	3.94	1	1	-6.81	1	1	-6.54	2	0	-38.01	3	2
2010-2012	-8.54	1	0	-0.73	0	1	-28.11	0	1	-5.26	1	0

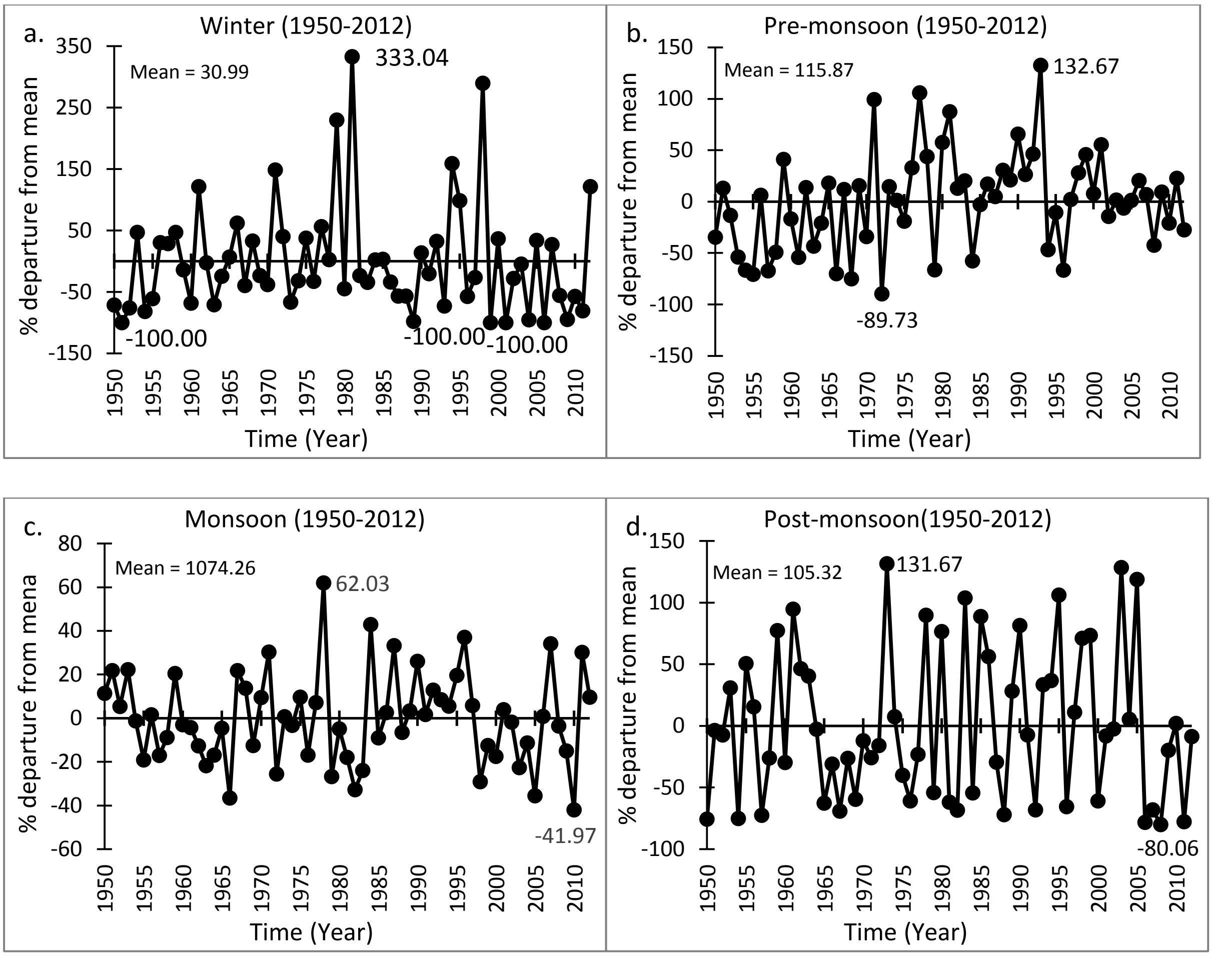

Figure 6.3 Season wise percentage departure of rainfall from seasonal mean for 1950-2012

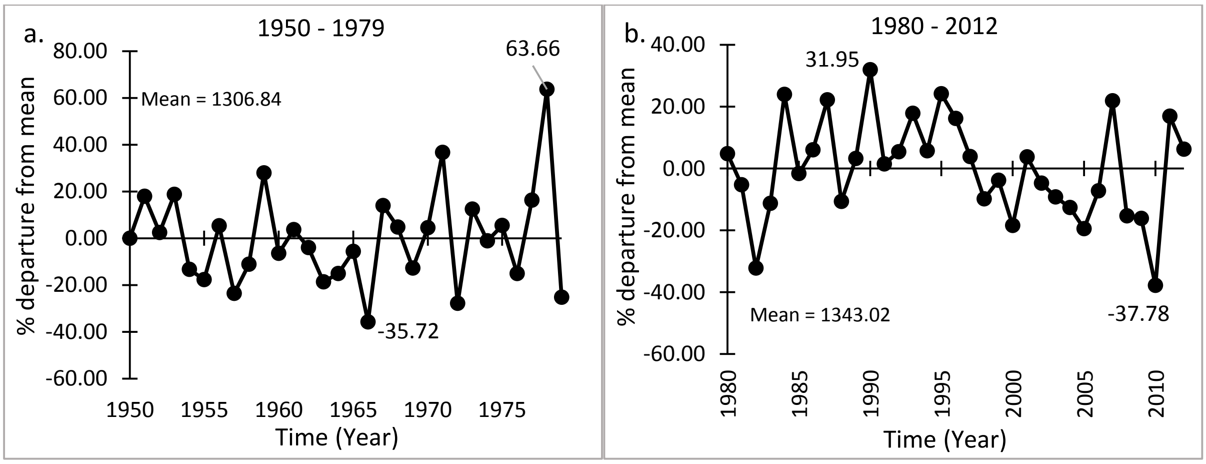

Figure 6.4 Departure of rainfall from decadal mean for (a) 1950-1979, and (b) 1980-2012

6.4.1.3 Variability in Rainy Days and Rainfall Intensity

An increased number of extreme weather events such as change in rainy days and rainfall intensity are very detrimental to *Kharif* agriculture (Mall et al., 2006). In India, a day is considered rainy when the amount of rainfall is 2.5mm or more. Annual rainy days in the district varied from 54 (in 1979) to 93 (in 1990) with a long period average (1950-1999) of approximately 74.0 ± 10 days. The distribution of rainy days across the months of pre-monsoon, monsoon, post-monsoon and winter was approximately 9, 55, 6 and 3, respectively (**Table 6.4**). Pre-monsoon, post-monsoon and winter months was found to show a wide variability (CV > 30%) and contributed to only 25% of the total rainy days. Non-parametric trend analysis of rainy days showed an insignificant increasing rate (at the rate of 0.01 days/year) annually. This can be attributed to the significant increasing trend at the rate of 0.08 days/year during pre-monsoon months and insignificant increasing trends in post-monsoon and winter months. Only rainy days during monsoon months showed an insignificant decreasing trend. At a monthly scale, June showed a significant (p = 0.013) increasing trend in the number of rainy days at the rate of 0.11 days/year where July and September demonstrated an insignificant downward trend at the rate of -0.05 and -0.04 days/year respectively.

Table 6.4 Descriptive and trend analysis of rainy days at a monthly, seasonal and annual timescale (1950-1999)

Months	Minimum rainfall (mm)	Maximum Rainfall (mm)	Mean (mm)	SD (mm)	CV (%)	MK	p-value*	Sen's Slope
January	0	6	1.32	1.33	100.88	0.07	0.54	0
February	0	6	1.88	1.48	78.71	0.08	0.46	0
March	0	7	2.06	1.97	95.80	0.03	0.82	0
April	0	8	2.62	1.92	73.11	0.04	0.71	0
May	0	12	4.26	2.62	61.62	0.16	0.12	0.03
June	4	19	11.12	3.72	33.48	0.25	0.01	0.11
July	10	25	16.40	3.33	20.32	-0.15	0.15	-0.05
August	9	24	15.80	3.40	21.55	-0.07	0.49	0
September	4	20	12.12	4.14	34.15	-0.10	0.33	-0.04
October	0	11	4.44	2.47	55.57	-0.09	0.39	0
November	0	4	1.12	1.19	106.17	0.11	0.34	0
December	0	4	0.66	1.08	163.73	0.16	0.16	0
Annual	54	93	73.80	9.72	13.17	0.10	0.32	0.10
Pre-monsoon	1	19	8.94	3.92	43.90	0.18	0.08	0.08
Monsoon	41	74	55.44	7.07	12.76	-0.04	0.72	0
Post-monsoon	2	14	6.22	2.81	45.16	0.03	0.77	0
Winter	0	10	3.20	2.06	64.38	0.10	0.35	0

Rainfall intensity is always important in studies of water capture and harvesting, infiltration, runoff and soil erosion. For the present study, **Figure 6.5** illustrates an increasing trend in annual rainfall intensity. Post- monsoon rainfall intensity was found to be highly variable among the four seasons. On a monthly timescale, October rainfall intensity contributes highest to the variability in rainfall intensity. A comparison of the post monsoon and monsoon rainfall intensity for the years 1959, 1961, 1980, 1985, 1990, 1994 and 1999 revealed a lower rainfall intensity in monsoonal rainfall but a higher intensity of post-monsoonal rainfall, which could have significant impact on the crop productivity of the district. Higher intensity of rainfall results in higher soil erosion which is already prevalent in the district owing to its undulating topography. High intensity post-monsoon rainfall may also damage the paddy panicles, resulting in significant crop yield reduction.

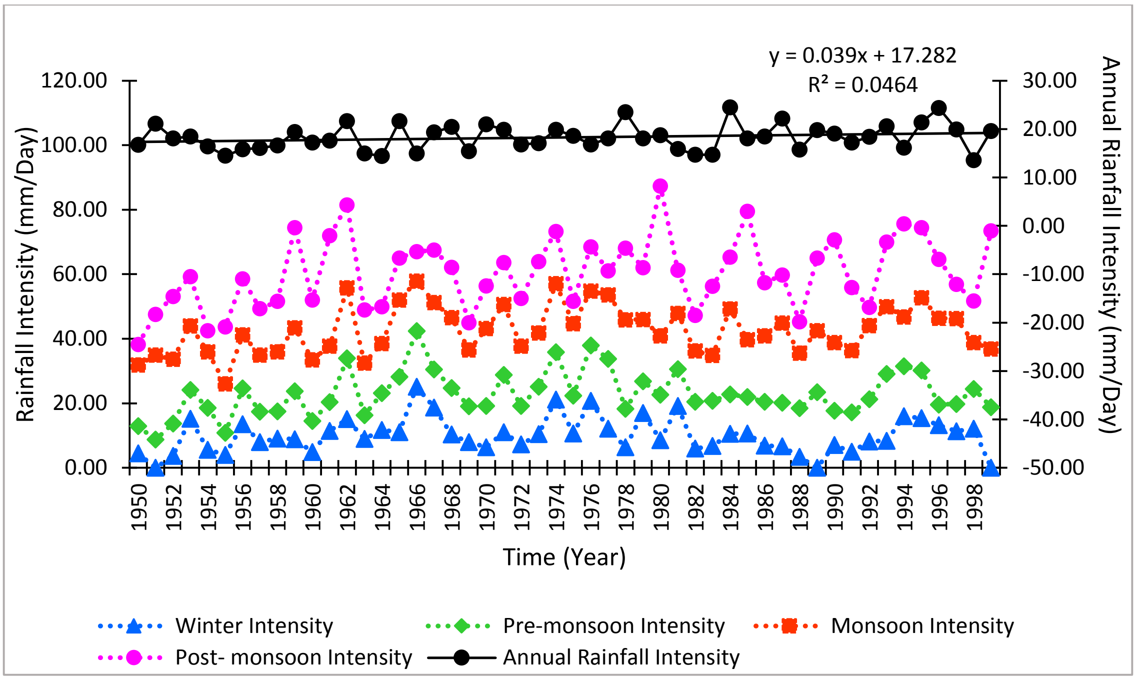

Figure 6.5 Annual and seasonal rainfall intensity in Purulia

6.4.2 Surface Temperature Characteristics

Table 6.5 demonstrates the descriptive statistics of monthly and seasonal minimum and maximum temperature of the district under study. Average monthly temperature was highest during May (32.2˚C), and lowest in January (18.3 ˚C). Mean (of 25 years) maximum and minimum temperatures recorded were 41.6˚C (in May) and 10.7˚C (in January). The highest maximum temperature experienced by the district in the period of last 25 years was 48.7˚C (May 2013), and the lowest minimum temperature was 7.1˚C (December 2007).

As shown in **Figure 6.6**, the average minimum temperature was not found to demonstrate any significant trend during parametric trend analysis. However, average maximum temperature was found to reveal a noticeable increasing trend at the rate of 0.27˚C year^{-1}. Seasonally, though winter and post-monsoon maximum temperature does not reveal any significant trend, pre-monsoon and monsoon maximum temperature reveal an increasing trend in the study area (at the rate of 0.37˚C/year^{-1} and 0.32˚C/year^{-1}, respectively). While minimum temperature for monsoon and winter display a decreasing trend in the district.

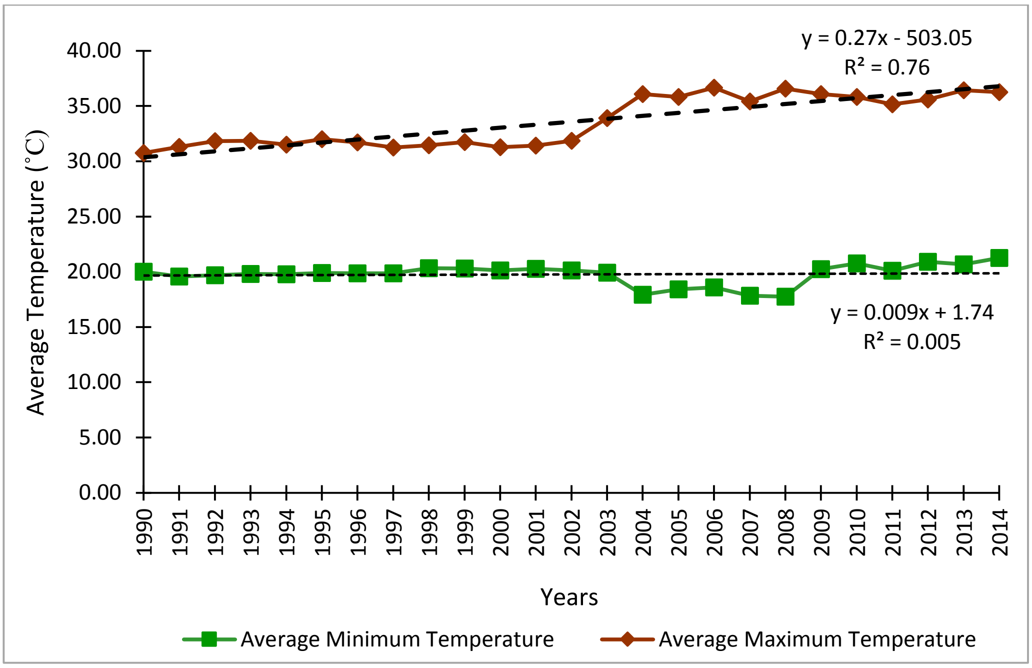

Figure 6.6 Average minimum and maximum temperature distribution in the district

It has been observed that the yield decrease of *Kharif* rice due to temperature increase by 1˚C (both maximum and minimum) is approximately 300 kg/ha. If temperature is increased by 2˚C, the potential yield may be reduced to about 800 kg/ha (Banerjee and Khan, 2008). In the initial period, the above ground biomass is more under increased temperature conditions. Due to temperature increase the rate of tillering is more, hence in initial period the predicted biomass and other related parameters are also higher than the normal situation. Again due to increase in temperature, the crop matures earlier, the biomass production declines and ultimately the yield is reduced.

6.4.3 Relative Humidity Characteristics

As the relative humidity data was available for last ten years only, no trend analysis can be conducted. A gradual increase in mean relative humidity was noticed from March (43%) to August (82.65%) and thereafter it decreased from 81.12% in September to 52.34% in February in the district. It indicates that the relative humidity is relatively low during summer and winter and high during monsoon months. It is the characteristics of dry sub humid tropics as considerable atmospheric moisture is carried by monsoon wind during monsoon, which results in high relative humidity. Otherwise, the relative humidity is low during winter and summer, and summer is characterised by dry winds called loo and is excessively torrid. Over the decade, mean relative humidity was found to be nearly constant and no visible change was observed.

6.5 Implications to Rural Water Security Framework

Planning for water security necessitates the consideration of all forms of relevant information about the various forms of uncertainties that may arise from changing climate. Particularly, for areas where rainfed conditions dominate the livelihood of population; any abrupt change in climate variables, particularly rainfall patterns poses serious threat to food and human security of the entire region. An understanding of the spatial and temporal distribution and changing patterns in rainfall is a basic and important requirement for the planning and management of water resources (Jain and Kumar, 2012). For a district like Purulia where rainfall is the only source of water, not only for agriculture but also to meet domestic as well as other needs of the community, knowledge about changing rainfall pattern is an integral part of the water security planning and for devising any conclusive mitigation and adaptation measures. For instance, the probable impact of change in rainfall pattern in the study area may be envisaged on the degree of soil erosion. During the end of monsoon (October-November), when the soil is already saturated with water, little more rain will accelerate soil erosion, as is the case in Purulia. By utilizing November rainfall, crops with low water requirement may be adopted after *Kharif* season. Moreover, as monsoon rainfall amount shows a decreasing trend, optimum sowing window based on the changed climatic scenario should be assessed and included in the micro-level water security plan. Provisions on storage of rainwater and its use after the monsoon season is over also includes a major part in the water security plan of a drought prone district like Purulia. Local communities react to the changing climatic conditions by adopting various adaptation measures. But this measures often fail as the community fails to presume the extent of change and uncertainty involved with it. Here comes the role of administration who have to help the community overcome the situation. Hence, studies like these provide information to the district administration to deal with extreme hydrological conditions and helps them in getting prepared to respond to the unseen uncertainties beforehand. It is important to have detailed information on climate, especially rainfall, characteristics at the district level for a

Table 6.5 Descriptive statistics of monthly and seasonal surface temperature in the district

Months	Minimum Temperature					Maximum Temperature				
	Minimum (˚C)	Maximum (˚C)	Mean (˚C)	SD (˚C)	CV (%)	Minimum (˚C)	Maximum (˚C)	Mean (˚C)	SD (˚C)	CV (%)
January	8.02	12.56	10.68	1.34	12.53	24.37	33.02	26.84	2.27	8.45
February	8.68	16.01	13.77	1.96	14.18	25.93	39.57	29.94	3.02	10.08
March	14.52	23.11	18.70	2.01	10.77	30.75	43.68	36.53	3.73	10.21
April	20.66	25.37	22.79	1.34	5.89	35.29	45.71	39.85	3.06	7067
May	21.31	27.86	25.04	1.57	6.28	37.15	48.72	41.58	2.94	7.06
June	22.87	27.65	25.19	1.33	5.27	31.00	45.96	37.89	3.51	9.25
July	23.42	26.33	24.61	0.63	2.55	29.83	39.61	33.80	3.01	8.89
August	23.94	25.27	24.55	0.54	2.21	30.22	41.54	35.03	3.60	10.27
September	22.47	24.55	23.83	0.55	2.31	30.16	38.33	33.39	2.47	7.40
October	19.22	23.05	20.92	1.08	5.17	29.35	35.82	31.96	1.66	5.20
November	12.34	18.47	15.67	1.53	9.80	26.89	33.31	29.51	1.71	5.80
December	7.62	13.74	11.36	1.47	12.95	24.74	34.10	26.72	2.37	8.88
Pre-monsoon	19.00	25.00	22.18	1.46	6.58	34.63	44.33	39.32	3.06	7.78
Monsoon	23.50	25.46	24.54	0.47	1.92	31.61	39.75	35.03	2.82	8.04
Post-monsoon	13.67	18.00	15.98	1.18	7.37	27.28	34.00	29.40	1.77	6.04
Winter	8.00	13.79	12.22	1.47	12.03	25.64	34.00	28.39	2.46	8.65

better planning of disaster management and water resource management through application of regional climate models with downscaling.

As mentioned earlier, ensuring water security not only includes the capacity to safeguard water sources and water quality but also harnessing benefits of water in a sustainable way to improve livelihood, human well-being and socio-economic development. Therefore, inclusion of change in climatic variables is an integral part of micro-level water security framework that will help in improving the livelihood, food security as well as the overall well-being of the community.

6.6 Concluding Remarks

It is necessary to understand the temporal distribution and changing patterns in local climate variables, mainly rainfall, to manage natural resources or agricultural development well. District level analysis of rainfall trends, based on the data from local rain gauge stations, presents useful information to the district authorities. Dry sub humid climate areas are characterised by frequent instances of water scarcity and are usually drought prone. This holds true for Purulia, the study area, which experiences water scarcity for most part of the year, every year. Long term rainfall (1950 – 2012) analysis at different timescales revealed an insignificant but increasing trend in annual rainfall as well as significant increasing trend of rainfall in pre-monsoon season. Because rural communities depend on rain fed paddy cultivation, monthly rainfall trends are very important for understanding the probable impacts of varying rainfall at different stages of crop growth. The study area witnessed an increasing rainfall trend in the sowing phase of paddy. But the transplanting and tillering phase, spanning from July to September, experienced decreasing rainfall, which in turn could have affected the crop yield.

The departure from decadal mean reconfirmed the decrease in monsoonal rainfall and there have been ten deficit rainfall years in the monsoon season compared to eight excess rainfall years. Because paddy cultivation requires reliable water supply, the varied rainfall intensity between the monsoon and post-monsoon season emerged as a serious concern. As the district is rural, poverty stricken and dependent on agriculture, decreasing monsoon rainfall compels local communities to shift their cropping season, use short duration rice variety, search for alternative livelihood or migrate. Average maximum temperature demonstrates an increasing trend, however average minimum temperature is nearly constant throughout the study period. Seasonally, though maximum temperature displays an increasing trend in all the seasons, minimum temperatures shows a decreasing trend in monsoon and winter season. It is difficult to assess any trend in relative humidity in the district because only 10 years data were available for analysis.

The initial climate data analysis and the subtleties of climate change provided information that allowed aspects of the climate-led changes in livelihoods to be recognised. Proper dissemination of results of such studies to the local rural communities and authorities will help them in understanding the local climate pattern in their area, thus preparing them to formulate effective decisions and respond to the uncertainties.

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CHAPTER 7

LOCAL PERCEPTIONS OF AND COPING TO WATER INSECURITY

"Tell me and I forget. Show me and I remember. Involve me and I learn."

Anonymous

CHAPTER 7: Local perceptions of and coping to water insecurity[1]

This chapter presents empirical evidences of coping strategies practiced in response to water insecurity and an emerging climate variability in Purulia. Non-climatic factors are found to be largely responsible for the existing water insecure conditions and, as perceived, climatic variations are found to magnify the misery. Counter responses, mostly coping strategies, are found to be spontaneous, reactive and are largely motivated by crisis which often degrades the resource base and are found to be detrimental to the health and well-being of the studied communities. This study criticizes the blind water supply provisions existing in rural areas which constantly ignores the water demand of rural communities.

Outline of the Chapter

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7.1 Introduction

Water security has physical, social, economic and ecological aspects. In addition, "water security has always been a societal priority— in its absence people and economies have remained vulnerable and poor" (Grey and Sadoff, 2007). Water security assessment at the national scale can mask significant variation at the local scale (Vörösmarty et al., 2010). Hence, achieving water security requires community level understanding and response, as processes at the local level influence global actions (and vice versa). Local observations often are absent in scientific studies and models (van Aalst et al., 2008). Although numerous studies have demonstrated the significance of perception (Alessa et al., 2008; Haldar et al., 2012; Grace et al., 2013; Murtinho et al., 2013), and many individuals make decisions based on perceptions rather than measured variables, most predictive models regarding the use of water resources do not include social components, such as perceptions (Alessa et al., 2008).

Public perception plays an increasingly important role in shaping environmental policy and management response systems. Perceptions influence decisions to act or not over both short- and long-terms (Alessa et al., 2008) and are key components of adaptation. This means that communities first need to perceive a change and then implement a set of strategies to address them. As discussed in Chapter 3, adaptation strategies are long-term and planned responding to expected continued decline or uncertainty in future crop productivity and food production. On the other hand, the coping strategies of communities, mostly rural poor and marginalized, are aimed at responding to short term shocks, and are unplanned (Nuorteva et al., 2010), autonomous and reactive rather than strategic (Bates et al., 2008). With a heavy dependence on water and other natural resources for their food and health security, livelihood and well-being, these coping strategies are generally applied in socio-economic sectors to overcome the immediate crisis and are just for *survival*.

The majority of the adaptation studies to date focus on perceptions of farmers and their adaptation to climate change (Ashraf and Routray, 2013; Dang et al., 2014; Baudoin et al., 2014). Farmers often have extensive experience in responding to adverse effects from climate variability and change (Halder et al., 2012). Although such studies are important to design mitigation strategies, these are less relevant in terms of providing critical insights for effective adaptation strategies at the household or community level. In addition, environmental behaviour studies typically indicate that women are more aware of environmental risks and more readily support environmental and climate initiatives (Barkan, 2004). Still, limited studies focus on the perception and adaptation/coping strategies of women, who are the principal carriers of water and plays one of the most significant role in ensuring water security at a household scale. Hence, the present study specifically focussed on women to understand water security status at a household scale, along with farmers to have an insight into agricultural water security. Moreover, village elders have been included in this study as elder cultures possess a deep knowledge base about the complex ecological systems with which they interact through the transmission of knowledge and wisdom from one generation to another. In communities, knowledge and awareness of changes in the quality and availability of resources, including water, held by an individual can be, and usually are, transmitted from generation to generation (Kurien, 1998).

Participatory Rural Appraisal (PRA) tools has been mainly devised to acquire information at the grassroots concerning people's livelihoods and daily existence. The main objectives of these tools is to collect information, be rooted with people in their communities, to foster active participation in the process, and provide the basis for them to discover their own means of solving their difficulties. The application of PRA tools has been found in a number of studies on exploring perceptions of rural communities on environmental issues that affect their lives (Gentle and Maraseni, 2012; Below et al., 2014; Dieye and Roy, 2012). Participatory rural appraisals enable the collection of large amounts of community level information in a relatively short time. Hence, PRA tools are found to be quite apt to harness perceptions of the rural communities about the status of water insecurity and also delineate the strategies practiced by rural communities to overcome the crisis.

7.2 Survey Approach and Methodology

7.2.1 Research Objectives

The primary goal of this study is to assess local perceptions and understanding of water insecurity in the district under study. Community views were also sought regarding localised climate variability and how the synergy of climate variability and water insecurity increases the socio-economic adversity of the rural impoverished population. The chapter argues that more than climatic and other natural factors, management factors affect water security in rural areas, and most of the strategies practiced by local communities are inadequate and unsustainable. The remaining gap in perceiving the changes and the adaptation capacities of rural communities requires policy intervention that will enhance water security in rural areas.

7.2.2 Selection of the Study Area

The *Blocks* for this study has been selected based on the water insecurity status of each *Block*, mentioned in Chapter 4. Out of the very high water insecure *Blocks*, mountainous *Blocks* like Arsha and Baghmundi are included in the present study. Similarly, Balarampur has been selected from six high water insecure *Blocks* whereas Purulia II and Banduan has been included to represent the medium water insecure *Blocks*. On the other hand, Neturia is found to be relatively water secured based on RWII score and has been included in the present study. The final call of decision regarding the selection of villages under different *Blocks* were taken after meticulous discussions with local administrative officials and feasibility of carrying out the study (**Figure 7.1**).

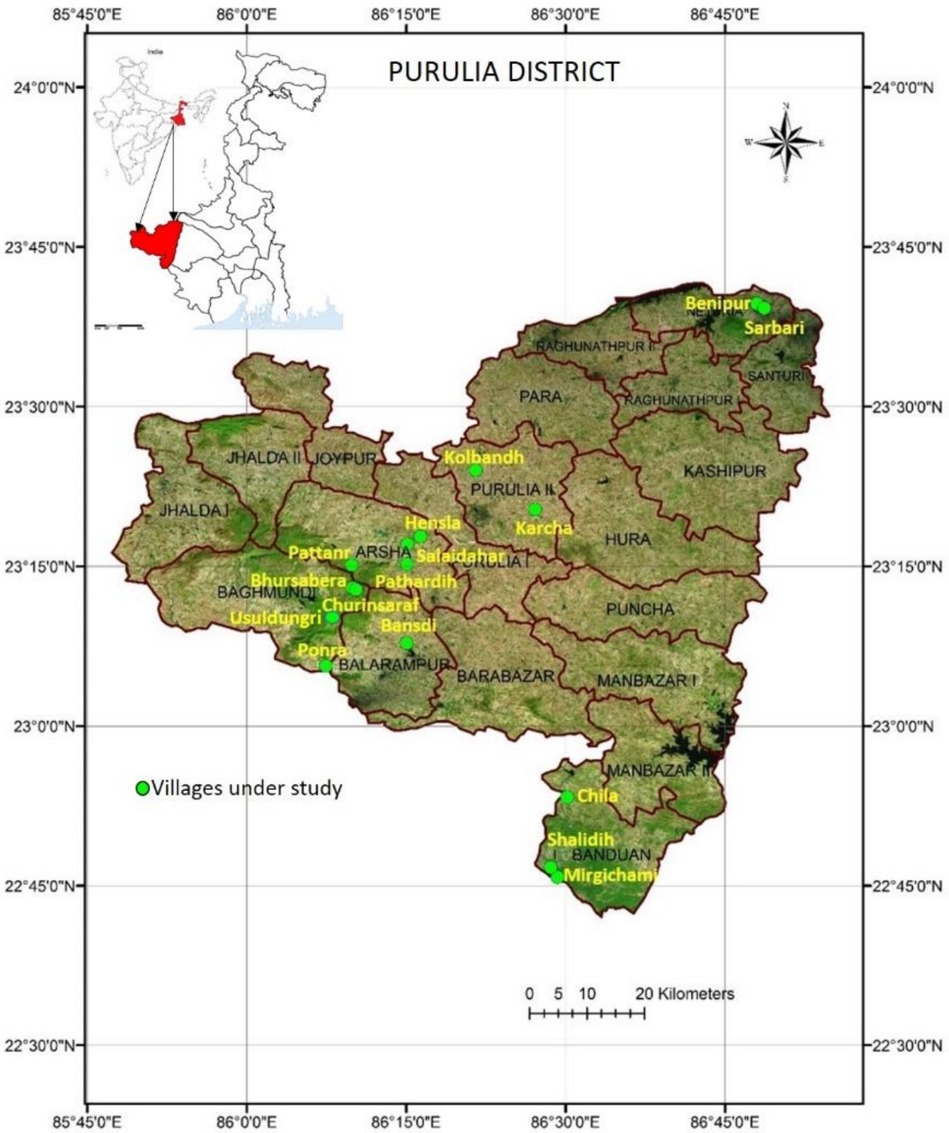

Figure 7.1 Map of the district with the location of the villages under study

Table 7.1: Details of the studied villages and their status of water security

Village Name	*Block* Name	Total Household#	Total Population#	Total Tribal Population#	Main Occupation#	Water Insecurity status*
Pattanr	Arsha	104	527	527	Agriculture, Forest Resources	Very High
Pathardih		114	627	37	Agriculture	
Hensla		737	4068	199	Agriculture	
Salaidahar		244	1335	8	Agriculture	
Ponra	Baghmundi	158	920	482	Agriculture	Very High
Bhursabera		129	657	657	Agriculture, Forest Resources	
Churinsaraf		25	137	137	Agriculture, Forest Resources	
Usuldungri		74	377	377	Agriculture, Forest Resources	
Bansdi	Balarampur	399	2308	344	Agriculture	High
Karcha	Purulia II	231	1215	0	Agriculture	Medium
Kolbandh		258	1503	207	Agriculture	
Chila	Banduan	391	2071	454	Agriculture	Medium
Shalidih		103	472	453	Agriculture	
Mirgichami		186	839	460	Agriculture, Forest Resources	
Sarbari	Neturia	636	3990	260	Agriculture, Industry workers	Low
Benipur		79	485	98	Agriculture, Industry workers	

(*# Based on Census of India, 2001; * Based on previous study discussed in Chapter 4*)

Out of the villages under study, only two villages, namely Bansdi and Sarbari, have piped water supply. Rest of the villages have to rely on hand pumps, dug wells or surface water sources to meet their water demand. **Table 7.1** delineates the demographic characteristics of the studied villages. Villages like Pattanr, Bhursabera, Churinsaraf, Usuldungri, Shalidih and Mirgichami can be designated as mountainous tribal villages as the population consists mostly of indigenous people (*Santhals*). Except for the above characteristics, the villages also have varied socio-economic, geomorphological and hydrological conditions which made them apt for this study.

7.2.3. Participatory Rural Appraisal (PRA) tools

Field investigation using various Participatory Rural Appraisal (PRA) tools such as Focus Group Discussion (FGD), transect walk, resource mapping and crop calendar (**Table 7.2**) are exercised to capture the perceptions and interpretations of local village communities.

Figure 7.2 FGDs and resource mapping exercises with various communities in the study area (A) FGDs with village women in Hensla; (B) Farmers participating in resource mapping exercise in Pathardih; (C) FGD and resource mapping exercise with village elders in Salaidahar; and (D) Village women gather for FGD in Pattanr.

Table 7.2: Objectives and key questions/themes of the PRA tools applied

PRA Tools	Objectives	Key questions/Themes
Focus Group Discussion (FGD)	To collect information on village water resources and livelihood assets To understand the perception of climate change and water insecurity of villagers across the years To get information on adaptation and coping strategies To understand the constraints in achieving a sustainable living	Key pressures on the local water resources and livelihood assets? Change in water quality and quantity in last 30 years or more? Change in climate and indicators of change in last 30 years or more? Impacts on daily life and livelihood assets? Communities mostly affected by change in water and climate? Adaptation and coping strategies in daily life and livelihood? Community or individual strategies? Key barriers to adaptation and coping strategies?
Resource Mapping	To delineate shape (appearance) of the community, boundary and the major features as understood and known by the community. To show where resources, activities, problems and opportunities are located.	Location of households, social and residential differences? Existing or missing resources, mainly water? Quality, use, distribution of and access to resources, mainly water? Landscape and land use of village? Location of key livelihood assets?
Transect Walk	To collect information beyond the initial reconnaissance and FGD, and verify the information on the Resource Map. To add detail on specific characteristics (landscape, vegetation, water, soils other sources) that further	Size, distribution, population of village? Location of social and economic features of village? Landscape and land use of village? Location, quality and functionality of water resources of the village? Location and sustainability of key livelihood assets?

	verifies understanding of the area.	
Crop Calendar	To gather information on current and previous agricultural practices of the village To understand community's production calendar To understand how water availability affects crop production as perceived by villagers	Crops grown in the village? Sowing and harvesting period of crops? Lost and newly-emerged crops? Production of crops?

Among various PRA tools used, FGD was of particular significance for assessing information on attitudes and perceptions of communities towards water insecurity and climate change (Appendix III). The information documented during the PRA sessions was summarized in reports containing observations, responses and video transcriptions of FGDs for each village. Subsequently, the collected data was divided into different themes and sub-themes for careful interpretation. The field visit and data collection has been carried out in January-February, 2014. The date, time and venue of carrying out PRA exercise in each village has been pre-decided with local administrative officials. Accordingly, the village population was notified by the Panchayat office. During the exercise day, particular communities gathered in the venue at the specified time. Volunteers from the Panchayat offices helped in selection of participants and looked after the arrangements. Each PRA exercise spanned for, approximately, 45 minutes to 1 hour.

Community, in this study, is referred to a group of people who lives inside a territorial boundary and utilizes a common pool of natural resources like land, water and forests, and also have some common characteristics like age, gender or occupation. In lieu of this, participants from each village were divided into three categories: 1) village elders – mostly men who are 60 years old or more and are residing in the village since birth; 2) farmers – mostly men who are less than 60 years old and are engaged in farming activities inside the village premises; and 3) village women (includes both young and old) – who are mainly bestowed with the responsibility of carrying out household chores and collecting water for domestic needs. When the village elders are hypothesized to delineate the observed changes in local climate, livelihood and water condition of the respective villages across the years, farmers and village women are expected to highlight the causes and consequences of water insecurity on agricultural practices and domestic life. As the themes of FGDs were different, the responses from the participating communities were interpreted separately. The total number of participants in each community of village elders, farmers and women are 108, 154 and 128, respectively. Each FGD consisted of 8-12 members from each community (elders, farmers and women) with a total of 48 FGDs conducted in 16 villages.

7.3 Results and Discussion

7.3.1 Community perception of climate variability

Rainfall data for the study area, as discussed in Chapter 6, reveals an inter-annual variability from 1950 to 2013. In the last decade, the district received significant amount of below mean rainfall and these recent experiences are what the local communities, mostly farmers and elders, were able to recall easily. Considering long period changes, village elders (76.1 %) from nearly all the villages perceived distinct reduction in the amount of annual rainfall compared to earlier times (approx. 20-30 years ago) (**Figure 7.3**). The village elders from Pattanr responded,

> *"Earlier the river in the village premises, the only source of water in the village, used to run full. We cannot cross the river. But now, the rivers run dry 9 months a year. Even in monsoon, we can cross the river by walking."*

Seasonal rainfall also displayed noticeable trends in last 64 years. Southwest monsoon is the principal source of water in the district and, farmers and village elders pointed out that monsoon has been highly variable in recent years and it often rains intensely for 3-5 days in the monsoon, then it ceases for 3-4 weeks. The amount of rainfall has also been perceived to be highly variable in recent years which can be reaffirmed from the variation in average monsoon rainfall i.e., 360 mm in 2007, 156 mm in 2010 and, again, 350 mm in 2011. The observed south-west monsoon (June-September) rainfall displayed an insignificant but declining trend from 1950-2013. In addition, more than 95% of participating elders and farmers recognized a significant delay in the onset of southwest monsoon in recent years (**Figure 7.3**). Earlier, southwest monsoon usually started from *Asharh* (15^{th} June-17^{th} July) – *Shrabon* (18^{th} July-17^{th} August). Now, it starts either by the end of *Shrabon* or *Bhadro* (18^{th} August-17^{th}/18^{th} September). Instead of monsoon months, heavy rainfall is encountered in *Ashwin* (18^{th}/19^{th} September-18^{th} October) and *Kartik* (19^{th} October-16^{th} November), the post-monsoon months. As responded by a village elder from Pathardih,

> *"We have never seen such high rainfall in Ashwin or Kartik months. But for the last 5-10 years, the amount of rain in these months has increased, with the highest in last year (2013)."*

The observed trend in post-monsoon rainfall also demonstrated a highly variable pattern with distinct alternate epoch of above- and below- mean rainfall, as shown in Chapter 6. In addition, a reduction in duration of winter months has been noticed by the studied communities (13.4%). Another characteristic perceived by communities during FGD is decline in duration of rainy months and number of rainy days. The village communities from villages like Kolbandh and Karcha emphasized that when the duration of rainy months has decreased, the intensity of rainfall has increased manifold.

Regarding changes in temperature, mixed perception were received from the communities. When no change in temperature has been perceived by communities in villages like Hensla and Bansdi, increase in number and duration of dry spells, and number of hot days has been noticed by the elder groups from almost all the villages under study. The village elders from studied villages identified that, for most part of the year, the climate in the study area has become hot and dry. Overall, the participants of the FGDs, mostly village elders and farmers, share the perception that climate conditions have become more unpredictable and challenging over the last few years. Also, the precision in perceiving the climatic changes by men, rather than women, can be attributed to the division of labor and differences in decision-making power in rural families. This also holds true for other studies where the farmers are found to perceive the changes by relating it to farming practices and farm productivity (Manandhar et al., 2011; Ashraf and Routray, 2013).

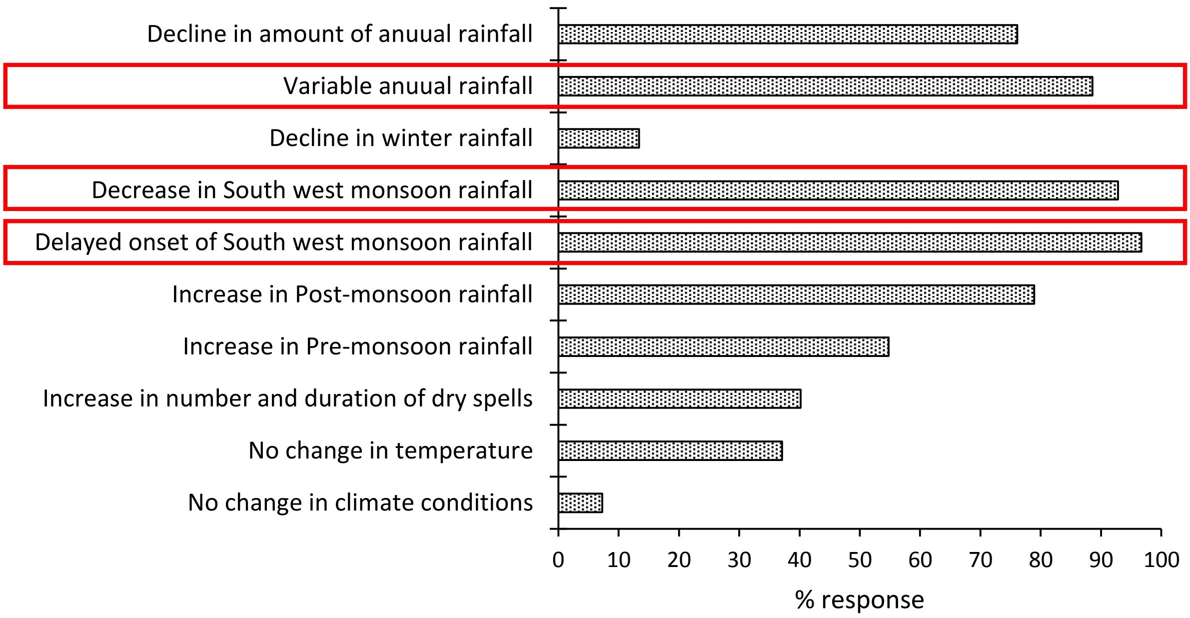

Figure 7.3 Farmers' and village elders' perception of climate variability in the study area

7.3.2 Perceived causes of water insecurity

In addition to the perceived climatic impacts on water insecurity, as mentioned in the previous section, various other causes were pinpointed by the communities during the PRA exercises. The outputs from each PRA exercise were analyzed individually and in concert and the recurrent findings were combined into factors, as shown in **Table 7.3**. Narrative statements are quoted, where appropriate, to illustrate the discussion with the villagers specified.

7.3.2.1 Natural Factors

Except for the climatic factors, several natural factors have been identified to influence water security by the local communities, mostly farmers and village elders (**Table 7.3**).

Table 7.3 Identified factors influencing water security in the study area

Natural factors	Management factors	Social factors
Existence of 'dry areas'	Fewer number of hand pumps/ public taps	Population pressure
Decline in groundwater level		Restricted right to get water
Low yielding capacity of aquifer	Inconsistent water supply	Caste discrimination on water use
Fluoride contamination	Breakdown of hand pumps	No community involvement in decision making process
Drying up of water sources		
Undulated and rugged topography	Lower water holding capacity of storage reservoirs	
Lower water retention capacity of soil	Lack of equitable distribution of water	
	Lack of survey, repair and proper maintenance	
	Upstream siltation due to construction of dams	
	Illegal tapping of water from main pipeline system	
	Depleted water quality	
	Distant location of water abstraction structures	
	Siltation of irrigation canals	

Decline in groundwater level has been perceived in nearly 62.5% of the studied villages' by referring to the difference in the depth of hand pumps or dug wells across the years. As highlighted by the elder community in Ponra,

> *"Previously water was available at nearly 60 feet. Now, it is available beyond 170 - 200 feet."*

Similar is the experience in Benipur where water was previously available in hand pumps at 12-15 mbgl (meter below ground level), which is not even found beyond 75-90 mbgl in recent times.

Also, as given in **Table 7.3**, lower water yielding capacity of aquifers has been perceived to be a significant challenge in 31% of villages under study. For instance, women in Kolbandh highlighted that each hand pump in the village premises needs a standing time of 30 minutes to one hour, which increases to as high as 1.5 to 2 hours during dry season, before it can fill up one bucket (20 L). Presence of perched aquifers, aquiclude and aquifuge is predominant in many parts of the district which restricts continuous groundwater flow and supply. In addition, groundwater contamination is perceived to be a major concern in the district. Hardness is identified to make cooking and washing of clothes difficult for almost every participating women in the FGDs. Symptoms like yellow cracked teeth and joint pains were pinpointed by the village elders and farmers, mainly in Karcha, Kolbandh and Hensla. Validation from the district authorities and related literatures confirmed the presence of fluoride in the groundwater in these areas (Bhattacharya and Chakrabarti, 2011; Chakrabarti and Ray, 2013; Roy, 2014). The fast recession of water table (due to excessive withdrawal) and long spells of water scarcity in the study area are found to trigger the gradual leaching of fluoride into the circulating water (Bhattacharya and Chakrabarti, 2011).

During the resource mapping exercise, participating communities in villages like Kolbandh, Karcha and Benipur identified various "dry" areas inside the village boundary (**Figure 7.4**). Groundwater is unavailable in these areas even after digging larger depths like in Karcha where water is unavailable even after digging 90 – 120 mbgl. Hard rock, mainly granites and granite gneisses, predominate the district and groundwater, in general, occurs in fractures that lie at a depth of 40-50, 70-80 and 120-150 mbgl. The most dominating fractures are within 70-80 mbgl (Roy, 2014). During lean period, most of the groundwater in shallow fracture zones get over-extracted or dried. The pressure on the hand pumps for extracting water, often, results in their breakdown. In many of the villages under study, hand pumps installed in the 'dry' areas lies defunct.

Irrespective of surface water and groundwater, seasonal drying up of water sources is a common phenomenon in the district. As perceived by all the participating village communities, surface water sources like ponds and rivers start drying as soon as the monsoon season is over. The increase in atmospheric temperature has been attributed to be one of the main reasons for drying up of water sources. For villages like Pattanr, Bhursabera and Churinsaraf, people depend solely on river water to meet all their needs. Because the rivers are mountainous and have high current, monsoon water flows down fast and, as per the community's view, little water remain in the river. This thin film of water also starts drying from *Falgun* (14th February-14th/15th March) till it rain again. Water availability from the hand pumps are also perceived to significantly decline from *Falgun* (14th February) till *Jaistho* (14th June). This escalates the water demand for domestic use manifold.

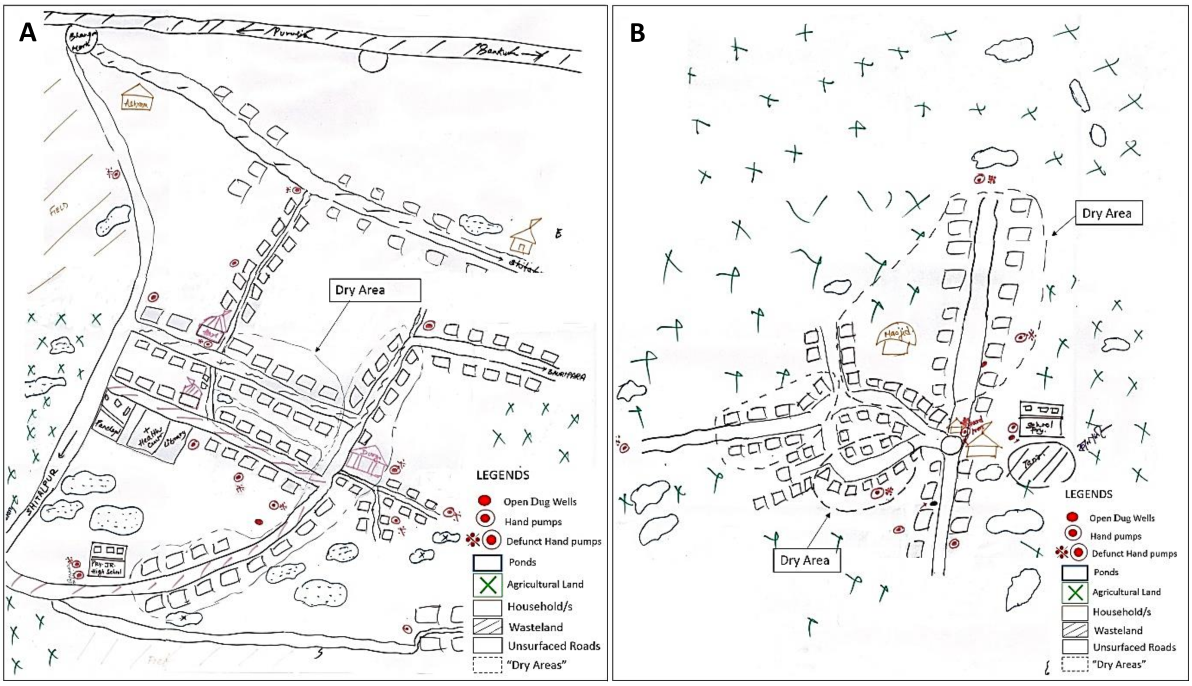

Figure 7.4 Village maps made during Resource Mapping exercise shows marked dry areas inside the boundaries of (A) Karcha and (B) Kolbandh

Undulating topography is perceived to be one of the major factors behind lack of water storage and loss of agriculture in the study area. Both resource mapping and transect walk with farmers and village elders from all villages demonstrated five different landforms in the study area (**Figure 7.5**). Homestead lands or *Badi* are uplands where proper agriculture cannot be carried out. These uplands are usually the backyards of home, which are either left vacant or used to grow vegetables for household use. *Tanr*, the un-terraced and un-bunded uplands, are mostly wastelands, highly eroded with occasional presence of bushes or stubbies of trees. In every village, almost every household has some proportion of *Tanr* lands, which was, previously, used to grow paddy. However, due to lack of water, *Tanr* lands are now laid vacant. Though *Kanali* and *Bohal* (lowlands) are the most productive land for effective crop growth, very few farmers own *Bohal* lands. Hence, *Baid* and *Kanali* are the most common landforms available to grow rain fed *Aman* paddy (**Figure 7.5**).

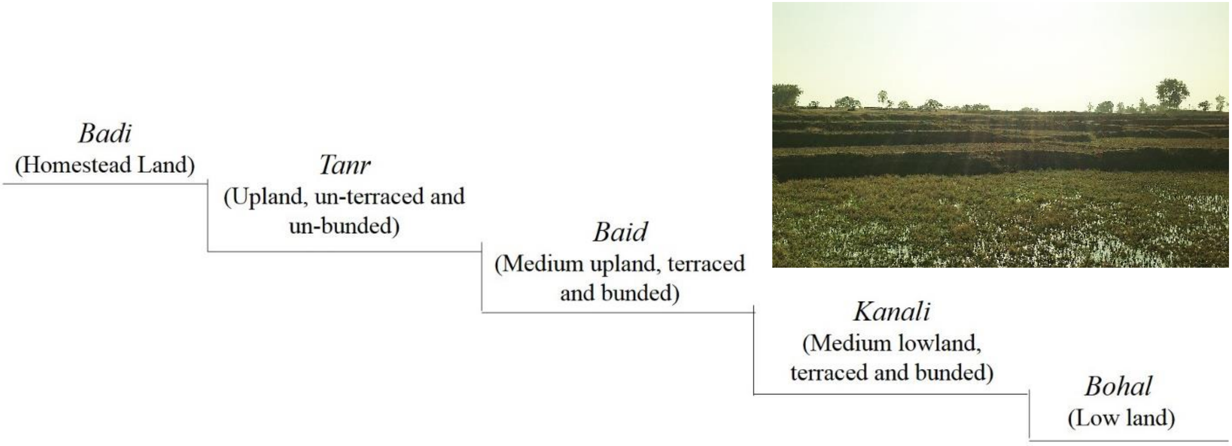

Figure 7.5 Agricultural land transect in the study area
(Inset picture: The land transect in the study area)

Farmers from Pathardih perceived,

> *"Most of the land, available in the village, is Tanr where cultivation is difficult. Only 1/3rd of the total land area are Kanali and Bohal lands, which are used to grow crops."*

Similar responses were obtained from farmers in Churinsaraf where only three households own *Bohal* land. In most of the villages, due to unavailability of adequate rainfall, cultivation has to be stopped in *Tanr* and *Baid* lands, and only the available *Kanali* lands are used.

7.3.2.2 Management factors

PRA exercises revealed a number management issues that are perceived to be detrimental to water security in the study area. With less than 20 percent of the district covered by piped water supply, groundwater is the only and most reliable source of water (DHDR, 2012). Notably, owing to economic status of local people, a handful of households can afford to have their own hand pumps and wells. Hence, community hand pumps and dug wells are installed, not only to meet domestic water demand but also for irrigation purposes.

Five of the studied villages have only one communal hand pump to meet the domestic water need for all the households like in Ponra where only one hand pump supplies water for more than 150 households. In addition, participating communities from nearly every village identify very few hand pumps to be functional throughout the year, as shown in **Figure 7.6A**. Regular breakdown of communal hand pumps is a common affair in all the villages under study. Excessive pumping and mishandling, and complex hydrogeological conditions (mentioned in the previous section) are perceived to be the reasons behind the frequent breakdown of the hand pumps. Lack of survey before the installation of water abstraction structures, and absence of proper repair and maintenance has been pinpointed to be a major management issue hampering water security in the study area. For example, as shown in **Figure 7.6B**, the participating communities from Pattanr identified this deep bore tube well that has been funded and constructed by local government. This is the only improved water source existing in the village and nearly 2, 31,084 INR (approx. $3600) has been spent in the construction of this deep bore well. However, as responded by the villagers, this well failed to supply water to the villagers, even for one day. Hence, the villagers have to use river water, the only existing water source in the village, to meet all their needs. The whole process of application to the local government and getting the personnel for repairing the hand pump takes long time, thus increasing the plight of local people.

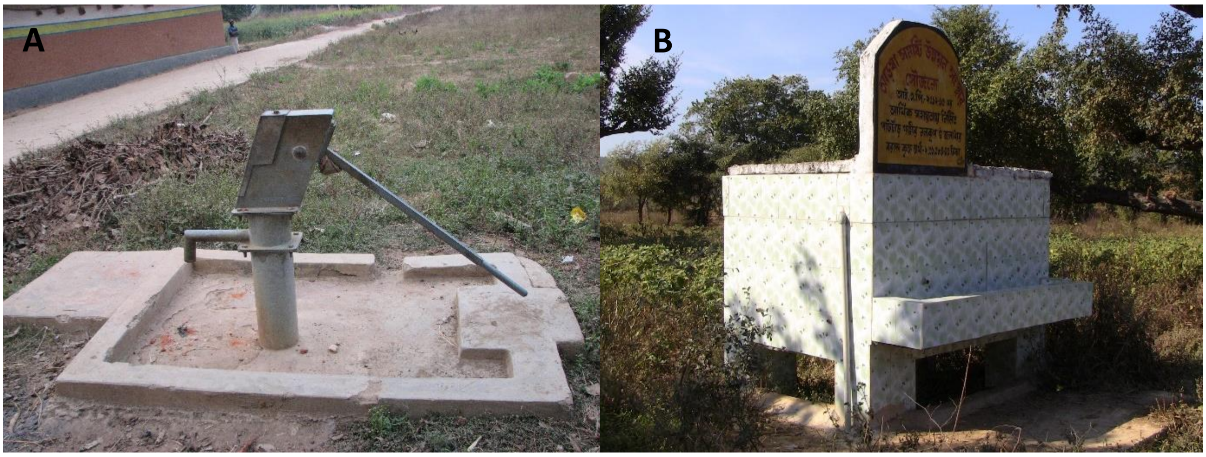

Figure 7.6: Defunct water sources in the study area; (A) a non-functional hand pump in Mirgichami, and (B) an inoperative deep bore tube well in Pattanr.

Similarly, there is no fixed duration of piped water supply in two of the studied villages. Irrespective of season, water is supplied only two times a day for a duration of 15-30 minutes. For e.g. in Sarbari, a single public tap supplies water for 80 households and interruption in supply can extend to 5-7 days a week in summer. However, amount of water supplied in a day is only sufficient to meet the domestic (only cooking and drinking) needs of 5-6 households. Also, there is illegal tapping of water from the main pipeline system, lowering the water pressure as well as the quantity supplied to the endpoint consumers. There are no water treatment plants in the district and the quality of supplied water is very low. Additionally, pipe bursts and leakages are frequent resulting in contamination of water and interruption of water supply.

As perceived by women from 56.25% of the total villages under study, water abstraction structures are often located far from the households. This can be either due to the unfavourable hydro-geological conditions of some villages like Karcha, Hensla and Benipur or due to improper planning like in Pathardih and Churinsaraf. Women need to fetch water 3 – 4 times or more in a day, based on their respective family size. With the onset of dry season, collection time increases due to the failure of nearby sources in supplying adequate amount of water and the alternative source are, often, quite far. To save time, women resort to collect water from unimproved water sources like small diches or ponds, especially during the crop growing season.

Moreover, drying up of surface water sources and lack of proper allocation has been identified to be one of the principal reasons behind, mainly agricultural, water insecurity in the studied villages (**Table 7.3**). Meagre amount of water is received by downstream villages like Ponra and Bansdi due to over-abstraction by the upstream villages to grow *Rabi* crops. Also, as highlighted by farmers, the irrigation ponds being very old, there has been large amount of siltation and the water holding capacity has significantly declined. The existing irrigation canals in Hensla, Bansdi, and Karcha are also found to be old and non-functional due to siltation.

Absence of proper sanitation and hygiene is another major concern for the local people in the study area. Most of the population practice open defecation, which can be attributed to both deprivation and prevailing water scarcity in the study area. Though few toilets have been provided to few households under different government initiatives in Karcha, Bansdi, Hensla and Benipur, no water connections are present in the toilets. The households are responsible for collecting water for toilet use. As perceived by women from these villages, fetching water for toilet use exerts extra work load for them. Hence, they prefer to use open defecation rather than toilets.

7.3.2.3 Social Factors

The participating communities identified various social challenges, as shown in **Table 7.3**, which significantly hinders attainment of water security in the studied villages. Many of the ponds, that has been built earlier, are owned individually with the right to use still lying with a particular household. This restricts the use of pond water by local villagers. In addition, participating communities from 10 out of 16 studied villages agreed on the existing discrepancy in allotment of water sources in their village. People considered belonging to the lower tier of social caste system, mostly *Santhals* (tribal people), are not allowed to collect water from the same source as other villagers. This, often, compels them to use unimproved or faraway sources.

The participating communities clearly pinpointed the lack of community involvement in any of the decision making process in the village, specifically regarding the location of water abstraction structure. The location and installation of water abstraction structures are mostly decided by village leaders or *Panchayat* members and often fails to meet the needs of the local communities. In addition, as demonstrated in **Table 7.3**, population pressure has been perceived to be highly deleterious for water security in every village under study.

7.3.3 Perceived impacts of water insecurity

As demonstrated in **Figure 7.7**, various impacts have been identified by the participating communities during the PRA exercises. The perceived impacts are different for each community and some of the impacts are identified by two different communities simultaneously.

Figure 7.7: Perceived impacts of water insecurity by the different participating communities

7.3.3.1 Agricultural impacts

As the village communities perceived rainfall variability, elder and farmer groups openly discussed about the brunt they face. All the farmer groups agreed that with the delay in onset of rainfall or lesser amount of rainfall received, sowing and transplanting of crops are highly affected. Earlier, all the households started sowing by 12-13th *Jaistho* (28th -30th May) and within 7 days, sowing was completed. It took 15 days for the seedlings to attain the required growth for transplantation. But nowadays, even if sowing is done on time, transplantation of the seedling to the prepared agricultural land gets delayed by 1-1.5 month due to the lower availability of required amount of water. The seedlings get over matured, thus, declining the overall crop yield. **Figure 7.8** demonstrates the crop calendar of the study area as told by the participating farmers. However, production of all these crop is subject to availability of water. Communities from villages like Pattanr, Bhursabera, Churinsaraf and Pathardih reiterated that the crop grown is sufficient for only 1-3 months and is mostly used for household consumption. The farmers also pointed out that income from selling vegetable is often more than from selling paddy. The village elders from Shalidih and Salaidahar highlighted that *Boro* paddy cultivation is now totally stopped due to unavailability of water. Mustard is one of the major *Rabi* crops grown in this area, but the cultivation is subject to availability of water. Sometimes, even after sowing is done, the crop dies due to the unavailability of adequate water. For example, farmer group from Hensla said that they have left the cultivation of maize and wheat due to the unavailability of required amount of water.

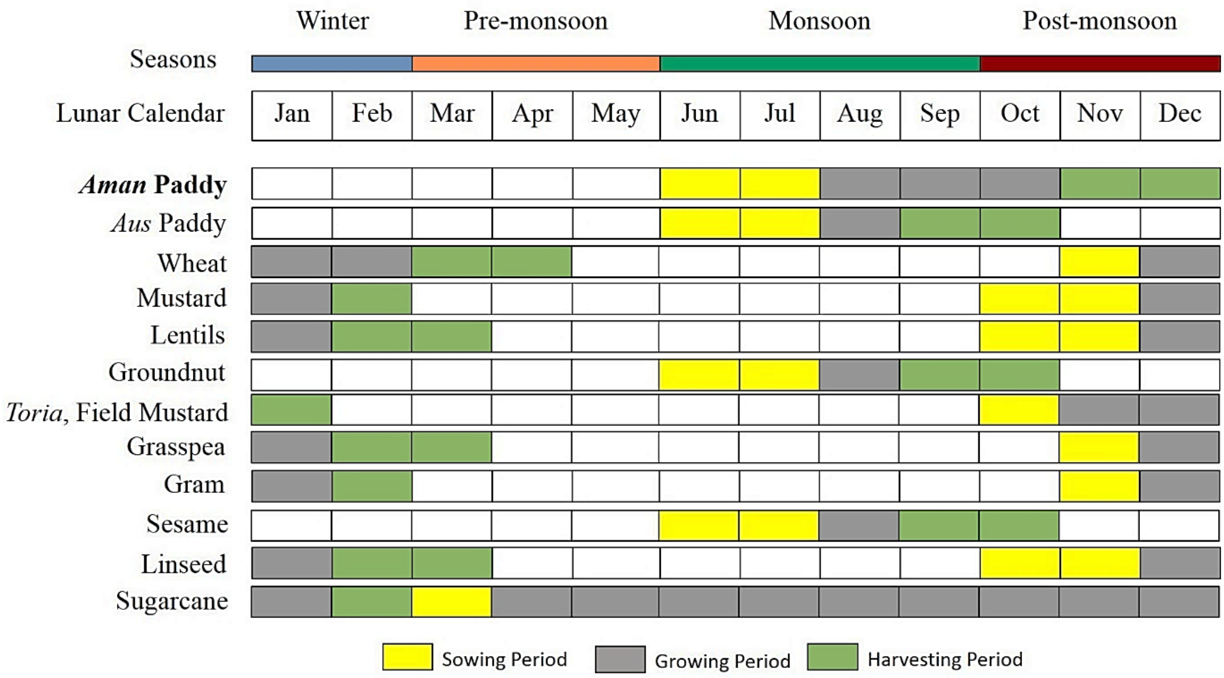

Figure 7.8: Crop Calendar of the study area

Higher rainfall in post-monsoon season has been identified to be detrimental to crop yield by 78.9% of the farmer communities. The ripened panicles sink and become prone to pest attack in case of heavy rain in this season. The farmers can easily recall many such instances, with the recent in 2013, when the crop yield was drastically reduced. Moreover, farmers, specifically, from tribal villages of Bhursabera, Churinsaraf and Usuldungri responded to have stopped growing *Tendu* leaves (*Diospyros melanoxylon*) sorghum, pearl millet (Bajra) and *kodo* millet (*Paspalum scrobiculatum* L.), owing to variability and unavailability of water. Uncertainty in crop growth and reduction in crop yield pays heavy on household income.

7.3.3.2 Health impacts

The local communities identified different water borne health impacts. As perceived, hauling heavily loaded water containers over long distances lead to physical damage to the neck and the back. During monsoon season, female members of the household has to work in paddy fields along with the men. Hence, in order to save time from queueing up, women collect water from unimproved water sources like small diches or ponds. With the parents away to work, the children drink water from these unimproved sources. This often results in various water-borne diseases, mostly diarrhoea which takes the form of an epidemic among children, especially in the dry and monsoon season, in the study area. Almost 77.1% of the participating farmers responded that diarrhoea often takes the form of epidemic in the study area, mostly during summer and monsoon. Nearly 62.8% of the participating village women expressed that they face emotional distress due to the prevailing water insecurity. During transect walk and FGDs, participants, mostly village women and farmers, repeatedly mentioned four emotions related to water insecurity: *fear, anxiety, to be angry* and *bother*. Village women commonly reported that they feel *fear* that their water supply would run out. The *fear* is found to be more prominent among women from villages with water supply through pipeline system like Bansdi and Sarbari and in almost all the villages in the dry period of the year. As pointed by a woman from Kolbandh,

> *"The fear and anxiety of running out of water don't let us sleep at night. We get up at the middle of the night, at around 2 a.m., and start queueing for collection of water."*

7.3.3.3 Domestic Impacts

A multitude of domestic impacts of water insecurity have been identified by the participating communities. Presence of improper and unhygienic sanitation facility is evident in the study area with most of the households practicing open defecation. Lack of proper sanitation facility has been pinpointed by nearly 98% of all the participating communities. In addition to poverty and lack of development, water insecurity has been perceived as a major factor behind lack of sanitation facility in the study area. Though few toilets have been built at a household scale by various government initiatives in some villages like Pattanr, Karcha, Bansdi, Hensla, Ponra, and Benipur, getting water in toilets is a major concern. The facilities provided by the authorities does not include any water points and the households are responsible for arranging water in the toilets. As women from Pattanr responded,

> *"Though we have toilets, they are of no use. We can't use them and hence, use open defecation. If we want to use toilets, we have to carry water separately from the river, which again take 2 to 3 hours. Thus, this becomes an extra work load for us. "*

Lack of availability of safe and adequate water often compels village women to resort to unimproved water sources (**Figure 7.9)**. More than 94% of participating village women that they rely on unimproved water sources like ponds, rivers, open wells and springs to collect water for domestic use. Use of unimproved water sources increases manifold during the scarce period i.e. the dry period of the year.

Figure 7.9: Village women and girls carrying and collecting water from unimproved open dug well

With increasing number of hand pumps getting defunct or dried, the water availability for domestic use significantly declines, as responded by 88.7% of the participating women during FGDs. A woman from Karcha said that usually she needs around 6 buckets (120 L) of water to meet all the domestic needs. However, in the dry period, she manages to get only 2 buckets (40 L). Irrespective of the source of water, the time taken to fetch water is a major trouble faced by the local communities, largely women, in the study area. The time to fetch water becomes more in summer as water may not be available in nearby sources and they have to search for alternative sources. With the other sources like ponds and rivers drying up, water available for livestock becomes restricted and separate water has to be collected for them also. As emphasized by women in Benipur,

> *"In summer, the children don't want to go to public water sources to take bath as it is very hot outside. So, we have to carry water for their bath. We fail to count the number of times we fetch water."*

7.3.3.4 Social impacts

At a sociocultural level, life in a water-insecure environment fails to meet people's expectations of an acceptable existence. Conflicts or fights regarding water insecurity is a common business in the study area. Conflicts occur at home and also among community members. Women from Hensla said,

> *"It takes long hours to carry water. We get delayed in cooking food and in doing other household work. This angers the other family members."*

As there are long queues to collect water, brawl starts when someone, later in the queue, tries to collect water before. Sometimes, the conflicts turn worse and local police has to intervene. Even in villages which have piped water supply, frequent conflicts erupt among the community dwellers as in Sarbari. The community people don't talk among themselves, due to the fights regarding water collection, as pointed out by the village women. The women group from Benipur also mentioned that they never invite any relatives to their home as they cannot provide water to them. Conflicts are also common among the well-off and poor farmers in a village, as the well-offs', often, use pumps to withdraw water from ponds or rivers which, in turn, deprives the poor farmers of water for irrigation. Also, there are conflicts between farmers in the villages located in the upstream and downstream of a river. Another woman from Kolbandh explained how water insecurity affects her quality of life:

> *"With more water, I could clean my house, clean my clothes and have proper baths. If surplus water is left, I can grow some vegetables that can be consumed by the family."*

The women community from Pattanr also pointed out that they would have never agreed to get married in this village if they knew that the village suffers from high water insecurity. The young girls and women from all almost every village highlighted that they feel lack of social security as they do not have toilets at home and have to go outside home for open-defecation. This often exposes them not only to health risks but also various social risks.

7.3.4 Coping and adaptation strategies

Based on perception and understanding, as shown in **Figure 7.10**, local communities develop some coping and adaptive strategies to mitigate the causes and impacts of water insecurity. Though bundled or community approaches are known to lead better adaptation options, a prevalence of individual or household approaches were observed. The mentioned strategies are mainly aimed at addressing both agricultural and household water insecurity due to both climatic and non-climatic factors.

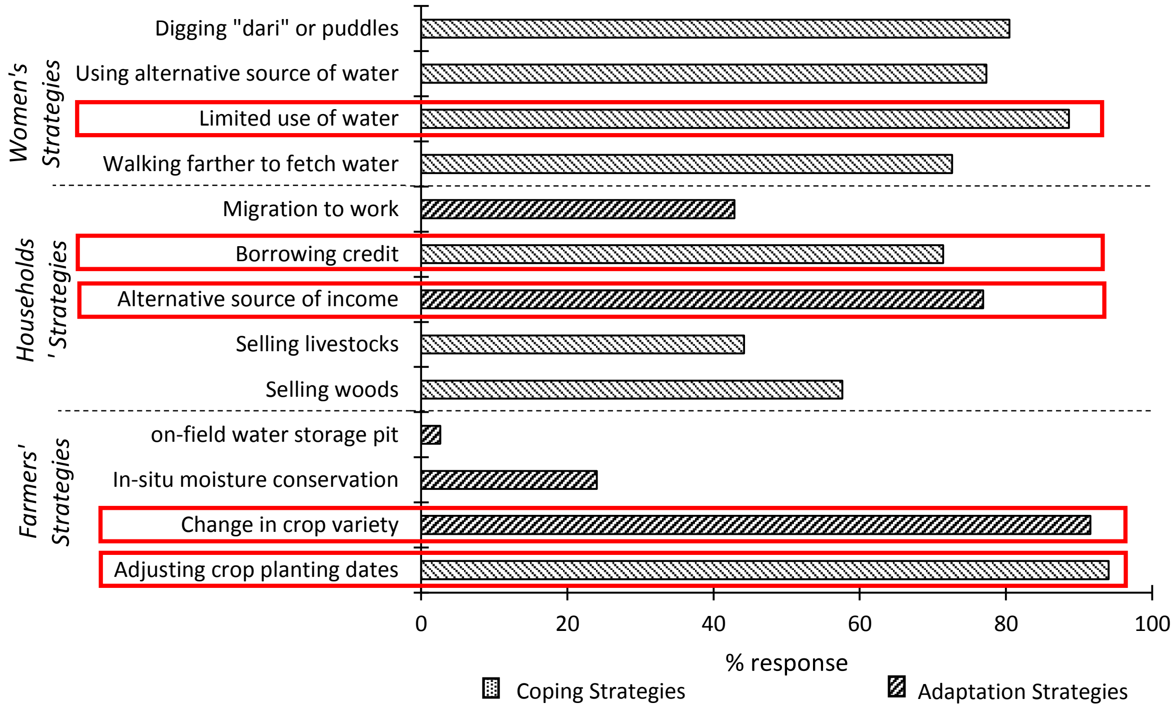

Figure 7.10: Coping and adaptation strategies adopted by local communities in the study area

7.3.4.1 Farmers' coping and adaptation strategies

Agricultural adaptation and coping strategies, to mitigate livelihood risks, were stressed upon by the local communities, mostly farmers. Crop calendar exercise with the farmers and village elders reinforced the variability and unpredictability of rainfall that impacts crop production which is largely rain-fed in the study area. The strategies practices are discussed below:

Adjusting planting dates. Adjusting crop planting dates is an autonomous and immediate strategy practiced by approximately 94% of the total number of farmers who participated in the FGDs. As expressed by both the elders and farmers from all the studied villages, there used to be fixed sowing and transplanting dates when rainfall was reliable. Nowadays, farmer groups from all the studied villages consented to the fact that they have to accommodate planting dates based on the onset and pattern of rainfall. The farmers identified that this adjustment involves lots of risks including crop loss. In spite of this, owing to the perceived high irregularity in duration, amount and intensity of rainfall, there is no guarantee on successful crop growth, even after adjusting the planting dates.

Change in crop variety. To adapt to the uncertainty in onset and amount of rainfall, nearly 92% of participated farmers agreed on using short duration high yield variety of rice like *Lalat* and *Swarna*. With the change in rice variety, the yield has increased manifold. For example, a farmer from Hensla highlighted,

> *"…previously I used to get 20-30 maunds (approx. 750-1120 kg) of rice. Now I get 70-80 maunds (approx. 2500 – 3000 kg) with the new variety of crop grown in a short spell of time."*

However the farmers perceived that the increase is solely due to the new variety of crop and not due to any irrigation provisions and, if water is not available, the yield gets drastically affected.

In-situ moisture conservation. Farmers (24.0%), mainly from the tribal mountainous villages, are found to use in-situ moisture conservation to grow vegetables. This agricultural practice is carried out in the fallow *Tanr* (upland) land which is unsuitable to grow any other crops. Dew is the condensation of atmospheric moisture on objects that have radiated sufficient heat to lower their temperature below the dew point temperature of the surrounding air. As responded, before planting the seedlings, the land is ploughed upside down in the evening and is left vacant for the whole night. The soil absorbs the dew for the whole night and the land is levelled in the next morning. After leaving the land exposed to sun for the whole day, the seedlings are planted in late evening. The vegetable yield is usually very high and is both sold in markets and used for household consumption (**Figure 7.11A**). Considering the low water availability to grow crops, this traditional agriculture technique appear to be very helpful for the deprived tribal communities.

On-farm water storage pit. For the farmlands that do not have access to water sources like ponds, some farmers (2.60%) are found to excavate water storage pits in one corner of their agricultural land. As shown in **Figure 7.11B**, this manually dug pits are mainly excavated to store water on the upper farmlands and earthen drainage channels connect the storage pit to adjacent lands owned by the same farmer. However, this water storage technique for crop cultivation is not practiced widespread in the district and is found to be more practiced by farmers of Balarampur *Block*.

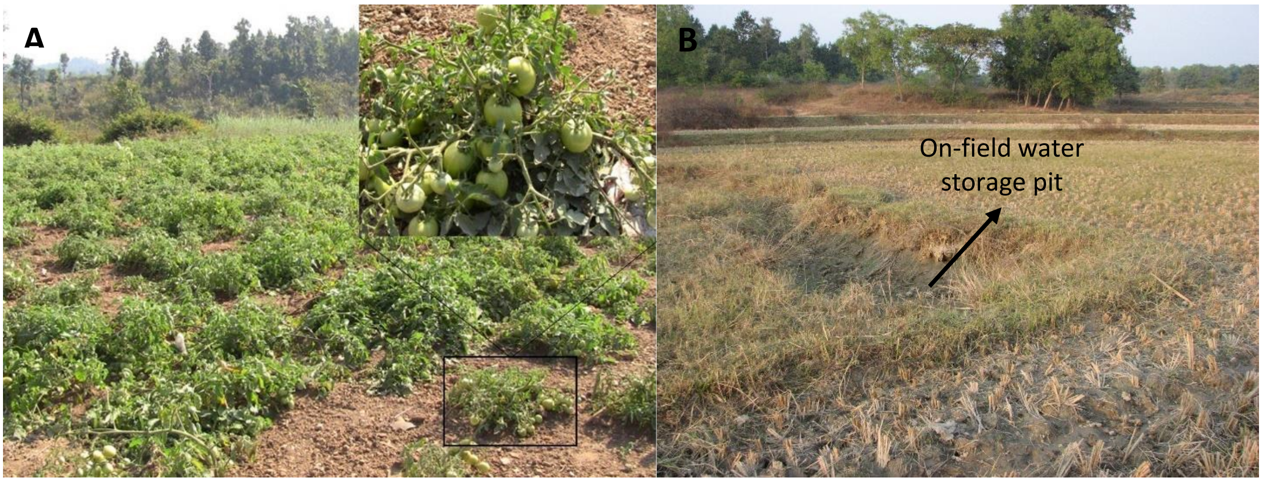

Figure 7.11: Agricultural adaptation practiced by farmers; (A) Tomato production in a mountainous village using in-situ moisture conservation, and (B) On-farm water storage pit

7.3.4.2 Households' coping and adaptation strategies

Uncertainty and unavailability of water severely impacts the agricultural yield and, hence, on household income. As mono crop cultivation predominates the study area, failure in agriculture pushes the household towards further deprivation. Hence, to overcome the deprivation, the households practice various strategies that may improve their economic situation.

Selling woods. As crop yield becomes highly unpredictable, wood selling emerges as a significant alternative source of income for the poor households. Nearly 57.62% of the total households under study, mainly from the mountainous tribal villages like Bhursabera and Pattanr, are found to rely on selling woods as a part of their coping strategy to overcome the continuing deprivation from inadequate or loss of income (**Figure 7.12A**). The communities also identified that availability of dry wood from the forest is decreasing as the forest is receding fast. And, if they are caught of collecting wet wood, monetary fine is imposed by the forest officials which is high enough for the villagers to pay. Still, increase in number of family members and lower income from agriculture due to water unavailability makes them highly dependent on forest wood. This is turn results in wood collection from the forests in illegal ways and receding forest lines.

Selling livestock. Selling livestock is the immediate response to sudden and unexpected changes in livelihood, income or food availability. Most of the rural households keep cows to help them in agriculture. In addition, the rural people from the study area have the tradition of buying a goat or sheep for the young children in the family. Usually, the household elders and children are given the responsibility of looking after their livestock (**Figure 7.12B**). Livestock are usually considered as assets in a rural household. As perceived, at the time of crisis, goats are sold first. As the goats cost less, the households can afford to buy it again as their financial situation gets improved. In case the situation gets worse and selling goats don't help, cows and buffaloes are sold.

Alternative source of income. The household income is often not adequate to meet all the household needs. Households diversify income from different sources particularly from off-farm activities. These include making local cigarettes (*Bidi*), making of bamboo baskets (*Jhuri*) and pottery (**Figure 7.12C and D**). More than 75% of the participating households agreed to do off-farm activities that may pull them out of the deprivation. These off-farm activities are mainly practiced by village women as the men are either busy with agricultural activities or have migrated to work out of the village.

Borrowing credit. This system is one of the most important security strategies practiced in rural areas. Borrowing credit from powerful persons in the village is practiced by nearly 71% of participating households to overcome immediate crisis. The year, when crop yield is not sufficient and, subsequently, income has greatly reduced, the farmers usually approach the powerful person in the community or the village. The system works within the family or community networks. The elders and farmers from Kolbandh informed that usually 5-6 bags of rice or monetary credits are borrowed from the lender at the interest rate of 8-10%. The borrowed money or grains are used to meet immediate consumption needs of the household and to purchase inputs for crop production. With increasing insecurity, the villagers keep on borrowing money or rice grain and there is deferment in paying the loans. Subsequently, the farmers have to sell their assets to pay the debts.

Migration to work. Migration has always been intimately linked with traditional coping strategies in the face of unexpected crises. However, a transition has taken place where migration is seen as more than a coping strategy, it is also adaptation (Tacoli, 2011). Migration is practiced by the local villagers, mostly men, as a means of overcoming the impacts from rainfall variability and decline in crop productivity. As shown in **Figure 7.10**, nearly 43% of studied households have one or more family members who have migrated in search of livelihood. Movement to work is pre-decided by the villagers as agriculture can sustain them for merely 6-7 months. Usually the mobility is seasonal in the study area, migrating after the crop is harvested (November-December) and coming back to homes before the crop growing season (i.e. April-May). Both inter- or intra state movement takes place to work as daily wage labours in brick making factories, construction sites, textile industries, steel industries etc. In villages like Hensla, Pathardih and Kolbandh, 30-50% of the village men are staying outside the village. When a household has more than one male member, the other man usually migrates outside the village to work. If the situation gets worse, sometimes, the only male member in the household also migrates. In many cases, they take their family along with them, where the other members also work as daily wage labours. Household migration is, many times, an immediate decision in response to the inability to bounce back to normal living conditions and often puts the family in hardships including staying in deleterious living conditions, children missing school, long working hours etc. in the migrated place. However, it was noticed that migration is not a common practice among tribal communities which might be due to their indigenous ability to get on with difficult situations.

Though migration explains the immediate response of the local community to counter the deprivation they encounter, the local community also demonstrated the impacts from migration. The daily wage is often not adequate and sometimes, they can't even send money back home. This leads to more deprivation for the family left behind. The family elders also emphasised that absence of guardians at home often turns detrimental for the growth of children in the family.

7.3.4.3 Women's coping strategies

Rural women, largely poor, come across multiple issues that threaten them and their families regarding water insecurity and changing climate. In the face of increasing uncertainties, women in the study area are found to practice some strategies to meet the household water demand. The strategies are identified to be, largely, coping strategies because they are spontaneous, reactive and, mostly, unsustainable.

Walking farther. With the onset of summer, sometimes in winter (January-February) also, as the water obtained from nearby hand pumps get limited, women have to walk farther to get water. A woman from Hensla responded, *"How is it possible to carry out any kind of household work if water is not available? So, when I don't get water from the nearby hand pumps in the school, I walk farther to collect it."*

Walking far, in case water is not available in nearby sources, is a common affair practiced by the women from nearly every village in the study area (72.65%) and is, often, an immediate response (**Figure 7.13A**). Even for bathing and other domestic needs, women walk to ponds or rivers that contain water, in other villages. For e.g. women from Benipur told that with the onset of dry months, villagers have to go to Ranipur and Parbeliya coal mines to take bath in the mine pit, which are nearly 1-1.5 km and 3.5-4.0 km from the village, respectively.

Figure 7.12: Various alternative sources of household income: (A) Women from mountainous villages going to sell collected woods in local market; (B) Livestock rearing in Salaidahar; (C) Making bamboo baskets to sell in local markets in Kolbandh; and (D) Making of *Bidi*, a local-made cigarettes, by women in Jhalda II

Limited Use. Nearly 89% of participating women agreed to cope with water scarce periods by limiting water use and consumption, as shown in **Figure 7.13B**. As briefed by a tribal woman from Churinsaraf village, *“Starting from the end of Falgun (March) till it rains, there is not enough water in the spring to take bath. We take bath once in 2-3 days.”*

Women from nearly all the villages expressed that with the onset of dry season, they have very limited water to use. As briefed, initially they don’t compromise with the cooking and drinking water needs and try to limit water use for other purposes like cleaning home or washing clothes. But as the stress increases, they have to compromise the drinking and cooking water demand. Women from Kolbandh pressurised upon the same fact and told,

“…we just somehow manage for the cooking and drinking water needs. For other needs, we prioritise. Someday we take bath, next day we wash clothes and the other day we clean home. All the water needs cannot be met in one day.”

In India, usually rice is boiled in large amount of water and, after the rice is done, the water is drained off and dried rice is consumed. However, almost every participating village women in the study area agreed that they consume undrained and watered rice in every meal. This way they can overcome poverty as the dish keeps them full for a long time and curbs hunger, and water is also saved from being drained off and wasted.

Using alternative source. Finding and fetching water from an alternative source is a common coping strategy among the rural households and women are mostly liable for this. In addition to walking far, when all the improved water supply sources fails, in this case hand pumps and wells, they have to use unimproved water sources like ponds and springs. When women need help in agricultural work with the male members of the family, as emphasized by women group in Pathardih, they don’t have enough time to go far and fetch water. To save time, they collect water from any nearby pond or small ditch for domestic use including cooking and drinking purpose.

Digging ‘Dari’. Digging *dari* is one of the most important coping strategy of the rural communities, mostly women, in the study area. *Daris* are man-made cavities, a form of shallow dug wells or puddles with a depth ranging from 2-5 feet and a diameter from 7-8 feet. This cavities are usually made on the sand beds of a dried river or by the river or spring side. The puddles receive water through capillary movement, seepage and percolation, which is stored in the cavities for use.

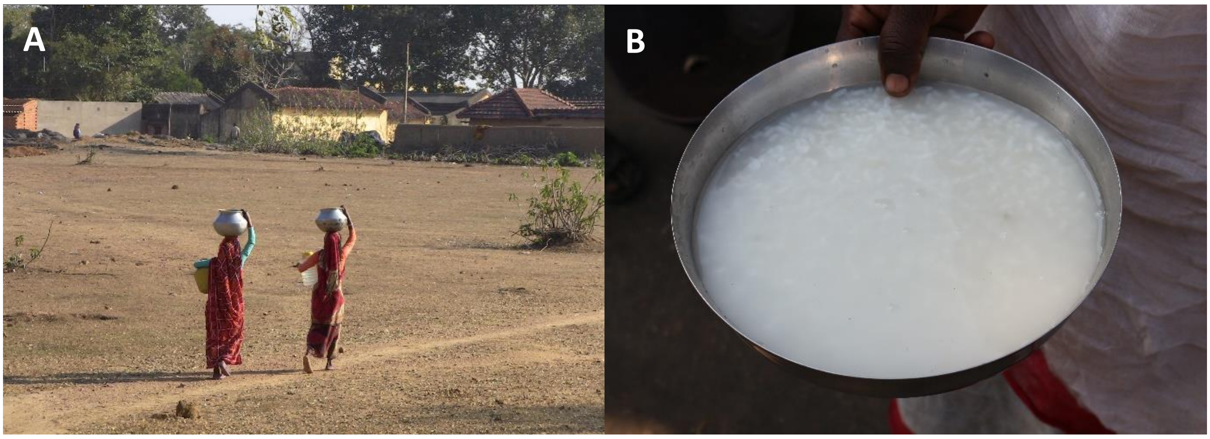

Figure 7.13: Coping strategies by village women: (A) Women fetching water from faraway sources in Karcha, and (B) A village women showing the watered, undrained rice consumed by the household in Usuldungri

As perceived, this water is better in quality because it percolates through different layers of sand in the river bed. This water abstraction structures are dug manually to collect water for domestic needs by more than 80% of the village women respondents.

Figure 7.14: Collecting water from *Dari* – one of the highly practiced coping strategy; (A) Group of women collecting water from *daris* dug in the Kansabati river bed, and (B) A girl collecting water from *dari* in Pattanr

Women from the studied villages explained that they generally dig the cavity early morning and leave it. Later in the day, they come back and take the collected water using small flat-bottomed bowls (**Figure 7.14 A** and **B**). As *Magh* (January-February) starts, they start digging *dari*. In *Boisakh – Jaistho* (April – June), the cavities have to be dug more deep and the water collected is also very less in amount, resulting in longer water collection time. The girls in the households, often, miss schools and have to scoop water all through the day as the other family members get busy with their own work.

7.3.5 Administrative mitigation measures

Besides farmers, women and household level adaptation and coping strategies, various administrative strategies are at a functional stage in the district to adapt to water insecurity and its impacts. As a response to serious drought conditions in the district, the government has undertaken various mitigation measures, which included provision of employment, distribution of drought prone seeds and other developmental schemes. Major mitigation measures are explained and discussed in the following sub-sections.

7.3.5.1 Employment Scheme

The National Rural Employment Guarantee Act (NREGA) was introduced in 2005 by Government of India aiming to provide 100-days employment to adult members of any rural household, who are willing to do unskilled manual work at the wage rate fixed by the government every year (Mukherjee and Ghosh, 2009). NREGA has been launched in the present district from the financial year 2006-07 with a primary goal to provide a strong safety net for the vulnerable community (mainly SC, ST and below poverty line families) by providing a fall-back employment source, when other employment alternatives are scarce or inadequate. The *Gram Panchayats* are the main implementing agencies that propose various developmental schemes to the respective *Block* and district level NREGA cell who in turn provide fund for the schemes. The main types of work undertaken in the district under different schemes include excavation and construction of ponds and tanks, check dams and rainwater harvesting structures. Along with these activities, it also includes activities such as drought proofing including afforestation and tree plantation, watershed development, nursery development, renovation of old water bodies by desilting and improving rural connectivity by making roads. As the scheme tries to provide alternative income to rural poor in the face of increasing deprivation and water scarcity, this scheme is considered as one of the administrative level adaptation and mitigation measures. An average labour wage per day range from 1.51 to 1.82 USD. The farmer and women group from nearly all the studied villages explained different opinions regarding NREGA in their village. The opinion, however, differed among households depending on number of family members, employment condition and living standard. Problems such as lack of timely employment, low and delayed payment of wages, corruption, fake jobs and lack of proper NREGA implementation guideline were reported by the respondents. The communities also pointed out that the work done under NREGA scheme are often below the mark. The communities complained that the excavated and desilted water bodies either get non-functional or often get dried in few months.

7.3.5.2 Agricultural Support

The district agriculture department takes various initiatives to support the farmers and improve the crop production scenario. One recent initiative is conducting *Krishi Mela* (Agricultural Fair) in every *Block* of the district. This initiative helps in increasing the awareness among the farmers regarding the cultivation of various short duration, high yielding and drought resistant crop varieties, alternative crops, irrigation needs, use of various agricultural methodologies, usage of fertilizers and pesticides, use of various agriculture machinery, horticulture and pisciculture development. Except this, minikits, composed of small quantities of seeds of new crop varieties with planting instructions and feedback cards, are distributed to the farmers by the district agriculture department. The agriculture department also sells seeds and fertilizers at a subsidised rate to the farmers.

7.3.5.3 Other developmental schemes

Various other developmental schemes are in operation in the district. For example, to ensure food security among rural people, the government has started distribution of rice at only Rs. 2 per kg ($0.03/kg). Each adult from tribal and non-tribal families, who are below poverty line, are entitled to get 2 kg of rice per week in the study area. In the year 2011-12, Government of India declared eight *Blocks* in Purulia, namely Jhalda I, Jhalda II, Arsha, Baghmundi, Balarampur, Barabazar, Manbazar II and Banduan, as Left Wing Extremism (LWE) affected. Rs. 30 crore have been sanctioned for the development of these *Blocks* under Integrated Action Plan (IAP). The proposed schemes under IAP included development in drinking water provisions, minor irrigation schemes, construction of roads, bridges, class rooms, rural market yards, community halls etc. A total number of 843 schemes have commenced in Purulia out of which only 36 schemes have been completed till now. As the proposed schemes mainly aims at strengthening the adaptive capacity of the local communities, IAP can be regarded as an administrative mitigation measure to improve the prevailing underdevelopment in the study area.

7.4 Implications to Rural Water Security Framework

The primary manifestations of climate change and water insecurity are of physical nature like changes in rainfall and temperature, increased drought or flood situations, changed river flow and lowered soil moisture content, the consequences or secondary manifestations are much more varied, including ecological, social and economic impacts. How people in any given area are affected by water insecurity will therefore not only depend on the natural causes in the area but also on ecological, social and economic factors (Adger and Kelly, 1999). People's ability to adapt likewise depends on a number of factors including availability of resources for adaptation, motivation and information about the changing state of the water and the links between human decisions and the environment (Adger and Kelly, 1999). **Figure 7.15** summarizes the findings through a problem tree and reinforces that multiplicity of factors, both climatic and non-climatic, endanger water security in the study area. The findings of this study agrees to the hypothesis of the chapter that factors other than climate plays an important role in lowering water security of the rural area.

The extent to which individuals and communities can perceive the causes and consequences of water insecurity determines their response to the same. Climate factors appear to be less important in shaping the dynamics of rural coping or adaptation strategies than economic, political and social factors (Adger et al., 2009). The strategies practiced by the communities under study clearly demonstrates the limitations and, hence, are targeted to respond to short-term shock rather than planned initiatives. Coping strategies outnumber adaptation strategies (**Figure 7.15**) and are practiced at an individual or household scale. Community level practices are largely missing in this rural area.

A fundamental part of rural water security framework is the inclusion of effective community participation in the whole process. Community perceptions, challenges and loopholes identified in this study demonstrates most important aspects that needs to be looked upon in the plan. This local perceptions reflect local concerns and focus on the actual impacts of water insecurity on people's lives which are dependent on local factors and cannot be estimated through scientific models. For example, water supply provisions like installation of hand pumps, increase in storage capacity or withdrawal from water sources dominate the present study area. However, for drought prone, poverty stricken and water insecure rural areas, like Purulia, demand side water provisions, pro-poor investments that confirms social protection like access to credit, crop and livestock insurance, agricultural extension, access to ownership and control over productive assets, mainly land ownership should be emphasized and included in water security planning.

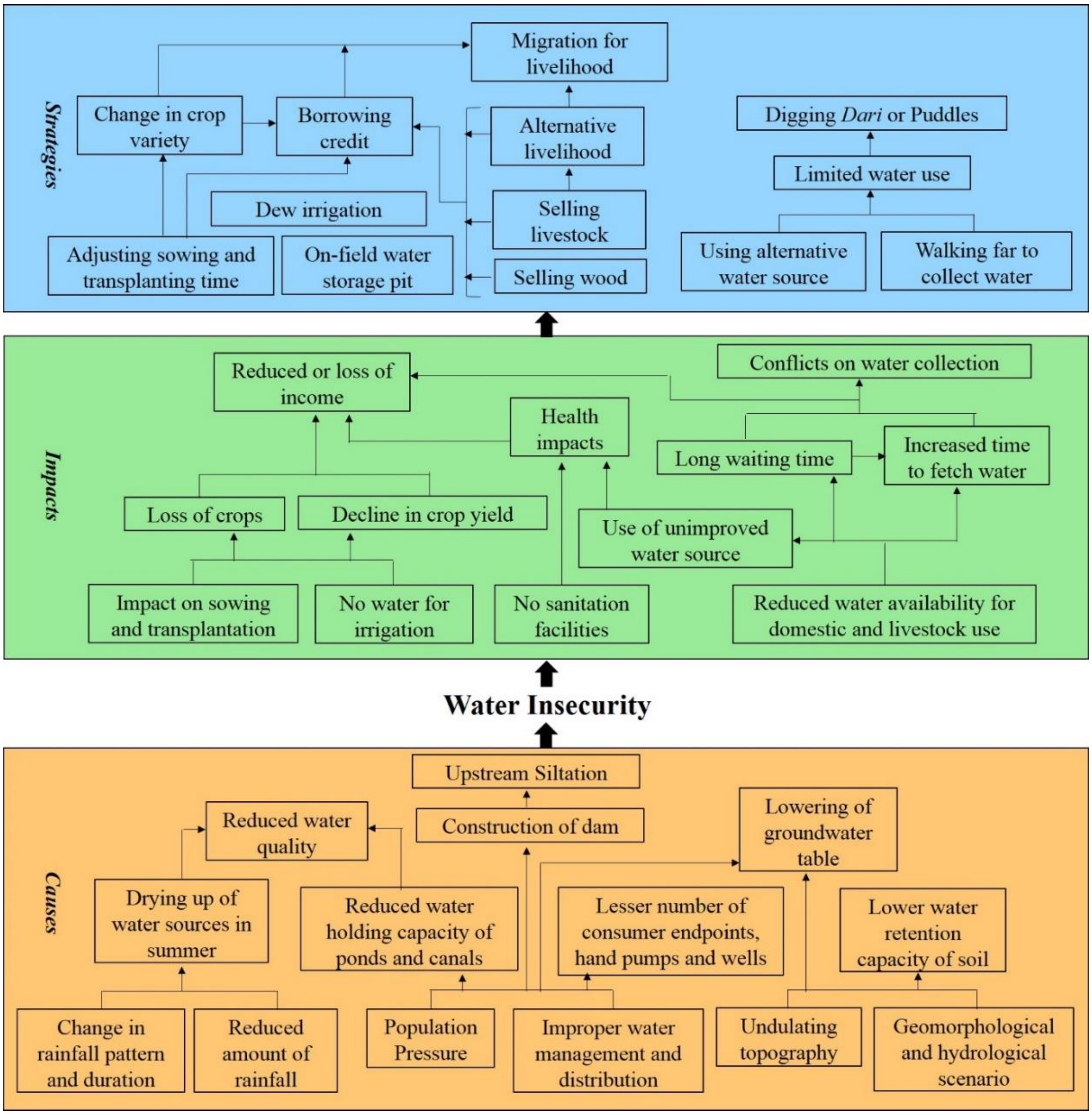

Figure 7.15 Demonstration of problem tree in the study area
(Direction of arrows shows the flow of the different aspects; Adaptation and coping strategies are combined under strategies)

7.5 Concluding Remarks

In the present study, it is apparent that the district is witnessing uncertainties in local climate, specifically rainfall and the local community, in spite of their limited capacity, can perceive the changes in terms of physical, financial or performance losses. The water supply scenario in the study area is identified to be far from satisfactory. Significant proportion of the water supply and storage infrastructures does not function or functions much below its design and potential and fail to meet the needs of the rural people. Management factors like scheme breakdown and lack of repairs (e.g. the washer inside the hand pumps has damaged or pump in the borehole has broken), poor design (e.g. the water level goes beyond the pumping depth in the dry season or inappropriate siting of hand pumps), lack of maintenance (e.g. siltation of irrigation canals and ponds) or local water crisis (e.g. drying up of rivers, ponds and springs) intensifies both household and agricultural water insecurity. The water points are accessed on community-basis, which limits the quantity of water that each beneficiary household can get. In addition, there are problems of acute seasonal insecurity. A severe decline in groundwater table as well as fluoride contamination, adversely affects the sustainability of drinking water sources in the study area.

Farmers and women have shown considerable fortitude in coping with the impacts of water insecurity and thus practices a number of techniques at both farm and off-farm levels. However, it can be inferred that the adopted coping and adapting strategies are inadequate to make any difference in the living condition of the rural communities. Hence, this chapter emphasizes that the gap between perceiving and reacting to the change should be taken into account before promoting any water security policies or projects in rural areas. External support in the form of insurances, knowledge sharing, skill training, land entitlement, good governance etc. are required to remove the poor and marginalized population from the vicious cycle of water insecurity and resulting poverty. This chapter also reinforces the role of women in ensuring water security and suggests implementation of these projects and/or policies through effective community participation, including women, as it incurs ownership and responsibility into the communities and motivate them to work towards their upliftment.

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CHAPTER 8

IDENTIFYING THE PRIORITIZED ACTIONS TO ATTAIN WATER SECURITY

"Plans are nothing; planning is everything."

D.D. Eisenhower

Chapter 8: Identifying the prioritized actions to attain water security

This chapter presents the findings of a study carried out to identify prioritized action at three different levels – community, local government and local administration. Suggested prioritized actions are mainly found to follow supply-side approach with a complete lack of demand-side provisions at all the three levels. A gap has been noticed over the actions prioritized by communities and local government, thus making it imperative for the local government and administration to consider the community prioritized actions in the decision making process. Also, the communities are found to be largely dependent on government and administration to fund, implement, operate and maintain the water sources, and community engagement is found to be almost absent in the study area.

Outline of the Chapter

8.1 Introduction

Attaining water security requires a 'narrowed framing', especially when the concept is applied at a local scale. It has been discussed and published through various literatures, time and again, that the demands and priorities of local people often fail to reach the higher authorities. This results in either failure of the schemes[1] or their under-utilization. Sanctioning authorities have made it a priority that any developmental scheme for a specific area should be proposed by the local community in many countries across the world. However, this is seldom achieved in developing countries like India. Moreover, for poverty stricken, largely illiterate and backward rural districts like Purulia, the local people are seldom engaged in the decision making process, as discussed in Chapter 5. Even when they are involved, the priorities and demands are rarely addressed. There exists a multitude of reasons behind this including corruption, political interference, social exclusion etc. which are beyond the scope of this research.

In case of the present research, assessment of the status of prevailing water security (Chapter 4 and Chapter 5), their causes including climatic variations (Chapter 5, Chapter 6 and Chapter 7) and impacts (Chapter 6 and Chapter 7) helps in identifying the scale of water insecurity in the study area. As the problems get identified, it becomes imperative to find out the solutions to these problems. It is well understood from the results presented in chapter 7 that the local communities are able to perceive the changes around them and they respond to them according to their limited capacity. Deriving from the research findings of the previous chapters coupled with the water security concept followed in the present study where people are considered to be the primary resource rather than the objects of development, it can be hypothesized that local rural communities must have ideas on how to solve the water insecurity crisis and can identify their needs and priorities which will help them in overcoming same. This approach motivates the water insecurity affected people to take the lead in the planning and implementation. The identification of prioritized actions should not be viewed as making a "wish list" of what communities want, but as a process of understanding their present situation.

In context of the present study area and other Indian rural areas, local government, represented by locally elected leaders, and local administration, represented by *Blocks*, are the first and most vital line of screening who decide what prioritized actions to be considered and what not based on their own limitations. Hence, it is essential to get their opinions on what

[1] The various projects, programmes or initiatives are often cumulatively termed as schemes at different administrative levels.

actions can actually improve the prevailing water insecurity status of the particular area. It can be assumed that if the gap between communities' prioritized actions and prioritized actions suggested by local leaders and Block officials is less, there are lesser scopes of conflict between them. This also implies that implementation of these actions may help in attaining and strengthening water security in the study area.

8.2 Survey Approach and Methodology

8.2.1 Research Objectives

Drawing from the findings of the previous chapters, it can be inferred that ensuring water security in rural areas is not under the domain of a single authority, rather needs a combined effort from all the levels. *Blocks*, the lowest administrative level in rural areas, are responsible for sanctioning the schemes and distribution of funds and other technical and human support, whereas the schemes, that need to be implemented, should be put forward by the local leaders as per the demand of the local community. Hence, the main research objective of the present study is to identify the prioritized actions that can be implemented or practised to attain and enhance water security in the rural district with detailed insights from three main levels – community, local leaders and local administration. The outputs from this analysis is considered as a significant input to the Rural Water Security Framework, the final output of the present research.

8.2.2 Survey and data collection

The Focus Group Discussions (FGDs) conducted to delineate about the perceptions of local communities (discussed in Chapter 7), also included detailed discussion with the respective communities, mainly farmers and women, about the prioritized actions that can be considered to ensure and improve water security. A total of 32 FGDs in 16 villages (details provided in **Table 7.1** in Chapter 7) were sorted out that discussed about the prioritized actions and that who are responsible for the initiation and implementation of the actions. Open ended questions were asked to the communities instead of giving them any options, to explore their own priorities and demands without giving them any pre-notion.

In a next step, semi-structured interviews through a pre-developed questionnaire (Appendix VI) were carried out with *Gram Panchayat* (GP) *Pradhans* or heads (**Figure 8.1**). Though all the GP heads under five *Blocks*, Arsha, Baghmundi, Purulia II, Jhalda I and Neturia were approached, only 29 GP heads (out of a total of 41 GP heads) participated in the interview process. The *Blocks* were selected based on the previous analyses carried out in these *Blocks* and their different levels of water security (discussed in Chapter 4). All the GP heads gathered on a pre-specified date and time in the *Block* Development Office where the interviews were conducted. The GP heads were asked to propose and prioritize actions that can work towards attaining or improving water security in their areas. In few cases, the proposed actions exceeded five but included in the study. The interview also asked about the implementing agencies for each of these actions and expected barriers in the process of implementation. No pre-conceived actions were proposed to enable the GP heads to work and suggest independently.

Figure 8.1: (A) GP heads filling up the questionnaire in Arsha, and (B) GP heads of Purulia II gathered for the interview

In the third step, the *Block Development Officers* (BDOs), the administrative head of the *Blocks*, *Block* Agriculture Officer and Assistant Engineers from five above-mentioned *Blocks* were approached with the same questionnaire. The respondents worked in a consensus to answer the questionnaire as it is difficult to answer all the queries by one official. The collective effort to answer the questionnaire resulted in detailed discussion and cross-validated the responses. Also, the research findings from previous analyses were presented to the *Block* officials and the community and GP proposed actions were discussed in detail to know about their feasibility and applicability in each *Block*. The study had been carried out from December-February, 2014-15. As the collected data were mostly qualitative in nature, simple descriptive analysis has been carried out.

8.3 Results and Discussions

8.3.1 Community level prioritized actions

Mainly two village communities, farmers and village women, were asked to prioritize the actions, they perceive, to be important to overcome agricultural water insecurity (which includes water security for livestock, fishery and other productive uses) and household water insecurity (which includes water for domestic use i.e. cooking, drinking, and bathing, washing clothes and utensils, and water for maintaining hygiene and sanitation).

The villages included in the study are found to be mostly dependent on agriculture and fishery is not found to be practiced by the local people. Hence, most of the responses by farmers are related towards improving the water availability for agriculture (**Figure 8.3**). Ponds are open access water resources dug over the land surface and used to collect rainwater (**Figure 8.2**) and are principal water storage bodies used for irrigation. A larger form of ponds are known as *hapas* in local language. Most of the ponds for agricultural use are found to be owned by government, with all people having equal access to it. The common custom is that the farmers having land (either owned or operated) near the vicinity of these ponds are entitled to get water for irrigation according to their demand. In case a farmer privately owns a ponds, other people are usually barred from using the pond water. Across the villages studied, it was observed that ponds within agricultural fields received little attention toward maintenance and repair and the water holding capacity of most of the ponds have decreased significantly due to increased siltation over time.

Figure 8.2: Ponds for agricultural use in the study area

Considering rainfall as the only source of water for irrigation and ponds being the only existing rainwater holding or storage structures widely used across the district, highest percent of farmers (68%) prioritized the re-excavation and maintenance of existing ponds/*hapas* in their villages (**Figure 8.3**) and agreed that regular maintenance of ponds can not only help in growing Kharif paddy but also in *Rabi* crops like mustard.

The second prioritized action identified by approximately 23% of the participating farmers is digging up new ponds for agricultural use. As the old ponds get silted and their water holding capacity has decreased over time, digging up new ponds is a viable option for many of the studied farmers. The third prioritized action suggested by the farmers is digging up of irrigation wells (**Figure 8.3**). The responding farmers emphasized that the irrigation wells should be solely used for irrigation purpose and should be located near the agricultural fields to aid water supply to the fields. Though the first two prioritized actions involved use of rainwater, the third action calls for abstraction of groundwater for agricultural use. Building check dams in mountains and along rivers has also been identified as a potential water source for irrigation, mainly for farmers from villages like Benipur, Shalidih, Bansdi and Mirgichami, which are either located near the mountains or river (**Figure 8.4**). Many of the check dams have been already built in the district and they are usually built to hold the water flowing as a runoff from the mountains or check the river flow and then using it for irrigation needs. However, the farmers also pointed out that the check dams dry out as soon as rainy season is over and over the years, due to lack of maintenance and siltation, the water holding capacity of the check dams also get significantly reduced.

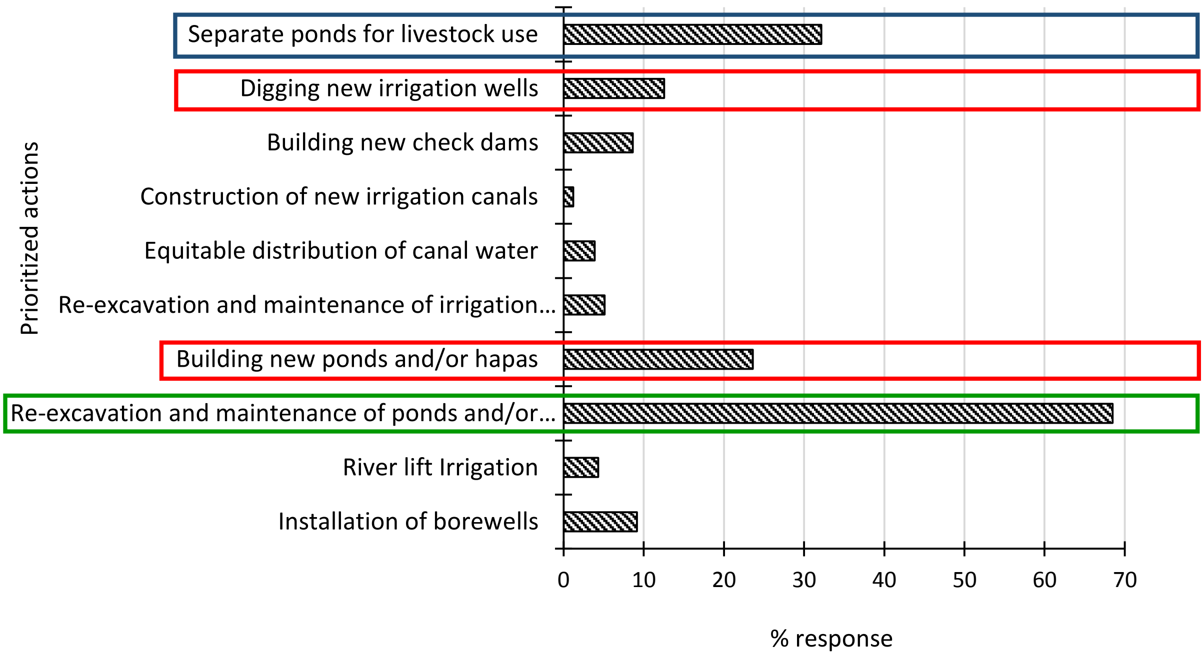

Figure 8.3: Prioritized actions identified by the farmer communities to ensure agricultural water security in the study area

For the villages with existing irrigation canals like Karcha and Hensla, the farmers responded that the canals are mostly non-functional due to lack of maintenance and high amount of siltation. Proper maintenance and monitoring of the canals and equitable distribution of canal water are some of the prioritized actions that can benefit the farmers from this villages. As the scope of supplying river water through irrigation canals is highly restricted in the study area either due to lack of perennial water supply, usage of river water by upstream farmers or high discharge rate of the rivers, less than 5 % of the respondents prioritized the construction of new irrigation canals. Other actions identified by the studied farmers include installation of bore wells and river lift irrigation (**Figure 8.3**).

Figure 8.4: Check Dams in the study area (A) inside the mountains in Jhalda I, and (B) Canal connecting the same check dam to agricultural lands

More than 30% of the participating farmers suggested that separate ponds entitled for livestock use will ensure that the animals get water all throughout the year as well as prevent reuse of the same pond water for other domestic use. However, rest of the farmers differed from the suggestion and responded that agricultural ponds can be used for livestock use also. The participating farmers identified the district and *Block* administration, and local government like *Panchayat Samiti* and *Gram Panchayat* as the main funding and implementing agency for the prioritized actions identified by them.

Village women were mainly approached to suggest prioritized actions to ensure household water security (**Figure 8.5**). More than 90% of the women respondents suggested that regular repair and maintenance of existing hand pumps, more specifically before the onset of dry season, can help in strengthening water security status in the district. The hand pumps often fail to supply water due to decline in groundwater level, excessive pumping and careless handling, as discussed in Chapter 7. Once a hand pump gets defunct, the pressure on other hand pumps in the area increases leading to the failure of more hand pumps. It is also difficult to get personnel to repair the defunct hand pumps which often takes longer time than anticipated. Hence, a regular maintenance can prevent the hand pumps from going non-functional.

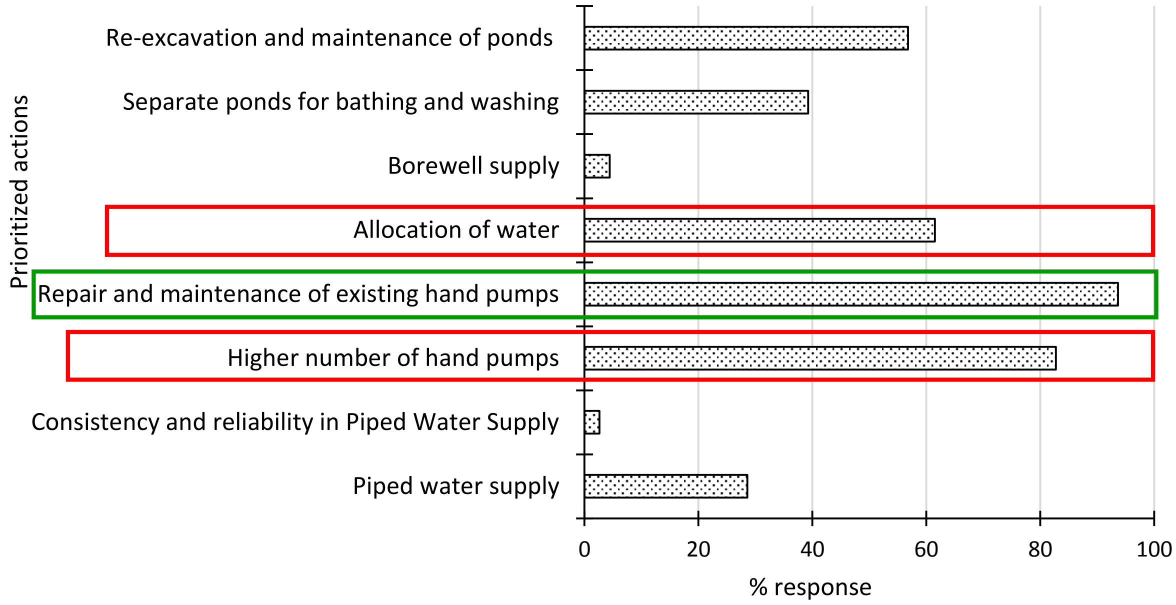

Figure 8.5: Prioritized actions to ensure household water security in the study area

Lesser number of hand pumps available for use is also a major factor behind lowered water availability in the study area (discussed in Chapter 7). Nearly 82% of the participating women agreed that higher number of hand pumps i.e. installing new hand pumps inside village boundary will lower the pressure on the existing fewer water sources as well as lead to increase in the amount of water available. The rate of use of unimproved water sources will also decline if more water is available through improved sources like hand pumps. The third prioritized action suggested is the equal allocation of water. There is inequity in availability of and accessibility to water. Households located near the water sources or those powerful in the society or belonging to higher castes manage to get larger volume of water compared to other people (already discussed in Chapter 7). Also, women coming from far are often late and have to stand longer in the queue. In this process, they often complaint of getting lesser volume of water for domestic use. More than 60% of the studied women responded that there should be some rules or regulations based on which that can be equal allocation of water to every households in the study area. For example, village women from Sarbari village in Neturia have devised a village rule that only the first five households can get water from the community water tap with piped water supply. Also, they can collect only two buckets (20L each) of water. Next day, the next five households can collect water from the same tap and so on. To keep an account, a record is maintained by a committee of village women specifying which household collects water on a specified date and the amount they collect. Similar community level rules may contribute to equal allocation of water to every household in a village. More than 55% of the rural women suggested re-excavation and regular maintenance of ponds located inside the residential areas of the village as they are one of the principal sources of water used for bathing, washing utensils and clothes, and for sanitation. These ponds are usually privately owned but people are generally not debarred from using the pond water owing to community level relations. Over a period of time, these ponds turn into common property resource and, as the ownership gets lost with time, they are seldom maintained. These ponds often become highly contaminated and due to excessive siltation, water holding capacity get significantly reduced. As the ponds are usually individually owned and often they don't agree to transfer the rights to government, the government also cannot maintain these ponds.

As the monsoon season comes to an end, the ponds used for agricultural use often get dried up. To meet the water demand of growing crops, the farmers usually uses the water stored in the ponds from the residential areas. This withdrawal of water often compromises with the domestic water demand of the local users. Hence, nearly 39% of rural women emphasized on allotment of separate ponds for bathing and washing purpose. Out of the 16 villages under study only two villages have water supply through pipeline system. Approximately 28% of the respondent women expressed their priority for water supply through piped system which they perceive to be a more consistent and reliable water supply system. Except for equal allocation of water, the participating women identified the district and *Block* administration as well as the local government as the principle implementation agencies for their prioritized actions. For equal allocation of water, the participating women identified that the Gram Panchayats may play a greater role than other implementing agencies.

8.3.2 Prioritized actions at *Gram Panchayat* level

The local government level prioritized actions are obtained through questionnaire survey with 29 *Gram Panchayat* (GP) heads or *Pradhans* who are local leaders elected through a democratic voting system. The elected GP head is usually the resident of the same GP and has an elected committee of people to look after the development of the GP (discussed in Chapter 3). The results of the semi-structured interviews and subsequent discussion with the GP heads are shown in **Figure 8.6**. Noticeably, not much difference is noticed between the prioritized actions suggested by studied farmer communities and GP heads regarding agricultural water security. However, a change in priority can be noticed among the responses of GP heads. Construction of new irrigation ponds and/or *hapas* is found to the prime priority of the GP heads (79.22%). But at the community level, higher priority is exerted on re-excavation and maintenance of the existing ponds, which is prioritized only by 26% of participating GP heads.

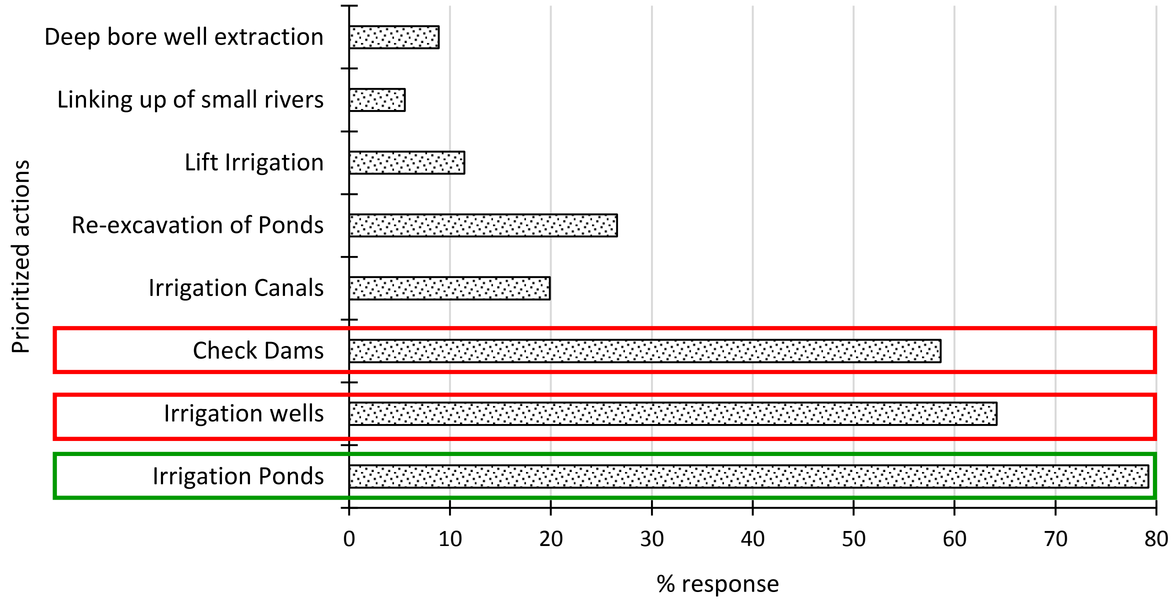

Figure 8.6: Prioritized actions identified by *Gram Panchayat* heads for agricultural water security

Next to irrigation ponds, construction of new irrigation wells has also been highly prioritized by 64% of the GP heads. This can be attributed to the fact that more funds are sanctioned under various schemes for construction of new ponds and/or *hapas* or irrigation wells as compared to re-excavation and maintenance of existing water sources. The GP heads stressed on the fact that the amount available for operation and maintenance of existing water sources is meagre to challenges they face, especially in the dry season. The operation and maintenance often fall short leading to failure of the water sources. Hence, the GPs stress on proposed schemes on new water storage infrastructure than on operation and maintenance. A significant level of corruption can also attributed for the above response. Construction of new infrastructures provide higher opportunities of profit making than operation and maintenance. Also, maintenance of existing water bodies needs regular monitoring and is a time consuming job. The participating GP heads also put importance on construction new check dams and irrigation canals to meet agricultural water demand. A growing reliance on groundwater is noticed between both farmer communities and GP heads as both of them stress on digging deep bore wells and extracting groundwater by electricity- or diesel- based machines for agricultural use. No prioritized actions were suggested for livestock water use by the GP heads which may lead to the fact that GPs are not so concerned about the water availability to livestock and consider it more as a responsibility of the individuals as the livestock are privately owned.

Except for a few cases, Local Administration (LA), *Zilla Parishad* (ZP), *Panchayat Samiti* (PS) and *Gram Panchayat* (GP) are identified as the principle implementing agencies of the proposed actions (**Figure 8.7**). Only GP Heads from Chatuhansa and Mankiary under Arsha *Block* highlighted that community is one of the important implementing agency in case of construction and maintenance of irrigation ponds and wells. However, the GP heads identified LA and ZP as the main funding agencies for the proposed actions. For construction of larger water harvesting projects like check dams and river lift irrigation, LA and GP are identified to be the main implementing agencies because the scheme should be proposed by the respective GP and, sanctioning and construction is usually carried out by the LA as it has both financial, technical and human capital to carry out this work. For construction of new irrigation ponds and wells or excavation of existing ponds, PS and GP are identified as main implementing agencies. These works are usually carried out under various scheme funds received by the PS and GP from local and district administration and ZP. The human capital to carry out this works involves engaging local communities under 100 day's employment guarantee scheme of Government of India. Though some NGOs are reported to be working the district, the reliance of local leaders on NGOs are found to be less regarding implementation of the prioritized actions.

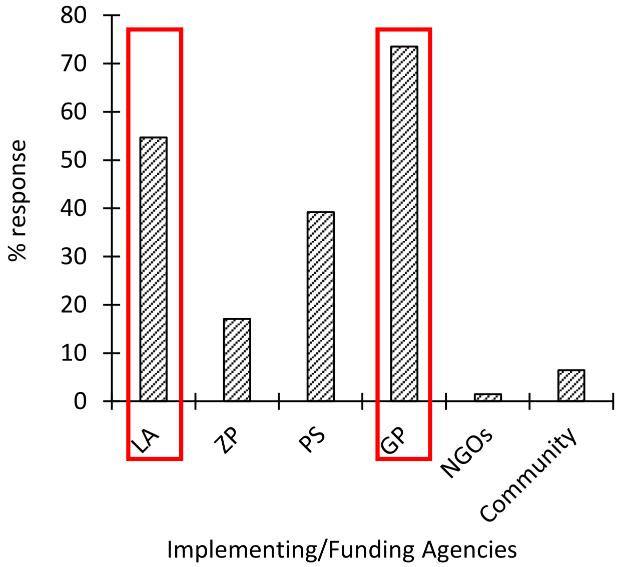

Figure 8.7: Main identified implementing agencies for the prioritized actions towards agricultural water security

Various barriers have been identified by the GP heads that may hinder the implementation and functioning of suggested actions (**Figure 8.8**). The main barriers can be identified as land disputes, lack of financial capital and natural barriers like hard rock terrain in the area, difficult hydrogeological characteristics and undulating topography in the study area. The most common barrier reported by the participants (91.4%) concerns the timely availability of sufficient amount of money to conduct the suggested actions.

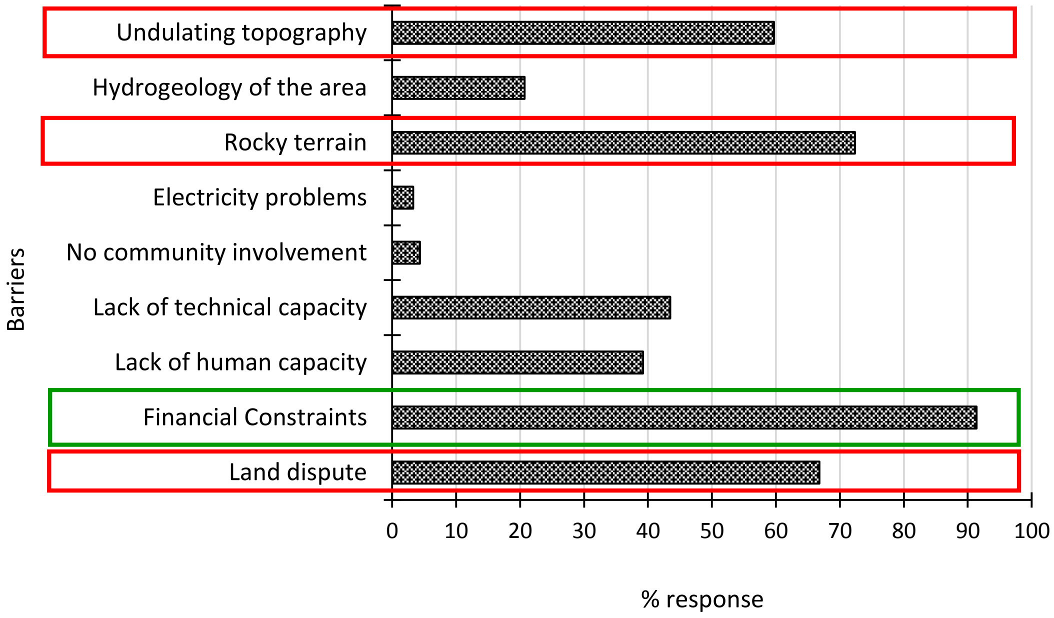

Figure 8.8: Main identified barriers towards attaining prioritized actions for agricultural water security

As responded by the GP heads, usually they start a scheme when they get initiation fund. But as the scheme progresses there are delays in release of more funds which results to subsequent delay in the completion of the schemes. Also, as mentioned above, the operation and maintenance fund available to GP is very low compared to the demand and this lands the GP into severe financial crisis, especially during the dry season. As responded, the GP has to often channelize funds from other schemes to meet the immediate needs regarding water issues. Similarly, if the work related to the water development scheme gets delayed due to reasons like lack of labour, the available fund under that scheme is channelized to meet the immediate demands of financial crisis which the GP is facing regarding a different scheme. Hence, the GPs usually follows a crisis management approach and a significant lack of proper rules and regulations is realized that would direct and guide the GPs on how to spend the fund they receive under each scheme. Once the money sanctioned under a specific scheme is used, they have to wait for the sanction of next phase of fund to start the scheme again. Also, the fund available to carry out the different projects and schemes are often found to be inadequate. As discussed in Chapter 4 and Chapter 7, the district is characterized by many natural barriers that hinders the attainment of water security. In the present exercise, nearly 72.35% of the respondents identified the hard rock terrain of the district as the second most severe barrier towards implementation of any prioritized actions (**Figure 8.8**). The GP heads responded that they often select an area for the construction of a new water source, however, the terrain of that specific area is not supporting and hence they have to stop the scheme. Sometimes, the difficulties arise after the work under the scheme has progressed and layers of hard rocks are spotted that restricts digging. Then the work has to be stopped and the money under that scheme also gets wasted. Once the money under that particular scheme is wasted due to natural reasons, no funds are released for construction of the same water source in a different site. Similar to existence of hard rock terrain, undulating topography of the study area also pose as a significant barrier to many of the proposed actions. Third most common barrier faced by the GPs (66.82%) regarding implementation of prioritized actions is disputes over land. Construction of new ponds, wells or check dams require land. However, the chosen land are often not available as the owner does not agree to give away his/her land for public works. The compensation asked by the land owner does not match with the one provided by local administration. Hence, the dispute grows and, with no more suitable lands available, many of the proposed projects or schemes have to be stopped, withdrawn or delayed in the study area. In addition, lack of technical capacity and human capacity for the implementation and effective maintenance of the proposed actions or schemes are major hindrances towards achieving agricultural water security in the study area. The GPs agreed that they lack adequate amount of skilled personnel who can meet the needs and demands of the communities. Often this lack of technical and human capacity results to delay in the completion of proposed actions or schemes.

In contrary to the community prioritized actions, the GP heads are found to mostly prioritize the installation of higher number of hand pumps (82.81%) to meet household water demand (**Figure 8.9**). The response matches with the response regarding agricultural water security where emphasis is put more on the construction of new structures rather than operation and maintenance of existing water structures. Unlike the community prioritized actions, more than 65% of the GP heads prioritized installation of piped water supply in every village to attain household water security. However, only 10% of the participants responded that not only installation but also the consistency and reliability in piped water supply will also matter. In addition, the GP heads suggested increasing the depth of bore holes (58.66%) so that there is consistent supply through hand pumps and they remain resistant to seasonal uncertainty. The need for maintenance of the existing hand pumps has also been prioritized by nearly 46% of the respondents (**Figure 8.9**). The participants also responded that there is unequal distribution of hand pumps in the villages with some villages having 5-10 hand pumps whereas other village having just one. Hence, nearly 27% of the respondents suggested a planned distribution of hand pumps in every village so that there is equal distribution of water. Similar responses were obtained from communities who also prioritized equal allocation of water. Also, in spite of high incurred costs, approximately 34% of the GP heads emphasized on the scope of withdrawing ground water, storing them in a reservoir and supplying them through piped system to one village or cluster of villages. Similar to actions for agricultural water security, GP heads are found to focus more on installing new structure for water withdrawal than re-excavation, repairing and maintaining the existing ones (**Figure 8.9**). In addition, most of prioritized actions (6 out of 10 actions) suggested at the GP level, to attain household water security, are aimed at utilization and extraction of groundwater rather than utilization of surface water.

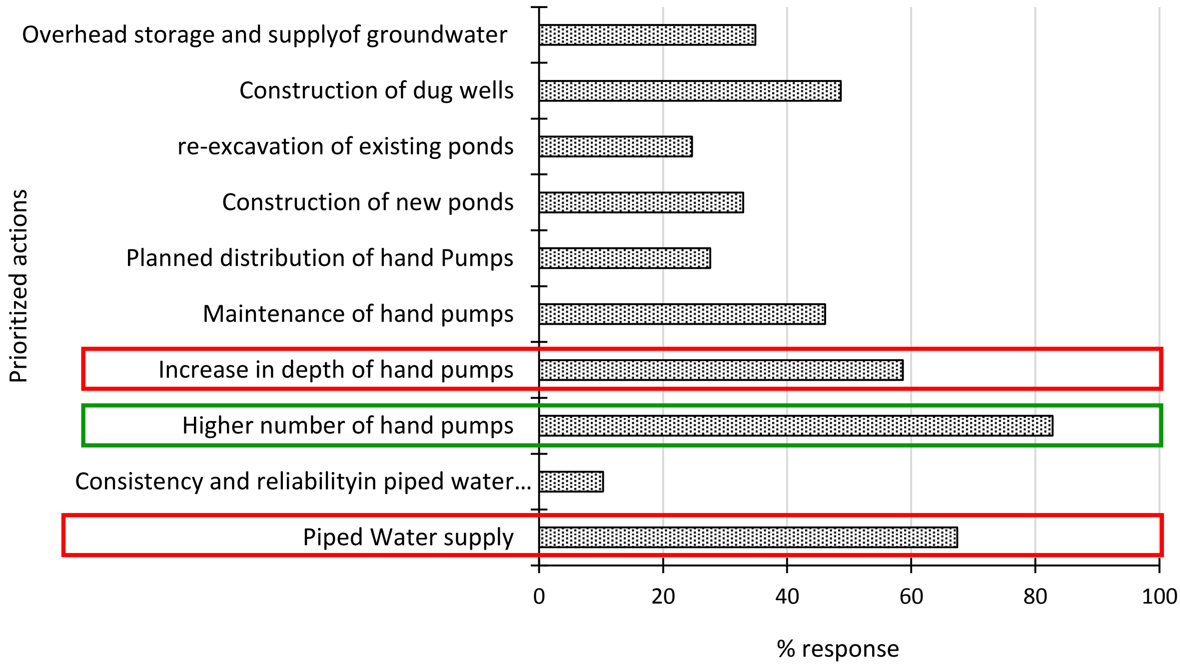

Figure 8.9: Prioritized actions identified by *Gram Panchayat* heads for household water security

Various implementing agencies have been identified by the participating GP heads who play a major role in household water security (**Figure 8.10**). Similar to implementing agencies for agricultural actions, GP has been identified to be the most important agency for developing the proposal of the schemes needed for the village as well as final implementation of the scheme. However, for piped water supply provisions, overhead water storage tanks and maintenance of piped water supply system, the GPs are bestowed with little responsibility and majority of the decisions, planning, funding and implementation are carried out by District Administration (DA) and LA. For other actions like installation and maintenance of water sources, usually LA provides funding as well as technical support to PS and GP to carry out the actions. Similar to agricultural water security, GP heads are found to less reliant on NGOs as implementing or funding agencies.

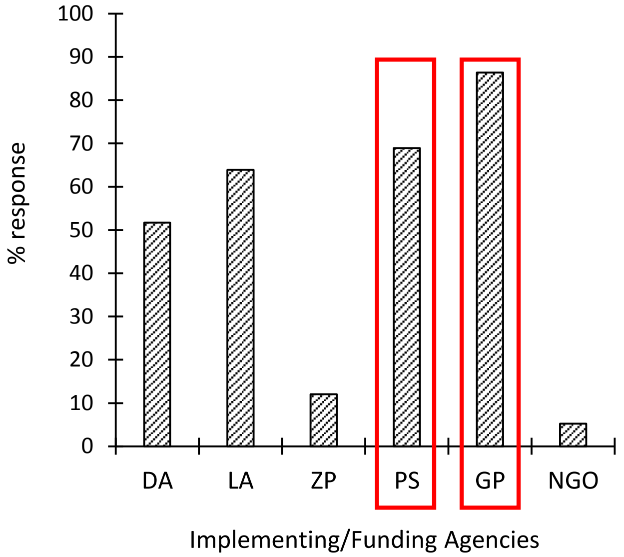

Figure 8.10: Main identified implementing agencies for the prioritized actions towards household water security

Out of the different barriers identified that hinder the execution of the proposed actions, financial constraints again emerged as a major barrier (88.67%) towards attaining household water security (**Figure 8.11**). The second major barrier identified is the lack of prior survey before installation of water abstracting structures like hand pumps and dug wells (84.71%). As the terrain and hydrogeology is not uniform across the study area, a wrong siting of the hand pumps often lead to their frequent failure to supply water and breakdowns. Also, a declining groundwater level emerges as a major barrier (nearly 77% of the responses) to the existing as well as the new water abstracting structures because the groundwater level is often below the depth of the bore hole. An interesting barrier identified by the GP heads is the tendency of local people to install the water withdrawing structures in their own land than in the public land (**Figure 8.11**).

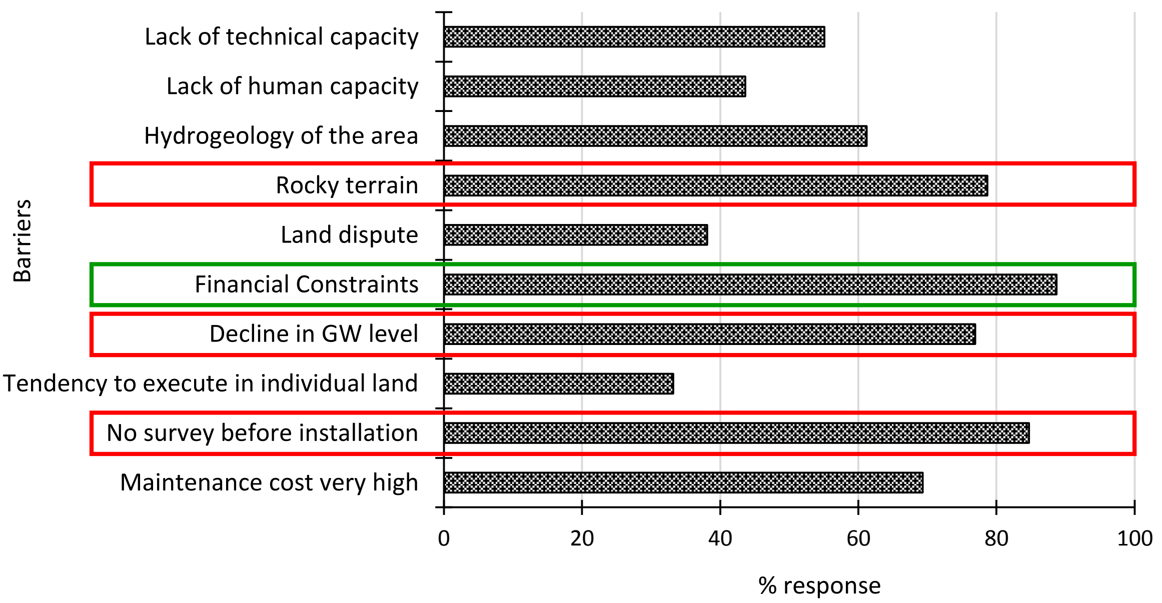

Figure 8.11: Main identified barriers towards attaining prioritized actions for household water security

This helps them in saving time and can give them a sense of ownership over the public water source. This results to conflict between water users and implementing agencies which often results to delay in installing or construction of water sources. Similar to the barriers identified in case of agricultural water security, natural barriers like hard rock terrain and difficult hydrogeology, lack of technical and human capacity, and land disputes are identified as main hindrances towards household water security also. Except that the percent responses are found to be different. However, nearly 70% of the participating GP heads pinpointed that the maintenance cost is very high which restricts the effective operation and maintenance of the existing water sources, thus hindering attainment of household water security.

8.3.3 Prioritized actions at *Block* level

The administrative level prioritized actions are mainly obtained from semi-structured interviews with local administrative heads, the *Block Development Officers*, from five *Blocks* namely Arsha, Baghmundi, Purulia II, Jhalda I and Neturia. The major points highlighted by the *Block* heads and his team are provided below:

- In case of agriculture, a major emphasis is on digging on irrigation ponds in uplands which is mainly carried out as a part of the 100 day National Rural Employment Guarantee Scheme (NREGS).
- The demand for location of irrigation ponds usually comes from the GP and no prior survey is carried out before conducting the excavation. The *Block* calls tender and the most appropriate contractor is given the responsibility of digging the pond. The whole process involves a lot of political intervention and corruption, thus resulting to faulty planning.
- Irrigation wells are usually sanctioned at an individual level. When the *Block* receives fund, for say 20 irrigation wells, it calls *Panchayat Samiti* and asks them to develop the list of beneficiaries who will get the irrigation wells. The *Panchayat Samiti* (PS) develops the list and hand it over to *Block* officials who then construct the irrigation wells to the beneficiaries. This process also involves a high level of political intervention.
- Construction of new irrigation canals is not a priority for the *Block* administration unless the *Block* receives fund specifically for construction of canals. As the construction cost is very high, irrigation canals cannot be built using *Block* funds.

- There are no existing farmer associations in the studied *Blocks* that look after the demands and priorities of the farmers. *Gram Panchayats* are given all the responsibilities and the farmers can put their complaints or demand to them and PS.
- On a household front, *Blocks* prioritize the installation of hand pumps to meet domestic demands. Hand pumps are installed at a community level and follows the same procedure as sanctioning of irrigation wells i.e. PS and GP decide which village needs how many hand pumps and where they should be located.
- Monetary sanctions for digging up of dug wells for individual use to meet domestic needs is no more carried out in the study area.
- Building overhead storage reservoirs and laying of piped water supply system is beyond the capacity of the *Block* officials and is mainly planned and carried out at district level.
- Due to the varied hydrogeology of the study area, many of the installed hand pumps stops working, even after few days after their installation.
- Once a model scheme is proposed and sanctioned, the engineers have to follow it. For example, if the model scheme proposes that the depth of the bore hole will be 30 feet, then they receive money for just 30 feet. But water may not be available at 30 feet but at 40 feet. However, the engineers cannot dig 40 feet due to limited availability of funds. Hence, the newly constructed hand pump with 30 feet depth may stop working after few days as enough water is not available at that depth.
- The *Block* officials prioritized actions that involves effective community participation towards the maintenance of the hand pumps and other water abstraction structures. As the water sources are mostly communal, the *Block* officials highlighted a lack of sense of ownership among the water users which results to mishandling of the hand pumps and lead to their frequent breakdown.
- The *Blocks* admitted that they receive more fund to construct new structure than for maintenance of the existing structures. The fund available for maintenance is meagre and not sufficient to meet the demands, especially during the dry seasons when many of the water sources break down and fail to supply water.

8.4 Implications to Rural Water Security Framework

The core element of Rural Water Security Framework focusses on what can be done to attain water security in rural areas. In addition, the suggestions and guidelines provided in the framework should be resilient to seasonal variations and are sustainable. Though innumerable actions and steps to attain water security can be included in the framework, the framework is bound to breakdown if it does not address the needs and demands of the communities and the authorities who can work together towards attainment of water security. The framework should follow a bottom up approach and include the priorities and needs identified from the lowest existing levels. In lieu of this, the present chapter significantly contributes to the proposed Rural Water Security Framework by delineating the various identified prioritized actions proposed at different levels including community, local government and local administration. The identified prioritized actions, when included in the framework, is expected to strengthen it and minimize the gaps that may result from actual community needs and proposed actions in the framework. For example, the communities under study prioritized the re-excavation of ponds as well as repair and maintenance of existing water sources to attain both agricultural and household water security. Hence, provisions should be included in the framework that addresses both of these issues. On the other hand, though construction of new dug wells has been prioritized by both the communities and GP heads, the *Block* officials clearly stated that it is not carried out any more. Hence, this action can be put on a lesser priority list when framing rural water security. Identification of main barriers that can restrict water security like financial constraints, hard rock terrains, lack of technical and human capacity in the study area helps in identifying the immediate priorities that should be included in the framework. Like, provisions for availability of adequate funds, prior surveys to avoid waste of funds over incorrect selection of sites as well as issues regarding building human and technical capacity should be included in the framework. Identification of GP as the main implementing agency at all the three levels of study, presents GP as a viable option as the boundary on implementation of the proposed framework. Thus, carrying out this site specific assessment of prioritized actions, to be included in the proposed Rural Water Security Framework, contributes towards strengthening water security in the rural area as well as make it more acceptable to the target communities.

8.5 Concluding Remarks

A significant gap in the prioritized actions proposed at all three levels were noticed in the present study. When the community puts more priority on operation and maintenance of existing water sources, local government and administration emphasize more on construction and installation of new water sources than the maintenance and repair of the existing sources. This reveals that a heavy amount of money is wasted every year over construction of new water sources. In summary, the chapter findings demonstrate the lack of demand-side approaches at all three levels under study - community, local government and local administrative level - and an emphasis only on water supply provisions. On the supply side, organizations at higher level of hierarchy usually control the capture, storage, conveyance and distribution of water. Demand-side organizations, for example water user associations, are established to represent the interests of users and to introduce and enforce water allocation rules. However, no such associations are found to be functioning in the study area. There is a noticeable lack of suggestions on adaptive strategies that can be practiced by the communities to overcome agricultural and household water insecurity. Though ponds are identified as important water source for both agriculture and household water use, no existing organizations like pond owners' group or pond users' group are found in the study area that monitor the management of the ponds. Neither there are any setting rules and regulations developed for operation and maintenance of ponds. Owners as well as users are totally indifferent about the maintenance of these ponds. Operations including maintenance and financing of ponds are done by elected village council (*gram panchayats*) from the Government fund allotted for the 100 days employment generation scheme. This also holds true for other water sources like hand pumps. Numerous other barriers have been identified which mainly includes financial constraints as well as the natural barriers like difficult hydrogeology and rocky terrain of the study area. Also, lack of sufficient technical capacity and human capacity often hinders the achievement of water security in the study area. Moreover, the actions prioritized by both communities and at different administrative levels are not found to be resilient to seasonal insecurity and are not sustainable. A source that supplies water in wet season, may completely fail during dry season and increase the plight of rural communities. Indifferent attitude of the communities towards use and maintenance of the water sources is clearly visible in the study area and this can be attributed to the lack of financial and human capital among the rural population, and lack of initiatives that promote engagement of communities in whole planning process. Above all, a clear lack of community awareness and involvement in the action planning of the water sources in the study area is quite evident. Also, the communities are found to be dependent on district and *Block* administration as well as local government for all their demands and priorities. This denotes the lack of capacity of the communities in self-initiation and self-implementation of any water related issue in the study area.

CHAPTER 9

ATTAINING WATER SECURITY: DEVELOPMENT OF RURAL WATER SECURITY FRAMEWORK

"Never doubt that a small group of thoughtful, committed citizens can change the world. In fact, it is the only thing that ever has."

Margaret Mead, Anthropologist

Chapter 9: Attaining water security: Development of Rural Water Security Framework

This chapter has been divided into two parts. The first part delineates the key findings of all the previous chapters. These key findings, especially from chapter 4, 5, 6, 7 and 8 are then used as significant inputs for the second part of the chapter. As the causes, impacts and hindrances in the pathway to attain water security in rural areas are identified, a risk based Rural Water Security Framework is developed. The framework mainly constitutes two main parts – process cycle and support system. Process cycle includes the steps that can be followed to attain water security whereas support system mainly constitutes the assistances that are required for the effective functioning of the process cycle. The chapter argues that implementation of this framework will not only strengthen the local community but also work towards gradual attainment of water security in rural areas.

Outline of the Chapter

9.1 Introduction

The present research mainly aimed at answering three important research questions. Firstly, how can the status of water security be assessed in a rural dry sub-humid district. Secondly, what are factors that influence water security in a rural area and thirdly, how water security can be attained and strengthened in rural areas. In doing so, the research identified several thematic components that characteristically delineates the various factors that play havoc in influencing water security in rural areas including natural, management, social and institutional components. The components act in isolation or in combination that results to low water security for the communities. Water security, whether low or high, has been analyzed using various variables that denotes water supply and demand situation in the area as well as adaptive capacity of the area. The analysis has been carried out through the development of Rural Water Insecurity Index (RWII), which is thoroughly discussed in Chapter 4. As the status of water security is underlined in different provinces (*Blocks*, in the present study area) and an overview of components influencing water security at a provincial level is understood, it becomes imperative to understand water security status at household level. This is mostly measured through water availability and accessibility by households and the factors determining household water consumption were identified. The strategies, both adaptation and coping, practiced by different community groups like farmers and village women to overcome water insecurity conditions were discussed in detail in Chapter 7. The findings from this chapter primarily indicate that water security is at risk in rural areas and, not only climatic and natural factors, but also the management, social and institutional factors threat water security in the study area. The study also identifies that poverty and lack of community awareness and participation in various decision making process holds the rural communities back and hinder their progress towards development. As the problems concerning water security in the study area are identified in the earlier chapters, Chapter 8 mainly focusses on delineating the actions prioritized at three different levels – local community, local government and local administration – in the study area. The expected barriers that may restrict the implementation of the actions are also identified at these levels. Water security requires a multi-level planning process and enforcing it at a local rural scale need inclusion of these prioritized actions into the planning process to make the proposed framework more effective and acceptable to the local community, government and administration. The present chapter mainly aims at developing a Rural Water Security Framework by incorporating the research findings presented in the previous chapters, especially Chapter 4, Chapter 5, Chapter 6, Chapter 7 and Chapter 8.

9.2 Summary of Key Findings

Figure 9.1 briefly summarizes the findings from the present research which are used as essential inputs to the development of Rural Water Security Framework.

Chapter 1, **Chapter 2** and **Chapter 3** mainly presented the background of the current research. The literature review demonstrated that water security lies on five main pillars – availability of adequate and safe water, accessibility to adequate and safe water, water for productive purposes like agriculture and fishery, protection from uncertainties like in climate and water for protection of the surrounding environment. An important finding is that most of the water security studies is conducted at an international or national level – a dearth of studies at a local level is noticed. Though urban water security has been talked in some cases, studies on water security at rural areas in significantly absent in published literatures. Local administration is found to play an important role in water supply and management in rural areas, especially for developing countries like India. Local rural government channelize the opinions and demands of impoverished, often illiterate and highly resource dependent rural communities to higher administrative level and, implements and monitors the development in a rural area. The literatures agreed that though enhanced funds were earmarked under different projects and schemes, limited success could be obtained at the operational level. Moreover, provision of groundwater supply and management is noticeably absent from the published literatures on water security.

In lieu of the overview, **Chapter 4** developed Rural Water Insecurity Index (RWII) that measures the scale of existing water insecurity at a provincial scale in rural areas. The index has been based on variables under three different components – Supply Driven Insecurity, Demand Driven Insecurity and Adaptive Capacity. The index results show that **access to consistent and reliable water supply through piped water supply system** and **availability and equitable distribution of groundwater** are the keys to ensure supply driven water security in the study area. The chapter focusses on an important finding i.e. **the role of adaptive capacity of the local population in lessening the water insecurity** resulting from the gap in water supply and demand. A priority to increasing the vegetation cover of the rural area, female literacy rate and higher work participation will contribute to increasing adaptive capacity. The index results demonstrate a wider spatial distribution with only 10% of the studied provinces found to be relatively water secure. Very high water insecure provinces (*Blocks*) are the most intensely under developed *Blocks* in the study area characterized by high variation in piped water supply, increased groundwater use to meet domestic needs, low work participation rate, lower female literacy rate and higher dependence on agriculture based livelihood.

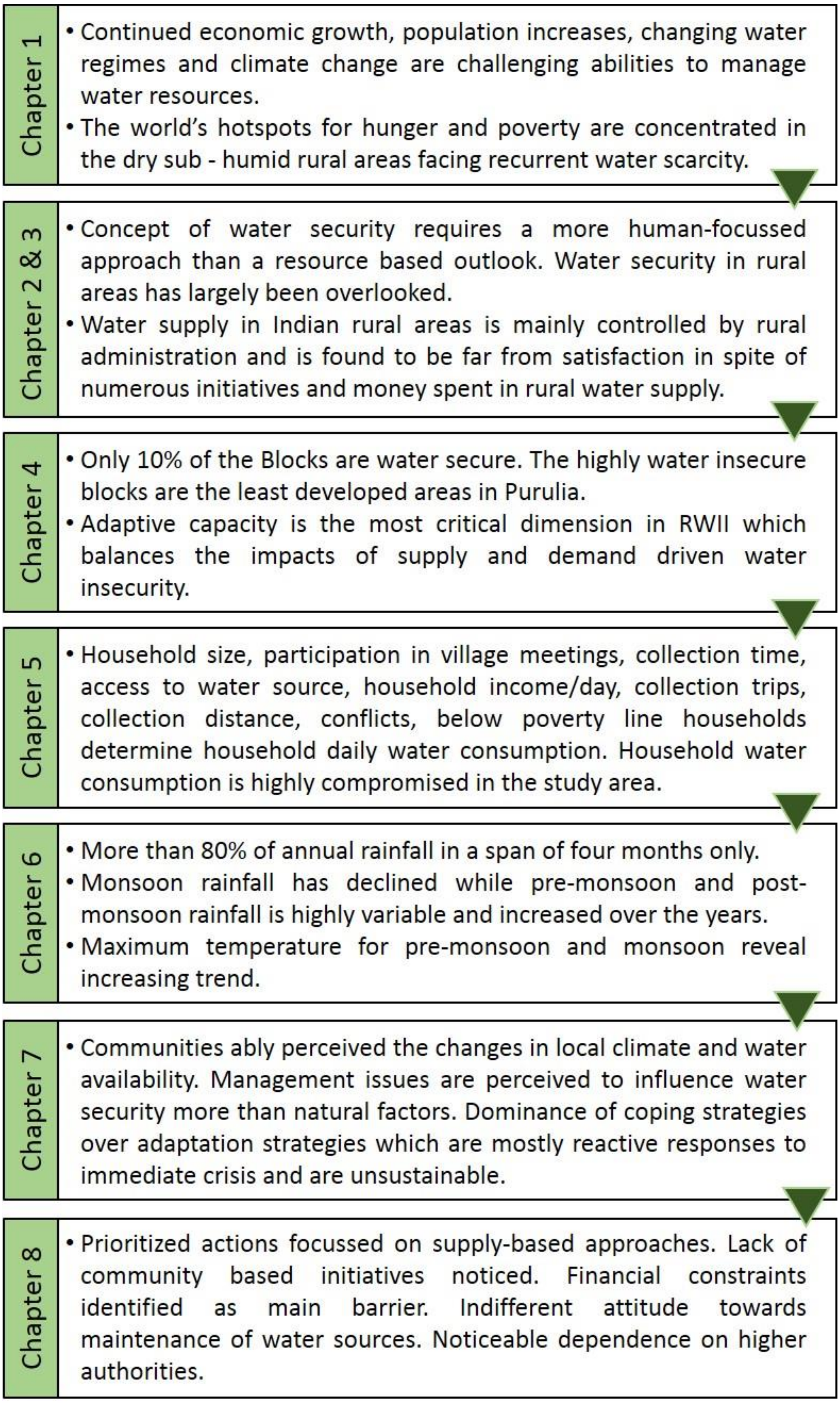

Figure 9.1 Briefly summarized key findings of the present research

Assessment of water security at a local scale requires evaluation of water security at household level, as household are the lowest unit of water users in any area. **Chapter 5** investigates household water consumption in the study area and analyzes the various determinants that affect water consumption. The average per capita water consumption of households in the study area are found to be much below the national as well as international recommendation. The **availability and accessibility to water is much below the satisfactory level** denoted by the **higher collection time, longer collection distance, dominance of community water sources, use of unimproved water sources and dependence on single source of water**. Syncing with the findings from the previous chapter i.e. water insecurity is more prevalent in impoverished areas, inequity in water consumption, availability, accessibility and other water variables for different socio-economic groups is observed at the household scale. **Quantity of household water consumption demonstrates the fact that household water security is largely compromised in the rural area**.

Climate is found to have a lasting impact on the hydrological cycle. Assessment of variability in local climate parameters like rainfall and has been carried out in **Chapter 6**. An increasing trend in annual and pre-monsoon season rainfall is noticed in the district and a decreasing trend in monsoon and winter season rainfall. Post-monsoon season rainfall displayed a highly variable, increasing rainfall. Hence, it can be concluded that **rainfall in the study area has been experiencing significant changes across the years**. Being a rain-fed mono crop area, **varied rainfall intensity between the monsoon and post-monsoon season emerged as a serious concern**. The chapter emphasizes **the need for inclusion of climate uncertainty and measures to overcome it in the proposed water security framework**.

Till now the present research has mainly focussed drawing findings from the data collected and analyzed in the study area. However, it is important to understand the perception of local people about the changing water security and climate, their causes, impacts and how they cope or adapt to overcome the impacts. **Chapter 7** reveals that local communities can, to a larger extent, perceive the changes around them, and the identified causes and impacts match with the findings of the earlier chapters. **Management factors** like scheme breakdown and lack of repairs, poor design, and lack of maintenance or local water crisis are identified to intensify both household and agricultural water insecurity. As well as a **severe decline in groundwater table** as well as fluoride contamination, adversely affects the sustainability of drinking water sources in the study area. In addition, **the adopted coping and adaptation strategies are inadequate to make any difference in the living condition of the rural communities** which demonstrates the lack of various capacities among the local communities. The gap between perceiving and reacting to the change should be taken into account before promoting any water security policies or projects in rural areas.

Including community views on what can be done to improve the water security status is a vital part of any local planning process. In addition, the limitations that may restrict the implementation and functioning of the proposed schemes/projects needs to be identified so that they can be properly addressed in the proposed framework. In lieu of this, **Chapter 8** presents the different prioritized actions identified at different local levels, barriers that may hinder the implementation of the actions, and the main agencies that may implement and fund the prioritized actions. A significant gap is found in the proposed prioritized actions at all three levels. **The community puts more priority on operation and maintenance of existing water sources, local government and administration emphasize more on construction and installation of new water sources than the maintenance and repair of the existing sources**. At all three levels, **demand-based approaches are completely overlooked**. This signifies **the need for change awareness among the concerned authorities and communities regarding the importance and utility of demand-based approaches**. In addition, communities are found to be dependent on district and *Block* administration as well as local government for all their demands and priorities, denoting **lack of capacity of the communities in self-initiation and self-implementation of any action** in the study area.

In summary, the present research findings clearly demonstrates the low water security status in the district along with its causes and impacts. It is clearly visible that in spite of suffering from recurring water scarce periods and being a drought prone area, management issues are impacting water security more than natural factors including climate. In addition, lack of community awareness and engagement in the decision making process is widening the gap.

9.3 Development of Rural Water Security Framework

9.3.1 Objective and Outline of the Framework

The key findings from the analyses carried out in this research emphasize the need for a strengthened risk-based framework to attain water security in rural areas. The risk-based approach seeks to increase water security by managing risks and reducing insecurities and looks at how local communities cope with variability. Absolute water security can never be achieved because conditions will change, demand for water will continue to grow, and limited financial resources will constrain what can be done. *In the current research context, Rural*

Water Security Framework (RWSF) presents a structural frame that specifies the various elements and explains the steps that can be followed in the planning process to attain water security in rural areas. The main objective of the proposed RWSF is to: **(a) identify the existing risks to water security** which mainly includes identification of the issues that hinder water security at different levels including at provincial and household scales, for example, the existing disparity between water supply and demand and lower adaptive capacity of people; **(b) reduce the underlying risks to water insecurity** i.e. controlling the issues and improving the water availability and accessibility of local people through, for example, development of sustainable water sources; **(c) manage future uncertainties** by mainly focussing on development and practice of various adaptation strategies to overcome water insecurity at community and household level and, sustain the principal livelihood of rural areas i.e. agriculture; and, finally **(d) strengthen water security** through a stronger support system that helps in effective functioning of the framework. These four objectives of RWSF are closely linked to each other. Instead of considering them as separate entities, they can be considered as a combined system where development and investment in one objective is going to have profound impacts on others. This framework may add value in rural areas where consistent and reliable water availability fluctuate, where access is not equitable, where there are competing demands for water, where conflict emerges over access, where communities are largely dependent on natural resources and where community engagement in local decision making process is lacking and must be strengthened.

The boundary for implementation of the framework is more likely to be a manageable geographical area of population. In a best way, it can be a village but for ease of assessment and application, cluster of villages should be considered as a boundary of the framework. For example, in the present study the framework can be applied at a *Gram Panchayat* (GP) level which includes a cluster of villages under its boundaries and is also the lowest level of governance existing in rural areas in India (**Figure 9.2**). The merits of including a cluster of villages as the boundary of the framework is that the local governance is same for all the villages. Therefore, local people know whom to approach and there are less chances of contradiction on division of responsibilities as complexity increases as we ladder up the hierarchical administrative levels. Also, a broader boundary may lead to difficulties in management and operation. However, considering the various limitations at a GP level, the framework will require support from various hierarchical levels for effective functioning as mentioned in subsequent sections.

9.3.2 Development of the Framework

Figure 9.2 shows a schematic diagram of the framework. The four major elements of the **process cycle** include **Resource Assessment**, **Source Sustainability**, **Operation and Maintenance** and **Adaptation Strategies**. These four elements include various components and steps that can be followed towards attainment of rural water security. However, they need not be followed in the same order demonstrated in **Figure 9.2**. For example, in case of an existing water source, the focus should be on operation and maintenance. Likewise, before installation of any new water source, it is advisable to follow the process cycle, starting from resource assessment. Similarly, for rural areas where climate plays or is expecting to play a havoc, formulation and practice of adaptation strategies will significantly contribute in attaining water security. These four elements are strongly interlinked to each other and carrying out evaluation in one element will lead the way towards the next element. The **support system** mainly includes **institutional**, **technical**, **social** and **financial** support which strengthen the process elements and helps them in working in an effective way. The elements and the components under it are open to modification with respect to location specific characteristics of the rural areas. Though the framework is proposed to be implemented within the boundary of the local government (outlined in continuous line, shown in **Figure 9.2**), various forms of support and cooperation is needed from higher hierarchical levels like local administration and district administration (outlined in dotted lines, shown in **Figure 9.2**) for effective functioning of the framework. The following sections include a detailed explanation of the proposed framework.

9.3.2.1 Process Cycle

Resource Assessment

This is the most important component of the proposed framework. Resource assessment at a rural scale involves understanding access, water demands, water supply, water availability, water use, risks, and current coping and adaptation strategies i.e. finding the risks to water security in the rural area under study. <u>The assessment should not be done just at the beginning but on an ongoing basis</u>. If the water resources and the changes in it are not monitored on an ongoing basis, it is not possible to manage them. An overall assessment may miss the knickknacks at the ground level. Assessment at different scales helps in having a comparative perspective about the resource and identifying the gaps in understanding the resource at different scales.

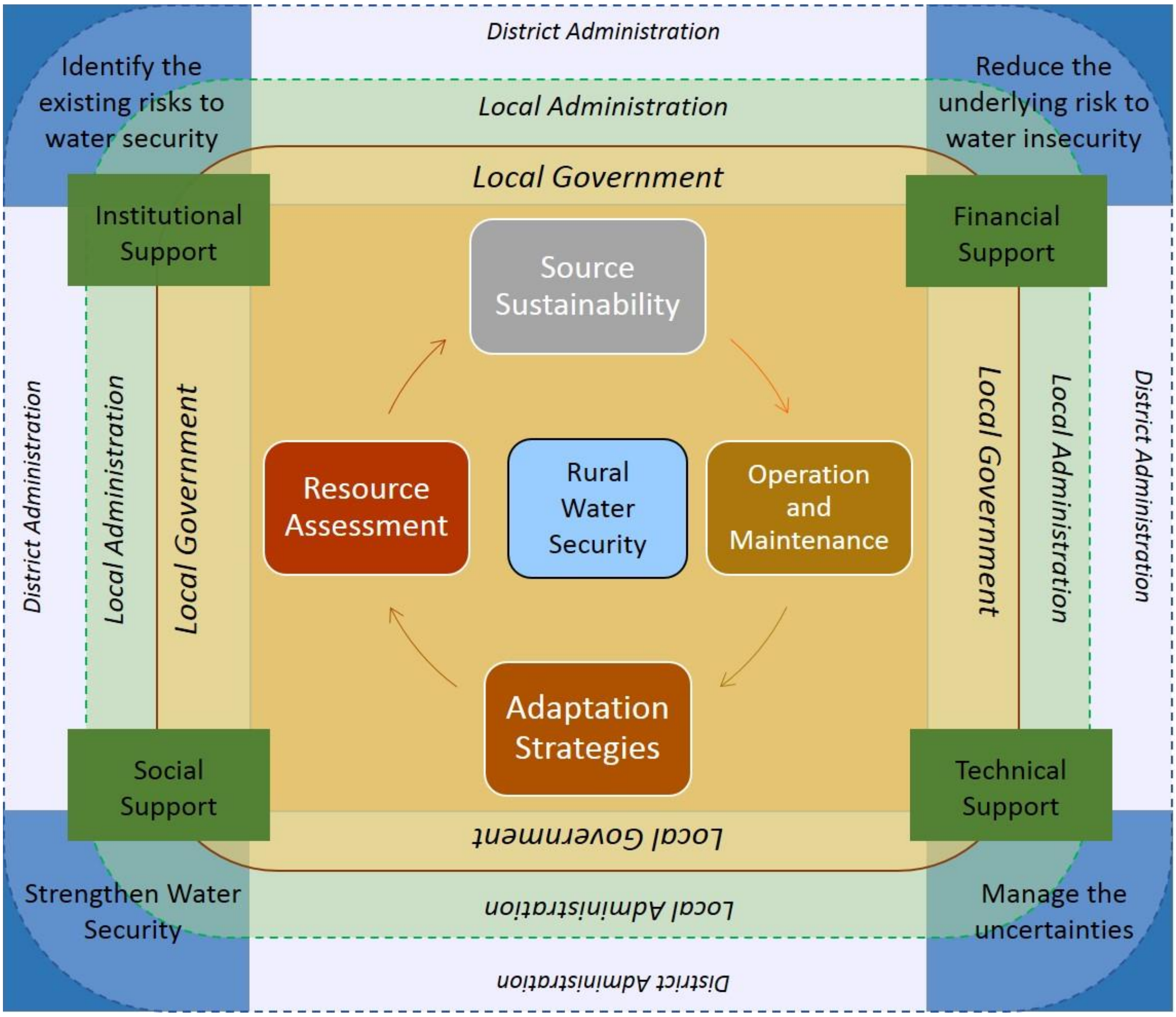

Figure 9.2 Proposed Water Security Framework for rural areas

Hence, an integrated approach is proposed for resource assessment. Though the framework will be functioning at the GP level, the initial assessment should start at the provincial level (*Block* level, in case of the present study). This assessment, based on the Rural Water Insecurity Index, will provide provincial administration the information about the water security status and can be considered as a guideline by them to assess the utility of the demands aroused by the water users and local government (for e.g. GP for the present study area). **Table 9.1** provides the details of what can be done to assess water resources, how to assess (methods of assessment) and when to assess (frequency of assessment). The criteria should be assessed strictly based on the frequency mentioned in **Table 9.1**, at least for highly water insecure rural areas. In other rural areas, the assessments can be done annually. The findings from the analysis of various criteria under resource assessment are also a significant input to other components and can save time and money. For example, findings from the assessment of availability and accessibility of water can act as significant input to the source sustainability component or findings from the assessment of current coping and adaptation strategies practiced by the studied communities can help in identifying the loopholes and plan accordingly in the planned adaptation step.

Table 9.1 Details of resource assessment to be carried out under Rural Water Security Framework

Criteria assessed	Scale of assessment	Method of assessment	Frequency of assessment
Existing water security based on **water supply**, **demand** and **adaptive capacity**	Province	Rural Water Insecurity Index (RWII)	Annual
Water Demand at different times of the year including productive and domestic demands	Community	Participatory Rural Appraisal exercise	Half-yearly
	Household	Questionnaire Survey	Annual
Water Supply from different water sources at different times of the year for both productive and domestic use	Community	Participatory Rural Appraisal exercise	Half-yearly
	Household	Questionnaire Survey	Annual
Access to water sources at different times of the year	Community	Participatory Rural Appraisal exercise	Half-yearly
	Household	Questionnaire Survey	Annual
Availability of water for basic water use including livelihood and domestic	Community	Participatory Rural Appraisal exercise	Half-yearly
	Household	Questionnaire Survey	Annual
Risks that influence reliable access, quantity and quality of supplies	Community	Participatory Rural Appraisal exercise	Half-yearly
Seasonal uncertainty	District/ *Block*	Data analysis assisted by department of agriculture and line departments	Ongoing
Coping and adaptation strategies	Community	Focus Group Discussion	Annual

Source Sustainability

Sustenance of water sources is the primary need for an area to be water secure. The source should be able to supply safe and adequate water throughout the year to meet water demand for various water uses, such as drinking water for humans and livestock, agriculture and industrial uses. However, in most of the rural areas, like in the present study area, supply from water sources are highly variable throughout the year with some sources breaking down in dry season or some sources supplying contaminated water in wet season (*findings from **Chapter 7** and **Chapter 8***). Based on the resource assessment findings, it is important to develop a water source plan that consists of sustainability structures for water harvesting and groundwater recharge. Water source Plan should include three major parts: **prior survey** of the area (hydro-geological mapping, location of the source etc.), **software inputs** (Community awareness on need for recharge, avoiding water wastage, rainwater harvesting, handling of water sources etc.) and **hardware inputs** (building water harvesting structures that can capture rainwater and surface water runoff, groundwater recharge through check dams, subsurface dykes, percolation tanks etc.).

Prior survey of the rural area is a must for source sustainability. As in the case of present study area and from in parts of Sub-Saharan Africa, poor siting is one of the major reasons behind the frequent breakdown of hand pumps in rural areas. Hand pumps, bore wells and dug wells, used for extraction of groundwater, are the main source of water not only for domestic but also for agricultural use in the present study area. The **optimal siting** of a well or borehole in areas where aquifers are most productive is essential for success and long-term sustainability. It is essential to use maps like topographic maps, geological maps and hydrogeological maps that provide the most basic information for undertaking a well-siting programme. However, only mapping cannot help in identifying the most appropriate site. Field visits and hydrogeological surveys are needed to locate the most optimal site for water sources. In addition, determination of best site requires consideration of a number of inter-related aspects, as shown in **Figure 9.3**.

Inputs from resource assessment (discussed in the previous section) will provide the information for access to source, water use and impacts and risks (**Figure 9.3**). Groundwater availability at the location of proposed source needs to be quantified in source sustainability. Prior survey is not only a pre-requisite for groundwater sources but also for surface water sources like piped water supply and other water harvesting structures. To determine the best location, some of the key factors that are of particular importance includes:

- *Sufficient yield for the intended purpose*. The groundwater aquifer should have a sufficient yield for a rural water supply hand pump. This can be determined by carrying out pumping test on an existing borehole.
- *Sufficient renewable water resources for the intended purpose*. Groundwater needs to be replenished by infiltration from rainfall or river flow to sustain it for a long time. It is therefore important to evaluate the likely recharge to the aquifer, and how this may vary with time.
- *Appropriate water quality*. Groundwater quality should be regularly checked against national standards and potentially contaminated sources, like fluoride contaminated groundwater in certain parts of the study area, should be marked and avoided.

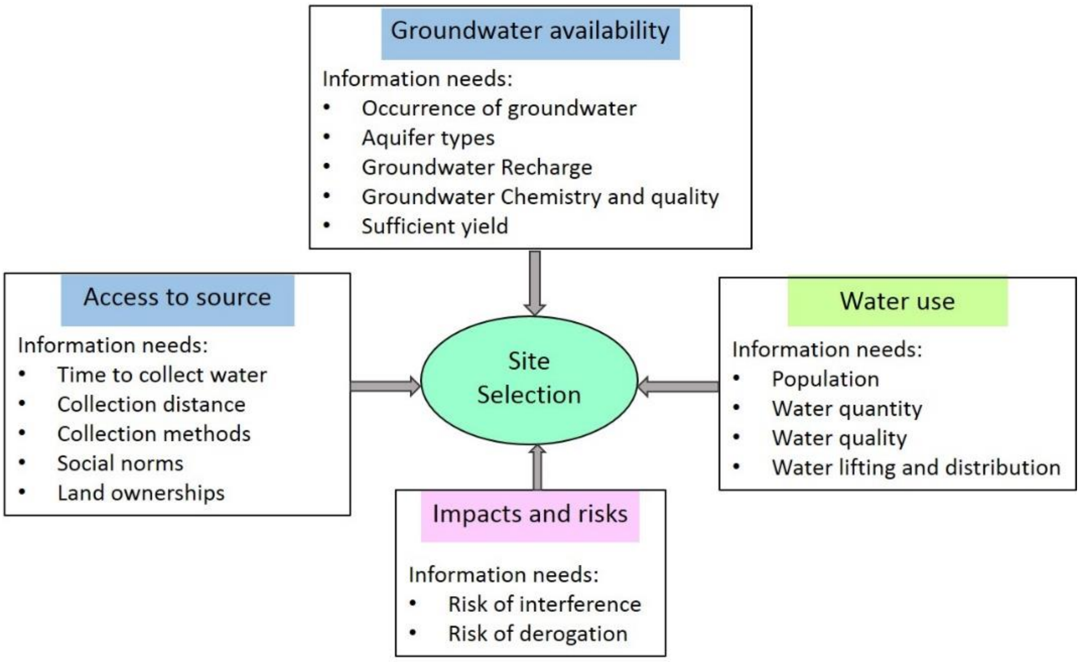

Figure 9.3 Information needs for a proper site selection of groundwater abstracting structure (*Source: RWSN, 2010*)

- *Community preferences, women's needs and land ownership*. Engagement with the community to agree on the location of the source is essential. It may require some negotiations to explain technical constraints whilst taking community preferences into account. Full consideration of the needs of women, who tend to be responsible for water collection, is essential. Land ownership issues, identified as one of the major barriers in the present study, also need to be considered to avoid subsequent disputes between land owner and water users.
- *Proximity to point of use*. The water sources, for both groundwater and surface water, should ideally be sited as close as possible to the point of use (*as shown in* ***Chapter 5***).

Interviews with householders will help to understand the community's preference for well location. In general, the community would be expected to indicate three preferred well sites in their locality, in order of priority.

Once the location of the proposed source is decided, **software inputs** play a major role in source sustainability. This can be mainly done by raising the awareness of local community and engaging them in the process, which is significantly lacking in the present study area. Therefore, major software inputs that can improve source sustainability in rural areas include:

- To prevent contamination, the spot source area should be cleaned on a voluntary basis and bleaching powders (disinfectant) should be spread in the area on a regular basis (*as waterborne disease like diarrhoea is identified to be one of the major health impacts in* ***Chapter 7***).
- To prevent contamination of open sources like ponds and springs, communities should be made aware about the use of water. For e.g. ponds for domestic use should not receive agricultural runoff (to prevent pesticide contamination) or should not be used for livestock bathing.
- Community awareness should be raised about the importance of groundwater recharge (*in response to decline in groundwater level identified in* ***Chapter 7** & **8***).
- Communities should be encouraged to participate in village meetings and prior attention should be provided to their views and demands. This way they can be motivated to protect the water sources (*identified in* ***Chapter 5***).
- Awareness should be raised about different adaptive strategies like rainwater harvesting and communities should be motivated to practice such strategies (*lack of adaptation strategies identified in* ***Chapter 7***).

Community engagement should be an ongoing process and should try to imbibe the sense of ownership (*identified as a barrier in the present rural area in* ***Chapter 8***) among the water users towards the communal sources.

Hardware inputs are the mitigation measures which are focussed upon to create sustainable water sources by building physical structures. As availability of surface water is highly variable owing to their dependence on rainfall, focus has been on making groundwater sustainable in rural areas including Purulia. Physical structures like sub-surface dykes, infiltration wells, recharge pits etc. can be constructed on a priority basis in areas where groundwater levels are declining on regular basis, where substantial amount of aquifer has already been desaturated and where availability of groundwater is inadequate in lean months.

Ponds. Construction of ponds has been the most common structure used to hold rainwater in rural areas in many parts across the world, including the present area. Pond water sustain for 4-5 months in the study area and with passing time, the volume of water decreases (*findings from **Chapter 7** and **Chapter 8***). Poor designing can be identified as one of the major issues behind this. Most of the ponds cover large surface area but are not deep enough. Ponds with higher depth and optimum surface area helps in recharging groundwater. Pits can be built inside the ponds for continuous recharging of the groundwater.

Series of check dams over rivers and streams. In this system artificial recharge is made to restrict the surface run off through streams and by making additional water available for percolation. The surface water is impounded during monsoon behind the structure and spread over the entire streambed and thereby increasing the wetted area. The impounded water helps in replenishment of groundwater. A series of check dams can be constructed on a stream to recharge the depleted groundwater aquifers. The topographical features of the study area is found to be suitable for construction of check dams.

Percolation tanks. Percolation tanks are generally constructed on small streams or rivulets, which is a common characteristics in the present study area, with adequate catchment for impounding surface runoff. These tanks are used entirely for recharging the aquifer through percolation. In comparison to ponds, percolation tanks conserve water to a greater extent because the filling and recharge occur mostly during the monsoon when the evaporation rate is about half of the potential rate in summer through which pond contain water. Selection of suitable site for the construction and maintenance is crucial for its effective functioning.

Sub-surface dykes. Sub-surface water harvesting systems exploit the infiltrated water. Technical possibilities of constructing the dyke and achieving large storage reservoirs with suitable recharge conditions and low seepage losses are the main criteria for siting sub-surface dykes. The limitations on depth of underground construction deems that the unconfined aquifer should be within a shallow to moderate depth (up to 10 m bgl) and have a well-defined impermeable base layer. Such situations occur in hard rock areas and shallow alluvial riverine deposits. A subsurface dyke may potentially deprive the downstream users the benefit of ground water seepage, which they received under a natural flow regime. Care should therefore be taken to see that a large number of users are not located immediately downstream and those affected are duly compensated through sharing benefits.

Dug well recharge. In hard rock areas, the dug wells either go dry or the water levels decline considerable. These dug wells can be used as structures to recharge. The groundwater reservoir, storm water, river runoff etc. can be diverted into these structures to directly recharge the dried aquifer.

Recharge shafts. In the areas where source of water is available either for some time or non-perennially, recharge shafts can be constructed. There are practically no loss of water in the form of soil moisture and evaporation in recharge shafts. Unused or even operational dug wells can be converted into recharge shafts, which does not require any additional investment. The recharge is fast and immediately delivers the benefit. Vertical recharge with injection wells are ideally suited for water levels more than 15 m.

In spite of the importance of various groundwater resource development agenda, there is a growing emphasis on the shift in focus to groundwater resource management. **Groundwater governance** proposes major reforms in the policy and practice of groundwater and keeps the principles of equitable access and distribution, efficiency of usage and sustainability of resources in its core (Kulkarni et al., 2015). Groundwater governance aims at applying a scientific understanding, community participation and stronger regulations both at local and higher institutional levels to manage groundwater at a local level. This can be mainly achieved through building capacities across a range of sectors and stakeholders that will enable healthy collaboration particularly in piloting groundwater management and governance. Establishing institutions and regulations towards development of groundwater governance will definitely play an important role towards securing water in rural areas.

Operation and Maintenance

A major challenge is to move from a project mode which focuses on creating infrastructure, to a programme mode which focuses on providing, improving and sustaining high standards of water supply services. As is the case with present rural district under study, the administration have been concerned with physical progress and financial disbursement, not on long term sustainability. There has been poor interaction with communities to involve them in planning, implementation and managing their own schemes. As a result, the dominant approach to service delivery has remained supply driven and characterized by large investments in schemes and works (one of the key findings of the present study), followed by deterioration of the infrastructure and long periods with low levels of service while communities wait for the government to rebuild the schemes. **Operation** refers to the everyday running and handling of water supply and proper operation results in optimum use and contributes to a reduction in breakdowns and maintenance needs of water sources. **Maintenance** refers to the activities required to sustain water sources and supply in a proper working conditions. Maintenance can be divided into *preventive maintenance* which involves regular inspection and servicing to preserve assets and minimize breakdowns, *corrective maintenance* which require minor repair and replacement of broken and worn out parts to sustain reliable facilities, and *crisis maintenance* which mainly concerns unplanned responses to emergency breakdowns and user complaints to restore a failed supply. The policy of crisis maintenance alone may appear cheap in the short term, as found to be practiced in most of the rural areas including Purulia. However, continuing crisis maintenance leads to frequent breakdowns, an unreliable supply, poor service levels, and a lack of user confidence. Reliance on crisis maintenance may ultimately lead to complete system failure. Hence, preventive and corrective maintenance should be stressed upon to sustain water sources for longer times.

Proper **training** can be provided to the local communities on the operation and maintenance of the water sources. The training should provide details about the functioning of the water sources, how it works, what can be the most probable problem areas and a menu of responses to deal with the problems. The training has to be customized as per the characteristics of the community and needs to be more in the "workshop mode rather than a classroom mode". **Monetary** or **developmental incentives** can be provided to community members who voluntarily repair the water sources. This will motivate those to get involved in the maintenance and can also become a source of income to them. Monetary incentive may include the fees for repairing the source and development incentives may include, for example, construction of sanitation facility in the member's household at a subsidized cost. Awareness about **community funds** need to be strengthened**,** like in the present study area**,** and created to bear the expenses regarding maintenance. The fund can be used to buy spare parts and carry out other maintenance work like surface the water point area or building drainage.

Adaptation Strategies

Adaptation to unforeseen changes and variability necessitates the adjustment of a system to moderate the impacts, to take advantage of new opportunities, and to cope with the consequences (IPCC 2001). Out of the various future uncertainties, climatic variability is the major concern mainly for small holder farmers depending on rainfed agriculture in rural areas like Purulia. A review of some of the current practices to mitigate the impacts of uncertainties, especially from climate, provides insight into the available options that can be considered for adoption, replication and up-scaling.

Collective action. The principle of collective action is building a strong, cohesive network to facilitate adaptation through the community and by individuals. This can be done by creating common interest groups (CIGs) such as Water User Associations and farming associations with common goals and interests transmitted through a structured communications system. For example, smallholder farmers can be organized into a CIG based on their production systems (e.g., using the same water source for irrigation), marketing and credit systems (cooperative societies) and socio-economic activities (women's groups). Though women's groups, commonly known as Self Help Groups (SHG), exist in the study area, there main function has been restricted to function as a bank where rural women deposit small amount of money every month as savings and can be used in face of crisis.

Agricultural Water Management (AWM). AWM is generally perceived to be a key step in improving low-yielding smallholder farming systems. AWM systems can be classified into several categories like soil and water conservation, run-off harvesting and management, supplementary irrigation, various irrigation technologies and conservation agriculture. For area with high surface runoff, like the present study area, **rainwater management strategies** through building of bunds, ridges, broad-beds and furrow etc. helps in concentrating rainfall through runoff to cropped area or other use. Terracing, contour cultivation, conservation agriculture etc. can maximize rainfall infiltration, thus increasing plant water availability. On the other hand integrated soil, crop and water management through conservation agriculture, improved crop varieties, soil fertility management, crop rotation and intercropping can significantly improve the plant water uptake capacity. Out of the several rainwater harvesting systems, **supplemental irrigation systems** are found to be affordable and appropriate for single household or small community investments and has the capacity to bridge dry spells and thereby reduce risks in rainfed agriculture. They are external rainwater harvesting systems that collect runoff from watershed areas outside the cultivated land and add it to rainfed cropland. The amount and timing of supplemental irrigation, particularly in water scarce areas, are not to provide water throughout the growing season but to ensure a minimum amount of water during critical stages of crop growth to help in optimal growth yield. Hence, supplemental irrigation systems can help in overcoming the uncertainties from rainfall variation in the study area. **Conservation agriculture** is also one of the most important strategies for enhancing soil productivity and moisture conservation. Noninversion systems, which replace conventional ploughing with ripping, subsoiling, and no-till systems using direct planting techniques build organic matter and improve soil structure. Conservation agriculture involves minimum soil disturbance and encompasses land preparation techniques that reduce labour and improve soil fertility and soil and water conservation; these are soil tillage practices that maintain or improve soil structure and increase infiltration and water holding capacity. Conservation agriculture is a premier practice characterized by short hydro-cycles. It is very efficient with reported crop yield increases ranging from 50 to 150 percent (Ngigi, 2003).

Shifting non-productive evaporation to productive transpiration. In semi-arid and dry sub-humid areas up to half of the rainwater falling on agricultural land is lost as non-productive evaporation. This non-productive evaporation can be shifted to productive transpiration through management of soil physical conditions, soil fertility, crop varieties and agronomy. This transfer of the evaporative loss into useful transpiration by plants is a particular opportunity in arid, semi-arid and dry sub-humid regions.

Crop varieties and diversification. Low crop yields result from degraded lands, inherent low soil fertility, nutrient depleted soils, unreliable rainfall and inadequate water supply related to climate change and variability. Given that shorter rainy seasons and increasing rainfall variability are predicted, shift to cultivating crops that are more tolerant of water stress or shorter rainy seasons, such as switching to maize and sorghum, either as a long term change or as climate prediction information might suggest the likelihood of drier seasons. Crop diversification, which can be defined as increasing the number of crops or the varieties and hybrids of a particular crop, is a potential farm-level response to climatic variability and change. Like in the present study area, high yield, short duration paddy variety has been introduced in response to changing climatology. However, introduction of other crop varieties is highly limited due to limited water availability. To diversify, the farmers can cultivate oilseeds, pulses, colocasia and sweet potato in the study area. Mixed cropping can be introduced in the study area like Maize-Jowar-Pulses.

At the community or household scale, adaptation to unseen challenges leading to water insecurity can be mainly reduced by practicing **rooftop rainwater harvesting**. However, individual or community level rainwater harvesting is found to be totally absent in the study area. Simple designs like roof top harvesting can be used to meet household demand, if not for drinking and cooking use, but for hygiene and sanitation purpose. Community level rainwater harvesting can be taken up as an initiative in rural areas like Purulia where schools or community buildings can be used to trap rainwater which can be stored for future use. Other than this, effective operation and maintenance of water sources (discussed in the earlier section) can significantly improve the water availability of household throughout the year. Introduction of water prices, to rationalize water use, is not a viable option for rural areas like Purulia as people are highly poverty stricken and asking prices for water use from improved water sources may lead them to use unimproved sources. Rather, using water storage practices at home with proper safety measures and creating awareness about less water wastage may help the households in responding to uncertainties.

9.3.2.2 Support System

Support system in the present framework mainly refers to the assistance or supports needed by the GP for the effective functioning of the framework. During the present study, the major hindrances are identified and the support system has been planned accordingly.

Institutional Support

Support from various institutions is a vital pre-requisite for the proposed framework to act. As in the case of present study area, the GPs have been hesitant to take over schemes for operation and maintenance due to both lack of technical capability as well as funds to run the schemes. To achieve higher levels of involvement, institutions needs to be strengthened, clear cut roles and responsibilities have to be given to them and their capacity should be enhanced. Some of the specific institutions, with their roles and responsibilities are given underneath:

- District Level: A separate multidisciplinary institutional body, **District Water and Sanitation Mission (DWSM)**, has been established to get action plans and projects prepared and examining them for sanction. In case of the present framework, DWSM can initiate the planning and management of the framework and involve various line departments like district statistical office and district department of agriculture to assist in the investigation using RWII. It can also direct each GPs to carry out resource assessment and report to the respective *Blocks* who will then report to DWSM. DWSM can include the findings of RWII in the District Water Vision and action plans and projects can be prepared for fund sanction to carry out the subsequent processes.

- *Block* Level: ***Block* Resource Centres (BRC)** are the newly proposed institutional set up at the *Block* level to provide continuous support in terms of awareness generation, motivation, mobilisation, training and handholding to village communities, GPs and VWSCs. BRC can play an important role in the next phase of resource assessment. It can act as the central planning body for carrying out the Participatory Rural Appraisal exercises and household survey in each GP and can provide training to the GP and VWSC members about carrying out the resource assessment. BRC will also play a significant part in execution of the software inputs towards source sustainability and in creating awareness about various adaptation strategies. It can provide training to the GP and VWSC members and communities about the operation and maintenance of water sources as well as to local communities on how to practice various adaptation strategies. It should act as a coordinating and monitoring agency and evaluate the functioning of the framework. As per the functioning of the framework, the BRC can propose various schemes and projects to be included in the GP plan which will be subsequently submitted to DWSM for appraisal.
- Gram Panchayat Level: GP is the focal point of the proposed framework. Findings from investigations carried below and above GP level should be included in the GP plan for the subsequent submission to *Block* level and district level. The identified priorities and demands should be included in the GP plan for effective mobilization of funds from higher levels. The GP should clearly notify the priority issues that need to be addressed on an emergency basis under its jurisdiction. It should also provide a menu of responses that can be carried out to address those issues. GP should also monitor the progress of all the processes being carried out as in the framework and should also coordinate the swift flow of funds.
- Village level: **Village Water and Sanitation Committee** (VWSC) is proposed as a standing committee of the GP and responsible for planning, implementation, operation, maintenance and management of the water supply system. The VWSCs have to be involved in implementing plans to agreed budgets and timeframes, and provide annual reports on progress and performance along with the GP and provide annual reports on progress and performance to the *Block*. Roles and responsibilities of VWSCs have to be strengthened as they are the locally available institutional body which the villagers have easy access to. VWSC members should be given proper training on carrying out prior survey for source sustainability as well as on carrying out operation and maintenance works. VWSCs members should also create awareness among local

communities on operation and maintenance, hygiene and sanitation and water use in the villages. VWSC should conduct training programs with other nodal agencies to engage communities in the proposed framework and create awareness among them regarding the various adaptation strategies and their utility which they can practice. Funds should be allocated to VWSCs such that they can meet the immediate needs of the villages.

- Community Level: A significant lack of water user associations or farmer association have been noticed in the present study area. This often leads to gap in communication between the local communities and VWSCs/GPs. The present study proposes creation of **Beneficiary Committee (BC)** in each village. Beneficiary Committee refers to the community who are supposed to get direct benefits from the existing as well as the proposed water sources. The composition and functions of the beneficiary community should depend on the type of source. For example, if the water source is for agricultural use, then BC will contain village farmers as its members and their main function would be to operate and maintain the water source such that the source become sustainable. Also, the farmer BC can have regular meetings and discussions among them on various adaptation strategies that can be practiced by them. The priorities and demands identified through this discussion should be put forward to VWSC and/or GP for their consideration. BC can be integral part of source sustainability and operation and maintenance processes of the proposed framework. Instead of including all the beneficiaries, representatives can be selected and, in case a source for domestic water is proposed, half of the community members should include women. The VWSC can coordinate the selection of members in BC and should impart proper emphasis on inclusion on marginalized and vulnerable population. VWSC should have periodic meetings with them and monitor their function and progress. BC will work under the supervision of VWSC and BC members can be provided training by BRC, GP and VWSC for repairing the water sources. BC can be provided monetary support from VWSC in case a water source fails and BC can spend the money in buying the spare parts and repairing the water source. In this way, more community members can be engaged in the local decision making process and it will be easier to meet the demands and priorities of local communities.
- Non-Governmental Organizations (NGOs): **Involvement of NGOs** is an integral part of the proposed framework. The proposed functions of NGOs include community mobilization, information dissemination, institution building, and planning, providing

training, monitoring and social audit. In addition they may also be involved in planning, designing and piloting of model innovative schemes which require a high degree of handholding.

Financial Support

Finance has always been the Achilles heel of local government in India, the availability of adequate funds is among important factors for efficient and active functioning of the GPs. Due to their limited financial capacity, local government has to depend on provincial, district and state administration for fluent fund flow. Financial constraints have been identified as one of the major barriers for provincial administration also. Some of the potential sources of funds that can be used for the present study are listed below:

- **Funds available under various government projects and schemes** can be streamlined for use. For example, in case of the study area, one of the potential livelihood scheme such as National Rural Employment Guarantee Act provides 100 days assured job opportunities to the poor unskilled workers through the GPs and the local *Block* Offices. This scheme can be used to meet the expenses of human capacity to be involved in implementation of the framework like salary for the volunteers who conduct questionnaire survey or labours who work in the construction of different water harvesting structures. Funds under similar other government schemes like National Rural Drinking Water Mission, Rainwater Harvesting Schemes, Total Sanitation Scheme and Integrated Action Plan can be used for the expenses under the proposed framework.
- Funding are also available from several **NGOs and national and international developmental agencies** that can be mobilized for the implementation of the proposed framework.
- As identified in the present study, a meagre proportion of fund available with the provincial administration is available for operation and maintenance of water sources. Allocation for Operation and Maintenance should be increased to take care of Capital Maintenance costs of pipes, pumps etc. to improve reliability of service delivery.
- For sustainability of the rural water supply schemes, all the completed schemes are handed over to PRI/VWSC for operation and maintenance for which incentive fund of 10% of State allocation has been provided in the NRDWP guideline. A proportion of this fund can be provided to the communities for maintenance of water sources.

- In addition, beneficiary committee (as proposed in the present study) may develop a **community fund** where money will be collected from all the beneficiaries of a water sources, which will can then be used for various maintenance and construction activities related to the particular water source. The collection and expenditure from the fund should be transparent and presented before the beneficiaries during the meetings. VWSC can serve as an overlooking authority over the collection and expenditure of the community fund.
- **Adaptation fund** can be created at the district level to support the development of adaptation strategies in rural areas facing high water insecurity and climatic variability. The fund can be mobilized to the local areas through provincial administration for implementation of various strategies. The auditing on the expenses should be carried out by the finance department at the district level. For India, Government has established the National Adaptation Fund on Climate Change (NAFCC) to meet the cost of adaptation in areas that are particularly vulnerable.

Technical Support

Ensuring water security through the proposed framework requires a background scientific and technical knowledge. Local governments, like GPs in the present area, as well as local administration and district administration may not have the required expertise or may not be adequately equipped to carrying out the technical assessments. Below are the possible technical support that would be needed for the proposed framework to work:

- The source sustainability process requires a substantial amount of technical and scientific information for carrying out prior survey. Similarly, technical knowledge and engineering skills are required for construction of a sustainable water harvesting structure like sub-surface dykes and check dams.
- Scientific expertise can be obtained from central nodal agencies like Central Ground Water Broad, Rice Research Institutes, District Agriculture Office, Regional Meteorological Centres, Indian Agricultural Research Institutes, Public Health and Engineering Department etc. to understand the topography, hydrology, geology, geomorphology, hydrogeology etc. of the area.
- The district can procure this knowledge from the nodal agencies and then distribute it to the *Blocks* and subsequent GPs.

- **Outsourcing** can be used to enable GPs to explore options to access professional experience and skills. District can support the GPs with appropriate knowledge and tools to prepare, tender and manage service agreements.
- Aquifer mapping, hydrogeological and hydrological studies, land use planning, agronomical studies, soil studies etc. can be outsourced to appropriate agencies. The reports should be submitted to the district administration. Both soft and hard copies can be kept with **NRDMS centre** (Natural Resources Data Management System) in the district which can be provided to the *Blocks* and GPs on demand.
- Satellite maps available with NRDMS centre should be properly interpreted and the communicated to district and *Block* administration. This would help in analyzing the feasibility of the proposed schemes or projects in the GP, *Block* or district plan.

Social Support

Increasingly, there has been a shift from state-led, technocratic water resources management programmes to 'participatory' and 'community-based' water management. Large scale infrastructure-focused water development projects often have had negative social and environmental impacts (McCully, 1996). Thus, there have been changes in the governance of water resources from state-controlled and managed to a focus on community based institutions. Social support in the form of community engagement in every phase is a crucial pre-requisite for the proposed framework.

Community members are expected to participate in schemes or projects in order to enhance equity and efficiency, as well as to feel greater ownership towards them, which is also expected to lead to better water resources management and greater ecological sustainability. For the proposed framework, more than participation, engagement of communities in every step of the process cycle is highly important. Community engagement is prioritized as it tends to imply greater involvement of a wider range of people and can be defined as any process that involves the community in the problem-solving or decision –making and uses community input to make better decisions (IAP2, 2003). Even before construction of physical structures for harvesting water, it is important to engage community and have their views and opinions about the proposed structure and the communities have to be convinced about the utility of the proposed scheme. Unless and until the utility of the scheme is clear to the community, it cannot get fully accepted and utilized. This invokes notions of inclusion, of people's abilities to make decisions, and to voice opinions ⁄concerns that are heard. Similarly, creation of beneficiary committee and community fund may incur a sense of ownership and responsibility among the community towards the communal sources of water. Moreover, community opinions on locations of the sources are also an important input towards source sustainability.

In the present study area effective community engagement can be achieved through **periodic meetings** with the community members and informing them about the progress, sanctioning and construction of the proposed schemes or projects facilitated by local institutions**, carrying out various research exercises** with them like resource mapping, transect walk, crop calendar etc., and **creating awareness** among them through mass media vehicles like road show, posters, leaf lets, folk drama, songs, wall paintings, radio and television spots etc., by providing various developmental incentives (discussed earlier). For motivating communities to practice the adaptation strategies, **pilot scale studies** can be carried out and the results should be disseminated to them.

Improving other rural infrastructures like connectivity, health facility, sanitation, education, energy, bank etc. may fulfil the gaps in development and hence increase the adaptive capacity of rural people. Also, establishment of **connecting markets and storage centres** and ensuring that the rural producers get a fair access to nearby urban markets may improve the economic status of rural households and, hence, should be an immediate priority for market based economic development. Creation of markets at strategic locations with proper access to urban markets, therefore, need to be facilitated. With improved socio-economic and education status, the rural community will be more aware and would take active participation in the decision making process.

Social Audit is an effective way of monitoring the progress and performance set out in the proposed framework. It has already been practiced in auditing the progress of the National Rural Employment Guarantee Act under Government of India and is reported to be significantly effective. However, it has not yet been included and implemented in any of the national level schemes or projects on water supply. The present study finds the concept of social audit highly appropriate and recommends its inclusion in the proposed framework. The social audit can be carried out by GP or VWSC by following the steps listed below:

- Place the main issues for discussion and decisions in the village meeting or *Gram Sansad*, including selection of sources and systems, community engagement, operation and maintenance and fund flow
- Facilitate and ensure active participation of community members especially women, lower castes, tribal community and poor households in the village meeting
- Ensure inclusion of poor, tribal, lower castes and marginalized households in the beneficiary committee

- Display key information on in public places about the proposed activities, budget, milestones and time schedule, contractor details and progress and performance reports
- File and maintain all key documents regarding the proposed framework and the progress and share it with any one from the village who wants to know details
- Prepare a citizen's charter to receive complaints.

GPs or VWSCs must send the annual progress report to the *Block* administration as to whether they are on schedule with respect to milestones identified in the GP plan and expenditures are within the budget estimates.

9.3.3 Implementation Plan

Implementation of RWSF requires identification of the appropriate potential implementers and stakeholders. Apart from the local community, the local government (represented by *Gram Panchayats*) and local administration (represented by *Block* administration) are identified to be the two main stakeholders for the execution of the framework. Though some NGOs are working in some pockets towards upliftment of Purulia, their active involvement is mainly limited to agricultural, education and health sectors. Specific NGO involvement in improving the water status of the district is negligible. Though the local community is found to completely depend on local government and local administration (*see **chapter 8***), many administrative bodies and departments exist that increases the complexity in implementation process. Hence, the present study emphasizes the establishment and effective functioning of separate bodies like DWSM and BRC (*see Institutional Support under section 9.3.2.2. Support System*). The formation of this institutional bodies have already been proposed by Government of India under the 12th Five Year Plan. However, clear and distinct roles and responsibilities are yet to be assigned.

All the projects and schemes regarding improvement of the water system is carried out through the three tiered Panchayat System (*shown in **Figure 3.3** and explained in **chapter 3***). However, *Block* offices are given the responsibility of supervision and channelizing the funds received from higher authorities under different projects and schemes. Other than this, various existing departments in the district administration can play an important role in the implementation of the framework. Some of the departments

- **Responsible departments and areas of operation**
  - Department of Agriculture (Distribution of agricultural facilities)

- Backward Classes Welfare Department (Educational and economic upliftment of Backward classes people in the district)
- Forest Divisions (Conservation and maintenance of forests and its resources)
- Public Health Engineering Department (Construction and maintenance of both groundwater and piped water supply system)
- Natural Resource Data Management System (Develop and maintain integrated database and provide geo-information support to line departments)

❖ **Implementers**

The main implementer of the current schemes and projects, both nationally funded and/or state funded, is the District Administration of the study area. The received funds are distributed to the *Blocks* who further channelize the funds to corresponding *Panchayat Samitis* and *Gram Panchayats* under its jurisdiction (*see* ***chapter 3*** *and* ***chapter 8***). The current existing system of program implementation has been recommended by the Government of India as a tool of decentralized management. However, decision making still remains mostly concentrated at the higher hierarchical level. Therefore, within the current hierarchical system, the needs and priorities of the local communities are often overlooked and rarely addressed by the higher levels. The decision making power often remain restricted to the *Gram Panchayat* level. **Table 9.2** highlights the roles and responsibilities of some potential stakeholders who can contribute significantly to the implementation of the proposed RWSF (**Figure 9.2**) in the study area.

Since the proposal for attaining water security is delineated for the study area and the steps are clearly identified on what can be done, the *Gram Panchayat* should call meeting with the villagers (*Gram Sansad*) and seek their approval before submitting it to the District (DWSM) for approval and financing. The technical options and their financial impact on operations and maintenance costs should be clearly discussed in these meetings. The *Gram Sansad* should approve the most suitable options considering what the community needs, wants and can afford. The approved provisions should be discussed at *Panchayat Samiti* level and with BRC before their inclusion into the annual plan to be submitted to DWSM. When the DWSM assess the plans, they should review technical, financial and management aspects of the proposed provisions.

9.4 Concluding Remarks

The proposed RWSF is suggested to be active at a local government level and effective community engagements has been clearly included at each phase of the framework. The framework also demonstrates the various support systems needed for its operation and have suggested formation and inclusion of various institutional, financial, technical and social supports that may work towards attainment of water security in rural areas. The Rural Water Security Framework is first of its kind that aims at ensuring and strengthening water security in rural areas and can be taken up for consideration and implementation in other rural areas also.

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Table 9.2 Proposed roles and responsibilities of some of the potential stakeholders in the implementation of RWSF

Tasks	Beneficiary Committee (BC)	VWSC	Gram Panchayat (GP)
Meetings and organization	• Hold meetings for decisions at key stages • Nominate and constitute VWSC	• Meet once a month • Attend BC/GP meetings	• Meet as required by law/rules • Appoint VWSC
Resource assessment	• Conduct surveys at household and community level • Delineate the issues and priorities	• Conduct RWII assessment • Supervise, conduct and analyze surveys and survey findings • Report the survey findings to GP	• Review and evaluate the resource assessment findings • Prepare and update plans
Source Sustainability	• Evaluate the utility of water source • Assess accessibility • Ensure seasonal sustainability • Provide inputs to VWSCs and GP	• Estimate the water budget • Identify risks • Mobilize the community/BC to provide inputs	• Outsourcing the support • Communicating the findings to local community • Incorporate the findings in plan
Operation and maintenance	• Day to day operation and maintenance • Collection of community fund • Sorting the spare parts needed • Repairing the water sources • Creating awareness about operation	• Buy spare parts • Training programs • Awareness creation • Hire and keep record of locally available mechanics • Financial management • Authorizing expenditure	• Channelizing funds and supports to VWSCs • Supervising and monitoring the progress done • Organizing training programs for VWSCs • Prioritizing the work to be done
Implementation	• Community engagement • Ensuring participation in VWSC and GP meetings	• Carry out resource assessment • Assist in prior survey • Identify the needs of the community and ensure community engagement	• Approve works • Submit the plan to BRC and DWSM • Supervising and monitoring • Channelize funds and supports
Monitoring, Audit and Reporting	• Social Audit • Analyzing the problems and take actions or report accordingly	• Review the report of Social Audit • Monthly review of funds and expenditures; Bookkeeping • Quarterly reports to BC/GP on implementation progress and operational performance	• Review the report of Social Audit • Half yearly review of budgets • Annual reports to Block/BRC on implementation progress and operational performance

CHAPTER 10
CONCLUSION

"Anyone who can solve the problems of water will be worthy of two Nobel prizes – one for peace and one for science."

John F. Kennedy

Chapter 10: Conclusion

The present research attempts to quantify the status of water security in a rural district in India. The probable causes behind the current status of water security has been evaluated at different scales – provincial, community and household – and their impacts have been delineated in detail. The study employed various qualitative and quantitative methodologies to derive the conclusions. The novelty of the present research lies on the fact that it is one of the few studies that have quantified rural water security. Moreover, the attempt to implement the concept of water security at a local scale is a unique feature as water security has been mostly applied at an international, national, transboundary or basin level. In an endeavor to ensure water security at rural scale, the findings of this study has been used to develop a Rural Water Security Framework. The framework employs basic do's that should be carried out and the precautions that need to be taken to ensure water security. The major conclusions drawn from the present research are provided below.

Rural Water Insecurity Index (RWII): A tool to assess the status of water security in rural areas

The first attempt of the current research is to find out how water secure are the rural areas. To assess, a drought-prone, dry sub-humid and rural district in India, Purulia, has been selected. Three dimensions, supply driven insecurity, demand driven insecurity and adaptive capacity have been considered to assess the status of water insecurity in the rural area. A tool, Rural Water Insecurity Index, is developed based on 21 variables that represents these three dimensions. To make the index more powerful and technically efficient, principal component analysis is used to compute the index scores. The index is applied at *Block* level, i,e, the lowest rural administrative unit in India. The findings helped in segregating the *Blocks* into four groups - low, medium, high and very high water insecure *Blocks*. Out of the 20 *Blocks* in the district, only two *Blocks* are found to have low water insecurity and nine *Blocks* are found to exhibit very high to high water insecurity. The spatial mapping of different dimensions of water insecurity also demonstration large scale variability. Interestingly, adaptive capacity is found to influence the current water insecurity and negate or minimize the influence of supply and demand driven insecurity. A higher adaptive capacity is found to upscale the status of water security and *vice versa*. In addition, the tool helps in identifying the different components that need improvement to improve the water security status in the studied rural area. In summary, the scientific information imbedded in RWII can be easily communicated to decision makers and politicians. Also, the tool is based on existing data which are easy to obtain and capture the essence of the complexity of water security yet is relatively easy to implement. RWII is a unique tool developed in this research and, on a broader scale, can be adopted for assessing water insecurity in other rural areas.

The determinants of household water consumption

Water security is a concept that displays wide variability across different levels and assessment at a wider scale may mask the realities at a lower scale. Hence, it is essential to assess household water consumption and the determinants that control it. To achieve this objective, 1780 households from 330 villages are surveyed to carry out the present study. Nine dimensions are chosen to represent household water consumption and assessment has been carried out based on 29 variables divided under this nine dimensions. The volume of per capita water consumption in the rural households are found to be much below the various recommendation levels. The time spent on water collection and distance to water sources enforces that accessibility to water sources is much below the guideline in the study area. Multiple regression analysis results delineated 11 variables that have significant control over household water consumption, household size being the dominant among them. Interestingly, household water consumption is also found to be influenced by household’s participation in village meetings and whether their priorities are properly addressed in the decision making process, which implies that active participation and engagement of households are some of the major determinants of household water consumption in rural areas. This fact can also be used to motivate more community participation in local decision making process. Households are found to demonstrate varied water consumption pattern based on their socio-economic status, calculated on the basis of asset ownership. ANOVA and post hoc test results revealed significant differences in availability, accessibility, choice of water treatment and access to toilets among the households with different socio-economic conditions. The richest group of households are found to be relatively more privileged than the poorer households. Understanding the determinants that influence household water consumption helps in identifying the issues that need to be focused to ensure water security at the household scale, the principal users of water. Though literatures exist on residential water demand studies, mainly in urban areas, household water consumption studies focussing on rural areas are difficult to find. Hence, the present research findings are definitely going to enrich the knowledge base on household water consumption patterns and play a vital role in the decision making process and in formulation of policies.

Local climate assessment and its possible impact on local livelihood

It is necessary to understand the temporal distribution and changing patterns in local climate variables, mainly rainfall, to manage natural resources or agricultural development well. District level analysis of rainfall trends, based on the data from local rain gauge stations, presents useful information to the district authorities. Long term rainfall (1950 – 2012) analysis at different timescales revealed an insignificant but increasing trend in annual rainfall as well as significant increasing trend of rainfall in pre-monsoon season. Because rural communities depend on rain fed paddy cultivation, monthly rainfall trends are very important for understanding the probable impacts of varying rainfall at different stages of crop growth. The study area witnessed an increasing rainfall trend in the sowing phase of paddy. But the transplanting and tillering phase, spanning from July to September, experienced decreasing rainfall, which in turn could have affected the crop yield. Because paddy cultivation requires reliable water supply, the varied rainfall intensity between the monsoon and post-monsoon season emerged as a serious concern. As the district is rural, poverty stricken and dependent on agriculture, decreasing monsoon rainfall compels local communities to shift their cropping season, use short duration rice variety, search for alternative livelihood or migrate. The initial climate data analysis and the subtleties of climate change provided information that allowed aspects of the climate-led changes in livelihoods to be recognised. Proper dissemination of results of such studies to the local rural communities and authorities will help them in understanding the local climate pattern in their area, thus preparing them to formulate effective decisions and respond to the uncertainties.

Community perception and responses to water insecurity and climatic variability

Reacting to an action is an inherent human nature. Similarly, people are also responding to climatic variability across the world by adopting various strategies. In some cases the responses are sustainable, in others they are not. The main aim of this study has been to understand how local village communities perceive water insecurity and climatic variability and how they respond to it. Three village communities – farmers, women and elders from 16 villages spread across six different *Blocks* in the study area were included in the study. Various Participatory Rural Appraisal tools have been employed to explore community perceptions. The district is found to experience wide climatic variability mostly rainfall variability and communities relate physical, financial or performance losses to these changes. Various factors have been perceived by the participating communities that influence water security in the area. Out of them, management factors like lack of maintenance, scheme breakdown, siltation etc. are found to be dominant than climatic or social factors. The communities pinpointed the lack of source sustainability that leads to severe water crisis during the lean period. As the farmers identified the different issues they have to face regarding agricultural loss, women highlighted the problems they have to face in their daily life due to the prevailing water insecurity. In spite of facing several water insecurity related issues in their daily lives, the responses are found to be largely unsustainable and are practiced just to overcome the immediate crisis. Though some adaptive strategies are found in the agricultural sector, strategies practiced at households and by women are mostly coping strategies. The study reveals how rural communities, despite their limited capacities, try to cope to the changes around them. Few of the practiced strategies are found to be indigenous to the study area. However, the gap in perceiving the changes and responding to the changes in rural areas is quite prevalent from this research.

Identification of prioritized actions to attain water security

Suggestions are sought at community, local government (*Gram Panchayat*) and local administration (*Block*) on how to improve the water security status in the rural area. Respondents' prioritized actions, identified the agencies who will be responsible for the implementation of these actions and specified the barriers that may possibly hinder the execution of these actions. The prioritized actions suggested in all the three levels are found be mostly supply side approaches. Demand side approaches are completely missing in the suggested actions that reveal the lower status of water management in the study area. Also, communities are found to be wholly dependent on local government and administration and there has been no initiatives, till now, to include them in the local decision making process regarding water. Along with the natural barriers like undulating topography and hard rock, financial constraints have been pinpointed to be one of the significant hindrances towards attaining water security.

Development of Rural Water Security Framework

In summary, the key findings of the present study revealed a gap in the proposed national or state level policies and regulations and their execution at ground level. Hence, as a policy implication of the present research, Rural Water Security Framework has been proposed. The framework consists of two main components – the process cycle and the support system. The process cycle includes various steps like resource assessment, source sustainability, operation and maintenance, and adaptation strategies that needs to be followed whereas the support system includes the various assistances in the form of institutional support, financial support, social support and technical support that are imperative to run the process smoothly. Using the community as well as administrative structure of the present study area as a background, the framework provides detailed methodology on implementation of the framework. It also provides a menu of possible approaches and provisions that can be taken up to strengthen water security in rural areas. In addition, the framework emphasizes community engagement at each and every step and has tried to implement the framework within the existing institutional structure to minimize complexities. Rural Water Security Framework is a unique attempt towards attaining and strengthening water security in rural areas and can be adopted for implementation in other rural areas also.

Limitations of the Research

Firstly, the study adopted a combination of qualitative and quantitative research methodology. Participatory Rural Appraisal tools such as Focus Group Discussions, Structured Interviews, Semi-structured interviews, Questionnaire survey have been extensively used in this study. While the study executed extreme precaution in performing the above mentioned PRA exercises, the results might have some systematic bias due to the inherent limitations of these tools. Additionally, the small sample size may not necessarily allow the projections of the results over the entire population. Yet, it is firmly believed that the results are representative of the ground realties irrespective of the sample size.

The unavailability of observed data on quantities of water consumed for various purposes and actual time devoted and distance travelled to water collection by households implied relying on households' recall ability to give this information. This may not necessarily correspond to actual quantities used and hence constitutes a limitation to this study.

Also, the Rural Water Security Framework is now only a proposal which has not been tested for its effectiveness and efficacy due to time constraints. Hence, it needs to be implemented at a pilot scale to check its applicability before being considered.

Scope for Future Research

The current research focusses on water security assessment and implementation in rural areas through the development of Rural Water Security Framework. The research outcomes have highlighted a number of areas for future research. Additional research to further develop the ideas and findings in this dissertation would include both theoretical and empirical work. One, water insecurity mapping based on Rural Water Insecurity Index (RWII) needs to be subjected to further testing, application, and reiteration for a more extensive range of dry sub-humid as well as other rural areas. Although RWII is designed for dry sub-humid environments in the present study, it needs to be expanded to identify comparable datasets that allow the RWII framework and indicators to be applied in other rural areas with climatic characteristics. Further work can be done to determine how to include measures of stochasticity of a phenomenon in the index; for example, measuring the timing and magnitude of water demand from irrecoverable losses would be a useful indicator because water availability might be affected by increase in temperature in the area.

Second, there is always a scope for inclusion of other variables and see their impacts on household water consumption. These variables may vary with every location and their relationship with household water consumption can be redefined for other locations. Another could be by incorporating some policy-related variables and linking household water security with them.

Third, the Rural Water Security Framework can be worked upon further and should be applied in other rural areas to make it more robust and acceptable. There is always a scope for improvement in the framework. Further investigations can establish whether interventions in rural water supply and management change the function and effectiveness of the framework. This is needed to give policy-makers the required feedback to improve on framework where necessary.

***

APPENDIXES

APPENDIX I

BLOCK LEVEL QUESTIONNAIRE SURVEY FOR THE ASSESSMENTOF WATER INSECURITY IN PURULIA DISTRICT, WEST BENGAL, INDIA

Brief introduction about the questionnaire

PART 1

1) This study aims to analyze the **Block level water insecurity** of local people living in **20 (Twenty) Community Development Blocks** of Puruliya District. This questionnaire is focused to assess the household level vulnerability assessment to climate change and water scarcity.

2) This questionnaire has been prepared by the Sustainable Rural Development Laboratory of Kyoto University. It is targeted to create a **Rural Water Insecurity Index (RWII).**

3) **All the information retrieved from this questionnaire will be used for the purpose of academic research only and shall not be given to any other party, except research team members from Graduate School of Global Environmental Studies, Kyoto University.**

4) **The name and address of the respondent is optional and it will not be disclosed in any circumstances.**

5) This questionnaire contains 5 pages and it will require approximately 30 minutes for filling up. We highly appreciate for your precious time and sincere cooperation.

RURAL WATER INSECURITY INDEX (RWII) **Block Level Survey**		Date: / / 2013 Q. No.:- --------------
District: Purulia	Subdivision:	Municipality/ Block:

Name of the Respondent:	Designation:
Official Address:	

Name of the Enumerator: ________________________________

1.	What is the **average annual population growth** of the block?
2.	What is the average **population density** of the block?
3.	What is the **Age Dependency Ratio** of Block population? *[Population below 15 years and above 65 years]*
4.	What is the **current rural population** of the block?
5.	What is the **average population belonging to the underdeveloped section** in the block (Population)?
6.	What is the **sex ratio (female: male)** of the block?
7.	What is the population **above and below poverty line**?
8.	What is the **total number of BPL card holder** in the block?
9.	What is the **% of migrants** moved outside the block? *[This includes moving out for temporary employment, seasonal employment and migration for other livelihood. Does not include migration for studies and marriage]*
10.	What is the **total literate population** of the block?
11.	What is the **ratio of female literate to male literate** population of the block?
12.	What is the **% of total population** covered under **MNREGA Scheme**?
13.	What is **the workforce participation rate** of the block?
14.	What is the **% of population dependent on agriculture** for livelihood?
15.	What is the current **occupational distribution** of the block?
16.	What is the **total agricultural land out of total land area (in hectares)** in the block? *[If it is in other unit, write it.]*

Question 5:

Scheduled Caste	Scheduled Tribe	Other Backward Class	General

Question 7:

APL	BPL

Question 15:

Main Workers	**Cultivators**	**Agricultural Labors**	**HH Industry**
Marginal Workers	**Non Workers**	**Other workers (specify):**	

17.	What is the percent of **cultivated area with irrigation facility** in the block?
18.	What is the **approximate** area (in hectares) of agricultural land under **permanent and temporary crops**? *[If it is in other unit, write it.]* Permanent crop area: ___ Temporary crop area: ___
19.	What is the % **paved road coverage** as per the block land use? *[Land area]*
20.	What is the % **electricity coverage** in the block? *[Total population coverage]*
21.	What is the % of population living in **settlements** like earthen buildings, mud houses etc.?
22.	What is the % of population with **various assets** in the blocks? *[Assets include television, motorcycle, car, jeep, refrigerator etc.]*
23.	What is the % of population **borrowing credit from both public and private sources** to maintain daily life?
24.	What is **the total vegetation cover** out of total land area of the bolck? Total land area (Ha): ___ Total vegetation cover (Ha): ___
25.	What is the total **% of wasteland (barren) area** compared to the total land area in the block? Total land area (Ha): ___ Wasteland area (Ha): ___

PART 2

26.	What is the **total area covered by surface water bodies** compared to total land area in the block? *[Surface water bodies: Ponds, lakes, rivers, etc.]* Surface water body area: ___ Total land area: ___
27.	What is the **average per capita water availability** of the block?
28.	What is the **total number of public water taps per 100 population**?
29.	What is the total **% of population** covered by piped water supply?
30.	What is the **net groundwater availability** of the block?

31.	What are the total number of existing and functional **groundwater sources** in the block? Dug wells Deep Tube wells Shallow tube wells Boreholes	
32.	What is total area under **dam or other water storage infrastructure** in the block?	
33.	What is the total number of **River Bed Tube Wells** in the block? *[The number of water harvesting structures extracting water from river]*	
34.	What is **the % (or amount) of groundwater withdrawal** for (a) irrigation? (b) domestic use?	
35.	What is total number of households with supply from **contaminated groundwater sources** identified as **unsafe**? *[Or areas where the qroundwater is considered unsafe]*	
36.	What is the total population with **improved sanitation facility** in the block? *[For e.g. Enclosed pit, Enclosed improved-ventilation pit, Enclosed pour-flush, Enclosed flush, Connection to public sewer, HH septic system etc.]*	
37.	What is the **livestock holding size** of the block? *[In absence of data on total number of livestock, Livestock holding per 1000 persons should be calculated.]*	
38.	What is the % of **water loss from irrecoverable sources**? *[From evapotranspiration of applied water, loss from distribution system etc.]*	

-------END-------

APPENDIX II

QUESTIONNAIRE SURVEY FOR THE ASSESSMENT OF HOUSEHOLD WATER CONSUMPTION PATTERN IN PURULIA DISTRICT, WEST BENGAL, INDIA

This study aims to analyze the **household scale water consumption pattern** of local people living in different **Community Development Blocks** of Purulia District.

This questionnaire has been prepared by the Sustainable Rural Development Laboratory of Kyoto University.

All the information retrieved from this questionnaire will be used for the purpose of academic research only and shall not be given to any other party, except research team members from Graduate School of Global Environmental Studies, Kyoto University.

The name and address of the respondent is optional and it will not be disclosed in any circumstances.

The questionnaire is divided into three parts-

Part 1: General information about the household (social, economic, livelihood, physical, health, education etc.)

Part 2: Status of water availability, use, quality etc. of the household.

1) This questionnaire contains 8 pages and it will require approximately 30– 45 minutes for filling it. We highly appreciate for your precious time and sincere cooperation.

2) **Abbreviations:** *Q. No.* – Questionnaire Number
   HH Code - Household Code [**BPV X:** First initials of **B**lock, Panchayat and **V**illage. X is the number of the household.]
   Subdivision: SE - Puruliya Sadar East, SW - Puruliya Sadar west,
   R - Raghunathpur.

Name of the Enumerator: ____

HOUSEHOLD WATER CONSUMPTION ASSESSMENT **Household Survey**	Date: / / 2013 Q. No.:- -------------- HH Code:-------------

District: Puruliya	Subdivision:	Municipality/ Block:
Census Town/ Gram Panchayat:		Village / Habitation:
Respondent's age: Sex= M(1)/ F (2)		GPS:

Relation to HH head: head (1)/ husband, wife (2) / son, daughter (3)/ grandchild (4)/ father, mother (5)/ brother, sister (6)/ nephew, niece (7)/ son-, daughter-in-law (8)/ brother-, sister-in-law (9)/ father-, mother-in-law (10)/other family relative (11)/ servant, servant's relative (12)/ tenant, tenant's relative (13)/ other (14)

HH head's name: *(Optional)*	HH head's age: *[only if relation not "1"]*
HH head's marital status= married (1)/ single (2)/divorced (3)/ widowed (4)	HH head's sex= M (1) / F (2) *[only if relation not "1"]*

PART 1

1. How many persons **are eating and sleeping together in this house for at least 6 months** in the last one year?

[ ] Number [ ] Males [ ] Females

2. What is the **age distribution** of the family members of the household?
[Make sure that the number of persons adds up to total HH members.]

0-5		6-14		15-64		65+	

3. Is the household registered under **BPL scheme**?

Yes (1)	No (2)

4. Is any member **living out of the house** for **more than 6 months**?
[Excluding the girls who have moved due to marriage or any household students who have moved for studies]

Yes (1)	No (2)

4a. If yes, what is the main reason behind the migration?
[Options can be more than two]

Job (1)	Loss of agricultural land (2)	Degradation of soil quality (3)
Crop failure (4)	Scarcity of water (5)	Others:

4b. Is the migration permanent, temporary, seasonal, return etc.?

Internal migration (1)	External migration (2)	Seasonal migration (3)	Returned migration (4)

5. What is **primary construction material** of the housing unit?

1.Grass/ Leaves	2.Thatch/bamboo	3.Plastic/fabric	4. Asbestos sheets	5. Mud
6. Bricks	7. Concrete	8. Others, specify:		

6. What is the primary **source of electricity** to the household?

1.Electricity from local grid	2.Electricity from national grid	3.Electricity from a generator	4.Electricity from solar cells, hydro power etc.
5.Kerosene Lamps	6.No electricity	7.Others, specify:	

7. What is the primary fuel **source for cooking** in your house?

1.Fuel Wood	2.Cow Dung	3.Leafs and hatches	4.Coal and Charcoal

	5.Kerosene	6.LPG	7.Others, specify:

8. Is there any household member suffering from **chronic illness** like tuberculosis, leprosy, heart disease, arthritis, diabetes, respiratory diseases, encephalitis etc.?

Yes (1)	No (2)

9. **Approximately**, how long (in minutes) does it take to reach the nearest health clinic?
[This include primary health care, Govt. hospitals, nursing homes etc.]

Private Clinic (1)		Primary Health Centre (2)		Block Hospital (3)	
Private nursing home (4)		Government Hospital (5)		Others (6)	

10. How many members of the household are **literate**?

11. What is the **highest completed level of education** of the household head?
[Select only one option]

1. Illiterate		2. Literate (Non-formal)		3.Primary Education	
4. Secondary Education		5. Higher Secondary Education		6. Graduate	
7. Post Graduate		8. Vocational			

12. What are the **main sources of income** in the household?

Agriculture	1	Small Business	2	Government Jobs	3	Private Jobs	4
Daily Labor	5	Vendor	6	Handicrafts	7	Remittances	8
Others (specify):							

[Major source – 1, Minor source – 2]

13. What is the **approximate household income** per day?

[If the monthly income is available instead of per day income, write it down. Also, Add up the income if the earner is more than one.]

1.< Rs. 50	2. Rs. 51 –100	3. Rs. 101-150	4. Rs.151-200	5. Rs. 201-250
6. Rs. 251-300	7. Rs. 301-400	8. Rs.401-500	9. Rs. 501-600	10. Rs. 601 - 700
11. Rs.701-800	12. Rs. 801- 900	13. Rs. 901-1000	14. > Rs. 1000	

13a. How does the **household income vary** throughout the year?
[For the different options refer to the above questions]

	Increase (1)	*Decrease (2)*	*No Change (3)*
During Summer			
During Monsoon			
During Winter			
During most of the year			

14. Are there any members of your family registered with **MNREGA**?

No (1)		Yes (2)		If, yes, how many?	Male		Female	

14a. How **long** you have registered in MNREGA? (*Please mark year of enrollment*)

2005 (1)		2006 (2)		2007 (3)		2008(4)	
2009 (5)		2010 (6)		2011 (7)		2012(8)	

14b. On an average how many **days (per year) of work** you got from the MNREGA scheme?

<10 days(1)		11-20 days (2)		21-30 days (3)		31-40 days (4)	
41-50 days(5)		51-60 days (6)		61-70 days (7)		71-80 days (8)	
81-90 days (9)		91-100 days (10)		>100 days (9)			

15.	What is the **approximate expenditure of the household** in **last one month**? Amount
15a.	How does the household expenditure **vary with seasons**?

	Increase (1)	*Decrease (2)*	*No Change (3)*
During Summer			
During Monsoon			
During Winter			
During most of the year			

16. During the last 12 months, for how many months did you have **sufficient food** to feed all members of your household?

Months	

17. Which one of the following does your household possess?
[Choices can be more than one]

Bank/ Post office savings account (1)	Health insurance (2)	Fixed deposits (3)	Car (4)	Radio (4)
Motorbike (5)	Ceiling fans (6)	Television (7)	Refrigerator (8)	Tractors (9)
Washing machine (10)	Water Pump (11)	Air conditioner (12)		Bicycle (13)
Others *(specify)* (14)*:*				

18. Who of the following assisted the household to deal with the difficult times?
[Read out all the options and ask. More than one option is possible]

Has assisted (1) / Has not Assisted (2)

Family	*1*	Friends	*2*	People of the community	*3*	Insurance Company	*4*
Financial Institution	*5*	Local Government	*6*	National Government	*7*	Local NGO	*8*
International Organisation	*9*	Others (specify):					

19. Does the household receive any **monetory or other kinds of assisstance** from any SHGs, NGOs etc.?

Yes (1)	No (2)

20. How much do the household participate in Panchayat or gram sabha meetings?

Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)

21. Is your priorities or demands addressed properly in the local decision making process?

Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)

PART 2

22. What is the **source** of water (i.e., the source water comes from immediately before being used) of the household? *[Choose the options from below. It can be more than one]*

Rainy season	Summer	Winter	During most of the year

1. Unprotected dug well	2. Protected dug well	3. Borehole	4. Unprotected pond
5. Protected pond	6. Shallow tube well	7. Deep tube well	8. River
9. Canal	10. Public standpipe	11. HH public supply	12. Rain water collection
13. Vendor provided/bottled water	14. Water tanker	15. Others, specify:	

22a.	During the last one year, for how many months was your household's main source of water **sufficient to meet** your household's needs? Months [ ]
22.	Do you have **personal source** of water? Yes (1) / No (2)
23a.	**If no, approximately**, how much time (in minutes) does it take for a member of your household to collect water from a common source in a normal day? [ ] min *[If water is collected from a piped connection or personal well or tube well in the household: record **1 minute**]*

During Summer		During Winter	
During Monsoon		During most of the year	

23b.	How **long (in km)** do the member of the household walk to fetch water? [ ] *[If water is collected from a piped connection or personal well or tube well in the household= 0 km]*

During Summer		During Winter	
During Monsoon		During most of the year	

23c.	**During the last 7 days**, how many days did the following household members go to fetch water? *[Total should add up to 7 days. If not applicable = 0]*

Males 0-5		Males 6-14		Females 0-5		Females 6-14	
Males 15-45		Males 45-60		Females 15-45		Females 45-60	
Males 60+				Females 60+			

24.	For how **long** does your community/household get public water supply? [ ] *[Ask this question only if the answer to question 27 is 10, 11 or 14. Write hour or min]*
24a.	Does it **change** with seasons?

	YES	*NO*	*NO CHANGE*
During Summer			
During Monsoon			
During Winter			
During most of the year			

24b.	In the last one month, how many times did the **public water supply interrupted**? [ ] Days
25.	How long does it take for a bucket (20L) to be filled up? [ ] min
26.	**Approximately**, how much water is needed for your **domestic needs in a normal day** (Including cooking, washing, bathing and other domestic needs)? *[Based on the buckets of water used.]* [ ] L

During Summer		During Winter	
During Monsoon		During most of the year	

26a.	**Approximately,** how much water (in Litres) is needed to carry out the following activities? *[Can be calculated by measuring the buckets of water used for each purpose]*

Cooking	Drinking	Bathing	Washing Utensils	Washing Clothes	Cleaning house	Toilet flushing	Gardening

27.	Does your household **treat water before drinking it**? (For e.g. Boiling, settling, filter, chemical treatment etc.) Never (1) | Sometimes (2) | Often (3) | Always (4)

27a. How do you treat drinking water **at home**?

No treatment		Boiling		Simple water filter	
Chemical treatment (Alum)		Advanced treatment		Others (specify):	

27b. Does the household **water quality degrade** with seasons? *[Tick the appropriate]*

	YES	*NO*	*NO CHANGE*
During Summer			
During Monsoon			
During Winter			
During most of the year			

28. What is the main purpose for which your household uses **groundwater**? *[Only if the household use GW (refer to Q. 27).There can be more than one option, Tick the appropriate]*

Cooking (1)	Washing (2)	Bathing (3)	Livestock (4)
Irrigation (5)	Others (specify):		

28a. Does the groundwater availability **change with seasons**?

	YES	*NO*	*NO CHANGE*
During Summer			
During Monsoon			
During Winter			
During most of the year			

28b. During the last 12 months, for how many months was there enough goundwater for your household?

29. How is the **quality of the groundwater** used by the household?

Odor		Turbidity		Fluoride	
Hardness		Iron		Others (specify):	

29a. Does the groundwater quality **degrade with seasons**? *[Tick the appropriate]*

	YES	*NO*	*NO CHANGE*
During Summer			
During Monsoon			
During Winter			
During most of the year			

30. During last year, what is the prevalence rate of **water borne disease** like malaria, cholera, typhoid, polio, diarrhea etc. in your household?

Never (1)	Sometimes (3)	Often (4)	Always (5)

30a. Does it **increase with seasons**?

	YES	*NO*	*NO CHANGE*
During Summer			
During Monsoon			
During Winter			
During most of the year			

31.	Does your household own land for agriculture? *[If the answer is no, there is no need to ask the questions]* Yes (1) / No (2)
31a.	How much land does your household have for agriculture? *(including the land which at present is not in use)* [ ] Bigha
31b.	What is the **total number of crops** that the household grows in one year? Number [ ]
31c.	What is the segregation of the agricultural lands according to the **cropping system** (in Bigha)?
31d.	What is the trend of **food crop yielding** from your farm land in last 5 years? Increased (1) / Decreased (2)

Question 31c:

Mono crops		Wasteland		Others (specify)	
Multiple crops		Fallow			

32. What is **the main source of irrigation** for your agricultural land?
[There can be more than one option, Tick the appropriate]

Rain-fed (1)	Canal (2)	River (3)	Shallow Pump (4)
Pond (5)	Tank (6)	Others (7), specify:	

32a. How much of the household's agricultural land is **under irrigation on normal days**?

During Summer		During Winter	
During Monsoon		During most of the year	

32b. During the last 12 months, for how many months was there sufficient water for your agricultural land? [ ] Months

33. During the last 12 months, which of the following did your household use on your farm? *[If at least one is used, skip to question 39b.]*

Compost / Manure		Artificial fertilizer		Pesticide		Used (1)	Not used (0)

33a. During the last 12 months, how often was your household able to make or buy enough compost/manure, artificial fertilizer or pesticide for each growing season?

Never (1)	Sometimes (3)	Often (4)	Always (5)

34. Does your land experience **soil erosion**? Yes (1) / No (2)
[If the answer is no, there is no need to ask the questions]

34a. In which season do you experience **highest soil erosion**? *[Only if the answer to Q 39. is Yes]*

	High (1)	Moderate (2)	Low (3)
During Summer			
During Monsoon			
During Winter			
During most of the year			

35. Does your household own **livestock**? Yes (1) / No (2)
[If the answer is no, there is no need to ask the Q. 40a.]

35a. How many livestock does your household own? [ ]
(Count male and female animals together)

35b.	During the last 12 months, for how many months was there enough water for your livestock? Yes (1) / No (2)
36.	What is the storage capacity of the household per day? ______ L. *[Calculate on the basis on buckets of water saved per day]*
36a.	Does **water storage capacity** change with seasons?

	YES	*NO*	*NO CHANGE*
During Summer			
During Monsoon			
During Winter			
During most of the year			

37. How often is there **conflicts over water use, allocation or distribution** in your neighborhood?

Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)

37a. How often are there conflicts over the use, allocation or distribution of water between your neighborhood and other neighborhoods?

Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)

38. What type of **toilet facility** does your household usually use?

(1)None (open defecation)	(2)Open pit
(3)Enclosed pit	(4)Enclosed improved-ventilation pit
(5) Enclosed flush	(6) Enclosed pour-flush
(7) HH septic system	(8) Connection to public sewer
(9) Other, specify:	

39. Please specify the **indigenous methods** used by the household for the following:

1. Water Storage	
2. Water Cooling	
3. Water Budgeting	
4. Water Quality	
5. Water Use	

40. Does the household practice **rain water harvesting**? Yes (1) / No (2)

41. Is there any kind of **financial or other support to the household** from Govt. agencies or other agencies for improved water condition? Yes (1) / No (2)
If yes, please specify:

-----------END-----------

APPENDIX III

Format of questions for discussion during PRA exercise

Time (for each group): 45-60 Minutes

Group Size: 10-15 participants

Number of Groups: 3 (Farmer, Women, Elderly)

1. Resource Mapping

   Primary Objective: Map local resources of water and assess their risk.
   Secondary Objective: a). Clarify the area under consideration in the group discussion.
   b). Gain a comprehensive understanding of the natural and physical features of the local area.

2. Coping and adaptation strategies assessment

   Primary Objective: Identify and assess the effectiveness of the current coping mechanisms practiced by communities.

Questions for discussion:

1. In the map, where are the key livelihoods located?
2. How has the quality and quantity of the water resources changed in the last 10 years?
3. What are the key pressures to the water resources in the area?
4. Can you locate the change in climate in recent years? What are the key indicators of each climate change impact?
5. Which communities are mostly affected by change in water condition and change in climate (if any) in the area? [If the communities are identified, why are they mostly affected?]
6. What are the changes that you are facing in your daily life in terms of water availability and climate change ?(*women only*)
7. How has the change in water situation affected agriculture? (*Farmers only*)

1. How are you coping with the change in the water situation and changing climate in the area?
2. Are the strategies designed to reduce risk, cope in the short term or adapt for a longer time period?
3. Are strategies used widely in the community or only by a few? Why?
4. How would you rate your current capabilities to adapt to climate change and water scarcity on your daily life (extremely capable to not capable)?
5. What are the key barriers in executing these adaptation strategies?

For Farmers and elder group, specifically,

1. How have the incidences of climate changes (drought, amount of moisture, winter and summer temperatures or growing season) changed in your area in the past 10 years?
2. How did you respond to the events in the past?

Final Questions

1. What would you like to see government do to help you respond/cope with the climate and water related risks? (*All three groups*)
2. What do you think are going to be the consequences and/or opportunities due to climate change and water situation in this area in the next 10 years?
3. What are the most important things that the community in the area can do to reduce the impacts of water scarcity and climate variability?

List of Participants

Date: / /2014

Block:

Gram Panchayat:

Village:

Focus Group:

Sl. No.	Name of the Participant	Age/Sex	Occupation	Period of Residence	Area of Agricultural Land (Farmers)

APPENDIX IV

Prioritized Actions: Block and Panchayat level responses

Name of the Block:-________________________

Name of the Panchayat:- ________________________________

Name of the respondent:- _____________________________

Designation:-___________________________________

Proposed strategies: Please write as per priority, 1 being highly prioritized and 5 being less prioritized;

Implementing Agencies: Please mention the different stakeholders who will play a role in implementing the strategies; GO: Government, LG: Local Government like District administration, PRI: Zilla Parishad (ZP)/ Panchayat Samiti (PS)/ Gram Panchayat (GP); NGO: Non-Governmental Organization; V: Villagers

Expected barriers in implementation: Please mention the barriers that may hinder the execution of the proposed strategies. 1 being the most important barrier and 5 being the least important barrier.

IRRIGATION NEEDS

Proposed Strategies	Implementing Agency	Expected Barriers in the implementation
1. **2.** **3.** **4.** **5.**	**1.** **2.** **3.** **4.** **5.**	**1.** **2.** **3.** **4.** **5.**

DOMESTIC NEEDS

Proposed Strategies	Implementing Agency	Expected Barriers in the implementation
1.	**1.**	**1.**
2.	**2.**	**2.**
3.	**3.**	**3.**
4.	**4.**	**4.**
5.	**5.**	**5.**