STUDIES ON WATER ACCESSIBILITY AND URBAN ECOLOGY OF NAGALAND WITH SPECIAL REFERENCE TO MOKOKCHUNG TOWN

A thesis submitted to the Nagaland University in
partial fulfilment of the requirements for the degree of
Doctor of Philosophy in Geography

By

JNANENDRA SARMA
PhD. Registration No. 569/2014

Under the Supervision of

PROF. SANGYU YADEN
Department of Geography
Nagaland University
Lumami

Department of Geography
School of Sciences
Nagaland University, Lumami - 798627
November 2020

Dedicated to my father

Late Chanmohan Sarma

Declaration

I hereby declare that the thesis entitled "*Studies on water accessibility and urban ecology of Nagaland with special reference to Mokokchung town*" submitted to Nagaland University, Lumami in partial fulfilment of the requirement for the award of the degree of Doctor of Philosophy in Geography. It is a record of bonafide research work done by me under the guidance and supervision of Prof. Sangyu Yaden, Department of Geography, Nagaland University. This work has not been submitted either in full or in part to any other university or institution for the award of any degree or diploma.

Jnanendra Sarma
PhD. Registration No. 569/2014
Research Scholar
Department of Geography
Nagaland University
Lumami

Date:

Acknowledgements

First of all, I thank almighty to lead me to pass through a difficult time during this study period. I deeply acknowledge the timely support of my supervisor Prof. Sangyu Yaden, for his valuable support and advice. Due acknowledgement goes to the UGC-NERO, Guwahati, for sponsoring UGC teachers' fellowship programme for this study. I acknowledge the administration and academia of Nagaland University in general and faculty and stuff of the Department of Geography in particular for providing this platform of research. I duly acknowledge the support of my college Principal of different times and administration under the Nagaland Government for giving me the opportunity of doing this research. I am thankful to my departmental colleagues for sharing some academic burdens and office staff of Fazl Ali College, Mokokchung.

This work couldn't have been accomplished without relentless support and inspiration from my family members, especially my wife Barnali and daughter Hriddita. I am also grateful to my uncle and academic mentor, Dr Siddheswar Sarma for his inspirations.

I appreciate the Land Records Department, and District Urban Planning Department, Mokokchung, for providing me ward base map of Mokokchung. I also acknowledge the officials of PHED, Mokokchung and Kohima for providing some technical information about the water supply system of the town. I thank the Soil & Water Conservation Department, Nagaland for providing weather data.

I thank Mr R. Ayim Longkumer, President, All Wards Union Mokokchung, along with chairman and secretaries of different wards of the town for the informative interview about the area. The MMC officials are also to be acknowledged for their interview.

I must appreciate Mr Tia of Artang ward who took me to hospital after a health problem during my fieldwork in that ward. I also have to acknowledge my workplace neighbour family of Mr T. Nungsang and Mr Nilakanta Kalita for their care and love.

Lastly, I thank those households of Mokokchung town including some water and fuelwood vendors who kindly spend their valuable time while interviewing. I am thankful to everyone who supported me through the work. I do apologize if due acknowledgement is missed out for any person unknowingly.

Jnanendra Sarma

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBRIVIATIONS AND ACRONYMS

AGB	Above Ground Biomass
ARWSP	Accelerated Rural Water Supply Programme
BIS	Bureau of Indian Standard
CEPF	Critical Ecosystem Partnership Fund
CGWB	Central Ground Water Board
COP	Conference of the Parties
DCHB	District Census Hand Book
DEF	District Executive Force
DPMS	District Planning Map Series
EC	European Commission
ES	Ecosystem Services
EU	European Commission
FAO	Food and Agriculture Organization
FSI	Forest Survey of India
GEMI	Global Environment Management Initiative
GI	Galvanized Iron
GIZ	The Deutsche Gesellschaft für Internationale Zusammenarbeit
GLAAS	Global Analysis and Assessment of Sanitation and Drinking-Water
GSI	Geological Survey of India
ham	hectare meters
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
ISFR	India State Forest Report
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Programme
lpcd	Litre per capita per day
LPG	Liquefied Petroleum Gas
LRSD	Land Records and Survey Department
MAB	Man and the Biosphere programme
MDF	Moderately dense forest
MDG	Millennium Development Goal
MEA	Millennium Ecosystem Assessment
MMC	Mokokchung Municipal Council
MoEFCC	Ministry of Environment, Forests and Climate Change
NATMO	National Atlas and Thematic Mapping Organisation
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
NFP	National Forest Policy
NHAI	National Highways Authority of India
NRDWP	National Rural Drinking Water Programme
NWP	National Water Policy
OECD	Organisation for Economic Co-operation and Development
OF	Open forest
PF	Protected Forest
PHED	Public Health Engineering Department

PVC	Polyvinyl chloride
REDD+	Reducing emissions from deforestation and forest degradation
RF	Reserved Forest
RWH	Rainwater harvesting
SDG	Sustainable Development Goal
SOI	Survey of India
SRTM	Shuttle Radar Topography Mission
SWCD	Soil & Water Conservation Department
ULB	Urban Local Body
UN	United Nations
UNCED	United Nations Conference on Environment & Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
VC	Village Council
VDB	Village Development Board
VDF	Very dense forest
WaSH	Water, Sanitation and Hygiene
WCMC	World Conservation Monitoring Centre
WHO	World Health Organisation
WWAP	World Water Assessment Programme

Abstract

Our planet from space is seen as a unique blue colour due to the abundance of water which supports life. The only tool-making animal species *Homo Sapience* is dominating this planet. The modern human is gradually concentrating in urban environments, where various resources are consumed synthesized and waste is generated. This growth of urban areas by transforming an existing natural ecosystem to a human-dominated 'urban ecosystem' bears importance to observe. The earlier ecologist was interested to study the habitat of some wild species adaptation in such converted urban ecosystem. This type of species adaptability study approach in an urban environment was called "ecosystem in cities". However, in the later phase, the approach of studying urban area was changed where the entire urban environment has to consider as an organism, which consumes resources from the surrounding environment and after synthesizing excretes waste. This approach is called as "ecosystem of cities". Sustainability of the urban areas gaining interest due to the huge flux of matter and energy.

This study bears significance due to location in the fragile mountainous environment and ecological hotspot areas though it is smaller than cities. Thus, we studied water and related metabolic processes of this small but important urban area, located in one of the biodiversity hotspots of the world, with the fragile mountainous environment.

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

The Ancient Hindu scriptures refer to the existence *panchabhuta* or five classical elements i.e. *kshiti* (earth), *apa* (water), *teja* (fire), *maruta* (air) and *byom* (ether). Greek philosophers also gave a parallel view of our physical world composed of four elements: land, water, fire, and air. Except for ether or space, all can be accepted because they are perceived physically but ether is invisible, so Greeks considered as a material world to be composed of only four elements.

Mankind's concerns are still focused upon these four elements, that can be conventionally symbolised as terrain (land), water (water), energy (fire), and atmosphere (air). It needs not much explanation that these elements are essential for supporting all form life on the Earth. As human populations have multiplied several hundred folds since the early civilisations, we are increasingly facing major crises with each of these elements.

At different stages of human development, each of these elements has risen to prominent importance. With man's ability to control fire, the land got increased prominence and the human population soared, and we managed to inhabit across the planet. Though the other two essential elements, air and water were until recently considered so abundant, by the end of the nineteenth-century people started to notice problems of contaminated air and water. That also was becoming difficult to find clean air to breathe safely and unpolluted water to drink. Further, by the end of the twentieth century, humanity discovered that reckless use of fossil-fuel energy was in danger by changing the atmosphere in ways that were threatening the survival of our species by causing global warming.

In this twenty-first century, mankind is challenged with a myriad of environmental problems. The two most salient global issues now facing by human are water and energy. Mankind's propagation as an intelligent species in this planet utterly depends on how do we manage one of the vital resources' 'water' in this twenty-first century and beyond.

1.1 *The urbanizing world*

According to the estimate of United Nations, (2018) globally, more people live in urban areas than in rural areas, with 55 per cent of the world's population residing in urban areas in 2018. But in 1950, only 30 per cent of the world's population was urban, and by 2050, about 68 per cent of the world's population is projected to be urban.

At present, the most urbanized regions of the world include Northern America (82 per cent) followed by Latin America and the Caribbean (81 per cent), Europe (74 per cent) and Oceania (68 per cent). The level of urbanization in Asia is now approximating 50 per cent. In contrast, Africa remains mostly rural, with 43 per cent of its population living in urban areas. Asia, despite being less urbanized than most other regions today, is home to 54 per cent of the world's urban population, followed by Europe and Africa (13 per cent each).

Nine countries will make up more than half the projected population growth between now and 2050. The largest increases in population between 2019 and 2050 will take place in India and around the year 2027, India is projected to overtake China as the world's most populous country (UN DESA, 2019).

1.2 *Ecosystem services and human well-being*

Biosphere ecosystems have provided various services to humanity since its inception. Ecosystem services are the benefits people obtain from ecosystems. Thus, the Millennium Ecosystem Assessment (MEA) was planned to provide an integrated assessment of the consequences of ecosystem change for human well-being and to analyse options available to enhance the conservation of ecosystems and their contributions to meeting human needs. According to the assessment, approximately 60 per cent of the 'ecosystem services' out of 24 services are being degraded or used unsustainably, including freshwater (MEA, 2005a).

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit. As described by MEA there are 4 (four) types of ecosystem services namely provisioning, regulating, supporting, and cultural services figure 1, which are for the benefits of people and obtained from the ecosystems:

1. Provisioning services are the products people obtain from ecosystems, such as food, fuel, fibre, *freshwater*, nutrients and genetic resources.
2. Regulating services are the benefits people obtain from the regulation of ecosystem processes, including invasion resistance, pollination, climate regulation, disease regulation, natural hazard protection, w*ater purification*, herbivory, seed dispersal, pest regulation and erosion regulation.
3. Cultural services are the nonmaterial benefits people obtain from ecosystems through spiritual and religious values, knowledge system, sense of place, education and inspiration, recreation and aesthetic values.

4. Supporting services are those that are necessary for the production of all other ecosystem services, such as, primary production, provision of habitat, nutrient cycling, soil formation and retention, production of oxygen and *water cycling*.

Out of all 24 services shown in figure 1, some are tangible services and some others are intangible. If changes occur in these services, then it may affect human well-being in many ways (MEA, 2005b). Therefore, understanding the relationships between these ecosystem services is having importance, which is mutually related.

Fig 1: *Biodiversity's contribution to ecosystem services*

Provisioning services	***Cultural services***
1. Food, fuel and fibre	1. Spiritual and cultural values
2. Genetic resources	2. Knowledge system, sense of place
3. Nutrients	3. Education and inspiration
4. Freshwater	4. Recreation and aesthetic values

Ecosystem and habitats

Supporting services	***Regulating services***
1. Primary production	1. Invitation resistance
2. Provision of habitat	2. Pollination
3. Nutrient cycling	3. Climate regulation
4. Soil formation and retention	4. Disease regulation
5. Production of oxygen	5. Natural hazard protection
6. Water cycling	6. Water purification
	7. Herbivory
	8. Seed dispersal
	9. Pest regulation
	10. Erosion regulation

(after Australian Govt., 2009)

The concept of an ecosystem provides a valuable framework for analysing and acting on the linkages between people and the environment. The Convention on Biological Diversity (CBD), states that the 'ecosystem approach' is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way.

The problem posed by the growing demand for ecosystem services is compounded by increasingly serious degradation in the capability of ecosystems to provide these services (MEA, 2005b). The prospect for sustainable development effort seriously diminishes due to the combination of ever-growing demands of resources placed on increasingly degraded ecosystems.

The world has witnessed in recent decades not just dramatic changes to ecosystems but equally profound changes to social systems that shape both the pressures on ecosystems and the opportunities to respond (MEA, 2005b). In such a situation, the gravity of the problem my further increase substantially with climate change phenomena.

1.3 *Role of water to mankind*

Without water, all organisms would disappear from the planet. Water plays an extremely important role in maintaining a sustainable life on this planet for all species including *Homo sapiens*. Only those few exotic species that have managed to survive in environments which do not require potable water would survive. Moreover, we cannot overlook the connections of water to other global resources, because water has a critical role to play in supporting and developing other resources that supports life on planet Earth. Thus, the major concern of resources studies remains focused on water.

Our life depends on the availability of water in many respects. All of our cultures are constructed based on the use and availability of water. Water is not only a commodity, but its true value also includes social, cultural, economic and environmental values. Archaeological evidence suggests that early civilizations preferred to settle near the river valley for their settled agricultural prosperity and daily activities.

Our modern civilizations are also intricately relied on the water uses from household activities to agriculture and industry. However, as demand for land increased, modern man can now adopt in areas of scarce water sources applying his wisdom to extract water from underground or transporting water from a long distance to fulfil his demands.

According to the UN estimation, the world's population has tripled since 1900, while during the same period water demand has increased six-folds. This contrast has forced the global community to emphasis on the management of water resources. Unlike the fear of using up energy, which has occurred very rapidly, the water crisis is slower – but indeed a grave crisis. The crisis creeps in imperceptibly without much contrast and we do not see the doubling of prices over periods of years or so, but it is undeniably slow and serious toward scarcity. The time frame may be years or even decades, which can be subtlety perceived by statistical analysis while estimating demands and availability on this global resource. Though there are technological alternatives against fossil fuel to power our cars or cook our foods, there is no alternative to replace water for various level of uses. Fossil fuels are usually described as non-renewable resources, they have a fixed reserve and could be exhausted. Whereas water (freshwater) is a renewable resource of an essentially fixed amount and is used by everybody on the globe, and cannot be used up in the sense that petroleum can be because it is a renewable resource, but access to it by growing populations overtaxes its availability.

The Union Ministry of Science and Technology, Government of India recognized the need for imminent technical solutions to the problems of water scarcity in the country. Challenges relating to water scarcity can be traced to several causes such as a) decreasing per capita availability of freshwater, b) loss of quality of available freshwater on account of contamination and poor management practices, c) inadequate harvesting of rainwater resources, d) excessive and inefficient use of water in some human activities, e) inability to use available water on account of natural contamination, for example, with arsenic, fluoride, iron etc, f) non-potability on account of salinity, g) non-viability of some available technologies like reverse osmosis and distillation in several socio-economic environments, h) inadequate water body management practices including lakes, reservoirs, rivers, groundwater sources etc, i) inadequate floodwater management systems, j) non-judicious use of water without renovations and recycling and k) urbanization with insufficient infrastructure for sourcing, delivering and recovery of water for multiple uses.

Urban population are fast increasing in the world accommodating more than half of the world's population. It is predicted that by the year 2030 urban living population is expected to increase by up to 60 per cent (Olsson & Head, 2015, p. 2). Consistency in water accessibility is required to maintain a sustainable healthy environment in the urban area. Only by addressing the issues of water scarcity, water accessibility, affordability, and quality, basic human needs could be met (Ray & Shaw, 2019b).

Thus, water is a prime natural resource and fundamental to life on Earth. Water is also an invaluable and scarce national resource in the context of growing scarcity of freshwater resources in the country. In the mountainous state Nagaland, water is a critical natural asset as it is fundamental to ensuring food security, maintaining of ecosystems health and services and daily activities of Naga people. It will continue to play a multifaceted role in the developmental planning of the state, especially in the growing urban sector. To achieve UN SDG pathway, it is necessary to initiate measures for ensuring economic, judicious and equitable use of water resources in the state.

Owing to the unique hydrological, social and legal context of Nagaland, a tailored to state-specific water resource planning is needed which will be responsive to its existing and future needs encompassing a long-term water resource management program.

1.4 *The rationale for selecting the area*

The urban locality was selected due to the higher demand for water than the rural counterpart. Also, the hilly area has more challenges to supply water due to terrain factor. As a global phenomenon, the world population is gradually transforming as urban population. Globally more than half of the population lives in the urban area. Therefore, the study also bears demographic gravity for future. It invites challenge for the planners to manage essential water supply to urban dwellers. Moreover, the climate change phenomena also add another dimension to the intensity of unpredictable water challenge in future.

A common view among ecologist is that Earth's biological diversity is being reduced at an alarming rate that is likely to increase over the next several decades. Though some new species of plants and animals are being introduced naturally in an area, it is estimated that the rate of loss of species is much greater than the rate of evolving a new species.

Hypothetically, it is said that "diversity begets diversity" which means, diverse elements of the environmental processes will generate more diversity (Whittaker, 1960, Janz et al., 2006 and Norton, 2014). This hypothesis suggests that losses of diversity can further reduce the number of species by becoming threatened as their mutualists become endangered or extinct (Askins, 2008, p. 16). Based on the said assumption, human civilization may face serious consequences due to reduced biological diversity in future. It will also create serious consequences in the field of agriculture followed by industrial development and raw materials for medicines.

1.4.1 Mokokchung town

The framework of this study is confined to the mountainous urban area of Nagaland where Mokokchung town is located. The area is unique in the sense that it is located at the hilltop of mountain ranges of Nagaland, that is centrally situated as headwater region of three important watersheds belonging to the three tributaries of the Brahmaputra basin. Moreover, the area is also part of Indo-Burma biodiversity hotspot and as a growing human-dominated landscape, this urban area may pose threat to biodiversity. As the area suffers seasonal drought, the study explores the sustainability of this urban growth concerning water resources in the area. A detailed description of the study area is given in Chapter 2.

1.5 *Statement of the problem*

Access to clean water is fundamental to human well-being. In 2010, a milestone was achieved when the UN General Assembly recognized the human right to safe and clean drinking water and sanitation. Managing water to meet that need is a major and growing challenge in many countries of the world. Many people are suffering from inadequate quantity and quality of water, as well as stress from floods and droughts. This has implications for health, the environment and economic development.

The biosphere itself is the product of life on the Earth. The human species placed buffered against environmental immediacies by culture and technology, is ultimately fully dependent on the flow of ecosystem services (MEA, 2005b). Considering the graveness of the environmental situation in April 2000 United Nations former Secretary-General Kofi Annan stated that:

> *"It is impossible to devise effective environmental policy unless it is based on sound scientific information. While major advances in data collection have been made in many areas, large gaps in our knowledge remain. In particular, there has never been a comprehensive global assessment of the world's major ecosystems. The planned Millennium Ecosystem Assessment, a major international collaborative effort to map the health of our planet, is a response to this need"* (MEA, 2005b).

If major intervention in policy change and considerable improvements in water management processes and techniques is not done, by 2050 the situation is likely to deteriorate and will be compounded by increasing competition for water and increasing uncertainty about water availability (OECD, 2012). In a nutshell, around the world, individuals, cities, farmers, industries, energy suppliers, and ecosystems are increasingly competing for their daily water needs.

According to the estimate of the UNESCO & WWAP, (2018) with a rapidly growing global population, water demand is expected to increase by nearly one-third in 2050. However, the world population is expected to increase from 7.7 billion in 2017 to between 9.4 and 10.2 billion by 2050, with two-thirds of the population living in cities (UNESCO & WWAP, 2018). The state of water systems is affected by both human activities and environmental change. The key human drivers include population, income growth and economic activities. The GDP is expected to grow globally three to six times till 2050 compared to 2010, although there are and will be large differences among countries (Burek et al., 2016). Eventually, future global food demand is expected to increase by some 70 per cent by 2050, but will approximately double for developing countries (FAO, 2011).

Two-thirds of the population increase in Asia is due to developments in India. For example the *Middle of the road* scenario projects between 2010 and 2050 an additional 509 million people making India by far the largest nation of the world with a total population of 1.7 billion (Burek et al., 2016). Burek further estimated that by 2050 domestic water demand will rise by more than threefold in all African and Asian subregions, and it will be more than double in Central and South America (Burek et al., 2016).

Throughout the early-mid 2010s, about 27 per cent of the global population lived in potential severely water-scarce areas and in 2050 this could increase to some 2.7–3.2 billion. If monthly variability is taken into account, nearly half the global population are already living in potential water-scarce areas at least one month per year and this could increase to some 4.8–5.7 billion in 2050 (UNESCO & WWAP, 2018).

Globally it is estimated that by 2050 current population will increase to another 3 billion more and on the other hand economy will grow four times implying a considerable increase in demand for and consumption of biological and physical resources, as well as escalating impacts on ecosystems and the services they provide (MEA, 2005). The problem posed by the growing demand for ecosystem services will be further compounded by increasingly serious degradation in the capability of ecosystems to provide these services.

1.5.1 Background of the problem

This study considers the following conditions as the problem in the area:

1. The household of the area uses multiple water sources but not a single source is dependable as shown in figure 49.
2. Rainwater is the primary source of water in the area and feeds other secondary water sources (figure 3). After September monthly rainfall decreases sharply due to withdrawal of monsoon (figure 12), and other secondary sources also gradually dries-up causing water scarcity in the area. Though rainwater harvesting (RWH) is commonly practised among the dwellers but dependency is limited to rainy months only due to limited storage capacity.
3. Since the area is located in the hilltop region (figure 5) the headwaters of the streams originate from the town area and flows downstream. As a result, the post-monsoon period experiences significantly reduced the quantity of water in the stream.
4. The piped water supply through the Public Health Engineering Department (PHED) in the area is inefficient owing to geographical and technical problems. The water quantity supplied is much below than the demand of a household. The duration, frequency and regularity of water supply are also very erratic to depend on this water source. Moreover, such piped water service covers only about one-fourth of the total household in the town.
5. Sub-surface groundwater from Dug-well is also not adequate during the dry season and yield becomes limited from late November until April-May to meet the demand for the town population. Dug-wells are found in selected few

locations only depending on favourable geological and topographical condition. Dug-well water recharges only after rainfall.

6. Borewell also found in the town, but the limited yield is reported in some of them which are operational. Also, some borewells are reported as dried-up. In some location boring operation even did not strike water. Water quality in most of the locality from the borewell is not fit for consumption due to high iron and calcium content. Further, the water level is going down reportedly in some borewells than its initial level causing non-reliability on the groundwater.
7. As a last resort, when all options for water sources are exhausted, people have to buy water from the water vendors who provide water by tanker or by pipe from nearby borewell who can effort paying a higher rate than the government rate. Moreover, manual water vendor also gives limited service to some locality of the town which is costlier than all other sources.

The study investigates about sources of water available for domestic purposes in the area. The study further explores problems associated with present sources of water that is not so dependable in present condition. It is important to note that if water management in the mountain area is not scientific and robust, we may have to face irreparable environmental consequence causing a hazard for our survival.

1.5.2 Urban drought adaptation problem

In a natural system, when any disturbance (drought etc.) affects the organism, they find some sort of refugia. The disturbance caused by seasonal drought is well adapted in refugia as studied in the stream ecosystem. Nevertheless, it can be compared to other ecosystems also. As water is a dominant factor for the functioning of an ecosystem.

Similarly, in the urban environment also water accessibility is a dominant factor in the functioning of the urban ecosystem. Without the availability of a sufficient amount of water to the population, life becomes miserable and impacts normal functioning. The type of drought in the study area is primarily seasonal. Though seasonal drought is not so disturbing to a natural ecosystem an urban ecosystem may be severely affected by it. Unlike natural refugia, human dampen disturbance by adopting the technology. As moving to some refugia is not feasible for the urban settlement such temporal adaptation is having limitation and sustainability may not be possible in long run.

1.5.3 The need for a hygienic environment

Foundations of human survival upon which development begins are clean water, basic toilets and the practice of hygiene. Improving access to these basic needs has a positive impact on the growth and development of children and communities around the world. Water is essential for sustaining life on earth. Its movement by gravity and through evaporation and condensation contributes to driving Earth's biogeochemical cycles and to control its climate. Spatial availability of freshwater is calculated by Shiklomanov (1993) as shown in table 12, where among diverse sources majority amount of fresh water is trapped as solid form (about 69 per cent) while about 30 per cent is stored as ground water. So, only a little amount of water is directly usable by humans from various sources.

Rich or poor biodiversity is seen as per availability of surface water. The contemporary world is facing gradual to accelerated environmental degradation in various parts of the world related to water scarcity and inducing regional dispute leading to the tension of war. Globally, humanity now uses more than half of the runoff water that is fresh and reasonably accessible, with about 70 per cent of this use in agriculture.

Water is increasingly becoming scarce due to the rapid urbanization process and modern lifestyle. The world urban population is expected to be 69 per cent by 2050, according to a UN estimate. Such demand leading to a crisis of freshwater in general and drinking (potable) water in particular. Also, demand is growing with more agricultural practice and industrial growth. Thus, the study of water accessibility becomes a prime necessity to support a mass of the population in an urban environment in particular.

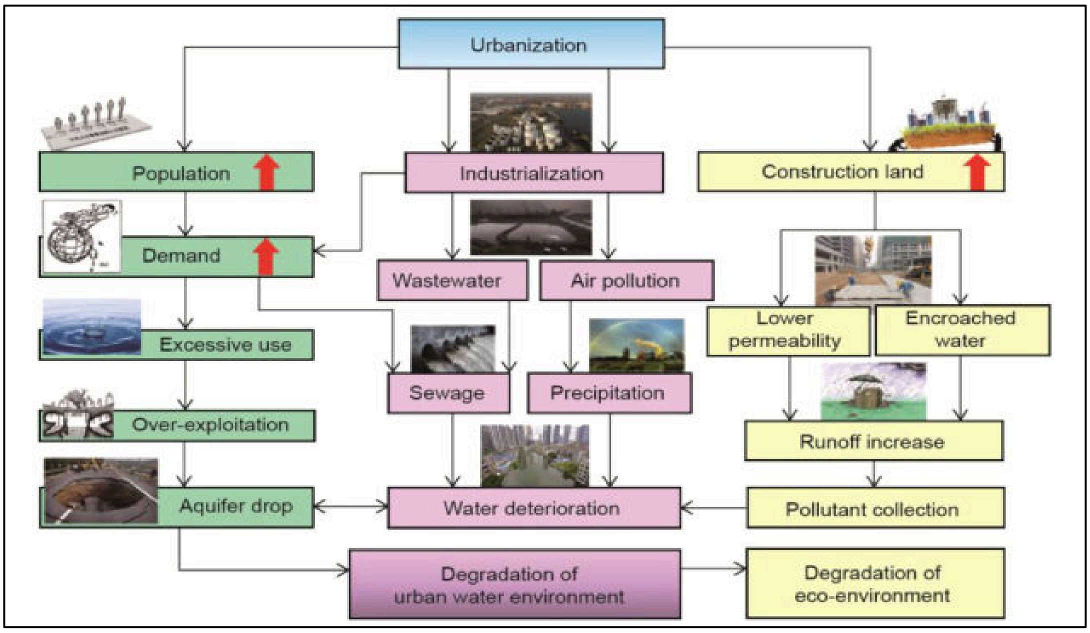
The prime cause of environmental degradation of a place is the population growth and its growing demand for resources from the environment. Southeast Asia is the most densely populated region of the world where China and India are two emerging global giants with the largest population and fastest economic growth. At the same time, this region also has a rich biodiversity with some endemic species. This contrast is a serious global concern to mankind.

1.5.4 The environmental importance of the study

The scarcity of water in an area effects biodiversity as it functions through water dynamics and availability in the environment. Continuous urbanization process may pose threat to urban water security by decreasing water quantity and deterioration of water quality that ultimately may degrade water ecology (Yu et al., 2018), which can prevent urbanization from being sustainable (figure 2).

The study area experiences water scarcity for about five months during winter and most of the household of the area suffers from water scarcity. As the water scarcity is prolonged and becomes acute towards the end of the dry season, the resultant water stress management is a concern to the functioning of the normal life of the urban habitats. Hence, this study primarily focuses on the water scarcity adaptation during winter period by the town population. Further, the urban ecosystem also discussed from the urban metabolism point of view in this fragile mountainous area.

Fig 2: *The pressure of urbanization on the urban water environment*



(after Yu et al., 2018)

India's North-Eastern region has been in focus for its high biodiversity and this region has been a priority for leading conservation agencies of the world (Chatterjee et al., 2006). The possible human impact on nature's biodiversity located in this Eastern Himalayan zone is a concern to humanity. Thus, this type of study may bring remedy to this problem of growing human impact, especially in urban areas. A spatial scientist should analyze and understand this growing ecological crisis happening in this urban region as an urgent need of the hour.

The study area is located in the fragile mountainous ecosystem of the Indo-Burma Biodiversity Hotspot of the Eastern Himalayan Region (CEPF, 2005). Biodiversity hotspots are large regions containing exceptional concentrations of plant endemism and experiencing high rates of habitat loss (*Biodiversity Hotspots Definition | Biodiversity A-Z*, n.d.).

To qualify as a hotspot, a region must contain at least 1,500 species of vascular plants as endemics and also it has to have lost ≥70 per cent of its original native habitat. The habitat in the Himalaya is patchy due to steadily increasing population in the hotspot region and has led to the extensive clearing of forests and grasslands for cultivation, and widespread logging (*Biodiversity Hotspots in India*, n.d.). Since the study area is located among one of the 35 biodiversity hotspots of the world, it bears importance to study water accessibility for mankind without effecting biodiversity of the area.

Thus, it invites attention to be studied in the issue of water crisis suffered by the urban dwellers of the area. Moreover, the use of forest resource as fuelwood by the population of the study area also studied, since the water flow regulation and retention capacity increase significantly in the mountainous area due to forest cover. However, this type of water crisis is not an isolated case for Mokokchung town area but a common scenario presently exists in most of the human-dominated landscapes of the Nagaland.

1.6 *Objectives of the study*

The study aimed to evaluate water accessibility to the households of municipal ward area of Mokokchung town with the following objectives:

1) To study various potable water sources availed by the residents.

2) To analyse seasonal water accessibility among the household.

3) To investigate the reliability of the water supply system through PHED.

4) To enquire availability and affordability of water from different sources.

5) To examine urban footprints on forest areas by fuelwood use.

6) To investigate the waste disposal system of the town.

1.7 *Research questions*

The study was conducted with the following research questions:

1) Whether urban footprint on water and forest resource is sustainable?

2) If water accessibility has topographical and geological control?

3) Whether the waste disposal system of the area is eco-friendly?

1.8 *Methodology*

The study was done based upon primary empirical data obtained from household sample survey through direct interview and collecting secondary spatial and non-spatial data. Also, Extensive online literature such as Journal articles digital books was reviewed from Google Scholar™. Also, related work was searched in the Shodhganga the digital repository of Indian Electronic Theses and Dissertations. Various digital resources form authentic websites related to the work was downloaded and cited.

1.8.1 Primary data

Water plays a prime role in an ecosystem, and we need to understand the ground reality of water accessibility about urban ecology. Though the Census of India (secondary) collects amenities (water source etc.) availed by all population, it only emphasizes the dependency on the primary water source. However, practically a household may depend on multiple water sources during a period of stress to a certain source of water. Hence, proper assessment of water source dependency is difficult from census data without direct inquiry from the users. A structured questionnaire was designed to collect household water accessibility from various sources available in the area.

1.8.1.1 Selection of sample household

The survey was conducted from January 2018 to April 2018. A sample household was selected from different topographical aspects of the area, assuming the possibility of the different requirement of water and fuelwood due to the difference in sunshine duration according to aspects. Moreover, an attempt was made to select households from both sides of the approach road (towards uphill or downhill). Also, a combination of poor and rich households was considered for the survey, that was guessed externally from the house type.

Though the attempt was made to select a household considering random sample framework, practically it was not possible to follow exactly. The reason is that some working people were not available at home during office hours and their maidservant was not able to give an interview. Again, some family members found busy in some activity and interview was not conducted. Few households didn't entertain the researcher under suspicion and denied to discuss. However, people were quite informative and cooperative when their water-related problems were asked.

Initially, 26 questionnaires were filled covering households of 18 (eighteen) ward chairman and some secretary as a reconnaissance survey. But few modifications are done with more refinement to include use of fuelwood in the questionnaire. Thus, a total of 163 households were surveyed personally by the researcher without involving any hired service. Apart from filling the questionnaire, some senior residents and socially active people of the town were also interviewed to understand the root problem. Also, the interview was conducted with Public Health Engineering (PHE) official, Mokokchung Municipal Council (MMC) official, Directorate of Census, Kohima official, water vendor, owner of boring well and some fuelwood retail sellers of the town.

1.8.1.2 Designing the questionnaire

A suitable questionnaire designed to collect household information. The interview was based on semi-structured questionnaires that focus on the type of water sources used with some detail about each source. Questions about garbage disposal and energy used in a household were also included. Basic household data such as persons sharing a kitchen regularly (not hereditary family members), livelihood, house type - was collected along with water and energy consumption pattern of the household. Amenities owned by a household was inquired to assess the income profile of the household. Detailed information related to fuelwood was asked, such as type and size of wood, type of *Chowka (*fuelwood stove) at the fireplace, source of fuelwood from where it was bought or collected and transportation cost up to home etc. Also, the interview was conducted with some fuelwood retail sellers of the town to get information about fuelwood sources. Data so obtained was fed into a computer spreadsheet for processing using MS Excel™.

1.8.1.3 The confidence level of the data surveyed

The Mokokchung town has 18 wards occupied by 8,327 households as per 2011 census. In this study, a total of 163 household survey was conducted. This sample size gives 99 per cent Confidence Level at 10 per cent Confidence Interval (Margin of Error) out of total households or 95 per cent confidence level at 7.6 per cent Margin of Error (*Sample Size Calculator*, n.d.). However, after refinement of the questionnaire by including fuelwood consumption, 137 households were randomly selected from 14 wards statistically satisfying 95 per cent Confidence Level at 8.3 per cent Margin of Error.

1.8.1.4 House types of surveyed households

The town has different types of house that also reflects the economy of a household. Though different building materials and architectures are used for the construction, houses were classified into four types as shown in table 1. It reflects that town has mostly Assam type buildings followed by single-story RCC buildings and bamboo type house. In recent time multi-storied buildings are also being constructed which constitutes only about 11 per cent of the surveyed household.

Out of total surveyed households, it reflects that the town is composed of a multi-cultural society with predominantly 93.87 per cent Ao population from different villages of the Mokokchung district.

Table 1: *The house types of the surveyed households*

Sl. No.	House type	Numbers of house	Household (%)
1.	Bamboo type	38	23.31
2.	Assam type	55	33.74
3.	Single-story RCC Building	52	31.90
4.	Multi-storey type Building	18	11.04
	Total	**163**	**100**

Among the surveyed households, 80.4 per cent reside in their own house and remaining about 20 per cent household accommodates in their rented house or government quarters. Most occupants found residing in the present surveyed location since the 1980s. However, after the year 2000, the number of settlements has been found to increase. Thus, it can be inferred that the town started to grow rapidly only after the 1980s.

1.8.2 Secondary data

Secondary spatial data was collected from appropriate sources. Toposheet No. 83 J/11 and 83 J/12 from SOI, DPMS (Mokokchung) from NATMO, Town ward map from LRSD, Mokokchung and Soil map was obtained from NBSS&LUP. Geology and Groundwater of the area were studied from GSI and CGWB reports respectively. Google Earth™ was used to study the core urban and its fringe areas.

Secondary non-spatial weather data was collected from the SWCD, Nagaland. Population related data was analysed from Census of India website. Forest resource data was analysed from ISFR of MoEFCC, Government of India of various years and State statistical department websites.

1.9 *The conceptual framework*

Mountains are amongst the most fragile environments in the world and are a repository of water, biodiversity along with other ecosystem services (Sharma et al., 2007). This study was conceptually developed and conceived on the backdrop of water scarcity related ecosystem processes in the mountainous area. In the tropical monsoon climate, scarcity of water arises mostly during the dry winter season when rainfall amount is markedly reduced than the rainy summer season. In such a climatic condition, biotic community adopt a different survival strategy as explained by biologists. During drought condition, a drought-resistant plant survives by regulating transpiration rate by shading its leaf or storing extra moisture in its stem. While animals have to be mobile in search of a water body for its survival. Animals do generally migrate several kilometres to access water source.

Mountains are generally believed to be the world's 'water towers' (Liniger et al., 1998; Messerli et al., 2004; Messerli, 2006; Viviroli et al., 2009) that have a unique position in the earth system (Meybeck et al., 2001). Despite the nomenclature as 'water tower of the world', mountains do suffer from the seasonal drought situation. As headwater region of a stream is commonly originated in the mountain area, it may face dryness much earlier than the downstream areas, as precipitate waters likely to drain out through inclined mountain surfaces by gravity after cessation of rainfall. Nevertheless, such area's dryness aggravates much earlier when build 'grey structures' prohibits water percolation to the soil. Also, water holding capacity of the soil reduces when vegetal cover is cleared for anthropogenic purposes.

1.9.1 The framework of the study

To understand water accessibility problem in the area, a conceptual model of water circulation was developed (figure 3). The model depicts a complex water flow system of the area. The prime source of water input in the system is precipitation only that is received in the form of rain. The available rainwater propagates through various channels to run the water-dependent ecosystem. This flow critically fulfils the domestic water requirement of the urban area and the overall ecosystem functions. To study the water circulation system, domestic water accessibility from different sources was primarily focussed, that also especially insisting on water accessibility during dry months.

As shown in the model (figure 3), domestic water sources are composed of 5 (five) different components or it can be said that multiple water sources are used in the domestic sector. To be resilient against seasonal drought, all components are functionally important. A study conducted by Elliott et al., (2019) in countries around the world across Asia, Africa, the Americas and the Pacific, noticed that use of multiple sources of water for different domestic purposes is practised. However, the study of 'main source of drinking water' among multiple water sources used by households is being neglected by UNICEF programmes, such as the global Water, Sanitation and Hygiene (WaSH) and development communities. Thus, UNICEF data sets not focused on domestic water-related interventions strategies and surveys.

1.9.1.1 Types of water

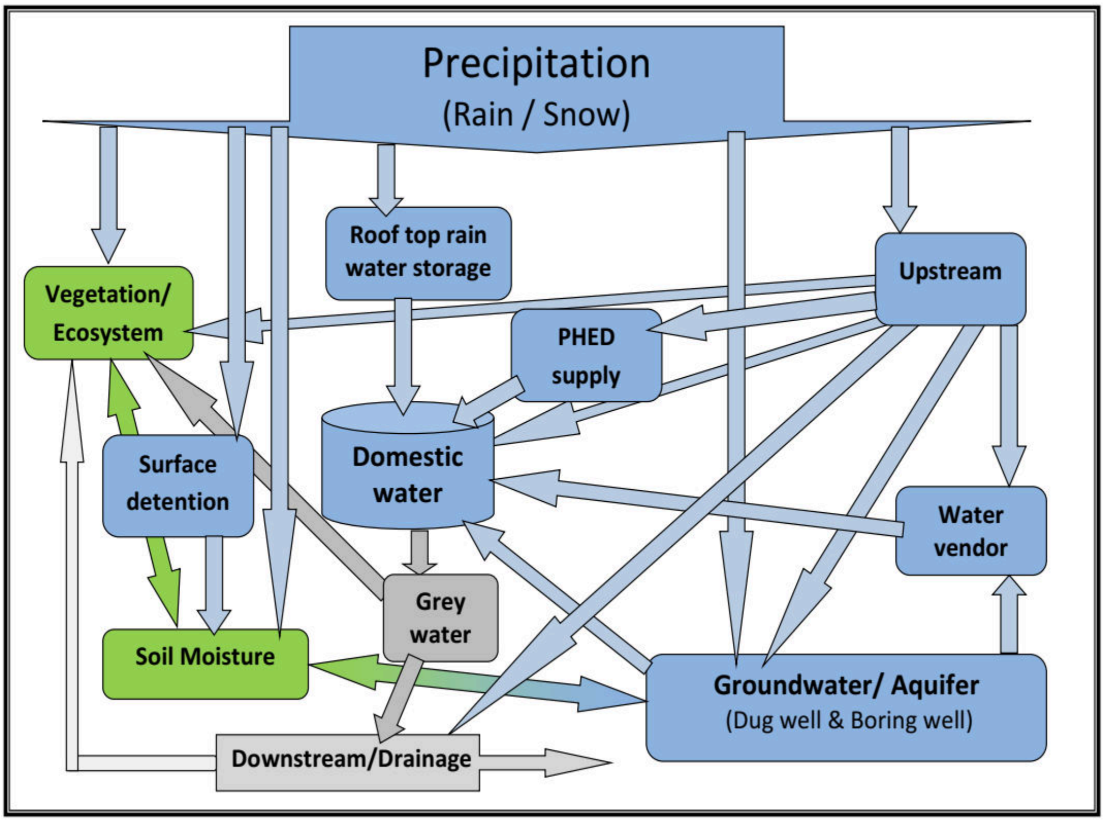
As reflected in figure 3, qualitatively there are three different types of water circulates in the system viz. Blue water, Green water and Grey water. They can be described as follows:

- *Blue water* is that freshwater component of surface water and groundwater which is available to use by human. Blue water refers to liquid and aquifers. The blue water flows have a consumptive (evaporation and transpiration) and a non-consumptive (return flow) portion (Rockström et al., 2009).
- *Green water* consists of the total evaporation, composed of one non-productive part (evaporation from the soil, water or canopy), and one productive part (water taken up by plants and returned to the atmosphere as transpiration (Falkenmark,

2003). Green water flow is always a consumptive use of freshwater (Rockström et al., 2009). Green water refers to naturally infiltrated rain, attached to soil particles and accessible to roots.

- *Grey water,* on the other hand, there is a volume of polluted water drained out by human after use (Hoekstra & Chapagain, 2011, p. 4). Here evaporated component of water from the system were not considered which is beyond the purview of this study.

Fig 3: *Blue water, Green water and Grey water circulation in the study area*



(conceptualized by author)

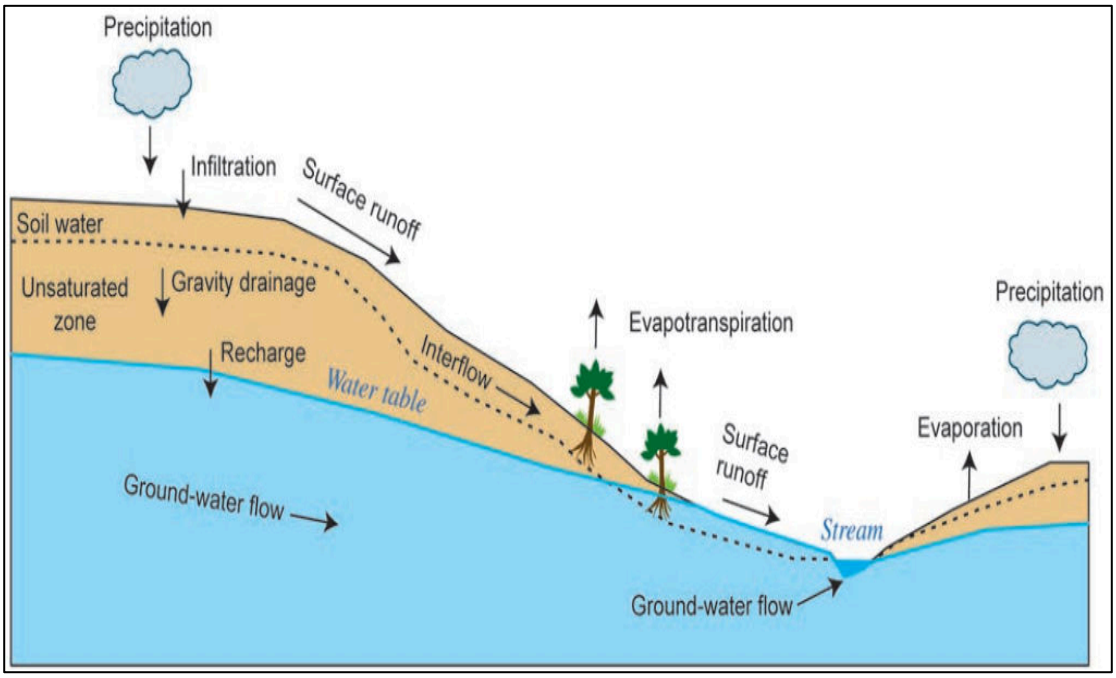
In the model, sanitation and waste disposal issue was also focussed as these are related to water circulation in the system.

Since PHED water supply source of the town is from distant mountain streams, the consistency of streamflow is inseparably related to forest coverage of the source area.

An assessment was made on forest resource usage in the surrounding area considering as urban footprint on forest resources by the fuelwood consumption from the forest. Also, topographical and geological controls on water resources were established.

In the mountain ecosystem, rainfall water is a prime source of water which feeds other water sources. Hence, the prolonged absence of rainfall may lead to other water sources exhaust. This study is concerned to find out how the town population cope with intermittent rainy days and periodic drought, particularly during post-monsoon season. Nevertheless, primarily the ecosystem gets water directly from soil moisture and rainfall which is classified as green and blue water respectively, however, the aquatic ecosystem also shares some amount of grey water flowing in the streams. Figure 4 shows water movement in a watershed.

Fig 4: *Flow of water in a watershed*



(after Feinstein, 2012)

Rapid population growth is making a footprint in critical headwater areas of the Himalayas through intensification of agricultural land use that has the potential to exert sharply accentuated pressures on the water resources, which in turn may lead to depletion of land and water resources in the region (Tiwari & Joshi, 2012). India is enlisted as 'megadiverse' country among 17 countries of the world with most biodiversity-rich countries with a particular focus on endemic biodiversity. The rich biodiversity found in the area is due to abundant rainfall and soil moisture storage.

In the Himalaya, about 36 per cent of springs have dried during the past 20 years resulting in a severe crisis of water for drinking as well as irrigation (Tiwari & Joshi, 2012). This study area also being a part of Himalayan territory poses a similar fate if an appropriate timely measure is not taken. According to Gleick, (1993) the 'values of water' use in various large regions of the earth are determined by three main factors viz. 1) the level of economic development, 2) existing population and 3) the geophysical (especially climatic) peculiarities of the territory. Therefore, we need to understand the interplay of all three factors for proper valuation of water in this geophysical setup along with population setup and urbanisation trend.

1.10 *Overview of the thesis*

The thesis is organised into five Chapters. *Chapter 1* introduces with the problem of the research topic along with objectives and research questions of the study. Further, the methodology is elaborated while executing the study. Also, the conceptual framework was described in the study. *Chapter 2* introduces the geographical identity of the study area, Mokokchung town. The area was elaborated from physical conditions to population setup. Review of literature is done in *Chapter 3* where different aspects of the study are discussed relating to water scarcity, water development, water accessibility, urban ecology and mountain ecosystem. *Chapter 4* is the core part of this study where the results of the surveyed data are analysed and interpreted relating to urban metabolism. Further discussion was made concerning research hypothesis considered in the introductory chapter. The study is summarised in *Chapter 5* discussing the benefits and importance of such study in future. This chapter concludes with the limitations of this study and discussed the future scope of further research.

CHAPTER 2

STUDY AREA

2 STUDY AREA

2.1 *Location*

This study was conducted in the Mokokchung town of Nagaland. Mokokchung town is endowed with beautiful scenery all around it. It is also the administrative headquarter of Mokokchung district situated at the hilltop location (figure 5). The geographical extent of the town is from 26°18′08″N to 26°20′20″N latitude and 94°29′42″E to 94°32′00″E longitude. Mokokchung town is located in the southern part of the Mokokchung district. The town municipal area (figure 6) formed merging of three Ao Naga villages viz. Mokokchung village, Ungma village and Khensa village covering 4.5 sq. km. according to Census of India, 2011 which is a reduced area than the previous census due to 'revised calculation' (table 14 and figure 14). However, the area calculated by the Land Records Department (2017) is nearly 7.0 sq. km. which is endorsed by MMC authorities (table 29).

Fig 5: *Part of the town seen at hilltop location from Khensa village*

(Photography by author)

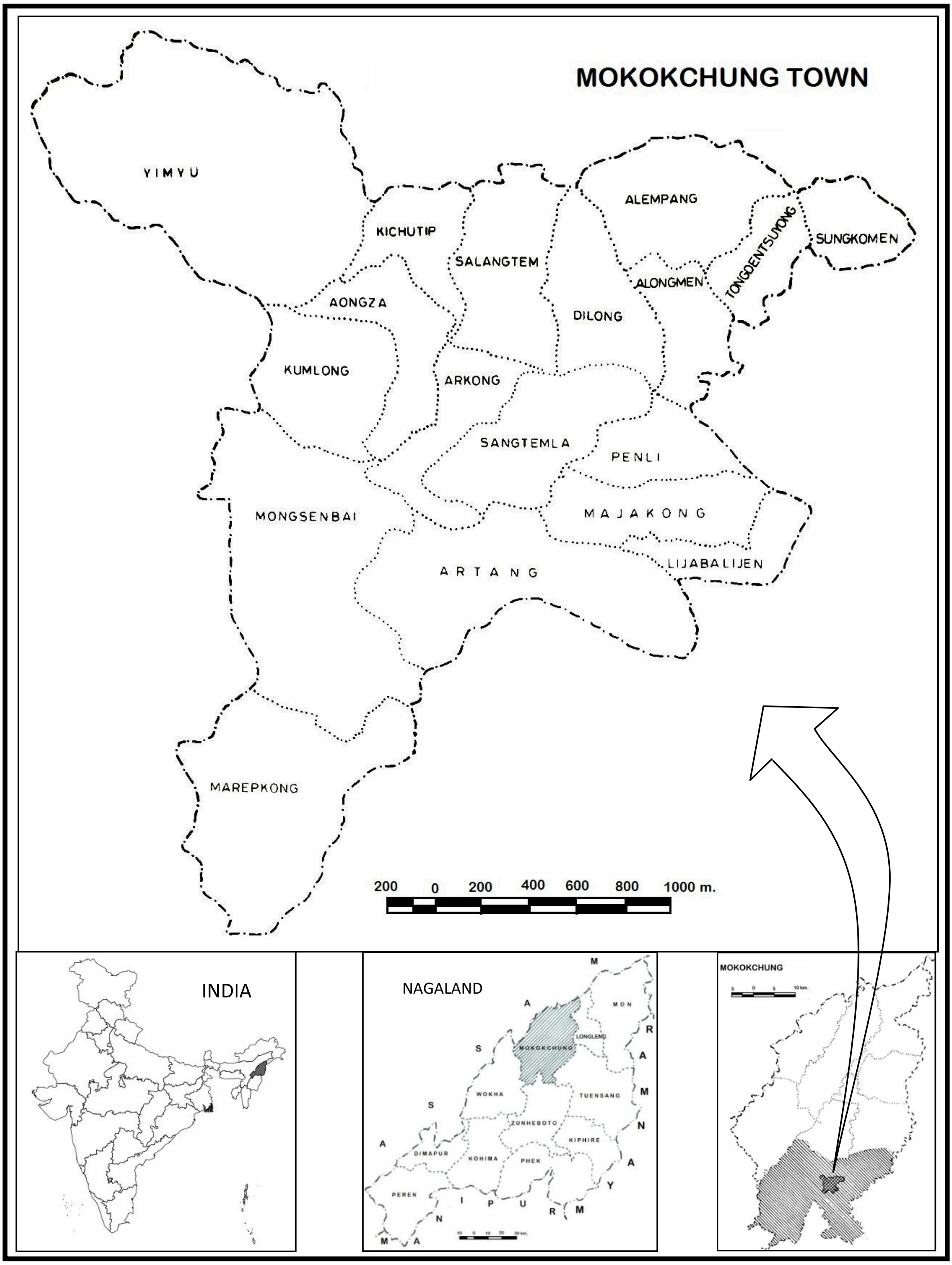
2.2 *Origin of Mokokchung town*

The place which is the district headquarters is the hub of all major administrative and commercial activity of the district. Mokokchung has a long history of British connection before India became independent in 1947. The story says (Census of India, 2011) that a group of early Ao people who had scattered to different places away from their original settlement in defiance of the wishes of their parent village, namely Koridang, came to a new place and established a new village which they named as 'Mokokchung'. The name means going away (*chung*) in defiance (*mokok*) of the wishes. The Mokokchung town was one of the first Naga Hills sites where the Assam Rifles, led by Britishers, established their outposts (then called stockades) in the later part of 19th century (Census of India, 2011). Much of the town initially grew around this post located in the DC Hill (now Sangtemla ward). The nomenclature of the district originated from the name of Mokokchung village, now an urban area and the headquarters of the district. Administratively, the Mokokchung town is under Ongpangkong circle of Mokokchung district of Nagaland. The town was celebrated its quasquicentennial (125 year) in 2015.

2.3 *Wards of the town*

The town is divided into 18 ward units (figure 6) administered by Urban Local Body (ULB) known as MMC. Each ward has a Chairman empowered with decision making under All Wards Union, Mokokchung. The wards are separated from each other by either a stream or a road as a means of demarcation. Brief description of these wards is given alphabetically.

Fig 6: *Wards of Mokokchung town*



(Cartography by author)

2.3.1 Alempang

Located in the east of Dilong ward this ward is generally sloping towards the north-west direction with maximum altitude 1250 m. and minimum altitude 1075 m. having a relief of 175 m. The ward covers an area of 0.36875 sq. km. The ward has 619 households with 2536 persons according to 2011 census.

2.3.2 Alongmen

In the east of Dilong ward and south of Alempang, this ward is situated in the upper part of Alempang ward with an area only 0.175375 sq. km. This ward has an altitude ranging from 1200 m. to 1325 m. thus relief of the ward is only 125 m. The general slope is towards the north-west direction. The ward has 425 households with 1,571 persons according to 2011 census.

2.3.3 Aongza

South of Kichutip and north-west of Kumlong ward, this ward has area is only 0.28138 sq. km. The ward highest altitude is 1275 m. and lowest 1175 m. hence relief is 100 m. It is forming a ridge running north direction. The ward has 396 households with 1,722 persons according to 2011 census.

2.3.4 Arkong

In the west of Sangtemla, Arkong ward has an area of 0.2263 sq. km. The highest elevation is 1300 m. and lowest elevation I 1200 m. Thus, relief of the ward is only 100 m. The ward has 532 households with 2,384 persons according to 2011 census.

2.3.5 Artang

Situated at East of Mongsenbai this ward s generally sloping towards the southern direction. Altitude ranges from 1075 m. to 1250 m. having relief 175 m. the ward has an area of 0.68985 sq. m. The ward has 835 households with 4,018 persons according to 2011 census.

2.3.6 Dilong

Sloping towards north from a saddle location (Police point) this ward has the highest altitude of 1300 m. and lowest altitude 1050 m. it is situated in the east of Salangtem ward. Thus, relief of the ward is 250 m. Area of the ward is 0. 2839 sq. km. The ward has 655 households with 2,490 persons according to 2011 census.

2.3.7 Kichutip

This ward is in between Yimyu in the west and Sangtemla ward in the east. This ward is north sloping from highest altitude 1175 m. to lowest 1050 m. Thus, relief of the ward is 125 m. Area of the ward is 0.20025 sq. km. The ward has 292 households with 1,237 persons according to 2011 census.

2.3.8 Kumlong

With an area of 0.31565 sq. km. Kumlong is located in the north of Mongsenbai ward. The highest altitude is 1275 m. in the eastern part and gradually lowers towards western part up to 1100 m. So, relief of the ward is 175 m. The ward has 517 households with 2,275 persons according to 2011 census.

2.3.9 Lijaba Lijen

This ward also sloping towards the south-east direction. Altitude ranges from 1050 m. to 1200 m. with a relief of 150 m. and area covering only 0.1819 sq. km. The ward has 187 households with 851 persons according to 2011 census.

2.3.10 Majakong

This ward is located in the south of Penli ward having a general slope towards east. Altitude ranges from 1125 m to 1300 m. having a relief of 175 m. The area of the ward is about 0.24485 sq. km. The ward has 347 households with 1,690 persons according to 2011 census.

2.3.11 Marepkong

Located in the extreme southernmost part of the town covering an area of 0.65646 sq. km. Highest altitude located in the Helipad with 1200 m. Altitude gradually lowers in the western part with minimum 1025 m. Thus, relief of the ward is 175 m. The general slope of the ward is towards the west. The ward has 196 households with 852 persons according to 2011 census.

2.3.12 Mongsenbai

In the north of the Marepkong ward, Mongsenbai ward is covering an area of 0.877875 sq. km. It has also general slope towards the west with highest altitude 1250 m. in the north-eastern part. Lowest altitude is in the southern part (1025 m.) Thus, the relief of the ward is 225 m. The road is following the general slope of the ward. The ward has 450 households with 1,950 persons according to 2011 census.

2.3.13 Penli

In the south of Alongmen and east of Sangtemla, this ward is sloping towards the south-east direction. The ward has altitude range from 1150 m. to 1300 m. with relief 150 m. Area of the ward is only 0.2139 sq. km. The ward has 436 households with 1,758 persons according to 2011 census.

2.3.14 Salangtem

This ward is situated in the east of Kichutip and west of Dilong ward. With an area of 0.346 sq. km. the ward has a general slope towards the north with highest altitude 1250 m. and lowest altitude 1050 m. thus the ward has 200 m. relief. The ward has 576 households with 2,417 persons according to 2011 census.

2.3.15 Sangtemla

This ward is situated in the nodal location of the Mokokchung town. Area of this ward is 0.4 sq. km. Highest and lowest altitude is 1350 m. and 1275 m. respectively. Thus, relief of the ward is only 75 m. The ward has 613 households with 2,631 persons according to 2011 census.

2.3.16 Sungkomen

Situated in the easternmost part of the town the ward has only 0.17062 sq. km. Altitude ranging from 1250 m. to 1325 m. this ward has relative relief of only 75 m. The ward has 364 households with 1,577 persons according to 2011 census.

2.3.17 Tongdentsuyong

This ward is in the east of Alempang ward with an area of 0.15435 sq. km. in the upper part of the Alempang ward with relief only 75 m. The ward has 417 households with 1,805 persons according to 2011 census.

2.3.18 Yimyu

Located in the north-western part of the town this ward is having two mounds. The highest altitude is 1250 m. which gradually decreases in north-eastern direction. Lowest altitude is 1075 m. Thus, relief of the ward is 175 m. Area of the ward is 1.18767 sq. km. The ward has 470 households with 2,149 persons according to 2011 census.

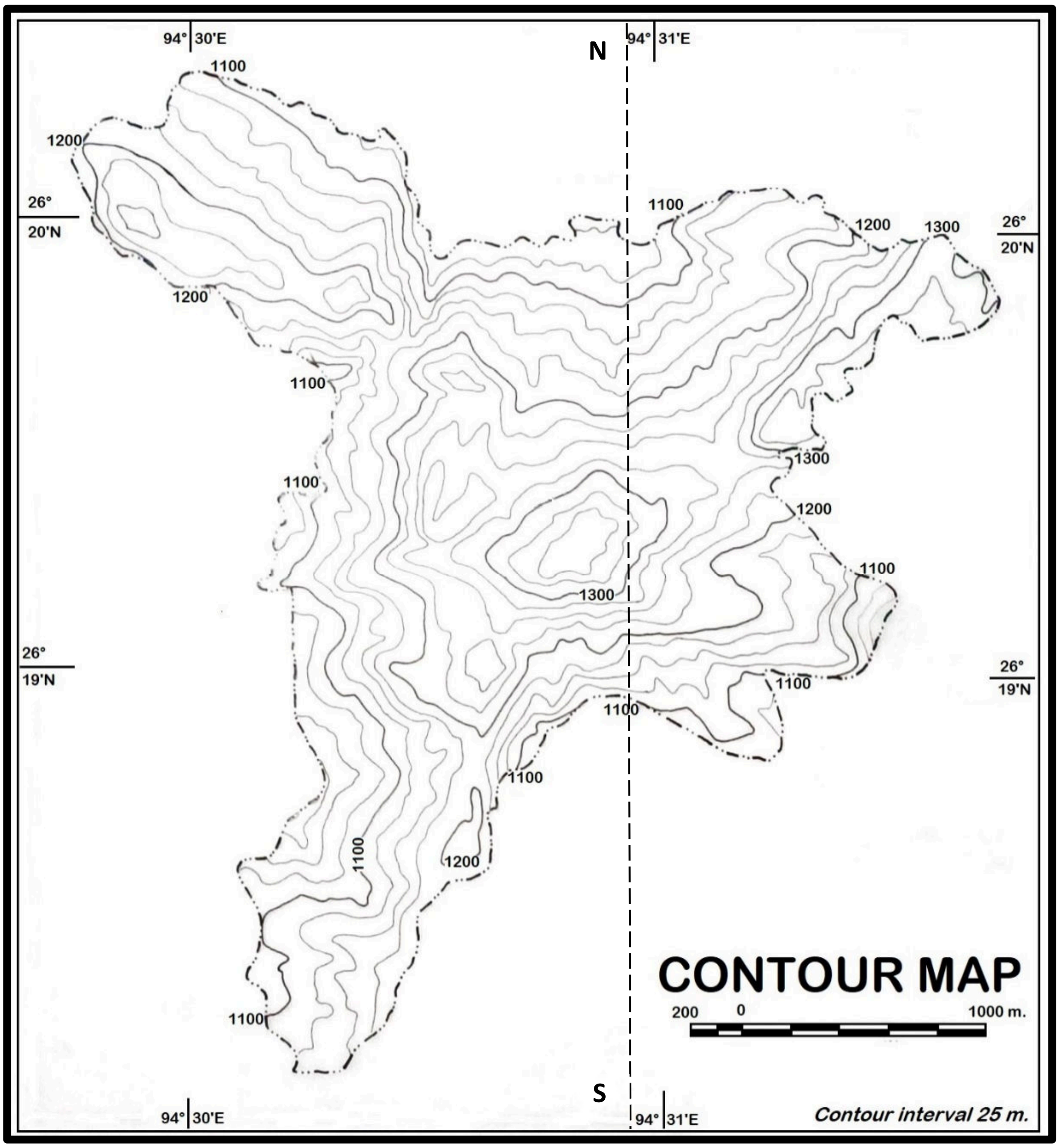
2.4 *Physiography and drainage*

There are 6 important hill ranges in the district. They are locally known as Japukong, Jangpetkong, Asetkong, Langpangkong, Ongpangkong and Tsurangkong. Japukong and Jangpetkong ran almost parallel to one another. Langpangkong is the easternmost range and Ongpangkong the southernmost while Asetkong is in the central position. The town is located in Ongpangkong range.

The town is situated on the hill ranges of Naga Hills which is a part of the eastern Himalayan mountain. The hill ranges traverse more or less parallel to one another in a north-east to south-west direction. The average height of the hills varies between 1,000 meters and 1,200 meters above mean sea level. The district headquarters, Mokokchung, is at an elevation of 1,325 meters above mean sea level.

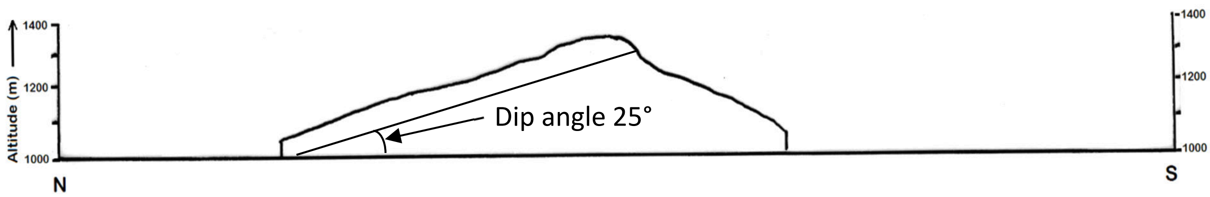
The relative relief of the town is about 450 meters. The northern aspect of the town is having a gentler slope of about 20 to 25 degree, while southern aspect is having steeper slope due to escarpment formation of about 30 to 35 degree slope (figure 8).

Fig 7: Contour map of the Mokokchung town



(Cartography by author)

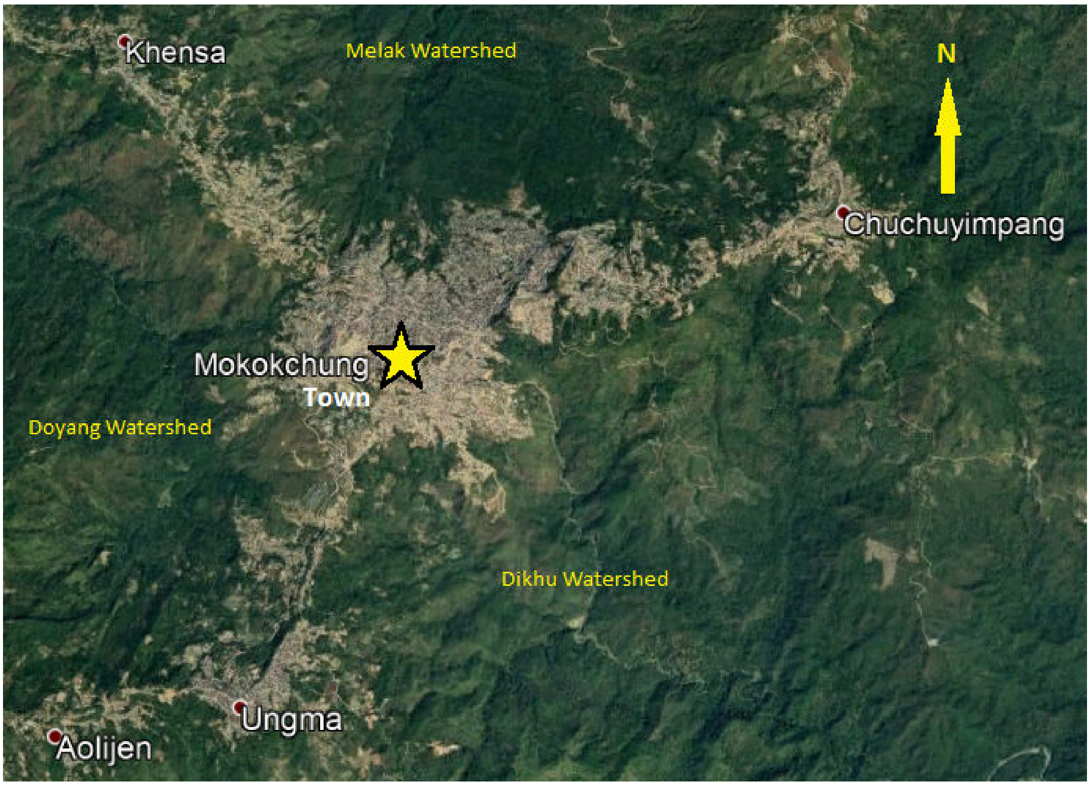
Fig 8: *Profile showing bedding plane across the N-S section of figure 7.*



Note: Dip angle assumed based on field observation in the northern aspect and figure 52

Few streams that are originating from this town and flowing out radially figure 52. The town is bounded by Melak Nala in the north a tributary of Jhanji river. Tsunge Ayong in the south and Aritao Ayong in the east are both tributaries of Dikhu river. Tsuza Ayong a tributary of Chubi river further flowing down to Doyang river in the west. Thus, the town is situated at the Headwater region amidst three important tributaries of the Brahmaputra river i.e. Doyang, Jhanji and Dikhu and bears hydrological significance in the downstream areas of the respective river system (figure 9).

Fig 9: *Mokokchung town amidst three watersheds*



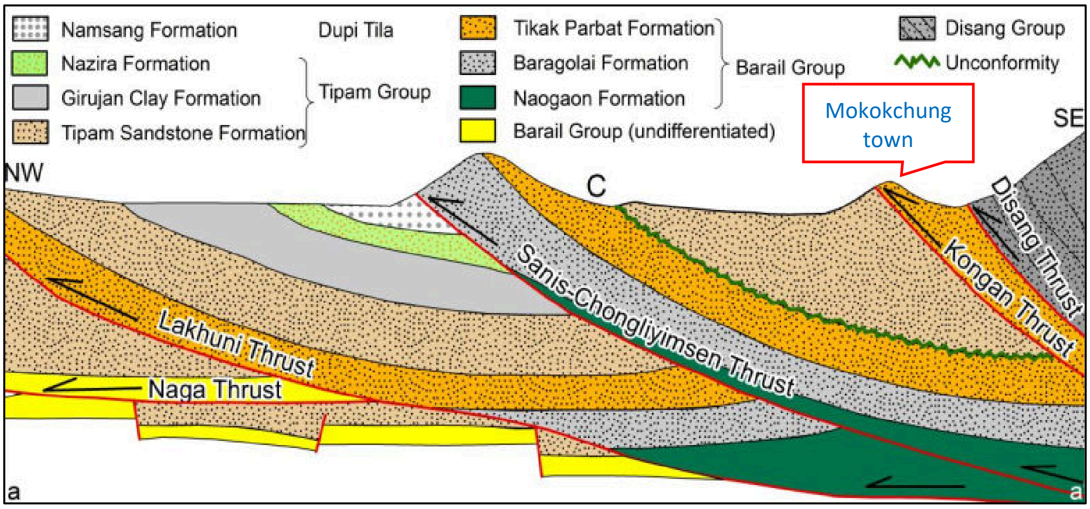
Note: Vegetated area is seen as shades of green (source: Google Earth™)

2.5 *Geology*

Mokokchung is situated at a stretch of a tectonically active zone known as 'Schuppen belt', trending NE-SW in the western sector of the Indo-Myanmar Ranges. This belt defines the western flank of Naga Hills. According to Geological Survey of India (GSI), this belt is a narrow linear belt of imbricate thrust slices which follows the boundary of

Assam valley alluvium for a distance of about 350 km along the flank of Naga-Patkai ranges. The belt is 20-25 km wide and extends for 200 km along the strike from Mishmi Thrust in the northeast to Maibong in the southwest, at the junction of Naga and Haflong-Disang thrusts (GSI, 2011). It is a composite of six tectonic blocks formed by several thrust slices occurring along with Naga Patkai hill ranges of Nagaland. The belt comprises Barail Group, Surma Group, Tipam Group, Namsang Formation and Dihing Formation (GSI, 2011).

***Fig 10:** Series of active thrust through the section of Mokokchung area*

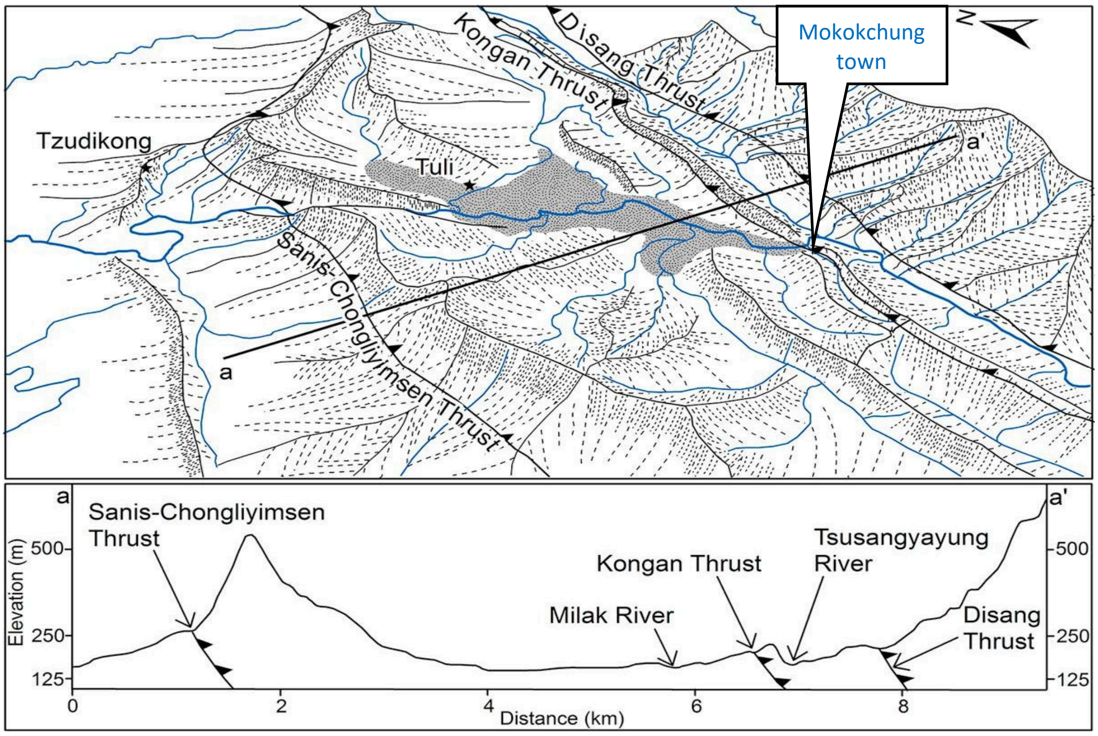


(after Longkumer et al., 2019)

The area undergoes 5 (five) thrust from south-east to north-west direction namely Disang thrust, Kongan thrust, Sanis-Chongliyimsen thrust, Lakhuni thrust and Naga thrust in the bordering foothills area of Assam. Mokokchung town is situated in between Disang thrust in the south-east and Kongan thrust in the north-east (figure 10 and 11).

The lithology of the town belongs to Disang Group of Middle and Lower Eocene age with Shale and Slate (figure 52). Roadside cutting and stream bed surface show that the general bedding plan is having a dip of about 30 degree to 35 degree towards north to the north-west direction (figure 8 and 52) due to this thrust force.

Fig 11: *Isometric view of hill ranges of Mokokchung town area and (below) tectonic profile along a – a' section of the area*

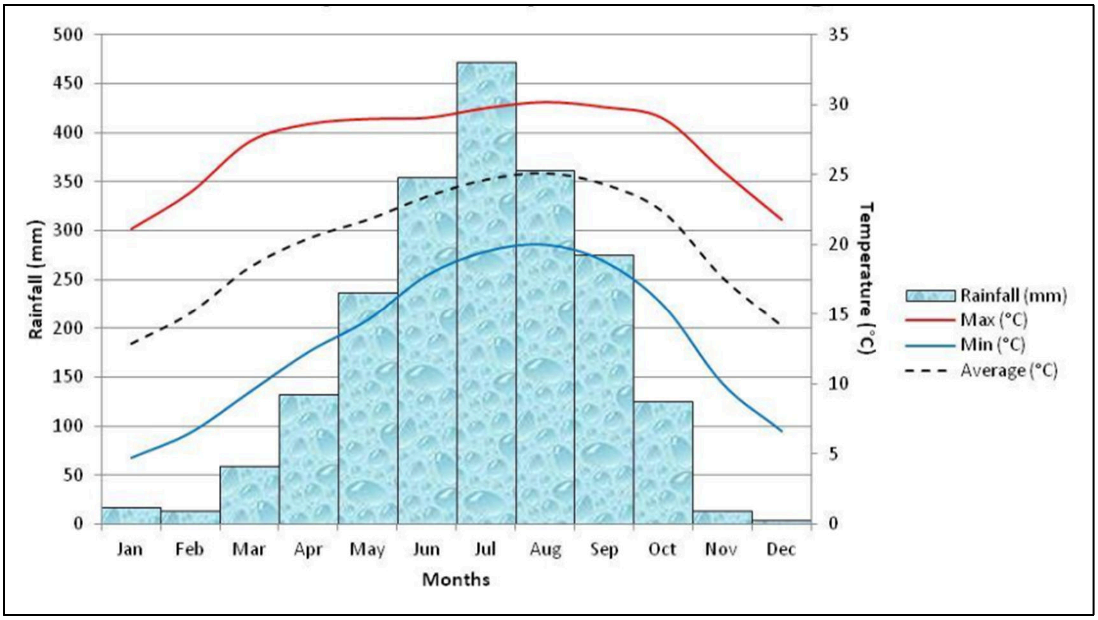


(after Longkumer et al., 2019)

2.6 *Climate*

With moderate rainfall (about 2,500 mm), the area is influenced by the south-western monsoon, that sets in the middle of June and continues up to the middle of September. Eighty per cent of the rainfall is received during the pre-monsoons and monsoons (IELO, 2016). The rainfall occurs for about nine months in a year, the heaviest concentration being in July and August. The temperature during the summer does not rise above 32°C, while during the January and February coldest temperature around 4°C. Overall, winter and rainy seasons dominate the year while spring and autumn seasons are very short. The rainfall nature of the area is periodic and functions according to the behaviour of the monsoon climate. As shown in figure 12, the rainfall amount gradually increases above 100 mm starting from April to October. Thus, the area is gifted with ample precipitation during the monsoon months and about 60.73 per cent of rainfall occurs during monsoon i.e. June to September (Kusre & Singh, 2012). The average annual rainfall occurs in the state is 859 mm to 2123 mm (Kusre & Singh, 2012) which is more as compared to the north-western part of the country. Kusre further categorises Mokokchung under Moderately high rainfall zone with 1634-1817 mm of rainfall.

Fig 12: *Average monthly rainfall and temperature at Mokokchung, 2005-2014*



(Data compiled from SWCD, Nagaland)

The rainfall data from 2005 to 2014 (table 26) also reveals that Mokokchung receives average annual rainfall above 2,000 mm. under the influence of tropical monsoon. However, the occurrence of rainfall is seasonal and the amount is unevenly distributed throughout the year where winter period is crippled by the scarcity of water quantity required for the basic survival of the people. As shown in figure 12 July is the highest rainfall receiving month with more than 450 mm. As shown in table 26, no significant rainfall occurs during the winter months from November to March. Though some occasional rainfall occurs during winter months it is insignificant (less than 50 mm) only.

2.7 *Vegetation*

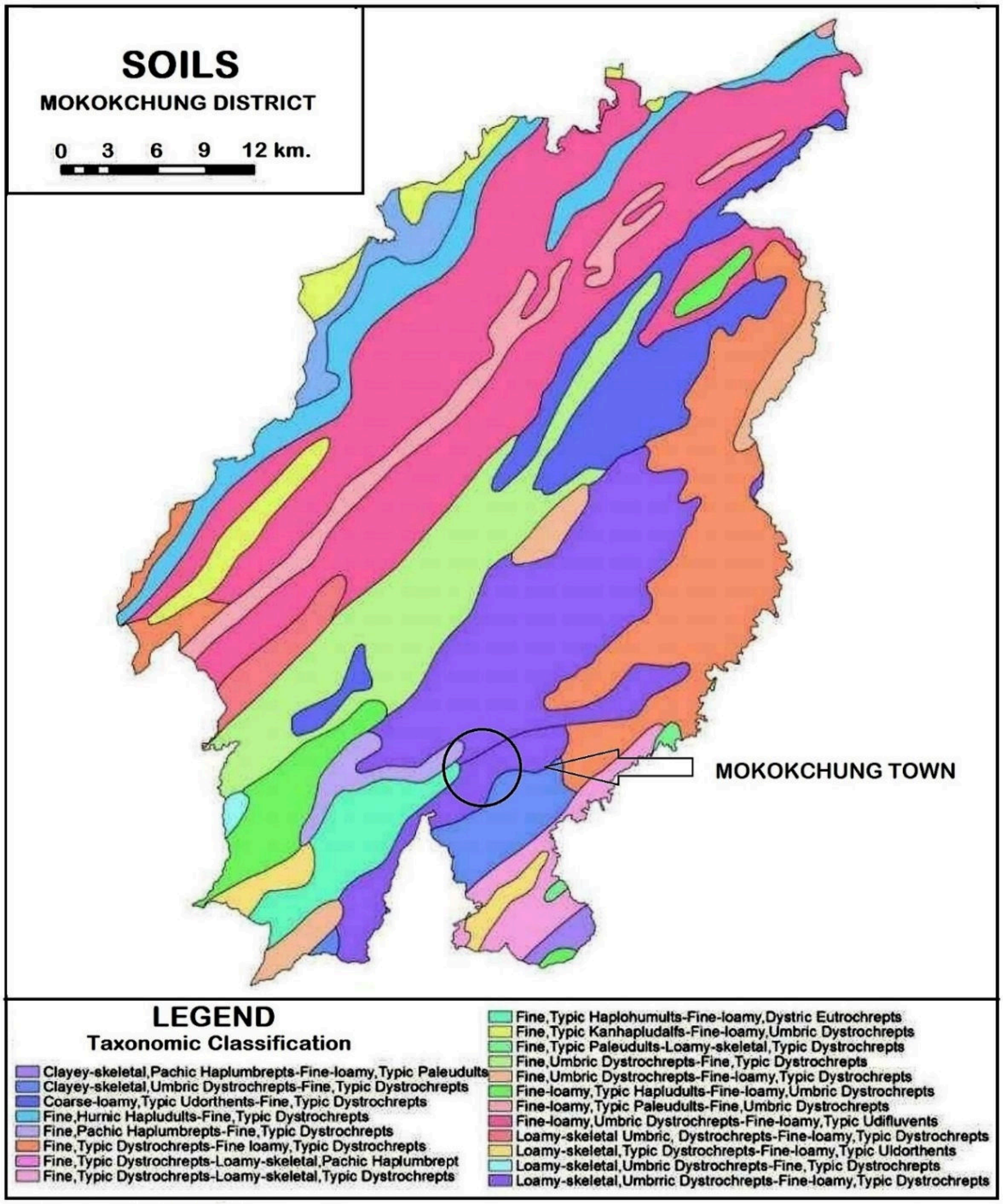
Though, most parts of the region are covered with jungles and deciduous trees which yield valuable timber and fuelwood, due to urban settlement in the town area vegetation is very limited within the town municipal area figure 9. However, during the household survey, it was observed that some people maintain orchards within their campus area if there is some vacant space. Such vacant space is having a sharp limitation towards the core part of the town. The only household of the peripheral ward is having such valuable homestead tree cover. It was also observed that within the municipal area some bamboo grooves are present along the stream bank due to steep slope and water factor.

2.8 *Soils*

Due to lithology (as parent material) according to the geological history of the area, topography and tropical climate described above, the soils of the town area is mostly skeletal from loamy to clayey in texture. According to USDA classification the soils are a combination of Ustalfs-Aqualfs-Aquepts, Udalfs-Orthents-Fluvents and Ochrepts-Orthents (Census of India, 2011) figure 13. The depth of the soil is not well developed due to topsoil erosion during heavy rain. Soil depth found in the town area is from 5 cm to sub-meter only. Soil pH is reported mostly acidic in most part of the district (Amenla et al., 2010).

.

Fig 13: *Soil map of the district showing the location of the Mokokchung town area*



Source: NBSS&LUP

2.9 *Groundwater*

The district-wise groundwater resource is assessed by CGWB in 2017 due to paucity of block-wise data. Total annual groundwater recharge of the district has been assessed as 27518.35 ham. and annual extractable groundwater resource as 24766.52 ham. after

2751.84 ham. drains away as natural discharge. The annual water extraction is only 78.37 ham. and the stage of groundwater extraction is only 0.32 per cent (CGWB, 2019). All the 11 districts including Mokokchung have been categorized as ‘Safe’ for groundwater extraction without any saline area.

Practically there is no groundwater development in the district. Groundwater extraction is also difficult. Most of the district area being hilly with high slope, the rainfall infiltration is very limited. Though there is a good amount of rainfall in the area, most of it goes out as surface run-off. In this type of hilly terrain, the scope for groundwater storage is limited to mostly secondary porosity developed due to structural features like fractures and faults etc. In this hilly terrain, groundwater emanates in the form of springs which are the only sources of water for drinking (CGWB, 2013).

2.10 *Transportation and Communication*

According to the new numbering scheme of NHAI, (2019), Mokokchung town is located in a junction connected by NH-2 from Amguri (Assam) to state capital Kohima. The town is connected to Zunheboto town of Zunheboto district by NH-702A, to Tuensang town of Tuensang district by NH-202 and Mariani (Assam) by NH-702D. Hence the town enjoys the locational advantage of road connectivity in comparison to some other areas of Nagaland. Besides, every village of the district is relatively better linked to the town by community roads. In recent time, original hilltop settlement is spreading out towards downhill and also expanding along the highways owing to topographic limitation and rapid urbanization.

From the communication point of view also the town is well connected despite hilly locality. Electronic communication service is provided by various telecom companies and Satellite television services. A Community FM radio station and Doordarshan station also operates from Mokokchung town. Various print media including some local newspapers circulates in the town. In recent time, various courier agencies including existing Indian postal service also operates in the town.

2.11 *Population*

With a total population size of 35,913 persons as per census (2011), the Mokokchung town is a Class -III urban area of Nagaland which represents as the third largest urban population in the state after Dimapur and Kohima. As per census (2011) male population is 18,898 against female population 17,015 representing sex ratio stands at 900 females against per thousand males. The population density of the town estimated at 8,000 people per sq. km. The town has a literate population of 94.6 per cent. As a tribal-state, the town also has dominant in ST population at 83.5 per cent while SC population is nil.

Majority of households of the town belongs to Ao community, where remaining households belong to Nepali, Sema, Bengali, Chang, Bihari, Marwari and Assamese community forming a multi-ethnic population mosaic.

Due to urban location, most people engage in tertiary occupation such as Government services and/or commercial activity. In recent time, due to population pressure and rapid urbanization of the town, original hilltop settlement is spreading out towards downhill and also expanding along the highways owing to topographic limitation.

2.12 *Population growth of Mokokchung town*

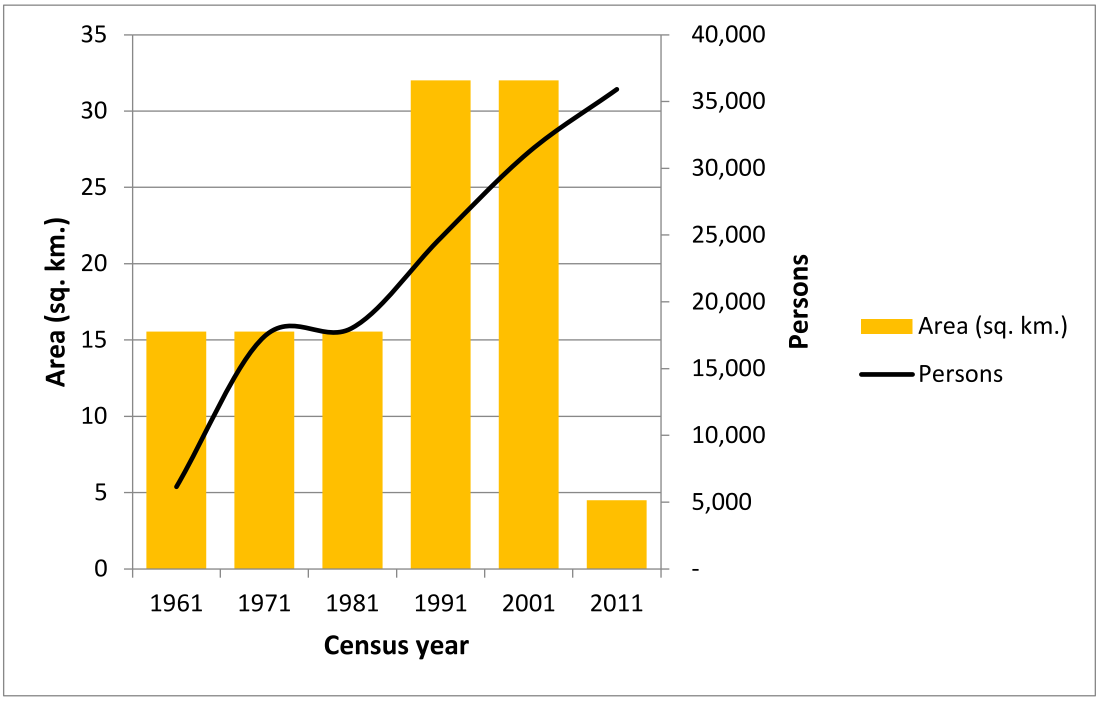
According to Census report (2011), the population in the district has gone down from 232,085 persons in 2001 to 194,622 persons in 2011 indicating a rate of population decrease of (-)16.14 per cent during the decade 2001-2011. But interestingly, the rate of decline for the rural areas comes to (-)30.85 per cent whereas in the urban areas the population increased by (+)78.53 per cent. In absolute terms, the population in the urban areas has grown during the period from 31,214 persons recorded in 2001 to 55,725 persons in 2011.

It should be noted here that while in 2001 Mokokchung town was the only urban area in the district the number of statutory towns increased to three and one Census town was also added. The increase in urban dwellers in 2011 therefore, is partly because of this reason. Figure 14 shows the population growth of Mokokchung town since 1961 to 2011 with drastic reduction in area due to revised calculation (table 14).

The proportion of the urban population to the total district population has increased from 13.45 per cent in 2001 to 28.63 per cent in 2011 indicating growth more than double in a decade. Out of nine circles in the district, the urban area is found in three of them namely Tuli, Changtongya and Ongpangkong. The proportion of the urban population in Tuli Circle is 52.53 per cent while in Changtongya and Ongpangkong it is 43.36 per cent and 42.86 per cent respectively. The urban population in Ongpangkong circle (Mokokchung town is located) has increased from 31,214 persons in 2001 to 35,913 in 2011 showing an increase of 15.05 per cent during the decade.

In Nagaland other than Dimapur city, Mokokchung town also has a significant sub-urban population. The trend of suburbanization in Mokokchung was started in the eighties with the mushrooming of satellite towns. Since the late nineties, this trend has speeded up and the erstwhile satellite town of Yimyu and Marepkong boomed and spread towards Mokokchung and became conjoined with it. Now both of these areas are included as wards of Mokokchung town. The continuous settlements have also extended from Alichen in the south, through Mokokchung town up to Khensa in the north-west; and from Mokokchung town through Fazl Ali College up to DEF colony in the North East. Besides, villages like Chuchuyimpang, Mokokchung Village, Ungma and Khensa have been engulfed by the spiralling urban spread of Mokokchung and have acquired urban characteristics as Outgrowths of Mokokchung town. As a result, people are now living miles away from the main town in smaller suburbs as well as villages, who drive to work daily to the main town. This phenomenon is in sharp contrast to other towns in Nagaland where an overwhelming majority of the population still tend to be concentrated in the main town.

Fig 14: *Urban population vs. Census Area of Mokokchung town, 1961-2011*



(Compilation of Census data)

CHAPTER 3

REVIEW OF LITERATURE

3 REVIEW OF LITERATURE

Studying water scarcity and related urban functions are the prime focus of this study. Various literature was studied from diverse fields to understand water-related problems. Thus, literature was studied relating to drought, water accessibility and urban ecology. Further, Mountain ecosystem services and headwater control of the mountain is also needing to understand, because the area is situated in the mountainous region.

Water scarcity of an area is caused by two reasons. One belongs to the natural phenomenon including biophysical conditions such as low rainfall, high temperature, soil characteristics, and vegetation cover. Secondly, it may occur due to man-made activities such as poor water management system and (un)human attitude. Both reasons affect both quality and quantity of the water resources, as well as human factors, overstress the water scarcity (R. B. Singh & Kumar, 2014**.** In respect to the study area, the discussion should be done on natural water scarcity which occurs in the area as seasonal drought and affects the normal life functioning.

3.1 *Drought as ecological disturbance*

The word 'drought' is derived from the archaic English and Scottish word 'drouth' that means thirst. Drought in an area may be viewed as a type of disturbance in water inflow in the streams or river flow. It causes a fall in water availability for an extended time to the available biota to an extremely low level. Droughts of the twenty-first century are characterized by hotter temperatures, longer duration, and greater spatial extent, and are increasingly exacerbated by human demands for water (Crausbay et al., 2017). Thus a drought is defined as a deficiency of precipitation over an extended period (a season, a year, or several years) of deficient rainfall relative to the statistical multiyear mean for a region (Eslamian & Eslamian, 2017). As suggested by Lake, (2000) drought is a disturbance and may best be defined by the nature of its destructive properties, rather than the response to it. In this way, comparisons between disturbance events are possible, in relation to their frequency, duration and overall severity (Humphries & Baldwin, 2003; Magoulick & Kobza, 2003).

The extent and severity of drought can be monitored in the following ways beyond conceptual definition and is normally dependent on the impact on a specific activity or phenomenon of drought in terms of: a) Deficiency in rainfall b) Reduction in groundwater recharge and streamflow c) The impact on primary activities such as agriculture and d) Perceptions of water deficiency against social expectations

In principle, drought can be determined by the balance between water supply and demand. The drought was previously recognized and categorized into 6 (six) general classes such as 1) Meteorological drought 2) Climatological drought 3) Atmospheric drought 4) Agricultural drought 5) Hydrological drought and 6) Water management drought. However, following research and review (Wilhite & Glantz, 1985 and Eslamian et al. 2017) only 4 (four) classifications were suggested further with basic approaches to measuring drought:

1. *Meteorological drought*—A period of abnormally dry weather sufficiently prolonged for the lack of water to cause a serious hydrologic imbalance in the affected area. The measure of water imbalance due to lack of precipitation is varied in different regions of the world (Wilhite & Glantz, 1985).
2. *Agricultural drought*—A climatic impact adversely affecting a range of crop production due to shortage of precipitation.

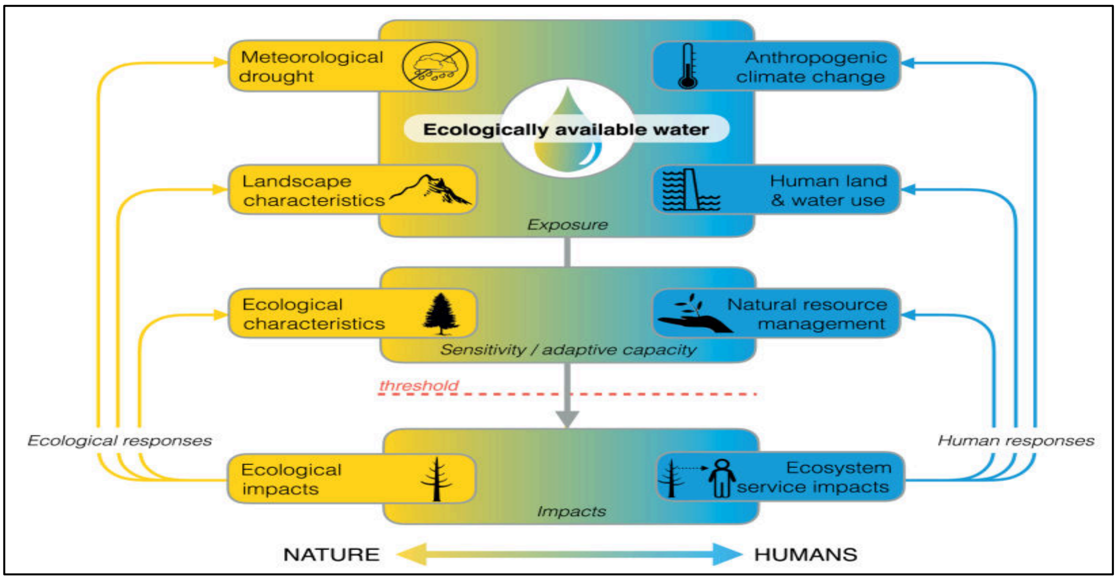
3. *Hydrological drought*—An environmental condition of below-average water content in water-bearing bodies such as streams, reservoirs, groundwater aquifers, lakes, and even in soils.

4. *Socioeconomic and environmental drought*—A situation when the declining water supply affects human activities and ecosystem demand function to cause a failure which may be associated with elements of meteorological, hydrological, and agricultural drought.

3.1.1 Conceptualizing ecological drought

The amount of water that is ultimately available to ecosystems during a drought is known as ecologically available water which is influenced by a combination of natural and human-modified processes. In the twenty-first century, the vulnerability components such as exposure, sensitivity, and adaptive capacity of community, population or individual arise from the interactions between natural processes and human activities (Crausbay et al., 2017).

Fig 15: *Conceptual diagram of ecological drought*



(after Crausbay et al., 2017)

The framework shown in figure 15 clarifies these human and natural dimensions of vulnerability portraying opportunities for mitigation of and/or adaptation to ecological drought. The yellow-blue colour gradient in the figure represents the continuum of coupled natural–human systems.

3.1.2 Drought and water scarcity differentiated

Common to all types of drought is the fact that they originate from a deficiency of precipitation referred as 'meteorological drought' that results in a water shortage for some activity (Wilhite & Glantz, 1985) and all other types of drought conditions are mostly linked to it only. Table 13 differentiates water scarcity, water stress and water shortage. According to the European Commission (EC), water scarcity is defined as a situation where sufficient water resources are not available to satisfy long-term average requirements (EC, 2007). Van Loon & Van Lanen, (2013) distinguishes the water stress phenomenon between drought and water scarcity. They explained that 'Drought' is caused by large-scale climatic variability which is a natural hazard and cannot be prevented by local water management while 'Water scarcity' occurs due to long-term unsustainable use of water resources, thus it is a man-made situation which water managers cannot control. However, both drought and water scarcity occur simultaneously and without much distinction that we generally use both words almost synonymously.

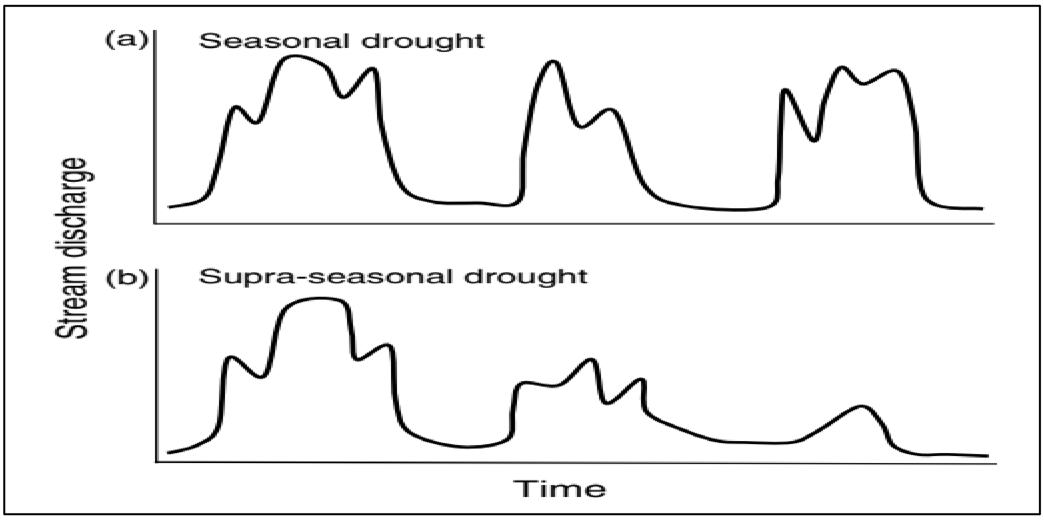
Degree of water scarcity has been classified by Hoekstra et al., (2012) into four levels:

1. Low water scarcity (<100%): where the water footprint is lower than 20 per cent of natural runoff; river runoff is almost unmodified; presumably environmental flow requirements is not violated.

2. Moderate water scarcity (100–150%): water footprint is between 20 and 30 per cent of natural runoff; runoff may be moderately modified; environmental flow requirements are not met.
3. Significant water scarcity (150–200%): water footprint is between 30 and 40 per cent of natural runoff; runoff is significantly modified; environmental flow requirements are not met.
4. Severe water scarcity (>200%). The monthly water footprint exceeds 40 per cent of natural runoff; runoff is seriously modified; environmental flow requirements are not met.

Drought may cause ecological process disruption and the ecosystem needs to respond accordingly for its survival. According to Lake, (2003) events of droughts can either be periodic or non-periodic. 'Periodic drought' is seasonal and cyclical which is predictable at a certain interval of time. 'Non-periodic droughts' are unseasonal or supra-seasonal having unpredictable event figure 16. Due to climate change, supra-seasonal drought is expected to occur in future with more frequency and intensity.

Fig 16: *Graphical concept between seasonal and supra-seasonal drought*



(after Lake, 2003)

3.1.3 A hydrological condition caused by drought

Drought causes a progressive decline in precipitation, stream runoff, soil moisture and groundwater depth which can be measured with instruments and also well observed in the environment. These parameters indicate a decline in water availability in the system.

In contrary to that Borchert, (1994) observed that, though tree growth should remain arrested during the 4 to 6 months long dry season of a year, it was found that most of the trees rehydrate before vegetative or flower buds begin to expand during this period. However, the degree of desiccation and the rate and timing of rehydration vary strongly with the availability of water stored in the tree trunks or in the subsoil, which cushions the impact of seasonal environmental drought (Borchert, 1994). This phenomenon indicates how physiological prosses of plants successfully adapt to a cyclical long dry season.

Droughts in streams disrupt hydrological connectivity for aquatic biota. Falling water levels reduce the amount of habitat available for most aquatic biota. It also may break surface water contact between the stream and its riparian zone reducing the hydraulic heterogeneity of flow (Lake, 2003). Shallow sections of the stream are the first to disappear and these sections can become a series of fragmented pools (Stanley et al., 1997; Magoulick & Kobza, 2003; Lake, 2003). Surface detention of water as the pool may persist in impervious sub-strata sections but pools may not stand longer with highly pervious bottom sub-strata although a hyporheic flow may continue (Stanley et al., 1997). Stream connectivity becomes disrupted by the cessation of longitudinal links (upstream-downstream) and the waning of lateral links between the stream channel and riparian zone (includes the flood plain) and vertical links between the surface, hyporheic zone and groundwater. During a severe drought, surface water may totally disappear from the whole sections of the streams loosing total hydrological connectivity (Matthews, 2012).

3.1.4 Ecological response due to drought

Drought may cause an ecosystem in distress (Glasby & Underwood, 1996) observed by the stream ecologist where stream water stress occurs at a certain time of the year. In freshwater systems, there appear to be two types of droughts: the predictable drought and unpredictable drought. Predictable drought is periodic in nature and mostly seasonal, which is more common that occur in the Mediterranean and wet-dry tropical climate. The unpredictable drought is unseasonal, often longer or supra-seasonal droughts marked by a decline in precipitation and water availability (Lake, 2003). The unpredictable drought may also lead one area to 'creeping disasters' as termed by Grigg, (1996). The drought disturbance causes the biotic responses in the ecosystem aftermath of drought event by the affected biota to the disturbing forces (Lake, 2000). As observed by Lake, (2000) two forms of biotic response may evolve to disturbance. One is the *resistance* –the capacity of the biota to withstand the drought and another one is the *resilience* - the capacity to recover from the drought.

3.1.4.1 Disturbance vs the Refugia

Disturbance can be defined either in terms of their effects on organisms or by their physical nature (Magoulick & Kobza, 2003). In a situation of stream ecosystem, drying of an intermittent stream system may not be considered as a disturbance if it dries cyclically in season and yet this drying may kill or remove individuals and impacts the population and community dynamics.

Such disturbance faced by the organism in a system may overcome by taking 'refugia'. The terms *refuge* and *refugia* have been interchangeably used widely in biological sciences (Keppel et al., 2012). The term refuge was used to denote temporal and/or spatial protection from disturbances (Magoulick & Kobza, 2003), predation, herbivory, or competition, and hence refers to microhabitats providing spatial and/or temporal protection from disturbances or advantages in biotic interactions (Keppel et al., 2012). This explains that refugia are relative, depending on species adaptations, spatial and temporal scale, and disturbance regime. Refugia are habitats that components of biodiversity retreat to, persist in and can potentially expand from under changing environmental conditions (Keppel et al., 2012). In the context of climate change, when the regional climate became unsuitable for species, their ranges contracted to places referred to as refugia with a limited spatial extent that provided suitable environments.

3.1.4.2 Use of refugia

In an ecosystem, a community or certain species may adapt to refugia during a disturbance to escape an adverse situation such as drought. A refugium is an area where conditions have enabled certain species or a community of species to survive in the event of adversity. In a stream ecosystem as studied by Lake, (2000) colonization of drought-affected streams or stream sections may occur by 5 avenues: 1) movement from subsurface (hyporheic) refugia, 2) hatching or reactivation of drought-resistant stages, 3) upstream movement, 4) downstream migration notably by drift, and 5) aerial recolonization. The extent of a refugium varies with changes in environmental conditions and may be taxon-specific (Keppel et al., 2012). Such refugia neutralise stress factors such as moisture, temperature, amount of light or nutrition created by the disturbance.

3.2 *Global water development*

A humble beginning of improving global water access target began in 1959, under the patronage of WHO. During the twelfth World Health Assembly, (1959) recognised for Community Water Supply Programme as an essential environmental health programme in its 48th resolution (Environmental Sanitation). In an analytical paper Fukuda et al., (2019) stated that the history of global drinking water targets can be divided into 5 (five) rounds over nearly 60 years as shown in table 16. According to these development stages presently fifth round of development needs to discuss, which will continue till 2030 under the United Nation (UN) Sustainable Development Goal (SDG) programmes.

3.2.1 The fifth round of development

The present fifth round of water development (table 16) started after the end of the targeted period of MDGs (table 17) in 2015 for another 15 years up to 2030. The UN General Assembly adopted a refined fresh action plan as Sustainable Development Goals (SDGs) with 17 agendas and 169 global targets to guide the development (United Nations, 2015b). This set of agendas and targets described as 'integrated and indivisible' to balance the three dimensions of sustainable development i.e. the economic, social and environmental (United Nations, 2015; Hall et al., 2017). The adopted 17 SDGs since 2015 are given in table 19. Among 17 goals for the development of SDGs, Goal 6 (table 20) seeks to ensure availability and sustainable management of water and sanitation by all in following 8 (eight) targets:

The above targets are structured in a gradual sequence maintaining right from basic accessibility and quality to achieving resilience during adverse climatic situation for sustainable development for all. While monitoring the global progress under Goal 6, UN-Water organizes the task within 3 (three) complementary initiatives as shown in table 2.

Over the past 25 years, the JMP has been instrumental in developing global norms to benchmark progress and facilitating critical reflection among WASH sector stakeholders. The JMP was responsible during the Millennium Development Goal (MDG) target 7-C for tracking progress and after 2015 JMP is responsible for monitoring the new 2030 Sustainable Development Goal (SDG) targets 6.1 and 6.2.

Table 2: *WHO initiatives for Goal six*

Initiative	SDG Target
1. WHO/UNICEF Joint Monitoring Programme (JMP)	6.1 and 6.2
2. Global Environment Management Initiative (GEMI)	6.3, 6.4, 6.5 and 6.6
3. UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS)	6.a and 6.b

3.2.1.1 The gravity of SDG Target 6.1

Among all the targets of SDG Goal 6 (Clean Water and Sanitation), Target 6.1 is the most challenging one in the history of global safe drinking water, because it aims to 'leave no one behind' and the monitoring indicators are more specific and demanding. It aims to provide water service accessible to local premises. With truly ambitious motive it should be achieved by 2030, which should be free from faecal and priority chemical (Arsenic and Fluoride) contamination targeting 2.1 billion people who currently lack such access of safe drinking water.

The text of target 6.1 has been carefully drafted and is far more ambitious than the previous MDG target. Firstly, it aims to achieve **universal access**, rather than just halving the proportion of the population without access as MDG programme. Secondly, it calls for **equitable access**, which implies reducing inequalities in service levels between population subgroups. Thirdly, it specifies that drinking water a household accesses should be **safe** from contamination**,** fourthly water pricing should be economically **affordable** with reasonable tariff and **reliably accessible to all** (JMP, 2017).

However, among all targets of Goal 6, target 6.6 (table 20) is set with the shortest deadline up to 2020 only, to protect and restore 'water-related ecosystems', including mountains, forests, wetlands, rivers, aquifers and lakes. Because without protecting water-related ecosystems, water availability and water quality would not be possible to meet.

All the SDG Goals and targets are mutually interlinked and the target 6.6 has strong interlinkages to other environmental SDGs and targets, together with SDG Goal 13 on climate change, specifically target 13.1 on strengthening resilience to climate change hazards and natural disasters. Some of these ecosystems, in particular, mountains and forests, play a pivotal role in water-related ecosystems, though they are not themselves included in this method. Dickens et al., (2017) advocate not to monitor for mountain and forest ecosystems in general, which are, anyway, specifically catered for in Goal 15 (target 15.1, 15.2 and 15.4) which has a conservation focus. However, the wetlands and other water-related ecosystems associated with the mountains and forests are indeed monitored. SDG global targets and indicators related to WASH program is shown in table 22.

For the interest of mankind and the environment, we need to give proper attention to preserve these ecosystems mentioned above to get water sustainably. Water for human consumptive use such as household, industrial and agricultural purposes is not transported from a long distance like other liquid commodities such as oil or gas. Thus, Oki et al., (2017) observed that because of the difficulty of direct transportation, water is an absolutely local resource without a single international price fixation. However, due to temporal and spatial scarcity, water may be transported from a distant location also.

3.3 *Accessibility of water*

Accessibility of water to human can be defined as the percentage of the population that has reasonable access to an improved drinking-water supply. From the public health standpoint, the proportion of the population with reliable access to safe drinking water is the most important single indicator of the overall success of a drinking-water supply programme (WHO, 2011). According to Eslamian, water accessibility refers to the rights or the ability of individuals or households to have an access to adequate quantities of affordable and safe drinking water and basic sanitation (Eslamian, 2014, p. 548).

On the other hand, Norman et al., (2011) define 'water security' as: 'sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health'. As to the ecological system, the lowest water requirement should be guaranteed to ensure the health of the ecological systems and the provision of ecosystem services.

Water supply must be available that is safe, adequate and also accessible for satisfying human needs. As defined by WHO guideline, safe drinking-water should not pose any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages (WHO, 2011). Access to safe drinking water is essential to sustain good health and is a basic human right, which is considered as an 'effective policy component' for health protection. Thus, logically development issues also of national, regional and local levels are related to access to safe drinking water. Hereby, effort should be made to achieve drinking-water that is as safe as possible.

Access to safe drinking-water measured by UN Joint Monitoring Programme (JMP) for Water Supply and Sanitation that assesses the use of improved drinking-water sources by households. 'Improved' sources are those that are capable of delivering safe water by nature of their design and construction. These include piped water, boreholes or tube-wells, protected dug wells, protected springs, and rainwater. 'Unimproved' sources include unprotected dug wells and unprotected springs. The JMP during SDG period recognizes that bottled water and tanker truck water can potentially deliver safe water, but previously during MDG period as reflected in the above classification of WHO, (2011), was treated them as unimproved due to lack of data on accessibility, availability and quality.

Table 3*: JMP service ladder for household drinking water*

Service level	Definition
Safely managed	Drinking water from an improved water source which is located on-premises, available when needed and free of faecal and priority chemical contamination.
Basic	Drinking water from an improved source provided collection time is not more than 30 minutes for a roundtrip including queuing.
Limited	Drinking water from an improved source where collection time exceeds over 30 minutes for a roundtrip to collect water, including queuing.
Unimproved	Drinking water from an unprotected dug well or unprotected spring.
No service	Drinking water collected directly from a river, dam, lake, pond, stream, canal or irrigation channel.

(Source: JMP, 2017)

To make the classification easier, JMP (2017) has developed a conceptual ladder as shown in table 3, to monitor SDG activities for drinking water improvement. It builds on the established source type classification, in continuation with MDG monitoring and introduces additional criteria on the accessibility, availability and quality of drinking water services. It enables countries at different stages of development to benchmark and compares progress over time (JMP, 2017).

The table 3 (conceptual service ladder) shows the bottom two divisions category of populations as '**unimproved**' sources who use unprotected surface water such as rivers, lakes and ponds (no service) and also other sources that do not protect against contamination (unimproved). While next upper three categories of the ladder classify as '**improved**' sources, whose design protects against contamination.

United Nations World Water Assessment Programme (UNESCO & WWAP, 2019) focuses on the theme of "Leaving No One Behind". The report argues that, fulfilling the human rights to safe drinking water and sanitation will significantly contribute to achieving most of the SDGs agendas for 2030. But the expectations are high enough as nearly one-third of the global population still deprived of safely managed drinking water services and only about two-fifths have access to safely managed sanitation services. Moreover, the intensification of environmental degradation coupled with climate change, population growth and rapid urbanisation poses considerable challenges to water security in recent time.

3.3.1 Assessing water accessibility

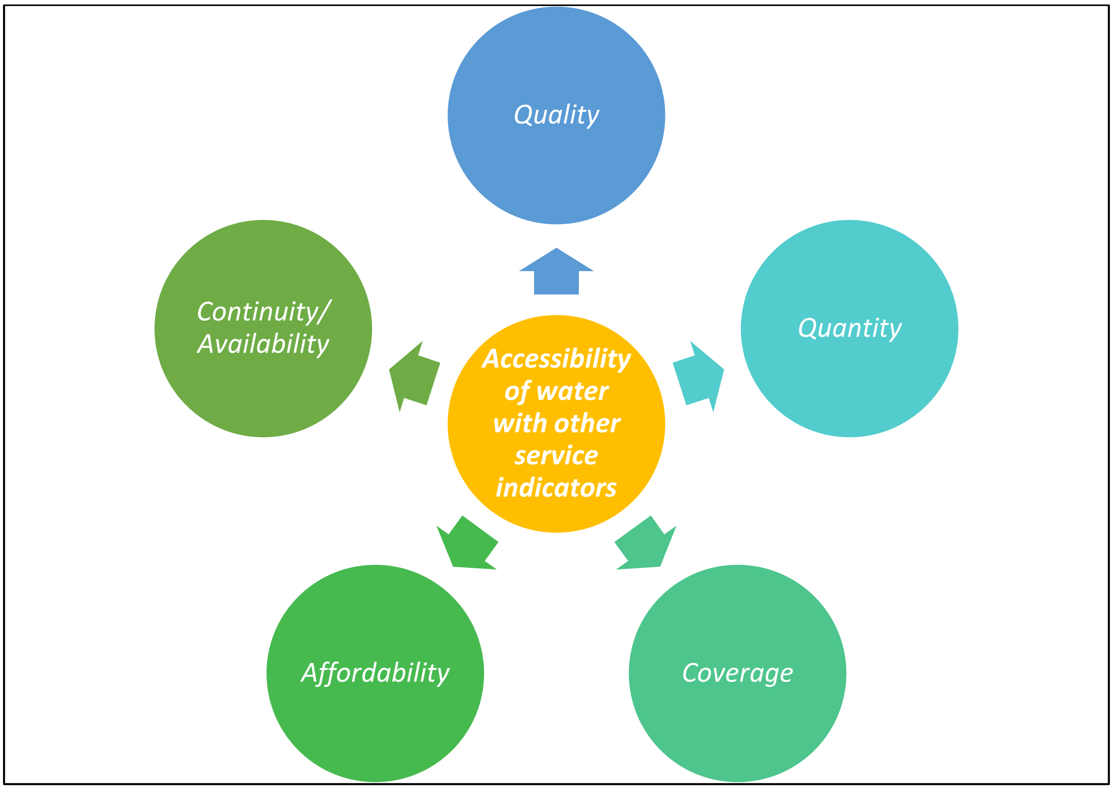
Population growth, urbanization, migration and industrialization, along with increases in production and consumption, have generated ever-increasing demands for freshwater resources (UNESCO & WWAP, 2015, p. 11). Evidence shows that the quantity of water used per capita depends on the accessibility of the water source. Those having access through a house or yard connection, or through a well inside the property, will use larger quantities of water than those having to fetch water outside, even if such a source is only a few minutes' walks from the house (JMP, 2000, p. 12). A human rights approach requires that individuals have rights to adequate water and sanitation services (UN Water, 2018).

Water insecurity is an effect, rather than a cause, of socio-political domination and infrastructural exclusion. While policy experts often respond to water insecurity by focusing on the issue of physical scarcity and estimates of water availability to explain water insecurity, it is often more than a technocratic response (Ray & Shaw, 2019a). The term 'security' is conceptualized as a function of 'availability', 'accessibility to services', 'safety and quality', and 'management' (Gain et al., 2016).

Conceptually, among all service indicators accessibility of water is central to all other indicators (figure 17). Because, from the public health standpoint, the proportion of the population with reliable access to safe drinking water is the most important single indicator of the overall success of a drinking-water supply programme (WHO, 2011).

According to JMP guideline, to determine the proportion of a population with reliable access to drinking water, the survey can be facilitated by establishing a common definition for reasonable access, appropriate to a local context observing related service indicators. Reasonable access of water is broadly defined by WHO as the availability of at least 20 litres per capita per day (lpcd) from a source within one-kilometre round trip distance or collection time up to 30 minutes from the user's dwelling. Explaining each of these service indicators will give a clear idea about the degree of accessibility of water-related services.

Fig 17: *Drinking water service indicators relationship*



(Conceptualized by author)

Thus, accessibility will be a criterion for both 'basic' and 'safely managed' drinking water services. As stated above JMP uses travel time or distance travelled in a round trip as an indicator for water accessibility. Estimation should be done for the time required to travel to the water source, queuing, fill containers, and return to the household. In the global context, household survey data shows that in most countries the majority of the population report either having water on their premises or spending less than 30 minutes collecting drinking water, thereby meeting the criteria for 'basic' service (JMP, 2017). However, a significant proportion of people report spending over 30 minutes to one hour or even over an hour, per trip to collect water.

3.3.1.1 Quality of water

Water quality accessed by an individual household should be acceptable for the functioning of basic household activities such as drinking and washing. It should not also pose any health concern while consuming. If quality does not meet the expectation of population it may be said as poor accessibility. Assessment of drinking water quality provides an important measure of safety, and most countries have national standards that are mostly aligned with WHO *Guidelines for Drinking Water Quality*. The highest priority water quality parameter globally is the contamination of drinking water with faecal matter. The quality of surface water outside the OECD is expected to deteriorate in the coming decades, through nutrient flows from agriculture and poor wastewater treatment (OECD, 2012). The consequences will be increased eutrophication, biodiversity loss and disease.

According to International Labour Office (ILO) Self-Training Handbook, safe or 'improved drinking water' drinking water or 'potable water' is water that is to be used of sufficient quality for drinking (as well as for cooking and personal and domestic hygiene) without causing a risk to health (ILO, 2016, p. 30). A lot of water that is intended for drinking is unfortunately not safe. The three main threats to drinking water are microbial, chemical, and radiological.

Faecal contamination of drinking water is usually identified through the detection of indicator bacteria such as *Escherichia coli (E. coli)* in the given sample. However, sometime contamination may show temporal variability also and brief contamination events may go unnoticed during routine surveillance but still, it may have serious public health outcomes. Though JMP considers the absence of *E. coli* in drinking water as a lone parameter for global water quality monitoring purposes, there may be some other contaminants also that may cause a health concern. The review done in series of JMP reports confirmed that improved sources are more likely to be free of microbial contamination than unimproved sources, but that contamination is nevertheless widespread (JMP, 2017). In addition to microbial contamination, high-priority chemical parameters at a global level are arsenic and fluoride.

3.3.1.2 Quantity (at service level) of water

Water quantity is another important parameter for assessing accessibility. The OECD, (2012) baseline scenario projects that by 2050, 3.9 billion people, over 40 per cent of the world's population, are likely to be living in river basins under severe water stress. Water so obtained should fulfil basic hygiene for per person per day. The quantity of water collected and used by households has an important influence on health. According to OECD (2012) projection, more than 240 million people (most of them in rural areas) are expected to be without access to an improved water source by 2050.

In many regions of the world, groundwater is being exploited faster than it can be replenished and is also becoming increasingly polluted. There is a basic human physiological requirement for drinking water to maintain adequate hydration and an additional requirement for food preparation. Further, an adequate amount of water is required to support hygiene, which is necessary for health. Estimates of the volume of water needed for health purposes may vary widely. In deriving World Health Organization (WHO) guideline values, it is assumed that the daily per capita consumption of drinking-water is approximately 2 litres for adults, although actual consumption varies according to climate, activity level and diet. Based on currently available data, a minimum volume of 7.5 lpcd will provide sufficient water for hydration and incorporation into food for most people under most conditions. Besides, adequate domestic water is needed for food preparation, laundry and personal and domestic hygiene, which are also important for health.

Water may also be important in income generation and amenity uses. Most public health problems arise due to the underlying cause of inadequate water quantity and quality in crises. The priority in such a situation becomes is to provide an adequate quantity of water, even if it is of intermediate quality (Sphere Association, 2018). People affected by crises are more vulnerable to illness and death from disease, particularly diarrhoeal and infectious diseases. Such diseases are strongly related to inadequate sanitation and water supplies and poor hygiene. WASH programmes aim to reduce public health risks. In WASH programmes, it is important to:

- manage the entire water chain: water sourcing, treatment, distribution, collection, household storage and consumption;
- manage the entire sanitation chain in an integrated manner;
- enable positive healthy behaviours; and
- ensure access to hygiene items.

People are aware of key public health risks related to water, sanitation and hygiene, and can adopt individual, household and community measures to reduce them. According to handbook prepared by Sphere Association, (2018), a minimum of 15 lpcd is established practice. However, In the acute phase of drought, 7.5 lpcd may be appropriate for a short time and in an urban middle-income context, 50 lpcd may be the minimum acceptable amount to maintain health and dignity.

***Table 4**: Service level and quantity of water collected*

Service level	Distance/time	Likely volumes of water collected	Public health risk from poor hygiene	Priority, intervention and actions
No access	More than 1 km / more than 30 min round-trip	Very low: 5 litres per capita per day	**Very high** Hygiene practice compromised Basic consumption may be compromised	**Very high** Provision of basic level of service Hygiene education Household water treatment and safe storage as an interim measure
Basic access	Within 1 km / within 30 min round-trip	Approximately 20 litres per capita per day on average	**High** Hygiene may be compromised Laundry may occur off-plot	**High** Provision of improved level of service Hygiene education Household water treatment and safe storage as an interim measure
Intermediate access	Water provided on-plot through at least one tap (yard level)	Approximately 50 litres per capita per day on average	**Low** Hygiene should not be compromised Laundry likely to occur on-plot	**Low** Hygiene promotion still yields health gains encourage optimal access
Optimal access	Supply of water through multiple taps within the house	100–200 litres per capita per day on average	**Very low** Hygiene should not be compromised Laundry will occur on-plot	**Very low** Hygiene promotion still yields health gains

(Source: WHO, 2011)

Howard & Bartram, (2003) and WHO, (2011) reviewed the requirement of minimum water quantity to maintain basic hygiene related consumption for hydration and food preparation. Table 4 indicates the likely quantity of water that will be collected at different levels of service. The estimated quantities of water at each level may reduce where water supplies are irregular and the risks of access to contaminated water into domestic water supplies increases. It is also possible that, where water supply is intermittent, a further health risk may result from the compromised functioning of waterborne sanitation systems, though the optimal amount of water access is achieved, as there may be a limited storage facility.

It is presumed that the quantities of water collected and used by households are primarily a function of the distance to the water supply or total collection time required. When the distance to the water source to be covered manually from the premises, the collected water amount decreases owing to less time available for collection. When drinking water sources are not located on-premises, households must spend time and energy in collecting water. However, most study shows that the burden of water collection is unevenly distributed among household members as is done mostly by woman and school-going children members (under 15 years of age) of the household. Thus, JMP categorises a ‘basic access’ trip of water as maximum tolerable distance /time to a source should be 20 lpcd, and located within 1 km of round-trip distance or spent 30 minutes including waiting time at the source.

3.3.1.3 Water service coverage

Water accessibility should also be evaluated for a given population in terms of coverage**.** Monitoring of water supply coverage will help to ensure water supply for the millions of people who still lack convenient access to a ‘safe’, reliable and affordable water source. Information about water service coverage can be collected quantitatively or qualitatively. Quantitative data about water service coverage often expressed in percentages of households having or not having access. However, qualitative methods are more exploratory and analytic, seeking a diagnosis or description of a problem. Rather, in certain time qualitative expression gives a better explanation than quantitative analysis discovering some new information that was unexpected and therefore was not included in the survey.

3.3.1.4 Affordability (tariff or labour) of water

The accessibility also to be measured in terms of universal affordability. The cost price or equivalent physical labour for required water should be tolerable by a household of poor economic profile. The affordability of water has a significant influence on the use of water and selection of water sources. Households with the lowest levels of access to safe water supply, frequently pay more for their water than do households connected to a piped water system. The high cost of water may force households to use alternative sources of water of a poorer quality that may pose a greater health risk. Furthermore, high costs of water may reduce the volumes of water used by households, which in turn may influence hygiene practices and increase risks of disease transmission.

3.3.1.5 Continuity or availability of water

Continuity or availability is another important criterion for assessing drinking water service levels. It can be assessed based on continuity i.e. frequency or duration of time it is available through a piped source. More the frequency or duration reflects higher accessibility. Interruptions to drinking-water supply, either because of intermittent sources or resulting from engineering inefficiencies, are a major determinant of the access to quality of drinking water. Interruption in continuity may affect hygiene in different ways. Any interruption of service is likely to result in degradation of water quality, and increases the risk of exposure to contaminated water and therefore increased risk of waterborne disease. Daily or weekly discontinuity results in low supply pressure and a consequent risk of in-pipe recontamination. Other consequences include reduced availability and lower volume use, which adversely affect hygiene.

In 2010, UN General Assembly recognized "the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights". It also specifies that water should be available continuously and in a sufficient quantity to meet the requirements of drinking and personal hygiene, as well as of further personal and domestic uses, such as cooking and food preparation, dish and laundry washing and cleaning. Supply needs to be continuous enough to allow for the collection of sufficient amounts to satisfy all needs, without compromising the quality of water (JMP, 2017).

To maintain uninterrupted service in the premises a buffer water storage may be necessary. However, and this may sometime lead to an increase in the risk of contamination during storage and associated handling. Also, Seasonal discontinuity often forces users to obtain water from inferior and distant sources. As a consequence, in addition to the obvious reduction in quality and quantity, time is lost in water collection due to remoteness of the source. Level of continuity of water services in decreasing can be classified as follows:

1. Year-round service from a reliable source with no flow interruption;
2. Year-round service with frequent (daily or weekly) interruptions;
3. Seasonal service variation resulting from source fluctuation;
4. Compounded frequent and seasonal discontinuity.

All these 'service indicators' are complementary to the quality control function of the drinking-water supplier (WHO, 2011). However, out of all the above-mentioned indicators first three (quality, quantity and coverage) are the most important indicators having a direct link with human health and sanitation. Thus, water service providers must monitor all these indicators whether the population is facing any water supply related issue or not. Though JMP monitoring includes drinking water facility in the education and health sector also, this study is confined to the domestic sector only as an essential area of community health.

Drinking water sources located on-premises may include a wide range of improved and unimproved source types. Some people must often travel to collect water from public taps. As reported by JMP (2017) in most of the countries the population is using rainwater and boreholes or tube wells has a source usually located on-premises, whereas protected dug wells and springs are equally likely to be found off-premises. Unprotected sources and surface water sources are usually not located on-premises. Overall, improved drinking water sources are more likely to be located on-premises, while collection from unimproved sources is more likely to take more than 30 minutes (JMP, 2017).

3.3.2 Indian scenario of water accessibility

India has more than 18 per cent of the world's population but has only 4 per cent of the world's renewable water resources and 2.4 per cent of world's land area (MEA-WHO, 2005). According to 76th round NSS report conducted during the second half of 2018, about 42.9 per cent of the households in the rural areas used *hand pump* as against about 40.9 per cent of the households in the urban areas used *piped water* into the dwelling as the 'principal source' of drinking water (NSO, 2018). The survey states that about 56.1 per cent of the urban population has a water source in their dwelling, and about 24.6 per cent urban population access their water in their premises. Though households getting sufficient drinking water from principal source throughout the year is about 90.9 per cent in urban setting but about 63.7 per cent of households reported no requirement of supplementary source of drinking water.

3.3.3 Human health vs. water accessibility

The amount of water available for a household is an important aspect of domestic water supplies (table 5) which influences public health in general and family hygiene in particular (Howard & Bartram, 2003). It is therefore important to establish a relationship between the amount of water available and associated health concern. Generally, people living in warm climate drink more water due to dehydration and urge for bathing more frequently than the people living in a cold climate (table 18). Again, there is more water requirement for a female during the lactating period and also to maintain menstrual hygiene than a male. Thus, there is a different requirement of water in daily life with the variation of temperature, sex and age.

Table 5: *Requirement for water service level to promote health*

Service level	Access measure	Needs met	Level of health concern
No access (quantity collected often below 05 lpcd)	More than 1000 m or 30 minutes of total collection time	Consumption – cannot be assured Hygiene –not possible (unless practised at source)	Very High
Basic access (average quantity unlikely to exceed 20 lpcd)	Between 100 and 1000 m or 5 to 30 minutes of total collection time	Consumption – should be assured Hygiene – handwashing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access (average quantity of about 50 lpcd)	Water delivered through one tap on the plot (or within 100 m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity of 100 lpcd and above)	Water supplied through multiple taps continuously	Consumption – all needs met Hygiene – all needs should be met	Very low

(after Howard & Bartram, 2003)

Grandjean, (2005) discusses various impinging factors responsible for water requirement on daily basis. He explores water requirements for metabolic processes in human at different age groups and possible adverse consequences of inadequate intakes and factors that affect fluid requirements. More water is required by young children, pregnant and lactating women, the elderly, and people with certain illnesses under a mild physical activity. Further drinking water consumption may be increased under stressful physical activity and hot weather up to 16 lpcd. Thus, people may require a high range of drinking water depending on aforesaid factors.

3.3.4 Basic water requirements

Use of water may vary according to societal needs in different sectors of use such as drinking, cooking, growing food, manufacturing process, producing energy, removing or diluting wastes etc. It is generally accepted that for each of these activities the water requirement does vary with climatic conditions, culture, diet, tradition, technology, lifestyle, and wealth. The type of access to water alone is an important determinant in total water use. Table 5 and 6 shows that the level of domestic water use varies with distance from the water source and with the climate (Gleick, 1996).

Table 6: *Domestic water use by distance to the source*

Source of water	Water use (litters/person/day)
Public Standpipe farther than 1 km	less than 10
Public Standpipe, closer than 1 km	20
House Connection, simple plumbing, pour, flush toilet	60 to 100
House Connection, urban, with gardens	150 to 400

(Source: Gleick, 1996)

3.3.5 Household water demand

Okun (1987) evaluated per capita use in household water demand in various climatic situation zones as shown in table 18. The table reflects that water use depends on climate and ease of access. Greater per capita water use will be in hot and dry zones as compared with cold, humid zones. Again, differences between the zones are likely to be higher when the supply is domestically used for animal and garden watering. There is a difference in estimation made by WHO and BIS as shown in table 15.

3.4 *Urban Ecology*

The 'Urban Ecology' is an emerging, interdisciplinary field that aims to understand how human and ecological processes can coexist in human-dominated systems and help societies with their efforts to become more sustainable (Marzluff et al., 2008). While studying urban ecosystems focus is given to humans who drastically modifies the natural environment for his living in urbanized landscapes. So, it is an amalgam of multiple disciplines such as sociology, geography, urban planning, landscape architecture, engineering, economics, anthropology, climatology, public health, and ecology. Because of its interdisciplinary nature and unique focus on humans and natural systems, "the term *urban ecology* has been used variously to describe the study of humans in cities, of nature in cities and of the coupled relationships between humans and nature" (Marzluff et al., 2008).

Alberti, (2008) pointed out that "Early descriptions of urban ecosystems have focused on both the *ecology in cities* (which primarily focuses on the study of habitats or organisms within cities) and an *ecology of cities* (which studies urban areas from an ecological systems perspective)". Urban ecology is the study of the structure and function of man-made environments, how the living and non-living parts of those environments relate to each other, and the quantification of the flows of energy, materials and nutrients - required to sustain urban systems (M. H. P. Hall & Balogh, 2019, p. 3). So basically, there is generally a distinction made between the *ecology of* *cities* and *ecology in cities.* Study of Urban ecology is done at various scales with these two distinct approaches.

3.4.1 Background of 'urban ecology'

After the second half of 20th century, the subject got more boost conceptually incorporating various principles of physics and engineering in the field of environmental biology mostly by the pioneer works of E. P. Odum and his brother H. T. Odum. They analysed the flow of energy into the functioning of nature or ecosystem as the main driving force, comparing as a 'machine system' which also performs by taking energy input in its various components to form the main source of energy (E. P. Odum, 1963; E. P. Odum, 1968; H. T. Odum, 1971; E. P. Odum, 1975; H. T. Odum, 2007). Thus in respect of their contribution the Odum(s) are considered as the father of systems and ecosystem ecology, a perspective that is ideal for studying a system as complicated as a city (M. H. P. Hall & Balogh, 2019). Gradually urban ecology started to develop into an important sub-discipline of ecology from the conceptual framework initiated in the late 1940s and early 1950s in Europe, North America, and Asia (Niemelä et al., 2011; McDonnell & Pickett, 1997; Marzluff et al., 2008; Alberti, 2008; McDonnell, Hahs, & Breuste, 2009). The work of earlier ecologist since the mid-part of the 20th century gave rise to the discipline of *urban ecology* to study mainly focuses on the biotic and abiotic structure and function of cities. It is an emerging, interdisciplinary field that aims to help societies to become more sustainable and seek to understand how human and ecological processes can coexist in human-dominated systems of the urban area.

The UNESCO- MAB is an Intergovernmental scientific programme that aims to establish a scientific basis for the improvement of relationships between people and their environments. The programme combines the natural and social sciences, economics and education to improve human livelihoods and the equitable sharing of benefits, and to safeguard natural and managed ecosystems, thus promoting innovative approaches to economic development that are socially and culturally appropriate, and environmentally sustainable.

Since the last few decades, the discipline of urban ecology is becoming wider in its scope by the amalgamation of several other related disciplines who studies urban areas from different perspectives and emerging as a relatively new discipline of landscape ecology. Urban ecologists are to be well-versed to utilize methodologies, terminology and paradigms from a diversity of disciplines such as ecology, human ecology, planning, architecture, geography, economics, political science, engineering, sociology, social work, anthropology, psychology, and health sciences (Niemelä et al., 2011; McDonnell & Pickett, 1997; Young & Wolf, 2006; Dooling, Graybill, & Greve, 2007; Alberti, 2008; McDonnell et al., 2009).

There was a conceptual deficit till about 1960s that human was treated as external to the system while studying ecology (Niemelä et al., 2011). It was thought that urban areas were not worth studying concerning ecology as under human-dominated environment only a few plants and animals can support, even under such view cities were seen as 'anti-life' (Sukopp, 1998, p. 3). In Europe itself, several early research work conducted in cities were focused on improving the human condition for biological, physical, and sociological problems (Niemelä et al., 2011).

There are various studies related to Urban Ecology and most of the studies are done in America and Europe. The term ‘Ecology’ was introduced in ‘City areas’ by a collection of biologist and social scientists at the University of Chicago in 1925 where Burgess presented an influential work titled “The Growth of the City: an introduction to a research project”. That may be considered as the beginning of the study of urban ecology where Park (1925) mentions “The city has been studied, in recent times, from the point of view of its geography, and still more recently from the point of view of its ecology” (Park & Burgess, 1984). But it was established as a separate discipline in the early 1970s with systematic studies of climate, soil, water and organisms. The European roots of Urban Ecology are reviewed by Sukopp, (1998).

According to Sukopp, (1998) early studies of ‘ecology in cities’ found interesting phenomena that environments created by humans provide habitats for characteristic species and the variety of species found in urban areas often exceeds than the urban hinterland. Thus, early descriptions of urban ecosystems have focused on the ‘ecology in cities’ which primarily focuses on the study of habitats or organisms within cities. Study of ecology in cities might be interested to explain the high number of monkeys frequenting in residential areas for hunting food or to study the effect of city traffic causing interruption to the movements of animals etc. Ecological studies of this type are more focused on habitats within the urban area and how the conditions of those locations alter by the build-in structure and function ecological systems at that level.

Till last part of 20th century, Botkin (1990) discussed that how it is difficult to suggest a popular metaphor, in part because of the power and historic weight of the ‘balance of nature’ metaphor, with its attachment to deeply and widely held myths. But gradually with logical pressure played by ecologist, there has been inclusion of human in contemporary paradigm after the 1960s. The openness of natural systems with immediate surrounding and their interaction with natural disturbances are recognized further. A short logical step to include humans as agents of flux and disturbances in ecological systems (Pickett et al., 1992) elevated the field of ecology to a rejuvenated stage. The emergence of a new 'non-equilibrium paradigm' that incorporates recent knowledge of how ecosystems are structured and function (Fiedler et al., 1997). About the emergence of the subdiscipline of 'urban ecology', this new 'non-equilibrium' paradigm explicitly allows for the inclusion of humans as components of ecosystems studied by ecologists (Egerton, 1993; Niemelä et al., 2011; Pickett et al., 1992; McDonnell & Pickett, 1997). Thus, humans are components of ecosystems and human-dominated ecosystems provide a new and challenging arena for inter and transdisciplinary studies involving the physical, ecological, and social sciences (Niemelä et al., 2011).

3.4.2 Urban metabolism

Though the habitat study of organisms within human-dominated urban environment remains an important part of urban ecology, in the view of the application of urban planning and landscape design, recent studies have focused increasingly on the 'ecology of cities' which studies urban areas from an ecological systems perspective (Alberti, 2008, p. 4). The approach to study .ecology of cities is to understand the metabolism process of an entire urban area as an ecosystem with its multiple subsystems that are interrelated (M. H. P. Hall & Balogh, 2019). Thus, understanding "urban metabolism" and its perspective has to be given priority to study urban ecology in recent times. For example, one might be interested to understand how much area outside the city must be exploited to supply fuelwood for the population, or to provide water for consuming into various purposes of daily use.

Study shows that urbanization also impacts on human behaviours due to environmental changes. Thus, to improve the well-being of urban dwellers we need to develop a critical, pragmatic and integrated approach for urbanizing regions to mitigate ill effects of rapid environmental changes. Urban planners and managers also must be prepared and impart appropriate training to face unprecedented challenges due to possible environmental degradation in urban areas.

When the population, economy and urban scales approach or exceed the water resources carrying capacity, the water resources system significantly slows down the development of socio-economic systems, including the urbanisation process (Bao & Fang, 2007). Urban hydrology has drastically modified compared to agricultural and wildlands (Pickett et al., 2001, p. 6). In hydrologic terms, urbanization is defined primarily as the increase in impervious areas (e.g., streets, parking lots, roofs, sidewalks, etc.) that results from urban and residential development (Dow & Dewalle, 2000, p. 2). The hydrology in urban areas can be further modified by ecological structures by maintaining and cost-effectively restoring tree cover to enhance the natural processes of the city's landscape (Hough, 2004).

3.5 *Mountain ecosystem*

Mountains have been flagship lands of conservation around the World (Catalan et al., 2017). Mountains cover about 32 million sq. km. of the world, which is 22 per cent of the world's land surface. According to a 2012 estimate, 13 per cent of the global population lived in mountain areas, of them, 90 per cent lived in developing countries

(Romeo et al., 2015). Mountain regions supply half of the world's population with fresh water, are repositories of important cultural and biological diversity, are sources of key raw materials and are important tourist destinations (Ariza, Maselli, & Kohler, 2013, p. 12; Körner & Ohsawa, 2005). Thus mountains of the world need urgent attention and monitoring from the global community to sustainably maintain goods and services provided by mountains and protect them from the ever-increasing demands of services from increasing human populations and climate change and associated impacts (Egan & Price, 2017; Gleeson & Greenwood, 2015; S. P. Singh & Thadani, 2015).

An emerging view is that people living in or near protected areas are not by default a threat to biodiversity rather they can be considered as 'management partners' of the area they belong. Their wellbeing needs to be part of the conservation equation, especially since poverty near protected areas creates a negative dynamic and can be alleviated by progressive management (Baldwin & Beazley, 2019, p. 12; DeFries et al., 2004). The conceptual framework of ecosystem services (ES) offers a standardised approach to classifying and quantifying these resources in ways that are meaningful in both ecological and socio-economic terms (Egan & Price, 2017, p. 9). Mountain ecosystems' vital role in the lives of upstream and downstream populations, whether rural or urban, is now recognized at the international policy level (Ariza et al., 2013, p. 10). Although the impacts of urban development on ecosystems occur locally, they cause environmental changes at larger scales (Alberti, 2008).

Mountains are also key centres of biological and cultural diversity as well as important sites of traditional ecological knowledge and influence the climate at many scales. Therefore, their effective management is not only important for mountain communities, but also a sizeable proportion of the global population. However, mountain ecosystems are particularly fragile, subject to both natural and anthropogenic drivers of change. These range from volcanic and seismic events and flooding to global climate change and the loss of vegetation and soils because of inappropriate agricultural and forestry practices, and extractive industries (*Mountain Ecosystems | IUCN*, n.d.). Humans influence and are influenced by, ecosystems through multiple interacting pathways (MEA, 2003, p. 49).

3.5.1 Impact of climate change on mountain ecosystem

Mountain ecosystems and people have already begun to experience the negative effects of climate change (Ariza et al., 2013). Although it is well known that global warming is more pronounced at high northern latitudes, there is some evidence that warming is also amplified by elevation (Gleeson & Greenwood, 2015).

Thus, globally mountains are gaining importance as a subject matter of research focused on sustainable development and the livelihoods of mountain communities on the wake of global climate change.

Given the emerging recognition of ES provided by mountain systems and the extent to which not only mountain communities but also lowland populations rely on these, the degree to which global change including both climate change and global demographic and economic driving forces may drastically alter these ES presents real threats. In particular, climate change is influencing mountain ecological and geosystems at a faster rate than other terrestrial habitats globally (Nogués-Bravo et al. 2007), and due to the rapid rate of deglaciation in the mountain cryosphere worldwide, mountain glaciers have themselves become key indicators of global climate and its warming.

Already, climate change is affecting the capacity of mountains to provide vital ES, which requires balancing between the potential of mountain regions to provide ES and the increasing demands for them. Thus, due to their high sensitivity, mountain ecosystems can serve as global early warning systems (Björnsen Gurung 2010). The potential medium-to-long-term impacts of climate change in mountain areas are predicted to herald a considerable and unprecedented change to their inherently fragile ecosystems, which are likely to be further exacerbated by various human interventions.

The anticipation of these changes can provide the first step in the formulation of local to regional level adaptation strategies to address all aspects of global change, as a component of much-needed mountain-specific planning and policy. A key element of this must be to strengthen the political relevance of, and attention to, the ES concept.

3.5.2 Mountains and altitude belts

Mountains were specially recognized as fragile ecosystem only after the Rio Earth Summit's mountain-specific chapter 13 of Agenda 21 in the which essentiality of mountain environments were emphasized to the survival of the global ecosystem (UNCED, 1992). Mountain environment provides to mankind with key resources like water, energy (hydro-electric, solar and wind), minerals, forest, biological diversity and also supports special agricultural products and recreational activities. There was no standard definition of mountain distinguishing from hills and plains until 2000, only when United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) defined mountains to represent the 'environmental gradients' that are key components of mountain environments according to topographic criterion combining elevation, slope and local elevation range (Romeo et al., 2015). Thus according to elevation criteria, UNEP-WCMC adopted the classification of Kapos, (2000) which includes minimum altitude as 300 m above sea level indicating six classes (table 7) of mountains (UNEP-WCMC, 2002). Kapos (2000) used 2500 m. altitude as the threshold above which human physiology is affected by oxygen depletion, as a limit above which any environment at all would be considered mountainous (Kapos et al., 2000).

Table 7: *Six categories of mountain terrain*

Categories	Mountain belt
1.	300 to 1,000 m (and local elevation range > 300 m.)
2.	1,000 to 1,500 m. (and slope > 5° or local elevation range > 300 m.)
3.	1,500 to 2,500 (and slope > 2°)
4.	2,500 to 3,500 m.
5.	3,500 to 4,500 m.
6.	more than 4,500 m.

(Source: UNEP-WCMC, 2002)

This classification does refinement to include slope below 2,500 m. The land between 1500 m and 2499 m is classed as a mountain if it slopes more than 2°; this threshold proved to be appropriate for eliminating mid-elevation plateaux. Between 1000 m and 1499 m, land that either surpasses a steeper slope threshold of 5° or has a local elevation range of 300 m or more, is classified as a mountain. Between 300 m and 999 m, the land was classed as mountainous if the local elevation range was 300 m or more (UNEP-WCMC, 2002). With the advancement of altitude measuring technique by remote sensing (SRTM data), higher resolution sensor provides more accurate area under each class of elevation.

3.5.3 Characteristics of mountain

The fundamental characteristics of mountains are slope, aspect, and altitude which determine the environment in an area of the mountain. Topographic diversity also adds significantly to the small-scale variation in living conditions. Climate and local weather pattern depend on the geographic position of the mountain such as latitude and distance from oceans which may affect the environment of some mountains as almost permanently wet or dry, and also highly seasonal. Geological substratum may add another dimension of geo-diversity influencing soil development and type, erosion processes, and vegetation cover (Körner & Ohsawa, 2005, p. 6).

Mountain climate shows some common features globally, but it can vary greatly regionally and locally. Factors such as reduced pressure and reduced air temperature associated with the reduction of water vapour pressure with increasing altitude are very common and relevant to predictable life processes change in mountains (Körner, Ohsawa, et al., 2005). Average temperature declines by 9.8° K per kilometre at normal lapse rate, with increasing elevation but may differ diurnally, seasonally, latitudinally, and from region to region. Also, air pressure decreases at the rate of about 10 per cent for every kilometre of elevation due to reduction of partial pressures of oxygen and carbon dioxide. Moreover, solar radiation increases with increasing altitude during clear sky due to higher radiation and greater short-wave radiation (UV). However, clouds and fog may reverse altitudinal trends in solar radiation (Körner et al., 2005; Körner, 2003; Yoshino & Yoshino, 1975).

Gravity also plays role in the physical processes relating to erosion, landslides, mudflows, avalanches, and rockfall, and these ultimately determine life conditions in many parts of the world’s mountains. Sometimes at a regional scale, volcanism and the associated sedimentation also may influence slope processes affecting biota, which may impact life conditions of people. Moreover, in the areas of geologically young and steep mountains, seismic activity may have a catastrophic effect in the physical environment of the mountain followed by adverse economic and social consequences (Körner, Ohsawa, et al., 2005).

3.5.4 Biotic composition in the mountain

Broad composition of vegetation on lower mountain slopes may be seen similar to that of surrounding plain lands. However, environmental changes associated with the elevation as stated above may typically lead to marked zonation.

In less humid regions, the availability of moisture may at first increase with elevation which can allow tree growth on mountains that emerge from treeless semi-desert plains. But in humid regions, evergreen cloud forest and epiphytes may occur above more seasonal deciduous forest. With further elevation, the temperature may decrease to a point where tree growth cannot be sustained. Though there is no common altitudinal trend of precipitation, in the temperate zone it commonly increases with altitude, but in the tropics, it often decreases beyond a maximum altitude (above 4,000 m.) leading to semi-deserts environment (Körner, Ohsawa, et al., 2005).

The temperature change rate in mountain altitude is about 600–1,000 times higher against the latitudinal gradient along the same longitude (Körner, Ohsawa, et al., 2005). Discernible vegetation belts on mountains may commonly span up to an elevation range of 1,000 meters. Over this elevation, the temperature decreases to appear fully developed bioclimatic vegetation. On the other hand, with the latitudinal change, the temperature range of a place depends on annual seasonal temperature change, which limits the poleward extension of certain species. Similarly, the colder climate of successive altitude belts restricts the growth of species from lower and warmer belts. One consequence of this is that ecosystems situated on mountain tops, with a species composition currently restricted by a cold climate, are likely to disappear as a result of climate change (Körner, Ohsawa, et al., 2005).

Because of the compression of climatic zones along an elevation gradient, exposure effects, and large habitat diversity, species richness in mountains commonly exceeds that in the lowlands at small scales. Körner (2000) also observed that within mountain regions, species richness decreases with increasing altitude, largely in proportion to the available land area, but endemism often increases, due partly to topographic isolation (Gentry, 1988; Peterson et al., 1993) and the often rapid formation and loss of links (corridors) in geological time (Körner et al., 2005). Tropical mountain forests have 10 times higher species richness than temperate ones (Körner et al., 2005).

Thirty-two per cent of all protected areas are located in mountainous regions, providing habitats for rare, relict, and endangered plants and animals (UNEP-WCMC, 2002, p. 53). Many species that survive in such refuges are at risk from habitat fragmentation. However, extended mountain ranges with continuous habitats provide a corridor for high altitude and cloud forest species, avoiding densely populated lowlands (Körner et al., 2005).

Ecological corridors that link isolated habitats are essential for many migrating species, which have extensive hunting or feeding territory requirements. Connecting remote nature reserves, such corridors are effective tools to compensate for natural and human-induced fragmentation of habitats (Körner et al., 2005).

As human populations and their activities proliferate into more remote areas, many protected areas are now embedded in human-dominated landscapes (Baldwin & Beazley, 2019, p. 4). Population growth is an important factor for local environmental change, especially the consumption level and the technology assume to play a vital role in the overall environmental change (Pradhan, 2004).

3.6 *Reviewing related study*

There is no such study found that integrates urban water crisis with urban ecology. However, there are studies on water accessibility issues relating to an urban area. Ganguli, (2013) studied Urban Water Sustainability issues in West Bengal where he found that lack of proper water management has kept the cities far behind from being water sustainable cities. Another study related to urban ecology is done by Haravi, (2010), in Panaji City, India with some geographical perspective. But none of these studies did any integrated study that combines water issues with urban environments. Thus, the present study holds significance from both water accessibility issue of the urban populations and also related environmental issues for the future prosperity and sustainability of the region.

CHAPTER 4

RESULTS AND DISCUSSIONS

4 RESULTS AND DISCUSSIONS

In this chapter, empirical results are discussed that were collected during the household survey data interview and observations. Also, discussions were done basing on the literature review.

4.1 *Available water sources of the town*

The town dweller is accessed to multiple water sources as shown in figure 49. But every source has some problems as reported by the household. But most dwellers are compelled to use a source not by choice but as a chance of the situation. Those sources are discussed below. Table 21 shows available drinking water options in the area.

4.1.1 Rainwater harvesting

Rainwater is the root source of all water, both surface water and groundwater. Rainwater harvesting is the most promising source of water to supplement the surface and underground scarce water resources in areas where the existing water supply system is inadequate to meet demand. As discussed in Chapter 2 the study area receives abundant rainfall under the influence of SW monsoon. Though rainfall amount received by the area is more than 2,500 mm., this amount is mostly concentrated in summer months, and the area suffers from seasonal drought during winter months. Therefore, a buffer water storage of large volume is required to store a sufficient amount of water for the lean period. Rainwater can be collected attaching some low-cost materials (a pipe, funnel etc.) from the roof to the tank figure 18. In the study area, people mostly use C.I. sheet surface as collection surface than the concrete surface as later type surface is not easily flushed by raindrops. Due to impurity first-flash of rainwater should be diverted from the reservoir. Many households of the town stores rainwater for drinking even though they may have access to another source of water.

Fig 18: *A simple rainwater harvesting of a household*

(Photography by author)

4.1.2 Tanker water

Though there is no tanker service provided by ULB, some private water tanker vendors provide drinking water to the town by mini trucks temporarily loaded with PVC tanks with a total capacity of 2,000 litres. The same vehicle is used for carrying goods when there is less demand for water. These vehicles are equipped with a water pump set powered by either an electric motor or a petrol engine. Due to inconsistency in power supply, an electric pump is replaced by a petrol engine pump (figure 21). Some customer whose residence is not accessible for the vehicle has to connect longer pipe for delivery. But due to hilly terrain, such delivery in upstream has a limitation in pumping. In such a situation, delivery is given by parking vehicle from above the residence.

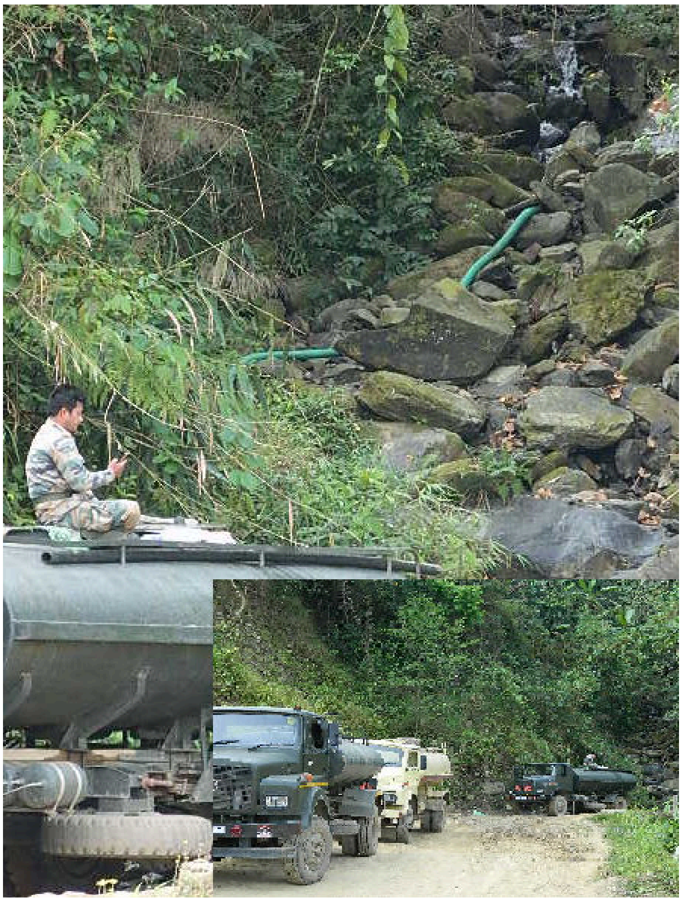
Fig 19*: A tanker is being loaded at Khensa village*

(Photography by author)

These vendors generally fetch water from some Dug-wells of Khensa village (about 5 km towards Mariani) or some boring wells within town area figure 19. Quality and price of Khensa village source are more than local boring water. But towards the late winter season, these vendors have to access water from distant locations such as Angetyongpang area or Yimchalu village (about 16 km towards Amguri). It was found that defence camps of the town carry water from such locations by investing man power and finance regularly (figure 20) under security cover. All these source locations are in the northern aspect of the Ongpangkong mountain range.

Private water tanker vendors service is mostly resumed after October till April. Because this period receives only occasional rainfall after the monsoon. Thus, the service is seasonal. Water vendors are not registered with the authority. So, the exact number of vehicles is difficult to get, though the service is placed the second position fulfilling water demand of the town population. These water vendors may play a critical role in future water service of the town. Indeed, during crisis time in late winter customers have to compromise with quality as there is no other choice.

Fig 20: *Stream water being loaded at Yimchalu village for the defence personal of Mokokchung town and (inset photo) tankers seen in the queue at the same location*



(Photography by author)

It was observed that some personal vehicles also used for carrying water from some distant location to their home (figure 22). Poor people specially women, go to some downstream water source to wash clothes and returns with loaded drinking water containers carrying manually.

__Fig 21:__ Water is delivered by using a petrol engine pump

(Photography by author)

While delivering water to the customer, the vehicle parking at the roadside in most roads of the town wards causes traffic congestion due to narrow passage. It also causes inconvenience to the residents who reside in that lane. A vendor doesn't take orders below 2,000 litres for a trip. Thus, if any customer has less than 2,000 litres capacity, they should share with some needy neighbour of their choice.

__Fig 22:__ Crisis compels people to fetch water in a private vehicle

4.1.3 Dug-well water

Dug-well water is serving as an important source of water in the town. Dug-wells accumulate water from the sub-surface aquifer. But water yield is limited towards winter. However, due to loose soils, dug-wells found in Khensa village area are of the concrete ring. Though, dug-well water is mostly free from iron content, in urban locality quality is not good due to pollution from faecal matter seepage from upstream areas, and some people found not using for drinking purpose due to this.

4.1.3.1 Community dug-well

In most wards of the town, community dug-wells are found in the bank of the streams. In the town area, digging dug-wells to a greater depth is difficult due to rocky strata and it is dug out more horizontally than vertically for retaining maximum water. Since these are located near the streams, it is protected against stormwater contamination under roof and wall (figure 23). Moreover, it needs protection from unauthorised entry of people during the dry season. So, the door is locked for protection and one can physically go down into these dug-wells through steps when needed. Therefore, a masonry structure is built surrounding the well with an overflow pipe. During monsoon, most dug-wells overflow through the pipe and gate is not required to open to get water. While during dry season timely water is taken out by opening the gate.

A community well is maintained by the respective ward people who is getting water from this. In some locality, a nominal fee is collected from the users for cleaning annually and one designated in-charge looks after for well maintenance and security.

Fig 23: *A protected community dug-well build below the steep slope*

(Photography by author)

At the beginning of winter, people are allowed to take a few buckets without restriction. The gate of the well is opened twice a day at a fixed time. But gradually more restriction is imposed to per family in buckets of water. When water yield further lowers in the late winter period, the frequency of opening the gate delays. It opens once a day, then an alternate day, three alternate days and finally a gap of after two or three weeks also. Thus, dug well may become dry and the households can't fully depend on it.

4.1.3.2 Private dug-well

Community Dug-well sources are unreliable as stated above. Therefore, some people dig well in their residential premises to get rid of manually carrying a long distance and long waiting time in queue. Though in some prospective locality people could strike aquifer, many did not succeed in their endeavour. Some private dug-wells found digging at very narrow space where subsequently building also has been erected over the well due to land constrain.

4.1.4 Water supply system of PHED

As stated in chapter one, in Nagaland PHED is the only State Government agency responsible for providing safe and potable drinking water supply. As per the rules of Executive Business of PHED, the department is also to work on safe disposal of solid and liquid waste and environmental hygiene. The department that was bifurcated from the erstwhile Public Works Department (PWD) and became a full-fledged Department in 1974.

Table 8: *PHED water sources with discharge and distance from town*

Source location (District)	Distance from town	By means	Discharge (Q)	Total = Q litre/day
Angetyongpang (Mokokchung)	17 km.	Gravity transfer and pumping	1.0 lit/sec	86,400
Techipami (Zunheboto)	40 km.	Gravity transfer	12.0 lit/sec	1,036,800
Water deliverable by PHED to town			**13.0 lit/sec**	**1,123,200**
Lithsami* (Zunheboto)	38 km.	Gravity transfer	5.3 lit/sec	458,000
		Total=	**18.3 lit/sec**	**1,581,200**
** Lithsami source is for Mokokchung village but shared to town also during crisis*				

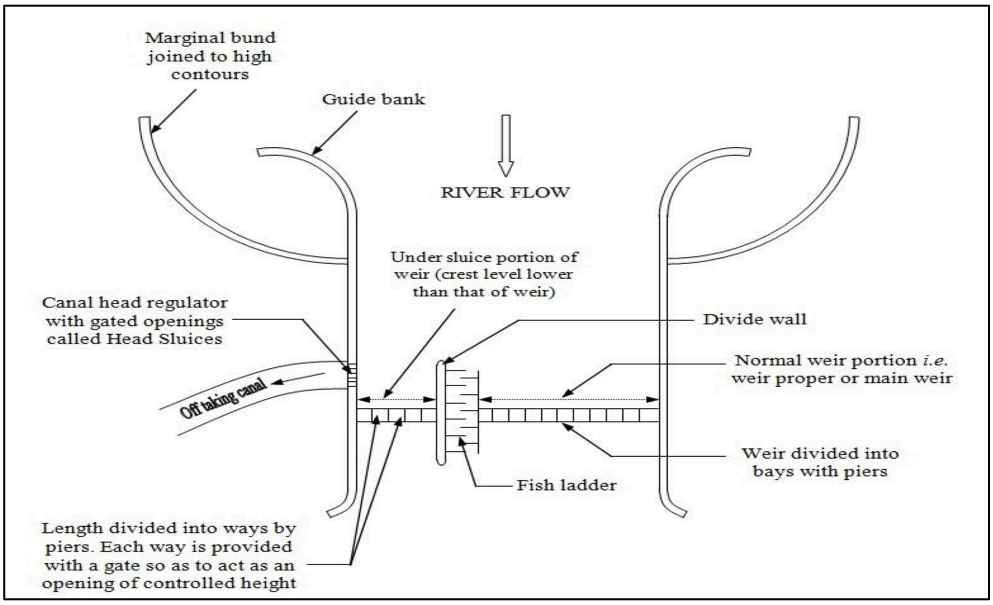
Source: Interview with PHED, Mokokchung, 2019

The PHED department is providing piped drinking water to the households of Mokokchung town in 17 wards out of 18 wards (table 29). The only ward deprived of PHED water supply is Yimyu, where some miscreants, as reported by some village people, destroyed the supply system due to insufficient amount of water supply. The water supplied by PHED is sourced from three different sources located at distant places (figure 50). Each location has a different yield or discharge from the source (table 8).

4.1.4.1 Angetyongpang water source

The nearest source is located at Headwater region of Angetyongpang (Angetyongtsu Nala) about 17 km. pipe distance from the reservoir of the town towards North-East direction from the town along Mokokchung – Amguri (NH 2), above 1.5 km off-road located at an altitude of 1,380 metres. This source is located inside Minkong PF of the Mokokchung district in the northern aspect of same Ongpangkong mountain range where Mokokchung town is also located. This north-facing source is the oldest water supply project of the town. Due to less 'Hydraulic head' pressure in the DC Hill reservoir from the source, in the first phase, the water is stored in a buffer tank by gravity, located at the downhill area of the town (Salangtem ward). In the second phase, this buffer tank water is pumped up by motor to distribution tanks located in the hilltop location (DC Hill or other). Finally, distribution is done to consumers located in different Wards of the town through metered connection.

Fig 24: *A standard layout structure of a diversion weir at the water source*



A standard 'diversion weir' is constructed at the source as shown in figure 24, and water is flown down by a connected GI pipe (size 150 mm) which delivers 70,000 litres per day during the lean period. This pipe can withstand maximum pressure up to 20 kg per sq. metre. But these ageing pipes need replacement by now, according to PHED official, which causes a frequent breakdown. As observed by the PHED official, the estimated discharge has decreased to one-fourth of the initial volume in recent years due to 'deforestation' in the catchment.

4.1.4.2 Techipami water source

Due to increasing population pressure, PHED did another project that pumped up water from Dikhu river flowing through the southern flange of the Ongpangkong range. But due to some technical problem, this project was abandoned. However, the department explored another source located at Headwater region of Techipami stream, across Dikhu river situated in the northern aspect of the western hill ranges of Zunheboto district, distanced at about 40 km. (pipe distance) to the water reservoir located at crest part of the town (in D.C. Hill). This source is transporting water by gravity only having a maximum discharge of 15 litter per second. At present Techipami source is the largest volume of water yielding source for the town. It is located on Akhikugha Nala towards the southern direction from Mokokchung town near Techipami village of Zunheboto district. Positioning at an altitude of 1,500 m. above sea level, it makes a relief difference of about 200 m higher than the D.C. Hill reservoir of the town (highest altitude of the Mokokchung town). So, the discharge easily reaches to the reservoir by gravity only. The source can be approached from Mokokchung - Tuensang road near Techipami village of Zunheboto district. It yields about 10 lakh litres per day, according to PHED official, during a lean period. Here also water is collected by constructing a Diversion weir through a ductile iron pipe of size 150 mm.

But unfortunately, this source is frequently disrupted by natural factors such as landslides along the route of pipe. Also, technical failure occurs from time to time by disjointing at Dikhu river valley area due to excessively high pressure (more than 80 kg per sq. metre). According to PHED official, the disjointing problem is due to wrong selection of 'slip-on joint' pipes in high-pressure sections across river Dikhu. However, that can be overcome by replacing with 'restrain joint' pipes for about 17 km stretch which will involve a huge additional expenditure again. Moreover, this source is also yielding about one-third less water than the time of commissioning the project, according to PHED official.

4.1.4.3 Lithsami water source

Another water supply project commissioned in the year 2013 from the source Atukopu stream which is located towards the south of Mokokchung town in Zunheboto district and east of Techipami source stated above. This source also can be approached from Mokokchung–Tuensang road near Lithsami village of Zunheboto district. This source is located at an altitude of 1,502 metres above sea level having a relief difference of 124 metres only with the Mokokchung village reservoir located at an altitude of 1,378 metres. The water pressure at the Dikhu river is 83 kg per sq. metre. So far, the project is yielding expected outcome. Here also water is collected by constructing a Diversion weir through a ductile iron pipe of 100 mm size. Though the project was implemented under Accelerated Rural Water Supply Programme ARWSP (NRDWP) scheme (figure 25), which was meant for Mokokchung village only, with the due kind understanding between the Mokokchung village council and Mokokchung town authority the water is shared in the alternative day with town water supply system during the lean period.

Fig 25: *Water reservoir at Mokokchung village (near watchtower)*

(Photography by author)

4.1.4.4 Reservoir capacity of the PHED

The PHED has constructed reservoirs of various capacity to store and distribute water to the town Wards, at different town locations as shown in table 9. All these reservoirs are of fabricated GI sheet. Total water holding capacity calculated is about 15 lakh litres only. Though this capacity is not sufficient for the entire town population PHED intends to satisfy existing consumers of the town. As reported by the PHED official, some ageing reservoir needs renovation or replacement.

Table 9: *List of available water reservoirs in the town*

Sl. No.	Location	Capacity (in litre)
1.	D.C. Hill near Circuit House	500,000
2.	MPP Hill	250,000
3.	Near Sangtemla Middle School	240,000
4.	Mokokchung Village (near watchtower)	140,000
5.	Near Mayangnokcha H.S. School	120,000
6.	Mission Compound	100,000
7.	Near Ao Senden Office	48,000
	Total=	**1,498,000**

Source: Interview with PHED, Mokokchung, 2019

4.1.4.5 Water distribution system

The water so collected is distributed to different Wards of the town through water metres housed in a secured chamber called “metre house” as shown in figure 26. Domestic water bills charged based on metre reading @ Rs. 50/- per thousand litres. Meter box units constructed for a certain number of consumers of the respective ward area. According to PHED official, due to limited water they receive from the said sources, water distribution on regular basis is not possible to all consumer. Therefore, during the lean period, the department can supply water only on a weekly or bi-weekly basis. This frequency of water supply is not at all adequate for a household as expressed by residents during the interview.

Fig 26: *A meter house of PHED for water distribution*

(Photography by author)

Due to fund crunch, neither ULB nor PHED provide any water tanker service to the public. As per an interview with PHED official, at present they have only one tanker vehicle, but it is not used for public service. Further, there is no public stand post for water distribution. Therefore, during crisis households have to depend fully on the private water vendors.

Moreover, surveillance and monitoring through licencing mechanism are not done by any authority on private water vendors (tankers and other). So, the exact number of private water tanker operators and other vendors cannot be ascertained, while they are imparting the most essential service to the town population.

According to PHED official, even though at present PHED is doing piped water supply services to the town population, the responsibility of urban water and sanitation affairs should have been taken by the ULB of the town, as a norm of all other urban areas of the country. But due to the financial crisis and some technical difficulty, it has not been done yet.

4.1.5 Boring-well water

In recent time Boring-well is emerging as an important source of water in the town. However, it is not possible for every locality of the town. For drilling operations heavy machinery to be transported to the site of drilling but due to the narrow path and high slope of the area, such operation is not possible in many localities of the town. As reported by the people of different wards, some boring attempt was unsuccessful due to the absence of confined aquifer. Also, some boring owner reported as a depleting level of groundwater than its inception. Moreover, in most locations water quality is not used for drinking due to high iron content. So, Boring-well may not be considered as a lasting water accessibility solution for the area.

4.1.5.1 Drilling method

Drilling can be done in three different methods. One can be chosen out of these three different mining operations, depending on the hardness of rock or soil, depth requirement and diameter of the hole. However, the wrong choice of these methods in a given situation may cause huge loss causing project unsuccessful. These methods are 1) Rotary drilling, 2) DTH drilling, and 3) Top Hammer (Percussion) drilling.

Out of all three methods, DTH is more appropriate in the case of Mokokchung town bore wells. Down-the-hole (DTH) drilling is to drive the hammer which behind the drill bit by compressed air via the drill pipe. The piston strikes the bit directly, while the hammer external cylinder gives straight and stable guidance of the drill bit. This makes the impact of energy is not lost in joints and allowing for much deeper drilling. The impact force acts on the rock at the bottom of the hole, which is more efficient than other drilling methods. This drilling depth is limited by backpressure that can penetrate more than even kilometre depth. Since Mokokchung town geology is of sedimentary rocks, DTH method has to be used to penetrate up to reaching the aquifer.

4.1.6 Stream water

As stated in Chapter 2, the town is situated at hilltop headwater region of three important tributaries namely Dikhu, Jhanzi (Melak) and Doyang of Brahmaputra river. Thus, the core area of the town has a number of first-order and second-order streams flowing down radially from this area to the surrounding region. So, some saturated aquifers expose to surface as a stream in some peripheral locations of the town. People residing nearby to such sources collect water from it. Since the streams are passing through dense residential areas, it is likely to carry waste along with undesired faecal matters. Moreover, stormwater also can easily contaminate these sources. Therefore, quality-wise it cannot be used for drinking as reported by such user household due to high turbidity during the rainy season. However, the source can be managed to improve if pollution is prevented in the upstream region. The yield during dry season becomes low even though it is without visible turbidity. Though it is not preferred to consume for drinking and cooking mostly satisfies for washing and cleaning purposes. Though water yield from such streams is limited, it is continuous when connected by a PVC pipe to their residence in downstream.

4.2 *Analysis of water sources*

4.2.1 Dependency on water sources

During the survey, residents were asked about their dependency on water sources. Majority of the residents (about 46 per cent) found using two types of water sources followed by three types and single water source table 10. Those who are dependent on a single water source (9.82 per cent only) were dependent either on Dug well or Boring water source. Some household also found using maximum up to four types of sources. However, none of the residents found using 5 (five) or 6 (six) types of water sources available in the area.

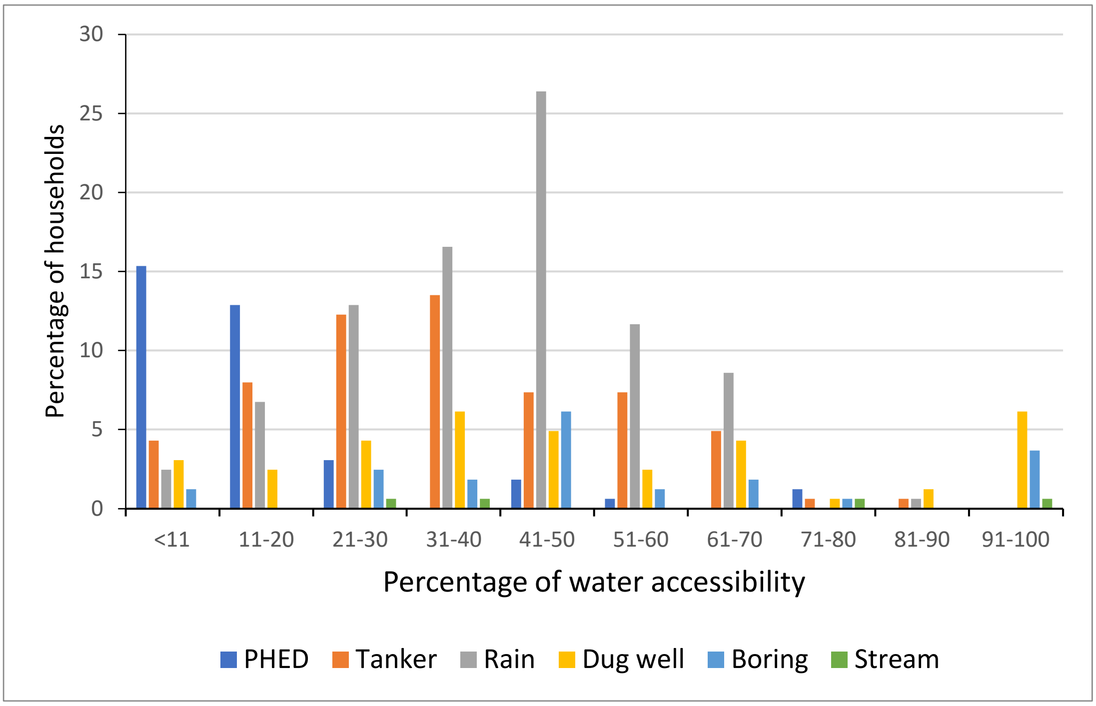
Table 10: *Households depend on water sources*

Water sources availed	One	Two	Three	Four	Five	Six	Total
Accessed by households	16	75	68	4	0	0	163
Percentage of household	**9.82**	**46.01**	**41.72**	**2.45**	**0**	**0**	**100**

Source: Field study

Respondents were also asked to guess the dependency ratio among all types of water sources availed by them. Figure 27 shows the dependency ratio of different water sources by each surveyed household. Considering whole year water use as a cent per cent, how they think about dependency from which they are accessing water. This query was thought-provoking to many respondents. Because it is not possible to measure how a household fulfils its requirements from different water sources at a different time of the year. But they expressed such dependency ratio of various water sources on which they depend throughout the year. Compiling all questionnaire, the pattern of using multiple water sources by the residents is shown in table 23 and the pattern was plotted graphically in figure 28.

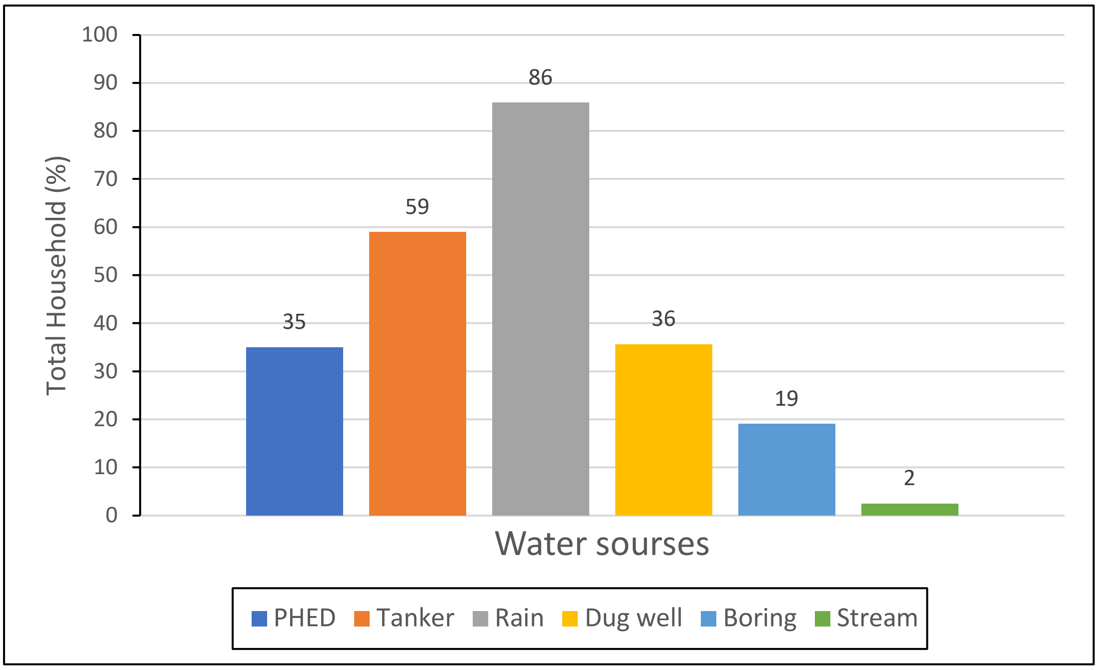
Fig 27: *Comparative water source dependency among surveyed households*



Source wise dependency can be observed in figure 27. It shows, Rainwater fulfils up to 50 per cent requirement of more than 25 per cent of surveyed households. Moreover, rainwater fulfils most of the household's water requirement at various proportions. However, rainwater dependency percentage decreases with less number of households. Only one surveyed house reported using rainwater up to about 90 per cent, who possesses a large capacity storage tank. No respondent reported to have a cent per cent dependency on Rainwater. Above 50 per cent dependency also fulfilled by rainwater followed by tanker and dug-well water.

Figure 27 reflects that PHED supply satisfies less than 20 per cent accessibility to less than about 15 per cent households. Very limited household expressed 70 per cent to 90 per cent water dependency on any type of water sources. But 90 per cent to cent per cent dependency shown by Dug-well Boring and Stream water.

Fig 28: *Water sources used by the percentage of total household surveyed*



A table was constructed by showing a matrix of all available 6 (six) water sources used by all the households (table 11). The table shows the highest values diagonally from upper left to lower right corner. A maximum of 140 household uses rainwater. The second highest used source of water is tanker water with 96 households availing it. Dug-well source is thirdly placed important water source which is accessed by 58 households. Fourthly placed most accessible water source is from PHED. Boring water and stream water are placed in fifth and sixth position respectively.

Moreover, in combination with PHED water people decreasingly use rainwater, tanker water, dug-well and boring respectively. While no one uses Stream water with PHED water. Likewise, in combination with Tanker water also, people decreasingly use Rainwater, PHED water, Dug-well, boring and Stream water. Again, in the combination of Rainwater, decreasingly people use Tanker water, PHED, Dug-well, Boring well and Stream water. Combining with Dug-well however, people decreasingly use Rainwater, Tanker, PHED, Boring and Stream water. Together with Boring water household decreasingly uses Rainwater, Dug-well, PHED and Tanker water. No household found using stream water with Boring water. Lastly, Stream water user also has a combination with Rainwater followed by Tanker water and Dug-well water. Stream water user does not have any combination with Boring water and PHED water.

Table 11: *Water source combination matrix of the households surveyed*

No of HH	PHED	Tanker	Rain	Dug well	Boring	Stream
PHED	**57**	41	54	10	5	0
Tanker	41	**96**	93	19	4	1
Rain	54	93	**140**	44	21	4
Dug well	10	19	44	**58**	6	1
Boring	5	4	21	6	**31**	0
Stream	0	1	4	1	0	**4**

Source: Field study

Thus, percentage-wise 86 per cent household uses rainwater followed by tanker water with 59 per cent as shown in figure 28. Weightage of Tanker water and Dug-well water is almost the same but still lesser than Rainwater. However, Boring water and Stream water source is placed at fifth and sixth position respectively. Of course, boring water is becoming more in number in recent time in some selected locations. But few Stream water users are located in downhill peripheral regions of the town.

4.2.1.1 Rainwater dependency

As analysed above, rainwater dependency is maximum than any other water sources among the surveyed households. Out of 163 surveyed households, as shown in figure 28, about 86 per cent household uses rainwater in their daily activity at various dependency level. During the interview, no respondents undermined rainwater usage. Even those households who depend on cent per cent on dug well or boring also uses rainwater occasionally during the rainy season. Few households who have an alternate source of water, use rainwater for drinking purpose.

Fig 29: *Rainwater dependency ratio of the surveyed households*

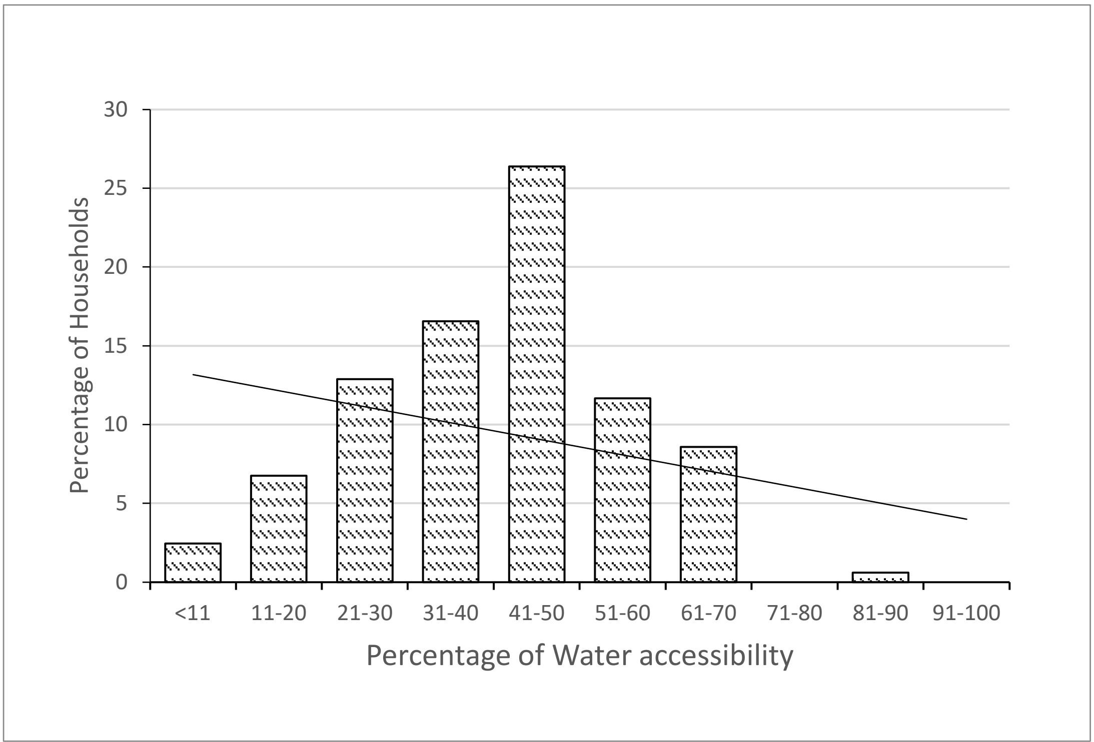


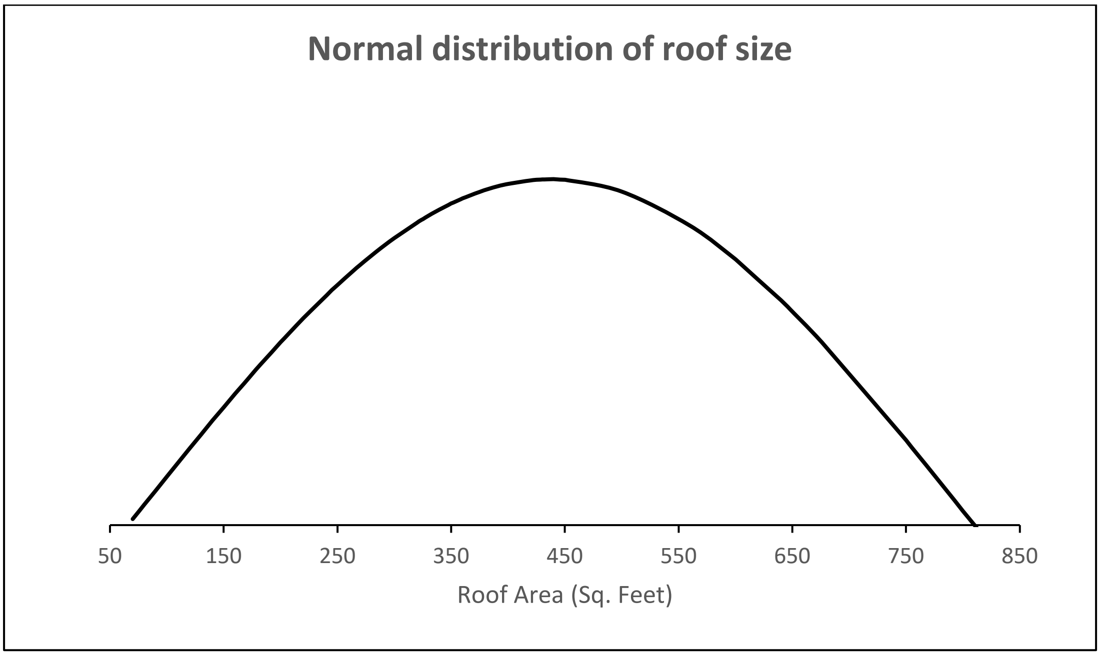
Figure 29 depicts that rainwater satisfies above 25 per cent population providing 41 to 50 per cent dependency. However, no respondent found depending on more than 90 per cent and 71 to 80 per cent. It can be noticed that due to seasonal behaviour and limited storage capacity above 50 per cent dependency among the population is decreasing.

The trend line shows a negative slope indicating decreasing accessibility with an increasing number of populations.

4.2.1.2 Rainwater collection surface

Out of total rainwater harvesters, about 98 per cent household collects rainwater from Tin roof surface. The roof area size varies from 70 sq. feet to 2,280 sq. feet. Average roof size is found to be 438 sq. feet (figure 30) where median and modal roof size is 320 sq. feet and 200 sq. feet respectively. The Standard Deviation is 365 sq. feet. That means most of the roof sizes are between 118 sq. feet to 848 sq. feet.

Fig 30: *Roof area used for rainwater harvesting in surveyed households*



4.2.1.3 Channelising of rainwater

Since rainwater is collected from the open dirty rooftop, it has to be channelized through pipe, filter and storage system. Water channelising from the rooftop is done by PVC pipes or Aluminium sheets with a funnel. Out of 163 surveyed households, 144 was found having storage tanks.

Most of the house was not found having sufficient space for water storage in comparison to their available roof size for rainwater harvesting. In other words, their rainwater collection area was larger than the available storage space. Nevertheless, a big collection area yields a sufficient amount of rainwater during a brief event of rainfall.

During the survey, only a few households (about 6.5 per cent) found using simple water filters using sand, gravel, brick, cloth, chlorine and also mosquito net before dropping to the storage tank. Many households don't use any filter system for rooftop water. Most households clean their tanks and collection channels annually before the monsoon rain.

4.2.1.4 Tanker water

The second most important water source for the town population is Tanker water. Figure 28 shows that about 59 per cent surveyed household uses tanker water at least in certain time of the year, especially in the winter season.

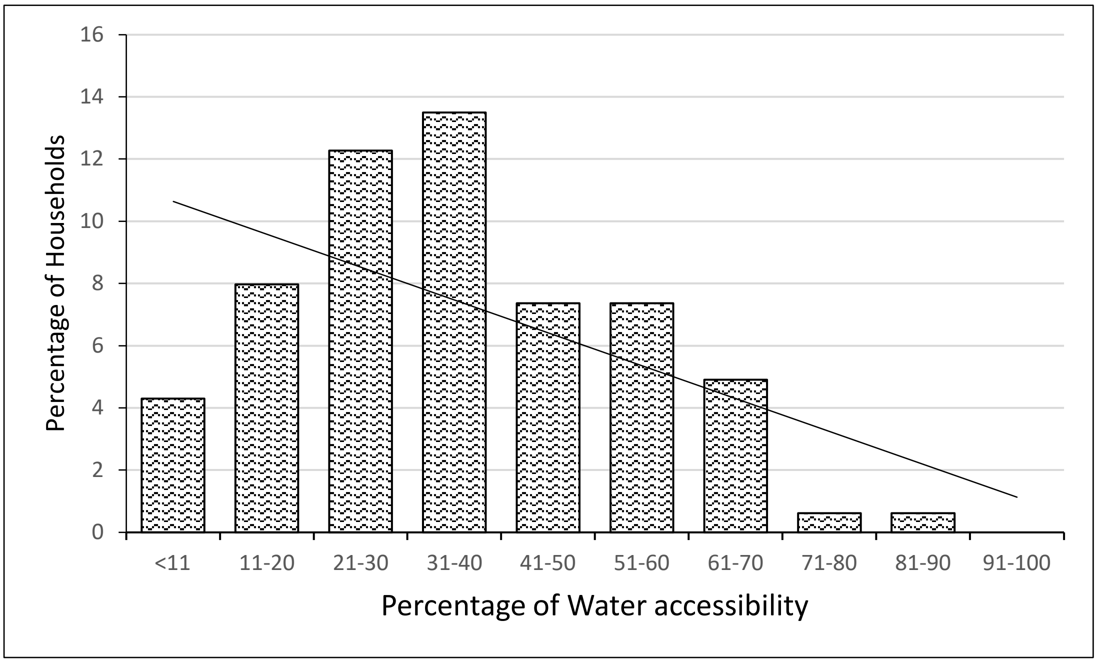
One trip of 2,000 litre costs Rs. 700 to Rs. 800 depending on a few factors. It becomes costly when they have to climb uphill of the town or fetches from remote areas of the town. However, it may be cheaper if it is carried from a boring within the town, which is supposed to be hard water.

The median and modal amount of water taking each time by the residents found to be 2000 litres. It reflects that majority of the population has a storage capacity of 2,000 litres who buy water from a tanker. About 68 per cent household out of all tanker water using household buys 2,000-litre water each time. While 23 per cent population takes 1,000 litres each time. Rest household takes either 500 or 1,500 litres each time. One house found taking 7,000 litres at a time by some defence tanker vehicle which is relatively cheaper. But it should be considered as an exceptional case only.

One resident found buying tanker water 15 times a month for about 5 months in a year. But it should not be considered as a general case because they have constructed a large storage tank of 66,000 litre capacity for rainwater collection from a nearby school building. They feel such water availability during rainy season causes their lavish habit to use water even during winter.

It was found that a household purchase required water by tanker about 14 times per year on average. While the median and modal requirement per year are 10 and 2 times respectively. The range of cost incurred for purchasing tanker water by a household in the town is Rs. 600 to Rs. 52,500 every year. While the average cost incurred for purchasing tanker water per year is about Rs. 8,600. However, the median and modal expenditure are Rs. 6,000 and Rs. 5,600 respectively.

Fig 31: *Tanker water dependency of the surveyed households*



It can be noticed in figure 31, tanker water satisfies maximum up to 13 per cent household by providing 21 to 40 per cent dependency. However, there is no household above 90 per cent dependent on tanker water. The trend line shows a sharp negative slope indicating decreasing accessibility with an increasing number of populations.

Quality-wise, about 90 per cent tanker water user reported water quality as soft and drinkable. While rest user reported minor concern about the moderate hardness. Thus, filtering is not done by most users. However, some tanker water user did not use for drinking but other daily activities.

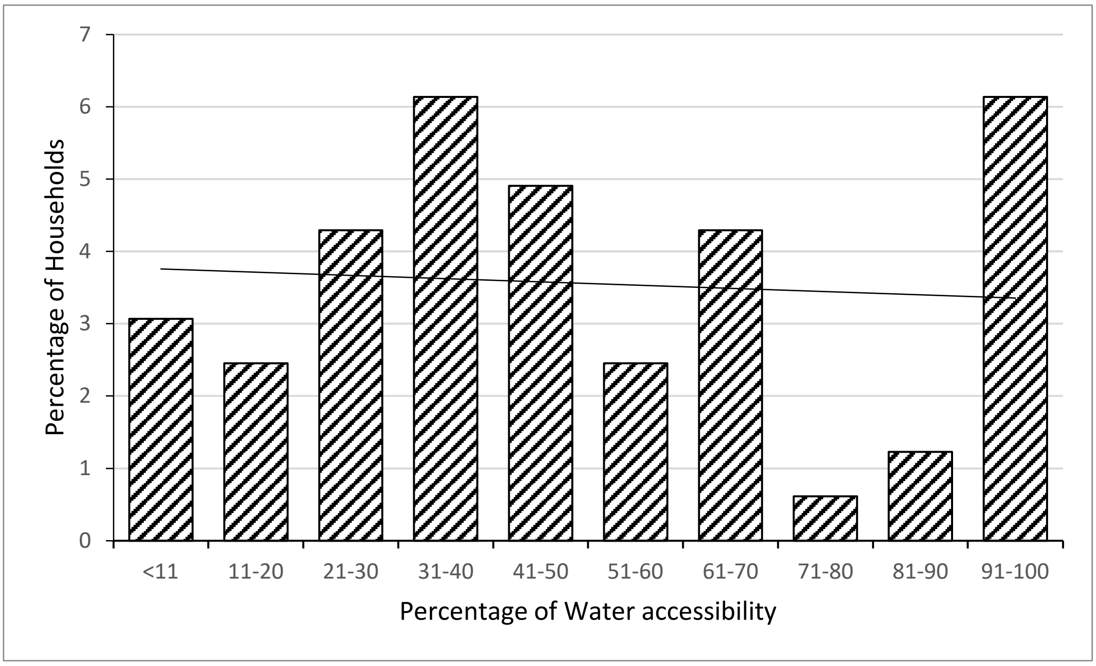
4.2.1.5 Dug-well water

As stated above (figure 28), dug-well water use is placed thirdly, where about 35 per cent of surveyed household uses it. Though some fortunate household can enjoy cent per cent dependency throughout the year, some owner has to purchase water towards a dry period. One respondent reported noticing declined water level in their dug-well after some new well was constructed in their downstream.

Analysis of the dependency on dug-well in the surveyed household is shown in figure 32. The figure shows that Dug-well satisfies up to 6 per cent household by providing 31 to 40 per cent dependency and another about 6 per cent household satisfying 91 to cent per cent dependency. The trend line shows a gentle slope indicating uniform accessibility among the limited populations.

An almost equal number of surveyed households found using community dug-well and also private dug-well. Though most community dug-well users told year-round adequacy of water in the well, 20 per cent user reported only 9 months adequacy in the well. Also, 15 per cent user found having adequacy for 10 months only as they have to feel crisis for at least two months.

Fig 32: *Dug-well water dependency of the surveyed households*



Some resident found going up to 300 metres upstream from their residence, while some resident was compelled to go downstream up to 500 metres to fetch water. Each manual trip they carry water load between 15 kg to 40 kg in the hilly terrain. During the water crisis, all family members including woman and children also get involved in water fetching activity. Duration to complete a cycle takes about 5 to 30 minutes. Though during summertime there is no such restriction in water collection, during dry winter most community well impose a restriction. As reported by respondents such restriction varies from 2,500 litres to even 30 litres per week depending on water availability in the well. Community wells are cleaned and maintained once a year by collecting Rs. 50 to Rs. 100 per household per year in some well. Though some community well does not show much fluctuation in water level between summer and winter there is fluctuation reported up to about 9 feet. This reflects hardship for drinking water facing the people in the study area.

Dependency on private dug-wells found since the 1970s, amongst household surveyed. The about two-third dug-well wall was concrete type and rest was a rocky wall. The earthen wall was insignificant due to prevailing geology. Cost of constructing a private dug well ranges from Rs. 5,000 to about Rs. 2,00,000. The average cost of construction calculated was Rs. 51,833. However, the median and modal cost of dug-well construction was found to be, Rs. 30,000 and Rs. 5,000 respectively.

Depth of dug well water level varies in different regions of the town. It varies from 6 feet to 70 feet, but the average calculated depth is 28 feet with the median 27 feet and modal depth is 15 feet only. Though community well have not installed any motor, about half of the private dug-well owner installed motor for lifting water. The capacity of motors varies from 0.5 to 1.5 HP.

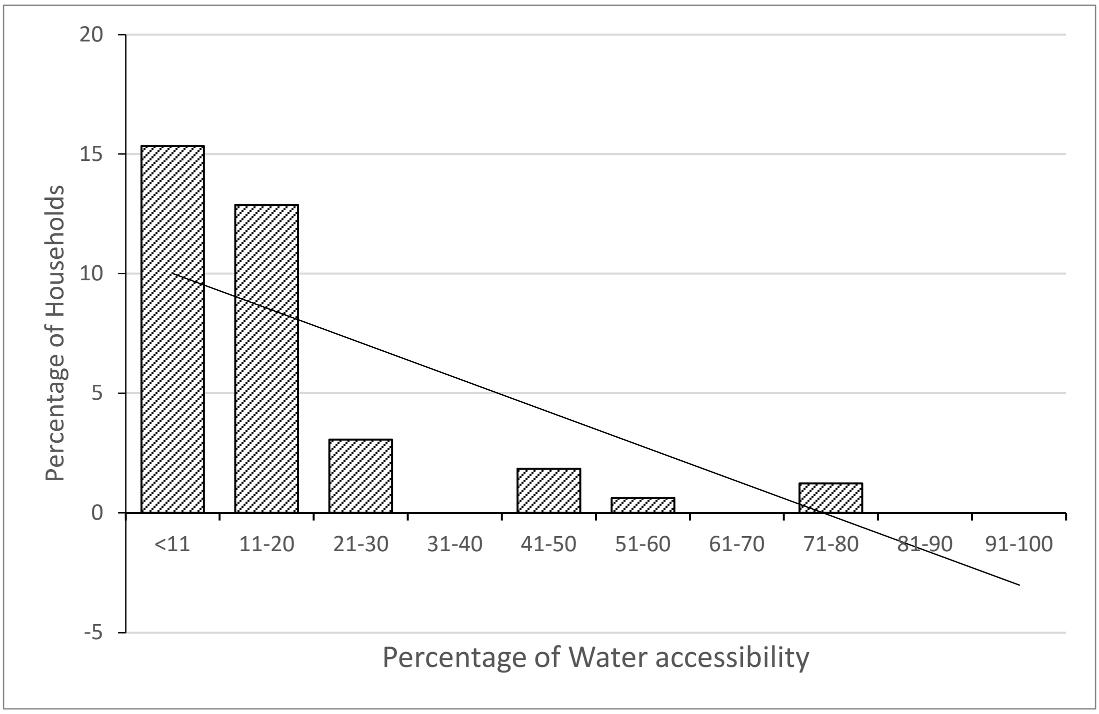
Water level fluctuation is a common phenomenon between summer and winter. But some dug-well owner reported no significant fluctuation. However, the range of seasonal water level fluctuation was found between 2 feet to 15 feet. For higher water security and availability during winter, some respondent found having two dug-wells in their premises with variation in water level and depth.

The water yield from dug-well generally differs between summer and winter season. Yield estimation from community dug-well was not possible. However, private dug-well yield estimation was possible based on the interview. The yield per day during summer was not so important. The yield during winter was calculated as Mean 1,031 litre while median and modal yield was the same as 500 litres. Majority of dug-well reported as yielding less or dried out during winter so the owner can't share it with neighbour or tenants. However, some dug-well did not report much fluctuation having a difference in the yield with the season. Ethically people don't sell water if they have plenty according to the custom of Naga. But some dug-well owner with sufficient yield during winter could sell water earning between Rs. 10,000 up to 1,44,000 per year.

4.2.1.6 PHED water accessibility

As shown in figure 28, PHED supplied water is accessed by about 35 per cent of the surveyed household of the town, occupying fourth important source of water. But according to data collected from the PHED, only about 26 per cent households of the town is having water connection. While it could have been a prime source of water for an urban area. Due to various associated problems, it is not getting importance.

Fig 33: *PHED water dependency ratio of the surveyed households*



Out of surveyed households, about 93 per cent uses PHED water for drinking. Some 25 per cent household reported receiving turbid or dirt water especially during summer and does not drink during that time. About 95 per cent of surveyed households reported that the amount of water received is not adequate for daily activities.

Figure 33 shows that the maximum population served by PHED is only up to 15 per cent household satisfying less than 10 per cent requirement of the household. It sharply decreases with increasing accessibility level. That means most of the town population who are having access to the PHED water service is unsatisfied. The trend line also shows a very sharp negative slope, even crossing baseline indicating a high level of inaccessibility.

From the household survey, the average water bill paid per month was calculated as Rs. 135. While both the median and modal bill calculated as Rs. 100 only. This indicates people mostly receives about 2,000 litres only per month. But while asking about amount how much they receive per month was reported by the most household as very erratic with average delivery estimated as 1,281 litres per month. While both the median and modal amount received was just 1,000 litres. However, this amount varies every month depending on the delivery amount. About 60 per cent consumer noticed a seasonal variation in delivery amount by the PHED. About 23 per cent respondent expressed doubt to have discrepancy to deliver water by the operator. Also, about 14 per cent respondent suspected to have meter reading anomaly too.

Frequency of water received per month was responded mostly in a pessimistic way and having a wide variation. As reported, some household even received hardly 500 litres only in three months duration. While some household could receive about 8 times every month also. However, the amount is not sufficient if the alternative water source is not available to them.

Some household found having old PHED connection that was taken during 1975. Also, some latest connection taken till 2015 was found. Connection cost could roughly be expressed by the respondent with great variation ranging from Rs. 500 (old-time) up to Rs. 60,000 (recent time) which depends on pipe length from metre house to their respective residence.

4.2.1.7 Boring water

Boring water is fifthly positioned water source as shown in figure 28 which is accessed by about 19 per cent of the surveyed household. Nevertheless, in recent days boring activity in the town is seen accelerated. But due to topographic limitation and space to operate the boring machinery only some people can avail this option.

Fig 34: *Boring water dependency ratio of the surveyed households*

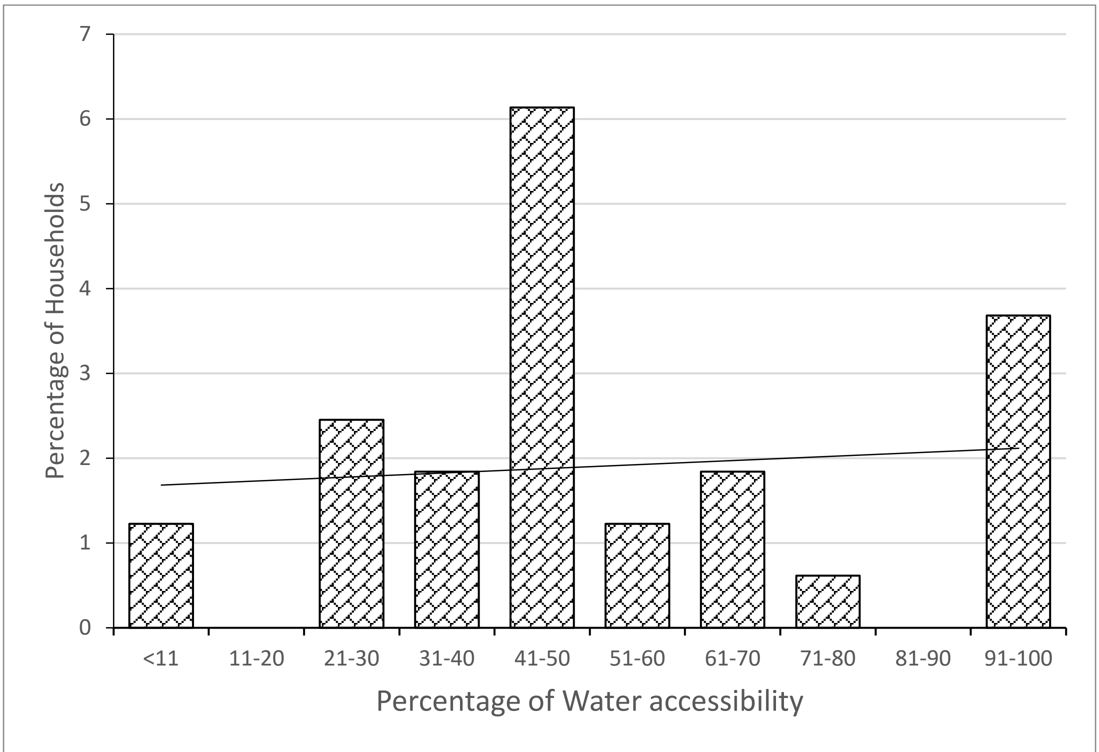


Figure 34 depicts that Boring water satisfies above only 6 per cent of the population providing 41 to 50 per cent dependency. However, no respondent found depending 10 to 20 per cent and 80 to 90 per cent. Nearly 4 per cent population is dependent above 90 per cent. The trend line shows a slight positive slope indicating increasing accessibility with an increasing number of populations.

Oldest boring among surveyed households was in the year 2012 only. Boring cost reported as Rs. 1,50,000 to even Rs. 5,00,000. Drilling depth of was from minimum 85 feet to maximum 290 feet. Some boring was found unsuccessful in certain location due to topographic limitation. As the motor is suspended above effective depth to save the motor from siltation, it was found that some motors kept suspended above 10 to 50 feet from the bottom of the borehole. However, the groundwater depth level inside borehole was reported as a minimum of 30 feet to maximum 120 feet in various sites. Most borewell owners found selling water to some neighbours by overhead pipe who had sufficient yield and also some of them only sell to tanker vendors. Per day yield from a borewell found minimum 4,00 litres to maximum about 15,000 litres. Though none of the boring water owners tested water quality in a laboratory, according to users, it qualifies for drinking after using iron removal filter. However, most boring water users don't prefer it for drinking than stored rainwater.

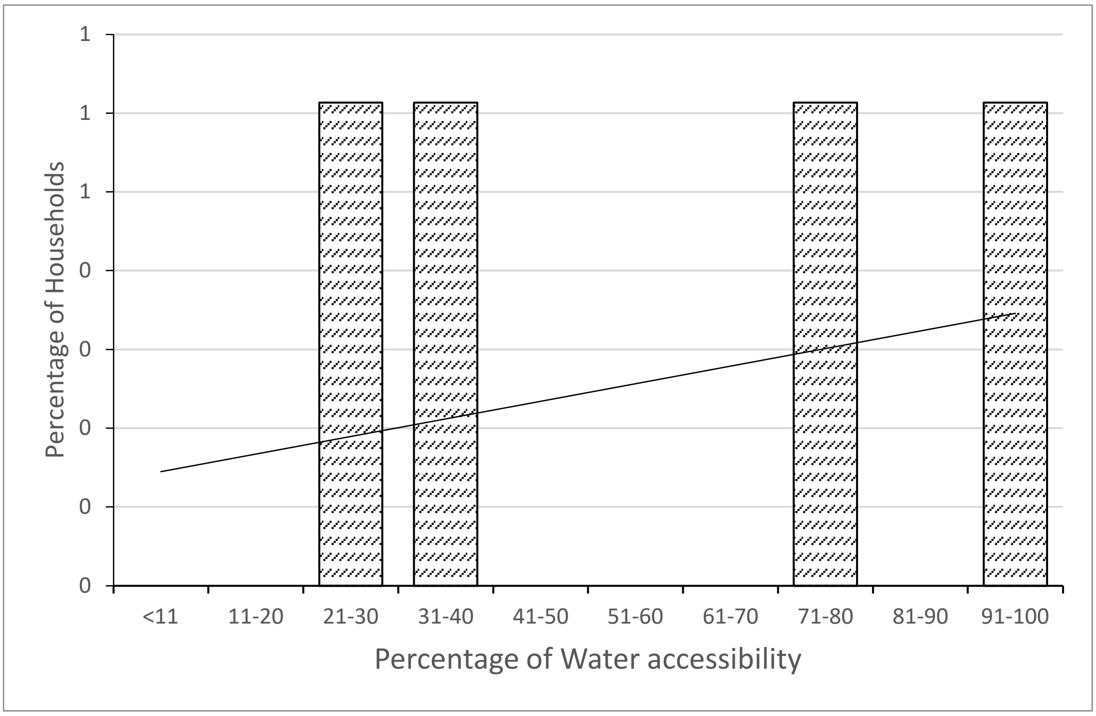
By selling boring water some household found earning up to Rs 70,000 per month for about 5 months in a year. While those households who buy boring water spends up to Rs. 10,500 per month. Thus, it seems, there is a growing business in the boring water sector in the town. On the other hand, in some borewell reported decreasing water level than earlier. This means those borewells is not able to replenish water than its extraction amount indicating unsustainability.

4.2.1.8 Stream water

Survey reveals that portion of the Headwater stream is tapped by few households in the peripheral downstream areas of the town. Only less than 3 per cent surveyed households in the lower altitude location of the town have managed to access stream water (figure 28). They have connected some long PVC pipe from the source to their residence.

Figure 35 depicts a positive trend in water accessibility with limited data analysis it may not be a sound projection. However, it holds promise for households of downstream regions if conservation and protection measure of the upstream region is done.

Fig 35: *Stream water dependency of surveyed household*



4.2.2 Processing of drinking water

Most surveyed households (about 52 per cent) drink water by boiling. About 15 per cent household use simple candle filter and about 36 per cent uses a ceramic filter. There was about 23 per cent or 38 surveyed households who used the Reverse Osmosis

(RO) filter. Only 3 households found buying mineral water regularly. However, except RO filter user some candle and ceramic filter user also boils water. Therefore, the total percentage values mentioned above is more than a hundred. Interestingly, one octogenarian found drinking his dug-well water without boiling. He argued that the quality of minerals available in the natural form of dug-well water deteriorates while boiling, thus he does not boil and claimed to remain healthy till date. On the other side, some RO filter users found cooking rice with drained out water though it supposed to be hard water.

4.2.3 Water storage facility

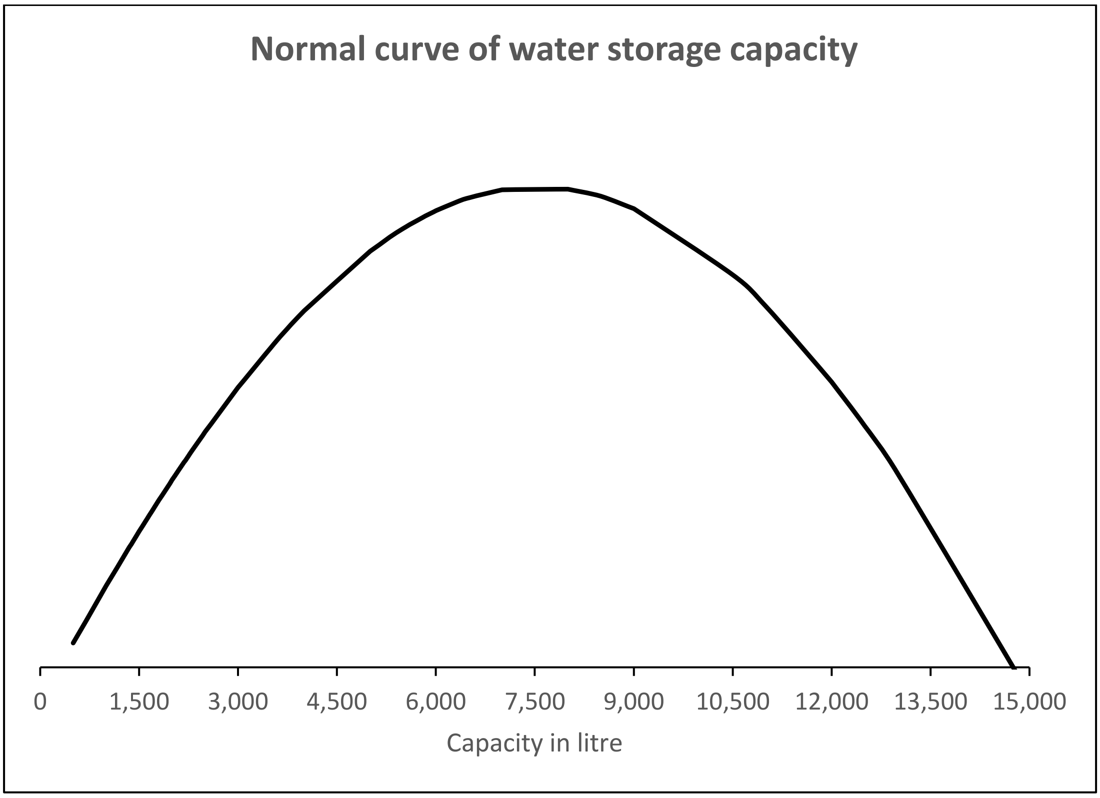
The type of storage container found during the survey was of various size, shape and material. Due to limited space and slopy surface (topography), most people can't keep a large storage facility in their premises. Some people used to construct RCC water reservoir under the basement of their building too. Thus, the storage capacity of a household depends on economic background and space availability.

As responded by the households the available storage capacity lasts only for a short period. It ranges from 2 days up to a maximum of 3 months. Average lasting period calculated is 39 days. While both the median and modal lasting period was 30 days only. Thus, who are having small storage capacity, they expect frequent delivery at least every alternate day if not daily. While those with large storage also expect delivery at least once in a week.

The construction cost of a water reservoir varies greatly among the surveyed households. Cost expressed by respondents is found sometimes exaggerated. It may be mere Rs. 200 if constructed by plastic/tarpaulin sheet up to a costly RCC structure costing about Rs. 1,30,000 as reported by some household. Thus, among surveyed household mean, median and modal cost of reservoir construction is Rs. 28,033, Rs. 15,000 and Rs. 5,000 respectively. If modal cost is considered, with Rs. 5,000 a PVC tank of 1,000 litres can be purchased at present market value.

A households' total storage capacity of water tanks varies from a minimum of 500 litres to 65,000 litres. Of course, it is divided among various size and types of tanks in each household. The Average water storage capacity of surveyed households' is 7,533 litres. The median and modal volumes are 4000 litre and 2000 litres respectively. The standard deviation is 11,138 litres, which is large enough due to those big RCC tanks with capacity more than 50,000 litres. The normal distribution of the storage capacity of the surveyed household is given in figure 36.

Fig 36: *Available water storage tank size in the household*



Water storage dependency also varies greatly based on the number of household members and the size of the water tank. As expressed by respondents, their water storage lasts for 4 to 10 days with small storage size and up to 4 -5 months with large concrete tanks. The ideal size of the water storage tank is found to be 1500 litre for a 4-member family to continue household activities during intermittent monsoon rain without much water shortage.

The expected volume of water also differs door to door. As mentioned above, none of the surveyed household getting regular delivery from PHED. So, expected delivery amount ranged from 150 litres to 2,000 litres at least every week. The average desired amount calculated was 729 litres per week, while both the median and modal expected amount was 500 litres per week.

The amount of water expectancy was based on their assumed usage and volume of available storage. A psychological factor also can be added, because no PHED consumer imagined that, water service could attain such irregular event for which they will have to consume accordingly. So, if some household has small storage capacity, they can’t expect to receive a higher volume, while those with higher storage capacity do naturally expect higher delivery even though that amount may not be consumed totally before next erratic delivery. Thus, the expected amount of delivery varies to a great extent. About 90 per cent consumer was willing to pay higher water tax if service is improved. While asking about PHED service satisfaction level out of 5-star, the average rating is given only 1.9 points.

Water from large size tanks may be withdrawn by motor, manually or by gravity. Out of all household having water tank, 83 per cent withdraws manually 41 per cent household withdraws by Gravity and 19 per cent household withdraws by the motor. However, among surveyed households, 11 per cent resident doesn't have any large storage tank because they are dependent on dug well or boring water.

4.3 *Discussion on water sources accessibility*

From the above analysis of water sources, it can be said that the town population are bound to depend on multiple water sources. But each source is having some form of disadvantages.

4.3.1 Using water from multiple sources

Most national surveys and censuses collect information about only the main source of drinking water used by household members. However, it is well known that households often may use multiple sources. This may be due to a matter of preference over other sources. But a secondary source may provide a higher or lower level of service, and can be an important way to ensure access to sufficient quantities of water throughout the year. There are several studies done in different parts of the world which shows, multiple sources of water is used by the households and for multiple activities according to the quality, quantity and reliability of water.

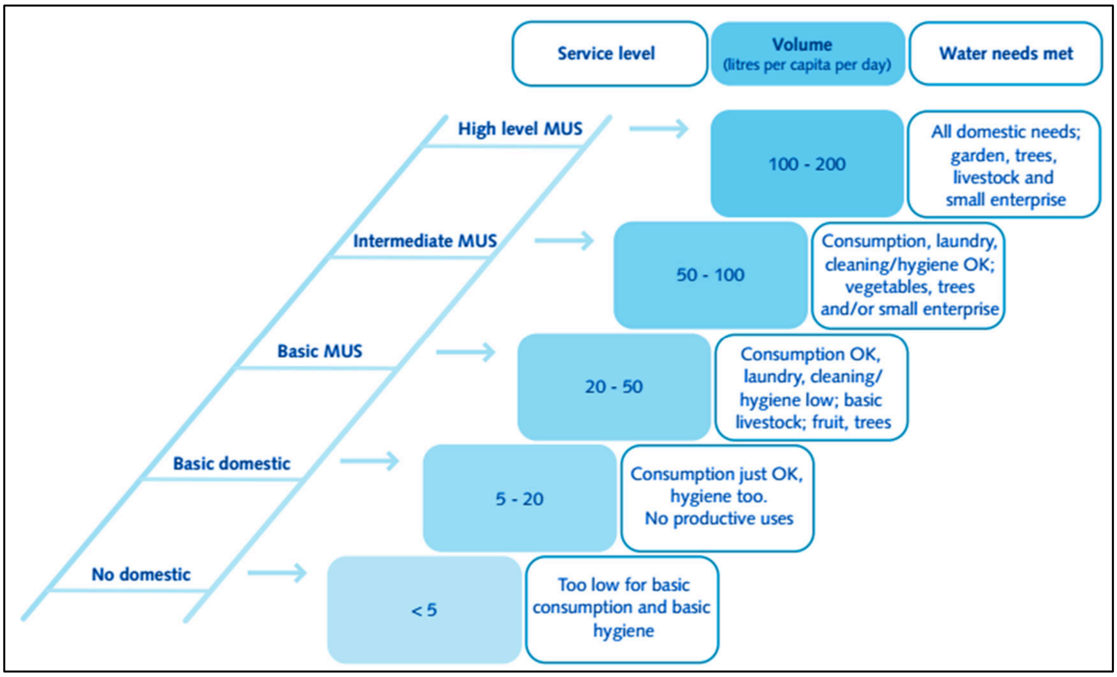
In Bolivia, Bustamante found that the multiple use of domestic water supplies used by the families of multiple sources to meet their water needs for both domestic and productive activities. (Bustamante et al., 2004). The study found that though generally non-domestic sources provided a far greater quantity of water for productive purposes, but the strengths of domestic water supplies are their availability (often 24 hours a day), reliability, and convenience.

Since the early 2000s (almost simultaneously with MDGs), multiple-use water services

(MUS) concept have emerged as a new approach to water services in rural and peri-urban areas in low and middle-income countries (Koppen et al., 2009). The concern of MUS project is based on the saying that, people use water from multiple sources for multiple utilities depending on seasonal availability of rainfall, surface water, groundwater or wetlands, and their access to storage and infrastructure for improved access to water during a longer period of the year, if not year-round (Koppen & Smits, 2010).

When water accessibility exceeds 20 lpcd as “basic domestic” level, water used for productive domestic purposes increases as shown in figure 37 enabling more productivity together with higher quantities of water accessibility. The model was developed by Koppen et al., (2009) based on table 5 of Howard & Bartram, (2003). Thus, MUS service levels are classified as basic, intermediate and high level accordingly with increasing water accessibility higher than 20 lpcd.

Fig 37: *The hypothetical model of MUS water ladder*



(after Koppen et al., 2009)

In a visionary paper Howard et al., (2010) also emphasized on multiple sources of water among several other technical adaptations such as innovations in water treatment, using more robust pipe material and leakage reduction to combat climate change, that would reduce vulnerability (Howard et al., 2010).

In Nepal Rautanen et al., (2014) investigated how the community-managed water systems are used for multiple uses, while they may not be designed for it. The study emphasises on household and community level changes and related institution-building and participatory planning through water use master plans and a step-by-step approach, recommending for scaling up of multiple-use water services (MUS).

A study was done in two Pacific Island countries by Elliott et al., (2017) and reported multiple household water source usage. The study found some implications for developing countries around the world. Study finds that communities adopt multiple sources of water depending on the climatic condition and locally available water sources. Moreover, the study suggests implementers for understanding the use of multiple sources in a community, including the relationship between consumptive and non-consumptive uses to attract community for supporting projects that supplement existing water sources. Also, the practice of multiple sources of water uses contribute to community-level resilience to climate change (Elliott et al., 2017).

Another study was done in Vanuatu, a South Pacific Ocean nation by Foster & Willetts, (2018) found that communities use multiple sources with both groundwater and rainwater as their preferred drinking option without much concern of their pathogenic health issues. Their study suggests groundwater as safer for drinking purpose and also more resilient to the climate-change due to some region-specific environmental issues such as cyclone and volcanic activities. The study findings urge for larger-scale assessment of multiple water source use and its health implications, according to the impact of seasonality and household storage and treatment practices.

4.3.2 Water accessibility assessment

As discussed in Chapter 3 water accessibility has five service indicators in figure 17. It was also discussed that, WHO gives the highest priority to public health and hygiene issue relating to water accessibility. Thus, whatever the water source accessed by the population of the study area as discussed above, it should be free from priority chemical contaminants and pathogens, consuming which may cause a health concern. Secondly, to maintain basic hygiene, people should be accessed to a minimum of 20 lpcd of water.

According to the above discussion about dependency on water sources, it was reflected that none of the water sources can fulfil the requirement of the town population. It was found that the majority of surveyed household uses rainwater. But rainwater obviously cannot be a source during winter months unless there is a voluminous storage tank according to the family size of a household. It was also discussed that in this urban locality constructing a large storage tank in the household's premises is not possible due to non-availability of space and topographical factor even though expenditure factor is granted. Similarly, the problems relating to other water sources also discussed in detail and a comparison is made in table 28.

4.3.3 Involvement of children, women and elderly

When drinking water sources are not located on-premises, household members must spend time and energy if not money for collecting water. However, the burden of water collection is not usually evenly distributed among household members. According to the *World's Women Report* in 2015, it shows that the burden of hauling water falls mostly on women (United Nations, 2015a). Water collection burden also falls on children, with a boy or girl under 15 primarily responsible in at least 1 in 10 households (JMP, 2017).

Fig 38: *Child labours involved to fetch water*

(Photography by author)

Interviewing with the household revealed that in most cases entire family members involved in fetching water from the community Dug-well. In some family child labourers (boys and girls) were found involved to fetch water figure 38. In the majority of cases, the women found to fetch water from the community dug-well figure 39. During the interview it was observed that woman of every Naga household is responsible for cooking, cleaning the house and washing clothes including caring for their child. Most Naga woman also found passionate about gardening even during winter. So, in all activities, water is inevitable that have to fulfil by sacrificing hard labour. The family, who cannot effort to buy water and located far from a community source, it even sometimes becomes a sleepless night to queue in for filling their container with meagre yield from a source, especially during late winter. It was disheartening to see some octogenarian also involved queueing in community dug-well figure 40.

Fig 39: *Women involved to fetch water through a week bamboo bridge seen in top-left corner and garbage also dumped near a protected community dug-well*

(above and below photography by author)

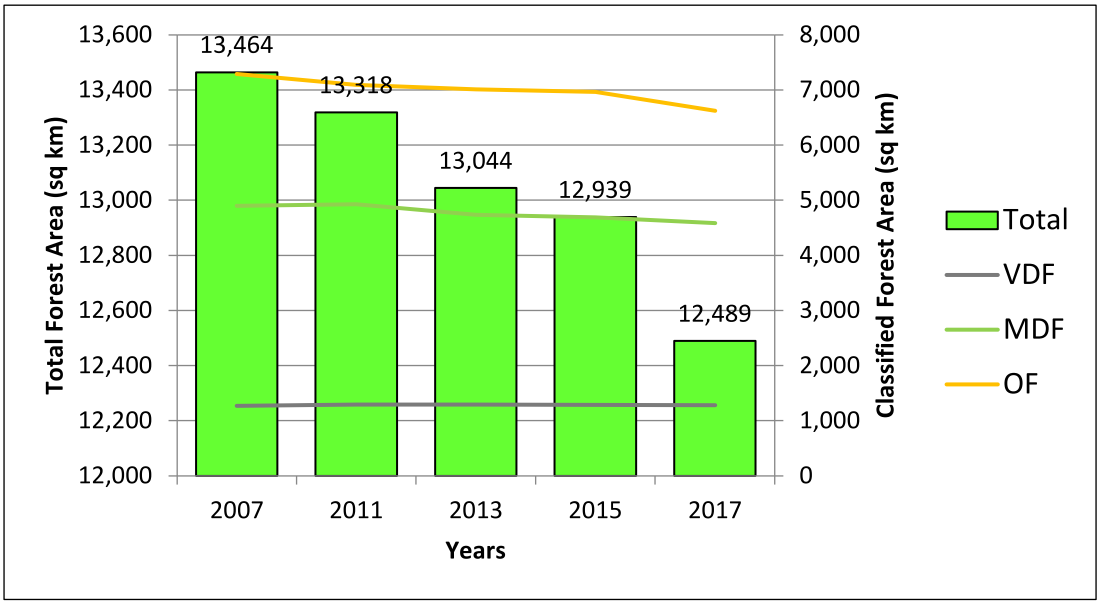
Fig 40: *A octogenarian also in queues for water*

4.4 *Forest resources of Nagaland*

According to India State Forest Report (ISFR) overall forest cover of Nagaland is 75.31% of the state's geographical area covering 12,486.40 sq. km (FSI, 2019). As per National Forest Policy (1988) in the mountainous regions, the aim should be to maintain two-third of the area under forest cover to prevent erosion and land degradation and to ensure the stability of the fragile ecosystem (NFP, 1988). Being a mountainous state, Nagaland satisfies forest cover above the norm 67 per cent.

Forest canopy density changes were compiled from biennial ISFR from 2007 to 2017. As shown in graph figure 41, state forest cover is gradually declining in various category of canopy density after every assessment period. However, a sharp decline is seen in recent time between 2015 to 2017, which was the second-highest forest cover loss record in the country with an area of 477 sq. km. This loss was highest in the category of Open Forest (OF) and Moderately Dense Forest (MDF) canopy cover. Thus, this loss should be looked at seriously by concerned stakeholders.

Fig 41: *Forest cover change in Nagaland from 2007 to 2017*

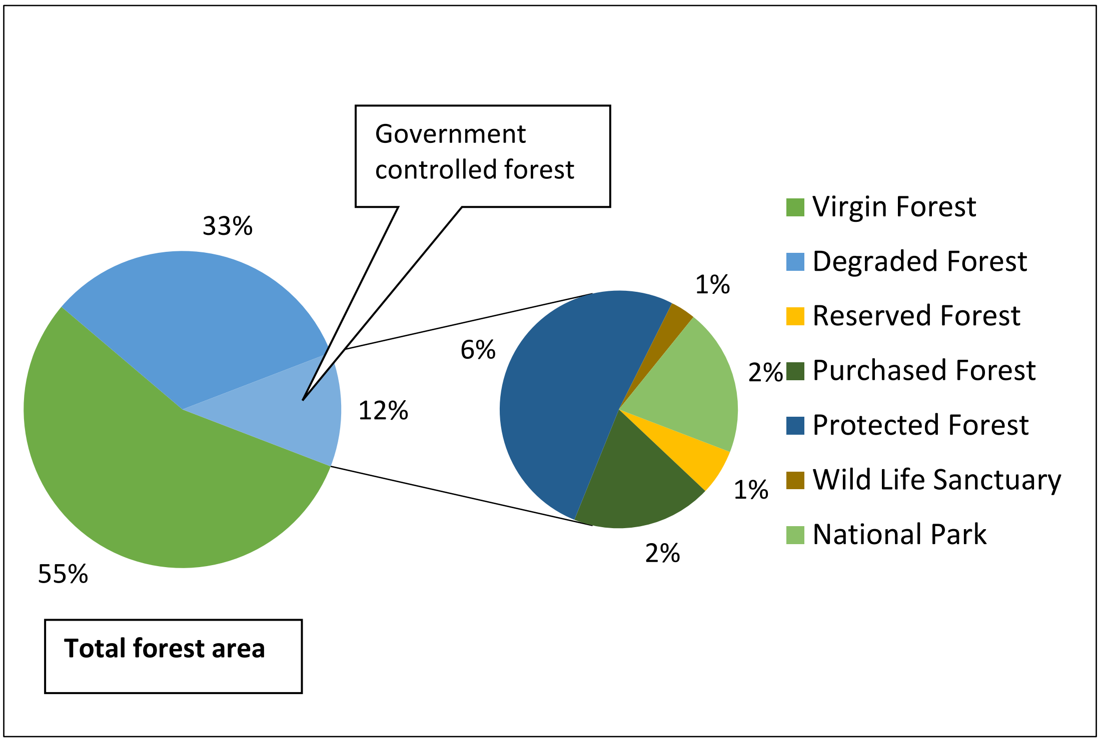


Compiled from ISFR

4.4.1 Ownership of forest in Nagaland

There are two categories of ownership within Reported Forest Area (RFA) of Nagaland (figure 42), out of which major share of 88.32 per cent is under Village forest category which is owned by individual, clan or community. Only 11.68 per cent share is under State Government control (SHBN, 2017). Within village forest category there is Virgin forest and degraded forest. While within the government-controlled forest area, there are classifications such as RF, PF, Wildlife Sanctuary, National Park and Purchased Forest land but canopy density can't be verified within these categories due to lack of digital boundary while preparing ISFR.

Fig 42: *Category of forest showing ownership in RFA of state*



(Source: SHBN, 2017)

4.4.1.1 Article 371A and community forest management

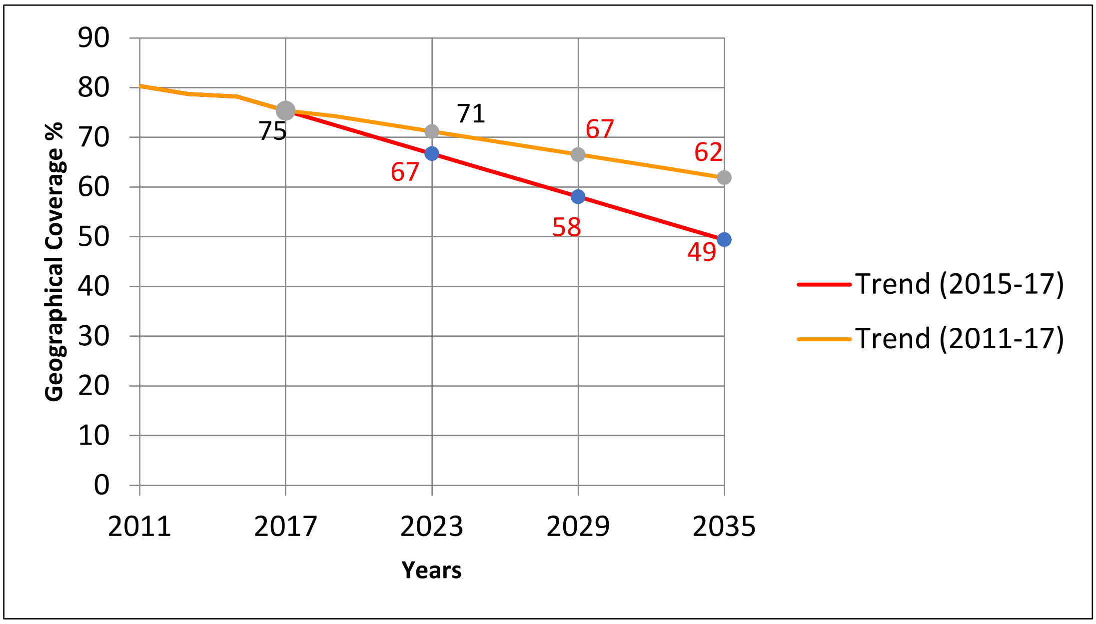
Since the pre-independent period, Nagas have enjoyed a distinct form of Village-State governance and after independence also the Nagas could retain their traditional form of local-governance structures through Article 371A of the Indian Constitution. This provision gives supremacy of the Naga customary laws and procedure, including the ownership of land and its resources, over the national statutes.

After the enactment of the Nagaland Village and Area Council Act 1978 by the Nagaland Government, Village Council (VC) and its development wing the Village Development Board (VDB) were established in every village of Nagaland as an attempt to codify and bring up uniform law in the administration of the village. Accordingly, villages own and govern its resources, plans its developmental activities, maintains law and order, delivers justice and secures defence. As ownership of land is by individuals or clans, the control of forests is predominantly by the community. Community Forest Management (CFM) is largely practised across the state in compliance with the respective customary law of various tribes of the state. The decision of the VC is final and anyone failing to abide by the Council's decision entails serious fines and penalty. Such measures are taken keeping in mind the fertility of the soil in a rotational practice of cultivation and to protect the forest for future use. Villagers are not allowed to cultivate any land apart from the land allotted by the council. This customary practice protects the random cutting of forest in the village and also reduce pressure on land (George & Yhome, 2008). Thus, the onus of forest management to sustain, increase, enhance and strengthen forest area largely lies with the communities (Pant et al., 2016 p-234). So, the state government has to play a limited role in decision making accordingly in support of the respective VCs.

4.4.2 The trend in forest cover loss

Forest degradation trend in Nagaland was assessed based on two recent assessment periods from 2011 to 2017 and 2015 to 2017 and graphically presented in figure 43. The trend lines indicate that, if degradation continues at the same pace then within 2023 to 2029 forest cover may reduce to below 67 per cent norm causing serious environmental consequences.

Fig 43: *The declining trend of forest cover change*

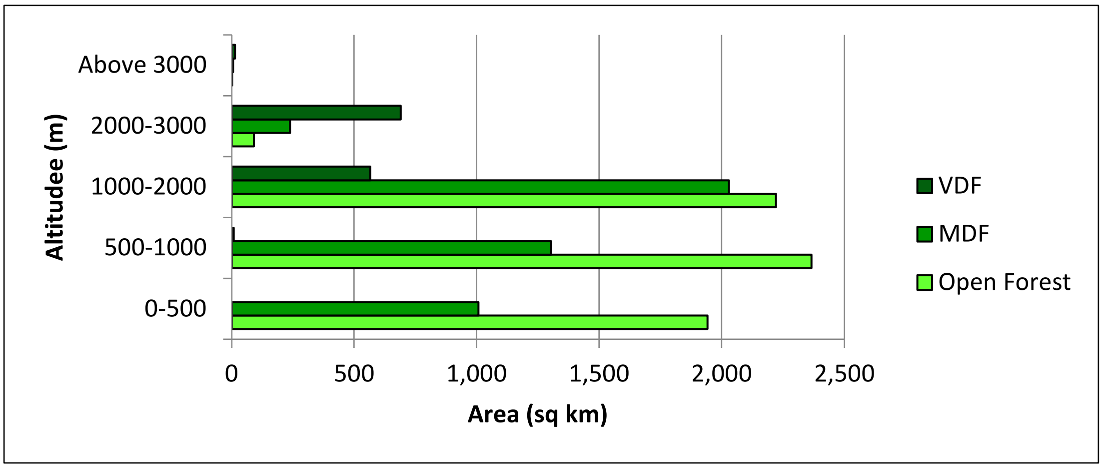


Projected based on ISFR, (2011 to 2017)

4.4.3 Altitude wise forest cover

There is an interesting variation seen in the density of forest category across different altitude range as seen in figure 44. Above 3,000 m. growth of vegetation is limited to all categories of forest due to low temperature. Between 2,000 to 3,000 m. altitude VDF is highest while OF is lowest. While between 1,000 to 2,000 m. altitude VDF is lowest but OF is highest. Below 1,000 m. altitude VDF drastically reduces while OF is almost double than MDF. From a water resource point of view VDF and MDF above 1,000 m. altitude is important.

Fig 44: Altitude wise forest cover of the state, 2019

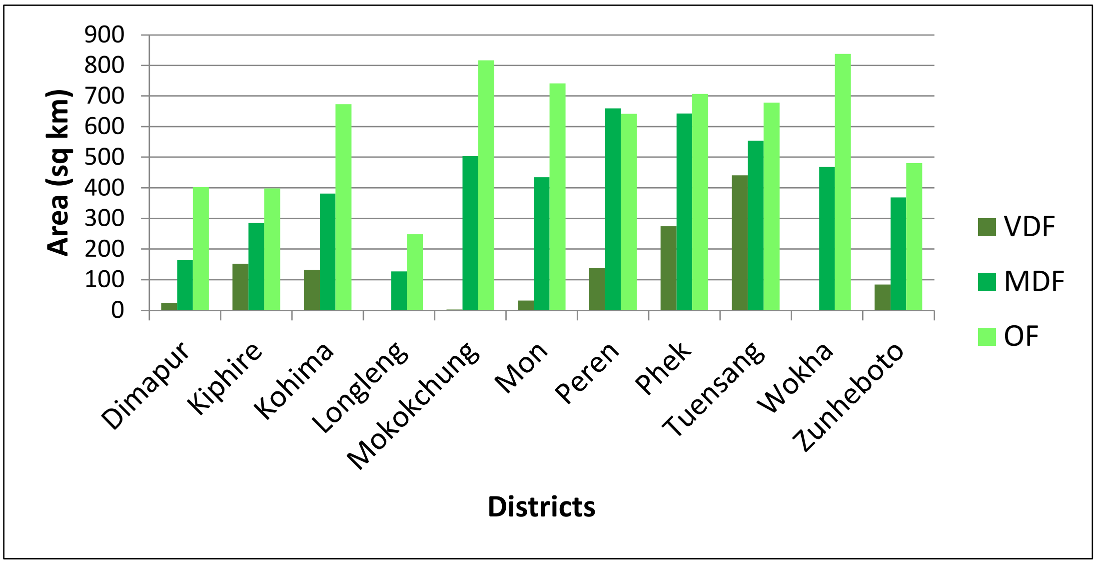


Source: ISFR

4.4.4 District-wise forest cover

District-wise forest density category is shown in figure 45. The VDF area is almost nil in Mokokchung and adjacent Wokha and Longleng district which are in the same mountain range with Mokokchung area which indicates poor forest cover relating to the water resource. Also, in these districts, MDF is about two-third to half of OF category.

Fig 45: District wise category of forest, 2019



(Source: ISFR)

4.4.5 Household cooking energy used

According to census data (DCHB, 2011 pp-112-113) of Ongpangkong circle (where Mokokchung town is located) shows that fuelwood share in the rural area was 90.61 per cent and in urban area 52.73 per cent. While for LPG use in the urban setup was 45.23 per cent and the rural area was 8.45 per cent only. It indicates that both in the rural and urban area, principal fuel for cooking is fuelwood followed by LPG. As stated in census data, an insignificant number of households also uses Electricity, Kerosene, Charcoal and Crop residues. The data reflect dependency on each type of fuel by a household, while in reality, a household may use 'fuel-mix' rather than sole dependency on a certain type of fuel.

Fig 46: *Roadside fuelwood Thaks for sale at Ungma village*

(Photography by author)

While sample household survey analysis of the town reveals that about 96.3 per cent of the family found to use fuelwood. Respondent was unable to tell the exact amount of fuelwood they consume in terms of weight because generally, they buy in bulk amount.

Rather, respondents commonly expressed the amount in terms of *Thak* or stack of fuelwood (figure 46) or roughly in load volume by certain types of fuelwood carrying vehicle in the locality as consumption per household per year (Table 1). However, the retail value of ordinary fuelwood was Rs. 350/- per quintal at the time of the survey. According to fuelwood retail seller of the town, *Thak* volume may not be fixed, as stem may cut into shorter length at source than the standard 3 feet.

4.4.6 The fuelwood consumption rate

Analysing the 137 households' data, it was found that average (± standard error) consumption of fuelwood was 610±42 kg per capita per year, while average household consumption of fuelwood was estimated as 2,460±140 kg per year and daily consumption estimated as 6.74±0.38 kg per household (Sarma et al., 2019).

Though there is high seasonal variation in fuelwood consumption rate, the variation could not be stated by the respondents. Thus, the average fuelwood consumption rate calculated roughly as one *Thak* per person per year. Table 24 was estimated from the interview.

4.4.7 Urban foot-print on forest resources

Sarma et al., (2019) estimated fuelwood needed for meeting the demand for entire Mokokchung town per year from the household consumption rate. Carbon stock in the forest of Nagaland in AGB is estimated at 12.93 ton per ha (FSI, 2017, p. 130). Thus, to meet the demand of fuelwood in the Mokokchung town forest area needed is of about 15 sq. km. However, such forest area presently located in between 20 to 40 km from the town (Sarma et al., 2019).

4.5 *Waste disposal from the town*

While discussing the urban ecosystem, as discussed in Chapter 3, it is also important to discuss the waste disposal system considering the urban area as an organism.

Urban Local Body (ULB) in Mokokchung town was established in 1959 as the Mokokchung town Committee (MTC). Later in 2005, it was upgraded to Mokokchung Municipal Council (MMC). According to MMC official, due to 33 per cent woman's reservation issue and subsequent political disturbance, the Election process for MMC could not be held yet. As a result, fund allocation from the government is not received as per the required amount to MMC. Therefore, presently Additional Deputy Commissioner (ADC) of Mokokchung is designated to administer the MMC.

Mokokchung Municipal Council (MMC) has 28 lady sweepers. They clean every morning and evening shift in three market areas of town namely MMC market complex, Old Town Hall complex and New Market (Salangtem market) complex. This activity is overall supervised by ULB of the town. A cooperation of the citizen is also important for successful waste disposal.

4.5.1 Types of waste generated

Being an urban area, different types of waste are generated in the town. The garbage generated in the town is from domestic and commercial activities. This plastic waste is generated from all sorts of packing materials and some disposable single-use items coming to the town as consumer goods. Though there is no significant waste generating industry, some solid waste is generated from vehicle repairing workshops and business localities. Also, there is some waste generated from hospitals which are disposed of by standard procedures.

4.5.1.1 Household garbage disposal

Household garbage is composed of biodegradable and nonbiodegradable waste. During the field survey, it was found that the majority of household disposes their waste from home at a frequency of one to three days. Household waste cannot be retained for more than three days, as it starts developing a foul rotting smell. According to MMC official, there are 57 RCC dustbins constructed by MMC in prominent locations of the town. But these dustbins are not adequate against the volume of garbage produced in the town. Also, the spacing between dustbins is not adequate. It was found that MMC dustbins are located at a distance up to 300 m. from their home. Therefore, some people don't put their garbage into MMC dustbin due to the distance factor. It was observed that those household residing near a steam *(Nalah)* disposes garbage daily to the stream bed though it was prohibited by the authority. Though MMC dustbins are located on the roadside, there is difficulty to park a pick-up vehicle due to the narrow lane of the Wards. Even in some ward, there is no space to construct a dustbin.

During the field survey, there were 6 Pickup truck vehicles deployed to collect garbage from every household in 6 (six) words of the town maintained by ward committee. These wards are Alempang, Kichutip, Mongsenbai, Artang, Majakong and Kumlong. These vehicles collect garbage from every household twice in a week from respective Wards. Each household is charged Rs. 30 per month as a garbage collection fee. Maintenance of these vehicles is done from this fee.

4.5.1.2 Disposal of sewage

It was described in Chapter 2 that the town has a number of streams flowing out radially into three river systems. Due to slopy topography streams flow swiftly after a brief rainfall also. Thus, people residing near the streams take advantage of disposing their household garbage and sewage into the streams without difficulty (figure 47).

Fig 47: *Remnants of solid waste flown down by stormwater seen down to a culvert*

Moreover, septic tanks are directly released into the stream during a storm. Of course, some loose prohibition is imposed by MMC not to release during day time and up to 10:00 pm. Many a time stream sections are occupied for constructing pig shed where faecal matters are directly released to the stream. Thus, there is always having a chance to enter some pathogens into Dug-well water which are mostly found near streams as discussed above.

4.5.1.3 Faecal matter disposal

As discussed above most of the people residing in the bank of streams discharges septic tanks directly to the stream. But people living away from the stream don’t have this opportunity though during an interview a house residing away from the stream also empty their septic tank by syphoning through a long pipe.

During the interview, only 45 households found using soak-pit for septic tanks. Some resident constructs innovative low-cost soak-pit as shown in figure 51, where latrine is constructed above the piled vehicle tyres. There is MMC Cesspool tanker service for emptying the septic tank. But due to inaccessibility, some people cannot take the service. In some house, this service is performed by parking the tanker below the residence crossing some other residential campus by a pipe due to slopy topography.

4.5.2 Disposal of municipal waste

MMC official during an interview expressed about the waste disposal problem of the town. Municipal waste is dumped away from the town by dumper vehicles. Presently municipal waste it transported to ‘Sabangkaba Menchen’ a location under Mokokchung village at a distance of about 13 km. from town towards Tuensang via Mokokchung-Amguri road. However, this dumping site is allowed to designated Wards only. Before this site, MMC used ‘Tsukjongkong’ under Ungma village towards Tuensang via Mokokchung – Kohima road located at a distance of about 7 km. from town which was closed down since 2016 following objection from the Ungma village council.

Table 25 shows that MMC dumping yards locality is changing after every few years, as it is objected by the concerned villagers due to pollution. In this respect, the administration has to convince the adjacent village council authority through some mutual understanding. According to MMC official, this garbage is burned without segregation after dumping when it is dry. Also, the fly is controlled in MMC dumping site, by applying chemical as shown in figure 48.

Fig 48: *Insecticide used at the garbage disposal site*

(Photography by the author at MMC office)

It can be stated form the above discussion that, waste disposal (like excretion of an organism) system of the town is not environment friendly, though an effort is made from the authority. A greatest growing concern in recent time is about plastic waste disposal problem. Though time to time awareness campaign is done, citizens are not able to follow it due to adequate dustbin facility at some optimum distance from their home. Moreover, the segregation of garbage is also not done at home. Though the administration has insisted to segregate plastic and, in some location separate bin is also installed, the response from residence is not encouraging.

For recycling of waste, there are some scrap collectors. But they don't collect plastic, glass or paper items other than some metallic scrap (iron, aluminium, battery etc.), saying it is not worth to collect as transportation cost to Assam become more than the value of such scrap. Authority may find some way to recycle those waste properly.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5 SUMMARY AND CONCLUSIONS

This study was conducted to understand, the type of urban processes undergoing in this mountainous terrain of the eastern Himalaya. This knowledge is important to understand the influence of human-dominated urban environment in the biodiversity hotspot region of the world. This study area is located in the Indo-Burma biodiversity hotspot region and a detailed geographical personality of the area is described in Chapter 2. Since biodiversity richness has a direct relation with the water availability and rich forest resource, these two natural resources consumption were considered for the urban environment as the basis of this study.

The study topic considered to emphasize how urban population faces water scarcity during the winter season when rainfall is almost absent in this monsoon-influenced region. Thus, according to UN SDG goal 6 as discussed in subsection 3.3.1, water accessibility was studied in this Class-III urban area. Though water accessibility "service indicators" are simple to assess according to WHO guideline for a locality where only one primary source is used throughout the year. But while studying water accessibility in this locality, it was found that during different season of the year, the same household may depend on multiple (up to four) sources of water. And each source has different accessibility level for different topographically located household and/or for economically different profile people. Thus, generalising water accessibility is difficult in this region. So, the issue was studied by conducting a household survey through structured questionnaire incorporating various qualitative and quantitative query in it. The results are analysed in subsection 4.2.

Moreover, it was found that people of this urban area use fuelwood for cooking and space heating. Since fuelwood is collected from the forest lands it will have an impact on water retention capacity of the forest area. Though presently fuelwood may not be collected from the same area from where water also is collected by the town, a study in this direction will enlighten the planners and policymakers to act accordingly. Thus, the consumption of fuelwood also analysed from the surveyed households.

While considering to study urban ecology of the area, it was important to study the area from "ecology of cities" viewpoint, where an urban area's metabolism process is studied considering the urban area like an organism, as discussed in subsection 3.4.2. Thus, the study explores the urban footprint on water and forest resource as "consumption" and waste disposal system as "excretion" from this urban area.

5.1 *Summary of the study*

While investigating the research questions few objectives were framed as stated in the introduction chapter. In this chapter, a summary is drawn about the study conducted with those objectives.

The first objective was to study various potable water sources availed by the residents. It was found that town households' avail 6 (six) different sources of water as discussed in subsection 4.1 viz. rainwater, tanker water, dug-well water, PHED supplied water, boring-well water and also stream water. But maximum optional source availed by some household is up to 4 (four) different sources. Out of all the sources, rainwater use dominates among the surveyed households. Tanker water is used mostly seasonally when other sources cannot meet domestic demand. Dug-well user has limited quantity access towards late winter. Quality of dug-well water is not tested by any household though there is a chance of some pathogens. The PHED water users expressed unsatisfaction about the meagre amount of supply and irregularity. Boring-well user has the problem of hard water and some are dried out. Some owner of boring-well can sell water to the neighbour by temporary pipe connection and occasionally selling to tanker water vendor. Stream water users are limited to the downhill location of the town. So, it has topographic control, though quality wise it is not preferred for consumption.

Seasonal water accessibility among the household was analysed as per the second objective. Among the sources, all sources are supposed to be available during rainy summer months because rainwater is the principal source of other sources as well. Some households reported not harvesting rainwater as they have some other water source such as dug-well or boring-well. During summer months also PHED water supply is not reliable due to frequent breakdown of the pipeline by a landslide or other technical problems. Generally, most PHED consumers do not expect supply during rainy months, as simultaneously they may have access to some other source. During the rainy season, stream water becomes more turbid and those households towards the downhill area, don’t choose to use it than rainwater. Interestingly, some household buys tanker water during summer months also, who cannot harvest rainwater due to some problem. Also, during intermittent rainy days, some people have to buy water from a tanker, who do not have a storage capacity of more than 1,500 litters with a four-member household.

While in winter months dug-well and boring-well user enjoy more consistency than other sources though some dug-well owner may have to buy from tanker vendors towards the late winter season. Delivery of PHED water also not sufficient during winter though all consumer keeps a high expectation for it. Turbidity of stream water reduces during winter months, and some downhill area population use it. Though it is not used for consumption, mostly it is used for other household activity.

It is also intended to investigate the reliability of the PHED water supply system. It is already discussed above that, most of the PHED consumers are not satisfied due to unreliability in the water supply system. It is neither in sufficient quantity nor in expected frequency or time. Due to technical problems, PHED is unable to receive water in its reservoir whatever yield is supposed to get from the source. Moreover, the department noticed that yield in the source is reducing than before basically due to deforestation. Thus, unreliability on PHED water is bound to increase in future if deforestation further continues.

The fourth objective was to enquire the availability and affordability of water from different sources. It was discussed that the availability and affordability of each source are different. Investment is needed to access each source of water. But people decide to invest based on the degree of expected reliability from a source. Investment may be onetime or recurring. The topographical and geological factor where a household is located, maybe a determining factor to invest in a source. The availability of different sources in a different season was discussed above. However, when the affordability of each source is considered, it has a vast difference among the sources.

Rainwater is the cheapest source in the area with acceptable quality when it is harvested from the metallic surface. Though it has no topographic or geological control, to have more reliability in needs high investment to possess a reservoir. Next higher investment is needed for dug-well construction. Dug-well water yield is controlled by topography and geology. Therefore, due to uncertainty on its success, financially capable household also may be hesitant to invest in dug-well. However, it is mostly dugout near a stream, at community or private investment.

For a PHED supply connection, a consumer has to pay the department for pipe cost needed according to the distance from the metre house to a consumer's residence. Among surveyed households maximum cost found was Rs. 60,000. During the survey, people found not interested to invest in PHED connection due to unreliability in supply. Even some surveyed households expressed to surrender the connection because of poor service.

Bore-well needs further higher investment than dug-well. The success of dug-well also has both geological and topographical control. Moreover, it needs nearness to a road for bringing heavy boring machinery to the site as discussed in subsection 4.1.5.

Tanker water is the most expensive among all other sources. But people have no choice remain when other sources cannot satisfy a household's requirement. Cost of tanker water varies according to distance from source and season as discussed in subsection 4.1.2.

Stream water though not a common source for the majority of the town population, it satisfies some downhill population. To have access to stream water, some people have to invest in PVC coiled pipe from source to their residence. But due to poor water quality, only a few households near to such source invest for it.

The fifth objective considered was to examine urban footprints on forest areas by fuelwood use. The study tried to investigate the use of fuelwood for domestic purposes. It was discussed in subsection 4.4.6. and in conclusion below.

The study also investigated the waste disposal system as part of the metabolic process of the town, according to the sixth objective considered. The town was considered like an organism as discussed in subsection 3.4.2, where solid and liquid waste is disposed from the town and whether the practice is eco-friendly was also discussed in subsection 4.5.

5.2 *Conclusions*

The study was conducted to investigate the research questions framed in the first chapter. Accordingly, the study investigated the *first research question in two parts* as the sustainability of urban footprint on *water and forest* resources. The arguments are discussed as follows.

5.2.1 Urban footprint on water

Water is a renewable resource and, in this region, it is received in the form of rain, mostly during the summer months. We can consider the water footprint of the town in terms of "blue water" transported by PHED pipe for the town consumption from distant mountain ranges as described in the subsection 4.1.4 above. Also, it was discussed in subsection 4.1.2, how blue water is transported by tankers from distant locations. Therefore, this extraction for human use may impact on those stream ecosystems, which may reduce the yield of water in long run.

5.2.1.1 Importance of headwater region

The lands of upper catchments situated in the margins of every river basins where zero to first-order watershed forms, are known as "headwaters". Headwaters are the places where water flow-lines originate and where much groundwater recharge occurs. They are the ultimate source of a great portion of terrestrial freshwater. These regions are most environmentally sensitive and most rapidly developing parts of many landscapes (Křeček & Haigh, 2019). The consequences of any change in water quality and yield in these headwaters are affected in the downstream. Headwaters are geomorphologically major landscape features. A headwater is characterised with a hydrological margin (a point of origin for downstream water) and also sometimes lies close to the socioeconomic systems (Haigh, 2004). Headwaters provide the recharge zones for both surface and ground waters. Unscientific development may have dramatic effects on the environmental, socio-economic and even political turmoil in the downstream areas.

If an undesired impact is noticed in the headwater due to some kind of human impact, and subsequent measures for correction is not made in time, it may take a longer time to rectify and recover the impact in the watershed. Therefore, identification of emerging problem must be done at an early stage of impact development. In the tropical climate, activities such as commercial logging, fuelwood gathering and Jhum cultivation may lead to a decrease in forest production. But as a cultural practice among tribal population of the tropical areas, it may not be able to stop despite negative pressure to nature.

According to Richardson, (2019), headwater streams are among the most sensitive of freshwater ecosystems, due to their intimate linkage with their catchments and how easily they are impacted. He believes that a unique ecosystem with many specialist species, headwater streams deserve better stewardship. Because, these small streams provide small, somewhat isolated habitats (nowhere to go but downstream) and can show high degrees of environmental differences among headwaters. It promotes diversification and endemism among the organisms found there, which deserves more conservation action.

According to a study conducted by Tiwari & Joshi, (2012), in the headwater region of the river Kosi (Lesser Himalaya in Kumaon, Uttarakhand), about 36 per cent of springs have dried heads during the past 20 years, those were perennial streams earlier and also water discharge in springs and streams has decreased considerably resulting into a severe crisis of water for drinking as well as irrigation. Moreover, the density of perennial stream also found reduced to about 6 per cent during the same period. This indicates that headwater regions are under threat due to human intervention in the Himalayan zone.

5.2.1.2 Conservation effort of headwater form Nagaland

In the context of Nagaland, holistic integration of programmes is recommended by Rawat, (2017) to protect headwater areas with the participation of local community and stakeholders by taking urgent action for halting further environmental degradation due to traditional shifting cultivation. The study proposes to undertake micro watershed planning approach, which is based on ecosystem services considerations for securing a better future for the citizens of these isolated mountain headwaters.

There is also a recent inspiring story of biodiversity conservation by community effort in Nagaland, where priority is given to protect the area by restricting Jhum cultivation practice. A significant part of headwater region of the Dikhu watershed is protected under the Longleng district of Nagaland. The area is now a safe haven for migratory Amur Falcon birds shelter and arguably major roosting ground in Nagaland since 2017. Under the aegis of the *Lemsachenlok* society, the Village Council Courts of three neighbouring villages (Yaongyimchen, Alayong and Sanglu) of the district resolved not to go for new Jhum land in 2018 onwards during *Jükdhok* (Council Court decide the location for the forthcoming Jhum) of 2017. Rather, the Village Council members decided to continue with the previous year's Jhum land in order to reduce deforestation and protect biodiversity in the area. According to Phom, (2019) who is also mentoring the society, the area is now a habitat for 85 species of birds, including Amur falcons, 15 species of frogs, as well as leopards, barking deer, serows and otters etc.

The similar effort of community forest conservation in the headwater regions of the state to be undertaken to check rampant deforestation due to Jhum practice and protect endangered biodiversity of the region, which is also a part of Indo-Myanmar biodiversity hotspots of the world.

5.2.1.3 Shrinking PHED sources vs increasing demand

It was discussed in the subsection 4.1.4 that, out of the three PHED water sources (table 8), Techipami (40 km.) source has the largest yield but having problems of frequent disruptions. Angetyongpang source (17 km.) is yielding gradually less water (about one-fourth) since last few years. Even yield from Techipami is also reducing. Lithsami source (38 km.) is not meant for the urban area as it is under NRDWP. However, with due understanding with the village council, some amount is shared with the town population, only during a crisis.

So, the deliverable capacity of PHED (excluding Lithsami) to town is only about 11 (eleven) lakh litre per day (table 8). While data of actual delivered amount is not provided by PHED and is expected to be far less than the capacity due to various problems. On the other hand, household requirement according to the population size of the town was 17 lakhs to 35 lakh litre per day (table 27) according to the population size of 2011 and considering WHO standard for urban water requirement of 50 lpcd to

100 lpcd. But the requirement will be about 48 lakh litres (2011 estimation) when BIS standard for the urban poor is considered as 135 lpcd. Present own population definitely shall be more than 2011, while PHED capacity is not increased since 2011. Rather yield is reducing than earlier. So, there is a huge gap between PHED capacity and water demand for the town population size.

According to PHED official, in recent years the amount of discharge is declining from the source due to deforestation. On the other hand, water demand is increasing in the town due to population growth and lifestyle change, causing a progressively wider gap between demand and supply of water. It causes concern for the future sustainability of the town water supply system. But deforestation due to logging and Jhuming can't be prohibited as land ownership is protected under Article 371A.

Though physical measurement of water flow from the source is not the purview of this study, interview with PHED official reveals that the department is exploring more water sources for the town away from the present sources towards the southern mountain ranges from the Mokokchung town. It indicates that the present source is not having adequate water volume for which new source exploration has started. This means, after a considerable volume of water is diverted through the pipe or tanker to the town, there will not be adequate water for sustaining life in the downstream environment of the stream ecosystem.

Thus, diverting stream water to the urban area creates urban footprint on water resource in the headwater regions, and from the ecological point of view, this may be considered as an unsustainable impact of the urban footprint. Hereby, the *first part of the first research question can arguably be rejected.*

5.2.2 Urban footprint on the forest

Forest is also considered as a renewable resource. Forest area absorbs "blue water" from rain and holds it as "green water" in soil horizons for a longer duration (up to late winter season). This green water is returned to streams as blue water as depicted in figure 3. The basis of rich biodiversity in this Himalayan region is the vast forested area.

Fuelwood consumption in surveyed households was studied by asking some empirical questions. Almost all people during the interview expressed that the quality of fuelwood is not found in the forest as it was available before 10 to 15 years. The same view was expressed by the fuelwood vendors and sawmill owners of the town. Forest area reduction is also reported by the FSI in their biennial reports.

On the other hand, as discussed in subsection 4.4, the town consumes fuelwood from its surrounding localities up to a distance of about 40 km. So, it can be assumed that presently urban footprint on forest resources spreads about up to 40 km from the town. It was also estimated that the town population consumes fuelwood from about 15 sq. km. per year, which is approximately three times more than the town area itself.

Thus, this type of fuelwood use will lead to unsustainable pressure of forest resource augmenting more water scarcity during late winter in future. Therefore, the impression of the urban footprint on the forest area is seen unsustainably. Hereby, this *second part of the first research question can arguably be rejected.*

5.2.3 Topographical and geological control on water accessibility

In the summary above it was discussed how multiple sources are accessed by the households. But every source has some spatial and temporal speciality that avails by the household in need. According to the second research question, we need to answer from spatial variation point of view.

The water accessibility from PHED has no such topographic or geologic control from a consumer point of view, as it needs only a pipe to be connected to their residence. However, it has strong topographical and geological control at the source region of PHED. As discussed in chapter 2, the topography of Nagaland is gradually increasing towards southern parts of the state. It can be observed from the present water sources of PHED for Mokokchung town that, all the 3 (three) water sources are located in the northern aspect of the mountain ranges which are headwater region of respective streams. There might be three causes behind it as follows.

Firstly, there is thick vegetation growth found in south-facing slopes of the hill due to higher moisture availability as a result of less insolation exposure. Secondly, due to series of thrust as discussed in subsection 2.4 and 2.5, geologically bedding planes of the hill ranges are having dip angle of about 30 degree, roughly towards the north direction (figure 8) which brings more dampness from 'lateral percolation' of water accumulating more surface water in the northern aspects of the mountain ranges. Thirdly, all these sources are seen in toposheet is under "greenwash area" (Dense mixed jungle).

It was also observed that the dug-wells located at the same altitude in the northern aspect of the town (Melak watershed) yields relatively more water than the southern aspect of the town wards. This is due to the same geological control as stated above. Lateral distance from a stream also determines the yield in a dug-well. Moreover, water accessibility from dug-well and stream aquifer is found higher towards the downhill portion of the town due to topographical control.

However, it was found that borewell water has both geological and topographical control. Though due to lack of sufficient observation from borewells it can not be stated properly, however, it was found that some borewell is dried up earlier than another borewell located at a higher altitude which indicates a dual control (topography and geology) on the borewell water accessibility. Thus, it can be said that borewell in the town has a prospect if it is located at unconfined aquifer though water quality may be hard for drinking purpose.

Other than these sources, tanker water also depends on the water source which has topographical and geological control. From a consumer point of view tanker water may not have any topographical control but relatively higher tariff to be paid depending on the altitude of a household.

There is no evidence of topographic control on rainwater is seen, as the area is a small one, though for a large region topographic control on rainwater may be present due to rain shadow effect.

From the above discussions, it can be said that the *second research question asked can be arguably supported*.

5.2.4 Urban waste disposal footprint

The third research question was about the eco-friendliness of the waste disposal system of the area. As discussed in subsection 4.5, town disposes of its solid waste by MMC dumpers to a distance of about 13 km. As reported by MMC, the present dumping site is sixth (table 25) after some objections from respective village councils to MMC on previous sites. There is also having problem to instal a sufficient number of dustbins along the town streets due to limited width of the road and slope factor. MMC also reported not getting required fund due to not conducting ULB election following 33 per cent women reservation issue in the state. The town is also making some amount of urban footprint by the waste disposal system.

5.2.4.1 Urban grey water streams

Streams of the town are full of polluted water or classified as grey water as stated in subsection 1.7.1.1. It was also discussed in subsection 4.5.1, that how households residing near the stream areas dispose of their solid and liquid waste in the streams despite the imposition of restrictions. Out of 18 wards areas only 6 wards (one-third) have been maintaining pickup trucks for garbage collection. But, some people of those 6 wards do not put their garbage in the pickup truck but in the stream, who are mostly located near the stream, though they pay garbage collection tax. Only 27 per cent of the surveyed household found using soak-pit for septic tanks. Due to non-availability of soak-pit, many residents along the stream bank discharge their night soil directly to the stream during a storm. Also, many households construct pig shed above or near the streams, discharging waste directly to the stream. There is a high chance of entering pathogen or faecal matter in the downstream areas causing health concern.

It is also observed that, in the upper part of the town where demand for space is high, some building is constructed covering the stream but without blocking it. Some portion of the streams is found narrowing down due to construction of retaining wall to increase residential plot area. Streams are also used for removing earth from some residential plot due to construction activity by dumping in the bed, which is flushed down after a storm. In this way stream after passing through the urban area is turning grey water from blue water. Therefore, the waste disposal system of the town also can be said as unsustainable and not eco-friendly. Hereby *third research question asked can be arguably rejected*.

5.2.5 Recommendations

An exhaustive list of guidelines and recommendations are given in the National Water Policy (2012) and Nagaland State Water Policy (2016). This study also endorses those recommendations which can be implemented in this area. However, some points of both policy documents are vague and open-ended, which needs more elaborations. After this study, we recommend some points which may be considered by the planners and policymakers.

It is important to keep in mind that rainwater is the prime source of all other water sources, through which both the natural ecosystem and urban ecosystem functions. Moreover, both ecosystems have strong correlation as discussed above. Therefore, this study recommends conserving rainwater to the utmost level, in both natural areas and human-dominated areas. In this respect, some steps to improve the situation in this fragile mountain environment are recommended as follows.

5.2.5.1 Rainwater harvesting

Rainwater playing a significant role to mitigate drinking water demand of the town population as discussed in subsection 4.2.1.1. But rainwater apparently cannot be a candidate during winter months unless there is a huge storage tank according to the family size of a household. It was also discussed that required space and slope for constructing a large storage tank in every residential compound of this urban locality is not likely to be possible, keeping expenditure apart.

Though harvesting rainwater is limited in the storage tanks, there are prospects for rainwater harvesting in undergrounds by converting blue water to green water. This can be planned by allowing an extra amount of rainwater from roof surface to an RWH chamber constructed underground at safe distance from the building foundation in each residential compound. The extra amount of water should be overflown to the municipal drain. Water so harvested is likely to retain underground for an extended period enhancing groundwater by saturating soil horizons through seepage. Thus, a dug-well constructed in the downstream area of such management structures, supposed to yield water for a longer duration. This system is also expected to reduce the intensity of surface stormwater discharge from the area.

In this respect, the concerned department or NGO may tie-up with the urban authority to implement rainwater harvesting as a compulsory practice. Also, ULB may constitute an RWH monitoring cell for effective implementation of RWH in the town. This should be done following the NWP (2012) para 4.4, 5.6 and 10.7, where the emphasis is given specifically for hilly areas (MoWR, 2012).

5.2.5.2 Groundwater development

A brief introduction about groundwater was given in subsection 2.9. The unconfined aquifer from dug-well holds promise to certain households located at a favourable position as discussed in subsection 4.1.3 and 4.2.1.5. But due to geological and topographical control, boring water from the confined aquifer is not possible at every location of the town. Since boring activity has started within a decade, some boring well owners reported depleting water level. Sustainability of all boring water presently serving is also in question. Moreover, the quality of most boring water is reported as hard water (mostly with high iron content). It was also discussed that how dug-well water may have some pathogens from upstream septic tanks.

5.2.5.3 Improving stream water

It was discussed in subsection 4.1.6 that in the downhill area unconfined aquifer is resurfacing as stream water. But due to turbidity and some urban polluted materials, this source is not usable in the kitchen. However, if proper waste management and rainwater harvesting (as stated in subsection 5.2.51) is done in the upstream areas, the yield of such stream water will increase with the required quality.

5.2.5.4 Prospect for developing Melak watershed

Looking to slope factor of the town area new settlements are growing along the highway as stated in subsection 2.10. Also, new settlements are growing in the downhill areas due to limited space in the uphill areas.

However, out of the three watersheds north-facing Melak watershed has a gentler slope than other two south facing and west facing watersheds. Moreover, it was discussed in subsection 5.2.3 that due to geological control, dug-well located in northern aspect has a higher yield. Therefore, it may be recommended to develop Melak watershed for future expansion of the town where groundwater and stream water from the unconfined aquifer will be having higher accessibility. According to the recommendation of NWP (2012) para 12.4 sub-basin level, IWRM can be successfully implemented in this area. If implemented successfully, this will also give relief to the increasing traffic congestion of the town area, which is becoming a growing concern in recent time.

5.2.5.5 Creating functional zones

It can be recommended that ULB should be empowered to decide on creating some functional zones within the urban area based on the water demand. Creating such zones may help the authority to allow setting up a settlement of residential, commercial, administrative, educational, recreational or industrial purposes which are having different amounts of water demand. As downhill locations have more water accessibility than uphill areas, high water demanding and polluting settlements may be restricted in the uphill locality.

5.2.5.6 Road widening

It was discussed in subsection 4.5.1.1 that the area is having garbage disposal problem from some wards due to narrow lane where eighter dustbin can be setup or some vehicle can be operated for garbage pickup service. Therefore, road widening is important for operating such services including some emergency fire service and water delivery tankers. Though it may be difficult to execute the task due to existing building's and topography, following the Nagaland Building Bye-Laws, 2012, road widening should be performed as early as possible for the benefit of all residents. ULB or appropriate authority may enforce to implement the said by-laws in letter and spirit.

5.2.5.7 Adopting REDD+ for enhancing forest

Forests bear considerable value as an ecosystem services provider in addition to economic value. It is also home to the world's most biodiversity and supporting the livelihoods of many people. It was discussed in subsection 4.4, about the rate of forest cover loss in the state. In this scenario, a community can take advantage of REDD+ mechanism, which is a framework created by the UNFCCC Conference of the Parties

(COP) to guide activities in the forest sector that reduces emissions from deforestation and forest degradation, as well as the sustainable management of forests and the conservation and enhancement of forest carbon stocks in developing countries. In this respect, Nagaland is a potential candidate for harnessing REDD+ activities with about 75 per cent of the total geographical area is covered by forests.

5.2.5.8 Strengthening water infrastructure

Since every nation has to work towards SDG target 6.1, this urban locality also should plan accordingly for piped water accessibility coverage in every household within 2030. Until that time the water requirement also will increase owing to population growth and more water demanding lifestyle in the town. Moreover, there should be appropriate climate change resilient planning and additional funding may be allocated for such infrastructure.

So, authorities have to prioritise funding in the urban water development projects to achieve said SDG target on time. The PHED has to work for its capacity building, enabling water supply from other sources, which may be a combination of surface water, groundwater and rainwater. Also, they have to boost storage capacity and increase Meter house density to serve entire town households in a phased manner. Present PHED water sources are from headwater regions, that may be restricted to use for sustaining ecosystem services in the downstream areas. Also, authority (ULB or PHED) should provide tanker water service to the urban residents to break the growing monopoly of private water vendors. Private water vendors may be brought under registration mechanism by the authority, to keep track of their public services rendered.

5.2.5.9 Enhancing urban habitats for biodiversity

In recent time, renaturing effort in the human-dominated environments through ecological engineering is carried out effectively to ensure re-connection of urban populations with nature. In this context, it is essential to understand how plants and animals interact with the urban environment (Rumble et al., 2019). Urban areas can pose a unique and hostile environment for many species, with extremes of climate and high levels of disturbance. Those species who can thrive, exploiting new niches, escaping predation and sometimes forming relationships with humans also are known as "synurbic species". On the other hand, urban green infrastructure can be tailored to suit the species in that associated environment by adopting suitable "ecomimicry" approach (Rumble et al., 2019). This bears hope to maintain urban biodiversity creating a symbiotic relationship with the surrounding biodiversity.

5.2.6 Significance of the findings

This study tried to understand the ground reality of the water scarcity and associated problems in the Mokokchung town. The study findings are stated below.

1. The water scarcity is seasonal in the town, that starts from post-monsoon and lasts till pre-monsoon.

2. Decreasing yield at PHED water sources from the headwater region is an important concern for the sustainability of the water supply system.

3. Urban footprint on water resource was established which may impact the stream ecosystem of those areas.

4. Urban footprint on forest resource was established, that may have an impact on water resource also.

5. Waste disposal from the town is not eco-friendly which pollutes stream water by dumping solid and liquid waste. Municipal dumping yards are not properly managed, thus, ULB has to negotiate with the surrounding village councils after every few years for another new dumping yeard.

5.2.7 Contributions of the study

This study contributes to improving the life of mountainous urban populations situated in the fragile Indo-Burma biodiversity hotspot. The study contributes knowledge about urban functioning through water, forest and waste disposal, which was established as unsustainable practice.

In the light of the urban ecosystem, the study considered this urban area as an organism which consumes resources (water and forest) and excretes waste (from domestic and municipal) under urban metabolic processes. Prospecting a sustainable urban future, few recommendations were suggested in subsection 5.2.5 for concerned authority by minimising the urban footprint on the surrounding fragile ecosystem. Further planning should be made to sustain a robust and resilient water supply system to the town and also to minimize dependency on fuelwood. Gravity delivered water sources of future water resources for the Mokokchung town may be explored in the northern aspect of the southern mountain ranges from the town.

Therefore, this urban ecological study holds an urgent need to investigate the health of an urban ecosystem that is very important to study in this mountainous eco-sensitive region and suggest for its prospects. Though Mokokchung town is yet to develop as a city, as an urban area it also deserves to behave like an organism where its functionality is dependent upon the external sources of resources. This type of urban study is expected to be helpful for the sustainable future of this town and also similar areas of the region.

5.2.8 Limitations of the study

This study is confined only to the municipal area of Mokokchung town. Due to physical, financial and time limitations, it could not be done maintaining equal sample density in the town. However, the sample size taken was statistically significant as stated in subsection 1.6.1.3.

5.2.9 Scope for further research

The study observes that there is a vast gap of knowledge in ecosystem functioning and the trade-off between ecosystem services which needs further research in this eco-sensitive fragile mountain environment. In this study area urbanisation phenomenon is only a few decades old. So, multidisciplinary research is needed to sustain the urban ecosystem within the fragile mountain ecosystem, not only for the interest of mere urban dwellers but for the holistic benefit of mankind.

REFERENCES

REFERENCES

Alberti, M. (2008). *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems*. Springer.

Amenla, T., Sharma, Y. K., & Sharma, S. K. (2010). Characterization of soils of Nagaland with reference to Mokokchung district. *Environment and Ecology*, *28*(1), 198–201.

Ariza, C., Maselli, D., & Kohler, T. (2013). *Mountains: Our Life, Our Future. Progress and Perspectives on Sustainable Mountain Development from Rio 1992 to Rio 2012 and Beyond*. Centre for Development and Environment (CDE).

Askins, R. A. (Ed.). (2008). *Saving biological diversity: Balancing protection of endangered species and ecosystems*. Springer.

Australian Govt. (2009). *Ecosystem Services: Key Concepts and Applications*. Dept. of the Environment, Water, Heritage and the Arts.

Baldwin, R. F., & Beazley, K. F. (2019). Emerging Paradigms for Biodiversity and Protected Areas. *Land*, *8*(3), 43. https://doi.org/10.3390/land8030043

Bao, C., & Fang, C. (2007). Water Resources Constraint Force on Urbanization in Water Deficient Regions: A Case Study of the Hexi Corridor, Arid Area of Nw China. *Ecological Economics*, *62*(3–4), 508–517.

Biodiversity Hotspots definition | Biodiversity A-Z. (n.d.). Retrieved September 25, 2018, from http://www.biodiversitya-z.org/content/biodiversity-hotspots

Biodiversity Hotspots in India. (n.d.). Retrieved August 10, 2018, from http://bsienvis.nic.in/files/Biodiversity%20Hotspots%20in%20India.pdf

BIS. (1993). *Code of Basic Requirements for Water Supply, Drainage and Sanitation*. BIS, Manak Bhavan, New Delhi 110002.

Borchert, R. (1994). Water status and development of tropical trees during seasonal drought. *Trees*, *8*(3), 115–125.

Botkin, D. B. (1990). *Discordant Harmonies: A New Ecology for the Twenty-First Century*.

Burek, P., Satoh, Y., Fischer, G., Kahil, M. T., Scherzer, A., Tramberend, S., Nava, L. F., Wada, Y., Eisner, S., & Flörke, M. (2016). *Water Futures and Solution-Fast Track Initiative*.

Bustamante, R., Butterworth, J., Hillion, B., Reynaga, M., & Zurita, G. (2004). *Multiple Sources for Multiple Uses: Household Case Studies of Water Use Around Cochabamba, Bolivia*. 11.

Catalan, J., Ninot, J. M., & Aniz, M. M. (Eds.). (2017). *High Mountain Conservation in a Changing World* (Vol. 62). Springer International Publishing. https://doi.org/10.1007/978-3-319-55982-7

Census of India. (2011). *District Census Handbook: Mokokchung: Village and Town Directory*. Directorate of Census Operations, Nagaland. http://www.censusindia.gov.in

CEPF. (2005). *Ecosystem Profile: Eastern Himalayas Region* (p. 100). The Critical Ecosystem Partnership Fund (CEPF).

CGWB. (2013). *Ground Water Information Booklet Mokokchung District, Nagaland*. Central Ground Water Board North Eastern Region Ministry of Water Resources. http://cgwb.gov.in/District_Profile/Nagaland/Mokok.pdf

CGWB. (2019). *National Compilation on Dynamic Ground Water Resources of India, 2017* (p. 306). Central Ground Water Board, GOI.

Chatterjee, S., Saikia, A., Dutta, P., Ghosh, D., Pangging, G., & Goswami, A. K. (2006). *Biodiversity Significance of North East India*. WWF-India, 172 B Lodi Estate. https://www.researchgate.net/publication/272362960

Crausbay, S. D., Ramirez, A. R., Carter, S. L., Cross, M. S., Hall, K. R., Bathke, D. J., Betancourt, J. L., Colt, S., Cravens, A. E., & Dalton, M. S. (2017). Defining Ecological Drought for the Twenty-First Century. *Bulletin of the American Meteorological Society*, *98*(12), 2543–2550.

DeFries, R. S., Foley, J. A., & Asner, G. P. (2004). Land-Use Choices: Balancing Human Needs and Ecosystem Function. *Frontiers in Ecology and the Environment*, *2*(5), 249–257.

Dickens, C., Rebelo, L.-M., & Luxon, N. (2017). *Guideline and indicators for Target 6.6 of the SDGs: Change in the extent of waterrelated ecosystems over time*. International Water Management Institute (IWMI).

Dooling, S., Graybill, J., & Greve, A. (2007). Response to Young and Wolf: Goal attainment in urban ecology research. *Urban Ecosystems*, *10*(3), 339–347.

Dow, C., & Dewalle, D. (2000). Trends in evaporation and Bowen Ratio on urbanizing watersheds in eastern United States. *Water Resour. Res.*, *36*, 1835.

EC. (2007). *Addressing the Challenge of Water Scarcity and Droughts in the European Union, Com (2007) 414 Final*. European Commission Brussels.

Egan, P. A., & Price, M. F. (Eds.). (2017). *Mountain Ecosystem Services and Climate Change: A Global Overview of Potential Threats and Strategies for Adaptation; 2017*. UNESCO.

Egerton, F. N. (1993). The History and Present Entanglements of Some General Ecological Perspectives. In *Humans as Components of Ecosystems* (pp. 9–23). Springer.

Elliott, M., Foster, T., MacDonald, M. C., Harris, A. R., Schwab, K. J., & Hadwen, W. L. (2019). Addressing How Multiple Household Water Sources and Uses Build Water Resilience and Support Sustainable Development. *Npj Clean Water*, *2*(1), 6. https://doi.org/10.1038/s41545-019-0031-4

Elliott, M., MacDonald, M. C., Chan, T., Kearton, A., Shields, K. F., Bartram, J. K., & Hadwen, W. L. (2017). Multiple Household Water Sources and Their Use in Remote Communities With Evidence From Pacific Island Countries. *Water Resources Research*, *53*(11), 9106–9117. https://doi.org/10.1002/2017WR021047

Eslamian, S. (2014). *Handbook of Engineering Hydrology: Environmental Hydrology and Water Management*. CRC press.

Eslamian, S., & Eslamian, F. A. (2017). *Handbook of Drought and Water Scarcity: Principles of Drought and Water Scarcity*. CRC Press.

Falkenmark, M. (2003). Freshwater as Shared Between Society and Ecosystems: From Divided Approaches to Integrated Challenges. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *358*(1440), 2037–2049.

FAO. (2011). *Climate Change, Water and Food Security*. Food and Agriculture Organization of the United Nations.

Feinstein, D. (2012). Since "Groundwater and Surface Water–A Single Resource": Some US Geological Survey advances in modeling groundwater/ surface-water interactions. *Acque Sotterranee-Italian Journal of Groundwater*, *1*(1).

Fiedler, P. L., White, P. S., & Leidy, R. A. (1997). The Paradigm Shift in Ecology and Its Implications for Conservation. In S. T. A. Pickett, R. S. Ostfeld, M. Shachak, & G. E. Likens (Eds.), *The Ecological Basis of Conservation: Heterogeneity, Ecosystems, and Biodiversity* (pp. 83–92). Springer US. https://doi.org/10.1007/978-1-4615-6003-6_9

Foster, T., & Willetts, J. (2018). Multiple Water Source Use in Rural Vanuatu: Are Households Choosing the Safest Option for Drinking? *International Journal of Environmental Health Research*, *28*(6), 579–589. https://doi.org/10.1080/09603123.2018.1491953

FSI. (2017). Carbon Stock in India's Forests. In *India State Forest Report*. Forest Survey of India, Dehradun. http://fsi.nic.in/isfr2017/isfr-carbon-stock-in-india-forest-2017.pdf

FSI. (2019). *India State of Forest Report 2019 (Vol-2)* (Volume-II). MOEFCC, Government of India.

Fukuda, S., Noda, K., & Oki, T. (2019). How Global Targets on Drinking Water Were Developed and Achieved. *Nature Sustainability*, *2*(5), 429–434. https://doi.org/10.1038/s41893-019-0269-3

Gain, A. K., Giupponi, C., & Wada, Y. (2016). Measuring Global Water Security Towards Sustainable Development Goals. *Environmental Research Letters*, *11*(12), 124015. https://doi.org/10.1088/1748-9326/11/12/124015

Ganguli, M. (2013). *Urban Water Management and the Question of Sustainability in Chandernagore and Hooghly-Chinsurah Cities, West Bengal* [University of Burdwan]. http://shodhganga.inflibnet.ac.in:8080/jspui/handle/10603/121468

Gentry, A. H. (1988). Changes in Plant Community Diversity and Floristic Composition on Environmental and Geographical Gradients. *Annals of the Missouri Botanical Garden*, 1–34.

George, J., & Yhome, K. (2008). *Community Forest Management: A Case Study of Nagaland,India*. 13. http://dlc.dlib.indiana.edu/dlc/handle/10535/2185

Glasby, T. M., & Underwood, A. J. (1996). Sampling to differentiate between pulse and press perturbations. *Environmental Monitoring and Assessment*, *42*(3), 241–252. https://doi.org/10.1007/BF00414371

Gleeson, E., & Greenwood, G. B. (2015). Big Data are all the rage—For mountains, too. *Mountain Research and Development*, *35*(1), 87–90.

Gleick, P. H. (1996). Basic Water Requirements for Human Activities: Meeting Basic Needs. *Water International*, *21*(2), 83–92.

Grandjean, A. C. (2005). Water Requirements, Impinging Factors, and Recommended Intakes. *Nutrients in Drinking Water*, 25.

Grigg, N. S. (1996). *Water resources management: Principles, regulations, and cases*. McGraw-Hill New York.

GSI. (2011). *Geology and Mineral Resources of Manipur, Mizoram, Nagaland and Tripura* (Miscelleaneous Publication No. 30 Part IV, Vol 1(Part-2)). Geological Survey of India.

Haigh, M. J. (2004). Sustainable Management of Headwater Resources: The Nairobi "headwater" declaration (2002) and Beyond. *Asian Journal of Water, Environment and Pollution*, *1*(1, 2), 17–28.

Hall, M. H. P., & Balogh, S. B. (2019). *Understanding Urban Ecology: An Interdisciplinary Systems Approach*. Springer.

Hall, R. P., Ranganathan, S., & G. C., R. K. (2017). A General Micro-Level Modeling Approach to Analyzing Interconnected SDGs: Achieving SDG 6 and More through Multiple-Use Water Services (MUS). *Sustainability*, *9*(2), 314. https://doi.org/10.3390/su9020314

Haravi, B. K. (2010). *Evolution of Urban Ecology of Panaji City -A Geographical Perspective* [Karnatak University]. http://shodhganga.inflibnet.ac.in:8080/jspui/handle/10603/107951

Hoekstra, A. Y., & Chapagain, A. K. (2011). *Globalization of Water: Sharing the Planet's Freshwater Resources*. John Wiley & Sons.

Hoekstra, A. Y., Mekonnen, M. M., Chapagain, A. K., Mathews, R. E., & Richter, B. D. (2012). Global Monthly Water Scarcity: Blue Water Footprints versus Blue Water Availability. *PLoS ONE*, *7*(2), e32688. https://doi.org/10.1371/journal.pone.0032688

Hough, M. (2004). *Cities and Natural Process* (Second). Routledge.

Howard, G., & Bartram, J. (2003). *Domestic Water Quantity, Service Level and Health*. World Health Organization.

Howard, G., Charles, K., Pond, K., Brookshaw, A., Hossain, R., & Bartram, J. (2010). Securing 2020 Vision for 2030: Climate Change and Ensuring Resilience in Water and Sanitation Services. *Journal of Water and Climate Change*, *1*(1), 2–16.

Humphries, P., & Baldwin, D. S. (2003). Drought and Aquatic Ecosystems: An Introduction. *Freshwater Biology*, *48*(7), 1141–1146. https://doi.org/10.1046/j.1365-2427.2003.01092.x

IELO. (2016). *Nagaland State Water Policy-2016*. Department of Soil and Water Conservation, Government of Nagaland. http://phed.nagaland.gov.in/assets/nagaland-state-water-policy-2016.pdf

ILO. (2016). *Wash@work: A Self-Training Handbook*. International Labour Office.

Janz, N., Nylin, S., & Wahlberg, N. (2006). Diversity begets diversity: Host expansions and the diversification of plant-feeding insects. *BMC Evolutionary Biology*, *6*(1), 4.

JMP. (2000). *Global Water Supply and Sanitation Assessment 2000 Report*. WHO; UNICEF.

JMP. (2017). *Safely Managed Drinking Water: Thematic Report on Drinking Water*. World Health Organization, Geneva, Switzerland.

JMP. (2019a). *Progress on Household Drinking Water, Sanitation and Hygiene I 2000-2017: Special Focus on Inequalities*. WHO/UNICEF. https://washdata.org/sites/default/files/documents/reports/2019-07/jmp-2019-wash-households.pdf

JMP. (2019b). *WASH in Health Care Facilities: Global Baseline Report 2019*. WHO and UNICEF, Geneva, 2019.

Kapos, V., Rhind, J., Edwards, M., Price, M. F., & Ravilious, C. (2000). Developing a map of the world's mountain forests. *Forests in Sustainable Mountain Development: A State of Knowledge Report for 2000. Task Force on Forests in Sustainable Mountain Development.*, 4–19.

Keppel, G., Niel, K. P. V., Wardell-Johnson, G. W., Yates, C. J., Byrne, M., Mucina, L., Schut, A. G. T., Hopper, S. D., & Franklin, S. E. (2012). Refugia: Identifying and Understanding Safe Havens for Biodiversity Under Climate Change. *Global Ecology and Biogeography*, *21*(4), 393–404. https://doi.org/10.1111/j.1466-8238.2011.00686.x

Koppen, B. V., & Smits, S. (2010). Multiple-Use Water Services: Climbing the Water Ladder. *Waterlines*, *29*(1), 5–20. JSTOR.

Koppen, B. V., Smits, S., Moriarty, P., Vries, F. P. de, Mikhail, M., & Boelee, E. (2009). *Climbing the Water Ladder: Multiple-Use Water Services for Poverty Reduction*. IRC International Water and Sanitation Centre; International Water Management Institute.

Korner, C. (2000). Why Are There Global Gradients in Species Richness? Mountains Might Hold the Answer. *Trends Ecol Evol*, *15*, 513–514.

Körner, C. (2003). *Alpine plant life: Functional plant ecology of high mountain ecosystems; with 47 tables*. Springer Science & Business Media.

Křeček, J., & Haigh, M. (2019). Land Use Policy in Headwater Catchments. *Land Use Policy*, *80*, 410–414. https://doi.org/10.1016/j.landusepol.2018.03.043

Kusre, B. C., & Singh, K. S. (2012). Study of Spatial and Temporal Distribution of Rainfall in Nagaland (india). *International Journal of Geomatics and Geosciences*, *2*(3), 712.

Lake, P. S. (2000). Disturbance, patchiness, and diversity in streams. *Journal of the North American Benthological Society*, *19*(4), 573–592. https://doi.org/10.2307/1468118

Lake, P. S. (2003). Ecological Effects of Perturbation by Drought in Flowing Waters. *Freshwater Biology*, *48*(7), 1161–1172. https://doi.org/10.1046/j.1365-2427.2003.01086.x

Liniger, H., Weingartner, R., & Grosjean, M. (1998). Mountains of the World: Water Towers for the 21st Century. *Berne (Switzerland): Paul Haupt*.

Longkumer, L., Luirei, K., Moiya, J. N., & Thong, G. T. (2019). Morphotectonics and Neotectonic Activity of the Schuppen Belt of Mokokchung, Nagaland, India. *Journal of Asian Earth Sciences*, *170*, 138–154. https://doi.org/10.1016/j.jseaes.2018.11.010

Magoulick, D. D., & Kobza, R. M. (2003). The role of refugia for fishes during drought: A review and synthesis. *Freshwater Biology*, *48*(7), 1186–1198. https://doi.org/10.1046/j.1365-2427.2003.01089.x

Marzluff, J., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., ZumBrunnen, C., & Simon, U. (2008). *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*. Springer US.

Matthews, W. J. (2012). *Patterns in freshwater fish ecology*. Springer Science & Business Media.

McDonnell, M. J., Hahs, A. K., & Breuste, J. H. (2009). *Ecology of Cities and Towns: A Comparative Approach*. Cambridge University Press.

McDonnell, M. J., & Pickett, S. T. A. (Eds.). (1997). *Humans as Components of Ecosystems: The Ecology of Subtle Human Effects and Populated Areas*. Springer.

MEA. (2003). *Ecosystems and Human Well-Being: A Framework for Assessment*. Island Press.

MEA. (2005a). *Ecosystems and Human Well-Being: Synthesis*. Island Press.

MEA. (2005b). *MA Conceptual Framework*. Island Press.

MEA. (2005c). Mountain Systems. In *Ecosystems and Human Well-being: Current State and Trends* (Vol. 1). Island Press. https://www.millenniumassessment.org/documents/document.293.aspx.pdf

MEA-WHO. (2005). *Ecosystems and Human Well-Being: Health Synthesis*. World Health Organization.

Messerli, B. (2006). Mountains of the World: Water Towers for the 21st Century. In *Managing Water Resources in a Time of Global Change: Mountains, Valleys and Flood Plains* (pp. 27–47). Routledge.

Messerli, B., Viviroli, D., & Weingartner, R. (2004). Mountains of the World: Vulnerable Water Towers for the 21st Century. *AMBIO Special Report*, *13*, 29–34. https://doi.org/10.5167/uzh-110516

Meybeck, M., Green, P., & Vörösmarty, C. (2001). A New Typology for Mountains and Other Relief Classes. *Mountain Research and Development*, *21*(1), 34–46.

Mountain Ecosystems | IUCN. (n.d.). Retrieved June 22, 2019, from https://www.iucn.org/commissions/commission-ecosystem-management/our-work/cems-specialist-groups/mountain-ecosystems

MoWR. (2012). *National Water Policy, 2012*. Ministry of Water Resources, GOI.

NFP. (1988). *National Forest Policy*. Ministry of Environment and Forests, GOI. http://envfor.nic.in/sites/default/files/introduction-nfp.pdf

Niemelä, J., Breuste, J. H., Guntenspergen, G., McIntyre, N. E., Elmqvist, T., & James, P. (2011). *Urban Ecology: Patterns, Processes, and Applications*. OUP Oxford.

Norman, E. S., Bakker, K., & Dunn, G. (2011). Recent developments in Canadian water policy: An emerging water security paradigm. *Canadian Water Resources Journal*, *36*(1), 53–66.

Norton, B. G. (2014). *Why Preserve Natural Variety?* Princeton University Press.

NSO. (2018). *Drinking Water, Sanitation, Hygiene and Housing Condition in India* (NSS Report 76 Round No. 584; p. 284). NSO, Ministry of Statistics & Programme Implementation, GOI.

Odum, E. P. (1963). *Ecology*. Holt, Rinehart and Winston.

Odum, E. P. (1968). Energy Flow in Ecosystems: A Historical Review. *American Zoologist*, *8*(1), 11–18.

Odum, E. P. (1975). *Ecology, the link between the natural and the social sciences*. Oxford and IBH Publishing.

Odum, H. T. (1971). *Environment, Power, and Society*. John Wiley & Sons, Inc.

Odum, H. T. (2007). *Environment, Power, and Society for the Twenty-First Century: The Hierarchy of Energy*. Columbia University Press.

OECD. (2012). *OECD Environmental Outlook to 2050: The Consequences of Inaction*. OECD Publishing. https://doi.org/10.1787/9789264122246-en

Oki, T., Yano, S., & Hanasaki, N. (2017). Economic aspects of virtual water trade. *Environmental Research Letters*, *12*(4), 044002.

Okun, D. A., & Ernst, W. R. (1987). *Community Piped Water Supply Systems in Developing Countries: A Planning Manual*. The World Bank.

Olsson, L., & Head, B. W. (2015). Urban Water Governance in Times of Multiple Stressors: An Editorial. *Ecology and Society*, *20*(1), art27. https://doi.org/10.5751/ES-07300-200127

Pant, M. (2017). *Nagaland State Human Development Report 2016* (No. 2). Department of Planning and Coordination, Government of Nagaland.

Park, R. E., & Burgess, E. W. (1984). *The City: Suggestions for Investigation of Human Behavior in the Urban Environment (Heritage of Sociology Series)*. University of Chicago Press.

Peterson, A. T., Flores-Villela, O. A., León-Paniagua, L. S., Llorente-Bousquets, J. E., Luis-Martinez, M. A., Navarro-Siguenza, A. G., Torres-Chávez, M. G., & Vargas-Fernández, I. (1993). Conservation priorities in Mexico: Moving up in the world. *Biodiversity Letters*, 33–38.

Phom, Y. N. (2019). *Longleng's YCBCA undertakes biodiversity project*. http://www.nagalandpost.com/longleng-s-ycbca-undertakes-biodiversity-project/207391.html

Pickett, S. T. A., Cadenasso, M., Grove, M., Nilon, C., Pouyat, R., Zipperer, W., & Costanza, R. (2001). Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas. *Annual Review of Ecology and Systematics*, *32*. https://doi.org/10.1146/annurev.ecolsys.32.081501.114012

Pickett, S. T. A., Parker, V. T., & Fiedler, P. L. (1992). The New Paradigm in Ecology: Implications for Conservation Biology Above the Species Level. In *Conservation*

Biology: The Theory and Practice of Nature Conservation Preservation and Management (pp. 65–88). Springer US.

Pradhan, P. K. (2004). Population Growth, Migration and Urbanisation. Environmental Consequences in Kathmandu Valley, Nepal. In *Environmental Change and Its Implications for Population Migration* (pp. 177–199). Springer.

Rautanen, S.-L., van Koppen, B., & Wagle, N. (2014). *Community-Driven Multiple Use Water Services: Lessons Learned by the Rural Village Water Resources Management Project in Nepal*. *7*(1), 18.

Rawat, M. S. (2017). Environmental Management in the Headwater Catchments of Kiliki River, Nagaland, North East India. In *Ecosystem Services of Headwater Catchments* (pp. 105–115). Springer.

Ray, B., & Shaw, R. (2019a). Defining Urban Water Insecurity: Concepts and Relevance. In *Urban Drought: Emerging Water Challenges in Asia* (pp. 1–15). Springer.

Ray, B., & Shaw, R. (Eds.). (2019b). *Urban Drought: Emerging Water Challenges in Asia*. Springer Singapore. https://doi.org/10.1007/978-981-10-8947-3

Richardson, J. S. (2019). Biological Diversity in Headwater Streams. *Water*, *11*(2), 366.

Rockström, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S., & Gerten, D. (2009). Future Water Availability for Global Food Production: The Potential of Green Water for Increasing Resilience to Global Change: Water Availability for Food Production. *Water Resources Research*, *45*(7). https://doi.org/10.1029/2007WR006767

Romeo, R., Vita, A., Testolin, R., & Hofer, T. (Eds.). (2015). Mapping the Vulnerability of Mountain Peoples to Food Insecurity. *FAO*, 82.

Rumble, H., Angeoletto, F., Connop, S., Goddard, M. A., & Nash, C. (2019). Understanding and Applying Ecological Principles in Cities. In F. Lemes de Oliveira & I. Mell (Eds.), *Planning Cities with Nature* (pp. 217–234). Springer International Publishing. https://doi.org/10.1007/978-3-030-01866-5_15

Sample Size Calculator. (n.d.). http://www.surveysystem.com/sscalc.htm#one

Sarma, J., Imti, T. T., & Yaden, S. (2019). Domestic Firewood Consumption Pattern and Degradation of Forest Cover: A Case Study of Mokokchung Town, Nagaland. *International Journal of Science and Research (IJSR)*, *8*(9), 7. https://doi.org/10.21275/ART20201096

Sharma, E., Bhuchar, S., Xing, M., & Kothyari, B. P. (2007). Land Use Change and Its Impact on Hydro-Ecological Linkages in Himalayan Watersheds. *Tropical Ecology*, *48*(2), 151–161.

SHBN. (2014). *Statistical Handbook of Nagaland, 2014*. Directorate of Economics and Statistics. http://statistics.nagaland.gov.in

Shiklomanov, I. (1993). World Fresh Water Resources. In P. H. Gleick (Ed.), *Water in Crisis: A Guide to the World's Fresh Water Resources*. Oxford University Press.

Singh, R. B., & Kumar, D. (2014). Water Scarcity. In *Handbook of Engineering Hydrology* (pp. 535–560). CRC Press.

Singh, S. P., & Thadani, R. (2015). Complexities and Controversies in Himalayan Research: A Call for Collaboration and Rigor for Better Data. *Mountain Research and Development*, *35*(4), 401–410.

Sphere Association. (2018). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response* (Fourth). The Sphere Project. https://doi.org/10.3362/9781908176202

Stanley, E. H., Fisher, S. G., & Grimm, N. B. (1997). Ecosystem expansion and contraction in streams. *BioScience*, *47*(7), 427–435.

Sukopp, H. (1998). Urban Ecology—Scientific and Practical Aspects. In J. Breuste, H. Feldmann, & O. Uhlmann (Eds.), *Urban Ecology* (pp. 3–16). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-88583-9_1

Tiwari, P. C., & Joshi, B. (2012). Environmental Changes and Sustainable Development of Water Resources in the Himalayan Headwaters of India. *Water Resources Management*, *26*(4), 883–907.

UN DESA. (2018). *World Urbanization Prospects: The 2018 Revision [Key Facts]*. United Nations.

UN DESA. (2019). *World Population Prospects 2019: Highlights*. https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf

UN Water. (2018). *Sustainable Development Goal 6: Synthesis Report 2018 on Water and Sanitation*. United Nations.

UNCED. (1992). *United Nations Conference on Environment & Development 1992: Agenda 21*. United Nations. https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf

UNEP-WCMC. (2002). *Mountain Watch*. http://archive.org/details/mountainwatchenv02blyt

UNESCO, & WWAP (Eds.). (2015). *The United Nations World Water Development Report 2015: Water for a Sustainable World*. UNESCO.

UNESCO, & WWAP. (2018). *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000261424

UNESCO, & WWAP. (2019). *The United Nations World Water Development Report 2019: Leaving No One Behind*. UNESCO.

United Nations. (2015a). *The World's Women 2015: Trends and Statistics*. United Nations, Department of Economic and Social Affairs, Statistics Division.

United Nations. (2015b). *Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations. https://doi.org/10.1891/9780826190123.ap02

Nagaland Building Bye-Laws, (2012). http://kmc.nagaland.gov.in/files/Building%20Bye-Laws.pdf

Van Loon, A. F., & Van Lanen, H. A. J. (2013). Making the Distinction Between Water Scarcity and Drought Using an Observation-Modeling Framework: Distinguishing Between Water Scarcity and Drought. *Water Resources Research*, *49*(3), 1483–1502. https://doi.org/10.1002/wrcr.20147

Viviroli, D., Messerli, B., Schädler, B., & Weingartner, R. (2009). *Water Towers in a Changing World*.

Whittaker, R. H. (1960). Vegetation of the Siskiyou mountains, Oregon and California. *Ecological Monographs*, *30*(3), 279–338.

WHO. (2011). *Guidelines for Drinking-Water Quality* (Fourth). World Health Organization.

Wilhite, D. A., & Glantz, M. H. (1985). Understanding: The Drought Phenomenon: The Role of Definitions. *Water International*, *10*(3), 111–120. https://doi.org/10.1080/02508068508686328

World Health Assembly, 12. (1959). *Twelfth World Health Assembly, Geneva, 12-19 May 1959: Resolutions and decisions: plenary meetings: verbatim records: committees: minutes and reports: annexes*. World Health Organization. https://apps.who.int/iris/handle/10665/85719

Yoshino, M. M., & Yoshino, M. (1975). *Climate in a small area: An introduction to local meteorology*. University of Tokyo press.

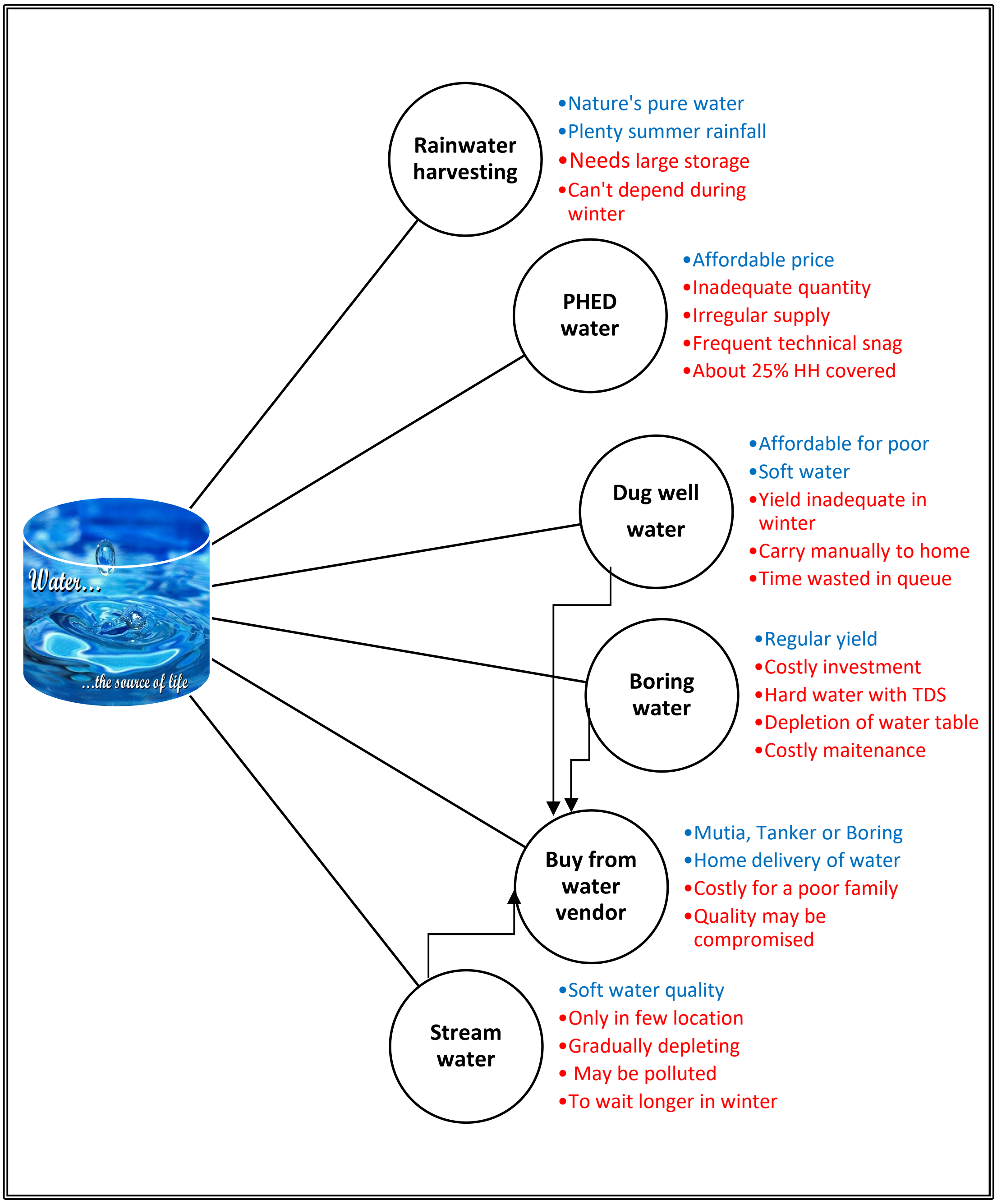
Young, R. F., & Wolf, S. A. (2006). Goal attainment in urban ecology research: A bibliometric review 1975–2004. *Urban Ecosystems*, *9*(3), 179–193.

Yu, H., Song, Y., Chang, X., Gao, H., & Peng, J. (2018). A Scheme for a Sustainable Urban Water Environmental System During the Urbanization Process in China. *Engineering*, *4*(2), 190–193. https://doi.org/10.1016/j.eng.2018.03.009

APPENDIX

APPENDIX: A

Fig 49: *Multiple water sources used by the households with pros and cons*



(Conceptualized by author)

Table 12:*Water reserves on the earth*

Water source	Percentage of global reserves	
	Per cent of total water	**Per cent of freshwater**
1. Oceans, Seas, & Bays	*96.5*	*0*
2. Groundwater	*1.7*	*30.15*
a) Fresh	0.76	30.1
b) Soil Moisture	0.001	0.05
3. Icecaps, Glaciers, & Permanent Snow	*1.74*	*68.74*
a) Antarctic	1.56	61.7
b) Greenland	0.17	6.68
c) Arctic Islands	0.006	0.24
d) Mountainous regions	0.003	0.12
4. Ground Ice & Permafrost	*0.022*	*0.86*
5. Lakes	*0.013*	*0.26*
a) Fresh	0.007	0.26
b) Saline	0.006	0
6. Swamp Water	*0.0008*	*0.03*
7. Rivers	*0.0002*	*0.006*
8. Biological Water	*0.0001*	*0.003*
9. Atmosphere	*0.001*	*0.04*
Total water reserves	**100**	**0**
Total freshwater reserves	**2.53**	**100**

(Source: Shiklomanov, 1993)

Table 13: *Water scarcity, water stress and water shortage*

Water scarcity, water stress and water shortage
1. *Water scarcity* is the general collective term when water is scarce for whatever reason. 2. *Water stress* is linked to difficulties in water use due to accessibility or mobilization problems (water infrastructures, flow control, costs). It is often expressed in terms of use-to-availably ratio, where values larger than 40% denote high water stress. 3. *Water shortage* refers to population-driven physical shortage of water when seen in relation to principal water requirements: • *Green water shortage,* relating to deficiency in relation to crop water requirements. • *Blue water shortage,* when the number of people competing for a limited resource quantity, i.e water crowding is “high” (empirically found to be >600 cap Mm-3a-1), or inverted, per capita availability is “low” to meet principal water requirements (< 1,700 m3cap-1a-1). Beyond 1.000 cap Mm-3a-1 there is *chronic* blue water shortage (or inverted. 1,000 m3cap-1a-1)

(Source: Rockström et al., 2009)

Table 14: *Change of urban area due to revised computation*

Sl. No.	District	Name of town	Area (sq. km)	
			2011	2001
1.	Dimapur	Chumukedima T.C.	28.00	10.02
2.	Dimapur	Dimapur M.C.	18.30	25.54
3.	Kohima	Kohima M.C.	15.00	23.00
4.	**Mokokchung**	**Mokokchung M.C.**	**4.50**	**32.00**
5.	Mon	Mon T.C.	6.50	9.00
6.	Phek	Phek T.C.	4.85	3.60
7.	Tuensang	Tuensang T.C.	19.50	31.98
8.	Wokha	Wokha T.C.	17.00	5.92
9.	Zunheboto	Zunheboto T.C.	16.00	6.00

(Source: Census of India, 2011)

Table 15: *Comparing water demand estimation for Mokokchung town according to WHO and BIS*

Water requirement litres per capita per day (lpcd)	WHO			BIS		
	Basic survival (lpcd)	Reasonable access (lpcd)	Urban range (lpcd)	Basic (lpcd)	Urban range (lpcd)	Urban poor (lpcd)
Individual requirement	7.5	20	50 to 100	70	100 to 150	135
Town water demand (in lakhs)	2.69	7.18	17.96 to 35.91	25.14	35.91 to 53.87	48.48
Note: Values of World Health Organisation (WHO) is less than Bureau of Indian Standard (BIS), 1993						

(Compiled by author)

Table 16: *WHO approaches for water accessibility 1959-2015*

Round	Year	Problems addressed	Remarks
I	1959 – 1970: First decade	Recognising safe and adequate supplies of water to inhabitants of communities.	Fund raising to create infrastructure
II	1971–1980: Second Development Decade 1981–1990: IDWSSD	*Reasonable access* • A house located <200 m from a public fountain or standpost (urban). The housewife or members of the household do not have to spend a disproportionate part of the day fetching the family's water needs (rural). *Safe water supply* • Treated surface water or untreated but uncontaminated water such as that from protected boreholes, springs and sanitary wells.	*Data collection* • Government engineers answered WHO questionnaires (administrative reports) *Indicators* • Population having some form of water supply through house connections or standpipes *Sampled nations* • Developing countries only
III	1991–2000 Third decade	*Safe drinking water coverage* • Percentage of population with access to an adequate amount of safe drinking water located a convenient distance from the user's dwelling.	*Data collection* • Government engineers answered WHO questionnaires (administrative reports) *Indicators* • Population having 'access' to safe water (definition determined by the respective reporting countries) *Sampled nations* • Developing countries only
IV	2001–2015: MDGs	*Reasonable access* • The availability of at least 20 l water per person per day from a source 1 km from the user's dwelling.	*Data collection* • Results of household surveys or population census *Indicators* • Percentage of population using improved water sources (piped water, public standpipe, protected dug well, rainwater collection, and so on) *Sampled nations* • The entire world (including developed countries)
V	2015 – 2030: SDGs	Achieve universal and equitable access to safe and affordable drinking water for all	Goal 6. Ensure availability and sustainable Management of water and sanitation for all

(Source: Fukuda et al., 2019)

Table 17: *UN-Millennium Development Goals (MDGs)*

Goal 1	To eradicate extreme poverty and hunger
Goal 2	To achieve universal primary education
Goal 3	To promote gender equality and empower women
Goal 4	To reduce child mortality
Goal 5	To improve maternal health
Goal 6	To combat HIV/AIDS, malaria, and other diseases
Goal 7	*To ensure environmental sustainability*
Goal 8	To develop a global partnership for development

Table 18: *Household water use by climate and source*

Climatic Zone	**Public Stand post (litres/capita/day)**	**House Connection without flush toilets or gardens (litres/capita/day)**
Humid	10 to 20	20 to 40
Average	20 to 30	40 to 60
Dry	30 to 40	60 to 80

(Source: Okun & Ernst, 1987, p. 45)

Table 19: *UN-Sustainable Development Goals (SDGs)*

Goal 1	No Poverty
Goal 2	Zero Hunger
Goal 3	Good Health and Well-being
Goal 4	Quality Education
Goal 5	Gender Equality
Goal 6	*Clean Water and Sanitation*
Goal 7	Affordable and Clean Energy
Goal 8	Decent Work and Economic Growth
Goal 9	Industry, Innovation and Infrastructure
Goal 10	Reduced Inequality
Goal 11	Sustainable Cities and Communities
Goal 12	Responsible Consumption and Production
Goal 13	Climate Action
Goal 14	Life Below Water
Goal 15	Life on Land
Goal 16	Peace and Justice Strong Institutions
Goal 17	Partnerships to achieve the Goal

Table 20: *Targets of SDG Goal six relating to clean water and sanitation*

Target	Description
6.1	By 2030, achieve *universal* and *equitable access* to safe and *affordable* drinking water for all.
6.2	By 2030, achieve access to *adequate* and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
6.3	By 2030, improve water quality by reducing *pollution*, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
6.4	By 2030, substantially increase water use *efficiency* across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
6.5	By 2030, implement *integrated* water resources management at all levels, including through transboundary cooperation as appropriate.
6.6	By 2020, protect and restore water related *ecosystems*, including mountains, forests, wetlands, rivers, aquifers and lakes.
6.a	By 2030, expand international cooperation and capacity building support to developing countries in water and sanitation related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
6.b	Support and strengthen the participation of local communities in improving water and sanitation management.

Table 21: *Available drinking water options in the study area*

Improved drinking-water sources		**Source available**
1.	piped water into dwelling, yard or plot	Yes
2.	public tap or standpipe	No
3.	tube-well or borehole	Yes
4.	protected dug well	Yes
5.	protected spring	No
6.	rainwater collection	Yes
Unimproved drinking-water sources		
7.	unprotected dug well	Yes
8.	unprotected spring	Yes
9.	cart with small tank or drum provided by water vendor	Yes
10.	tanker truck provision of water	Yes
11.	surface water (river, lake, pond, stream, irrigation channel)	No
12.	bottled water (unpackaged only)	No

(Based on field observation according to WHO guideline)

Table 22: *SDG global targets and indicators related to WASH program*

SDG global targets	SDG global indicators
6.1 *By 2030, achieve universal and equitable access to safe and affordable drinking water for all*	6.1.1 Proportion of population using safely managed drinking water services
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Proportion of population using a) safely managed sanitation services and b) a handwashing facility with soap and water
1.4 By 2030, ensure all men and women, in particular the poor and vulnerable, have equal rights to economic resources as well as access to basic services	1.4.1 Proportion of population living in households with access to basic services (including access to basic drinking water, basic sanitation and basic handwashing facilities)
4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all	4.a.1 Proportion of schools with access to... (e) basic drinking water, (f) single-sex basic sanitation facilities, and (g) basic handwashing facilities
3.8 Achieve universal health coverage (UHC), including financial risk protection, access to quality essential health care services, and access to safe, effective, quality and affordable essential medicines and vaccines for all	Proportion of health care facilities with basic WASH services

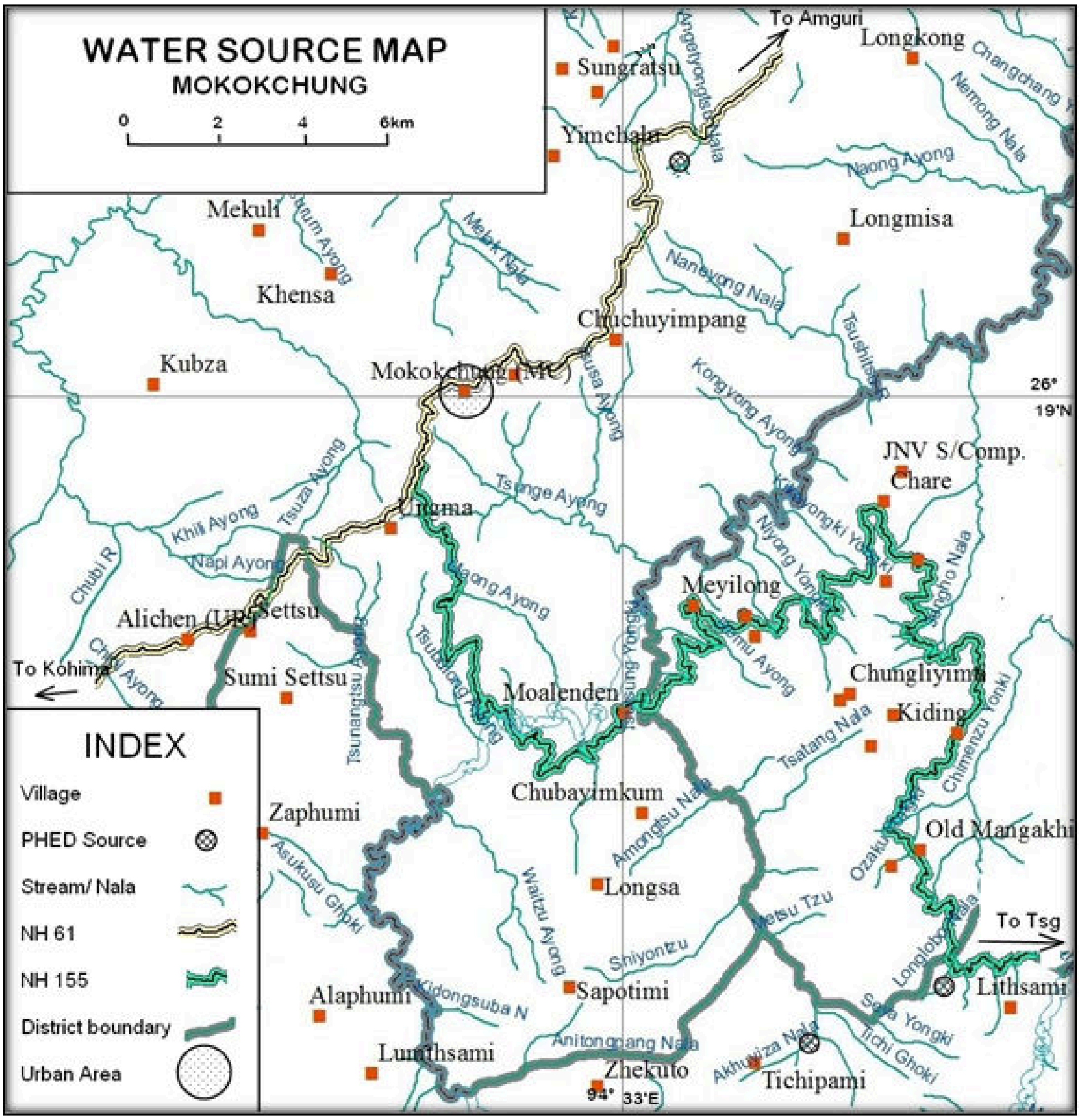
(Source JMP, 2019a, p. 10)

Table 23: *Multiple water sources accessed by the surveyed households*

Dependency (%)	PHED	Tanker	Rain	Dug well	Boring	Stream
10 or below	25	7	4	5	2	0
11 to 20	21	13	11	4	0	0
21 to 30	5	20	21	7	4	1
31 to 40	0	22	27	10	3	1
41 to 50	3	12	43	8	10	0
51 to 60	1	12	19	4	2	0
61 to 70	0	8	14	7	3	0
71 to 80	2	1	0	1	1	1
81 to 90	0	1	1	2	0	0
91 to 100	0	0	0	10	6	1
Total households (HH)	**57**	**96**	**140**	**58**	**31**	**4**
% of Total HH	**34.97**	**58.90**	**85.89**	**35.58**	**19.02**	**2.45**

(Based on interview)

Fig 50: *Location of three stream water sources accessed by PHED, Mokokchung*



Compiled from NGISRSC, Govt. of Nagaland

Table 24: *Estimated fuelwood weight by its volume*

Local nomenclature	Volume*	Weight* (quintal)	Remark
1 *Thak* (standard stack)	3′x3′x6′=54 cft	6	Weight may differ considerably depending on hardness and dryness of the wood
1 Bolero Pickup or 1 Tata DI	2 *Thak*= 108 cft	12	
1 Mini Tata or 407	4 *Thak* = 2 Pickup	24	
1 Tata	8 *Thak* *or* 2 Mini Tata=4 Pickup	48 (40 to 50)	

**Values are approximate (compiled from retail fuelwood sellers' estimate)*

Fig 51: *Model of low-cost soak-pit cum septic tank from piled tyres*

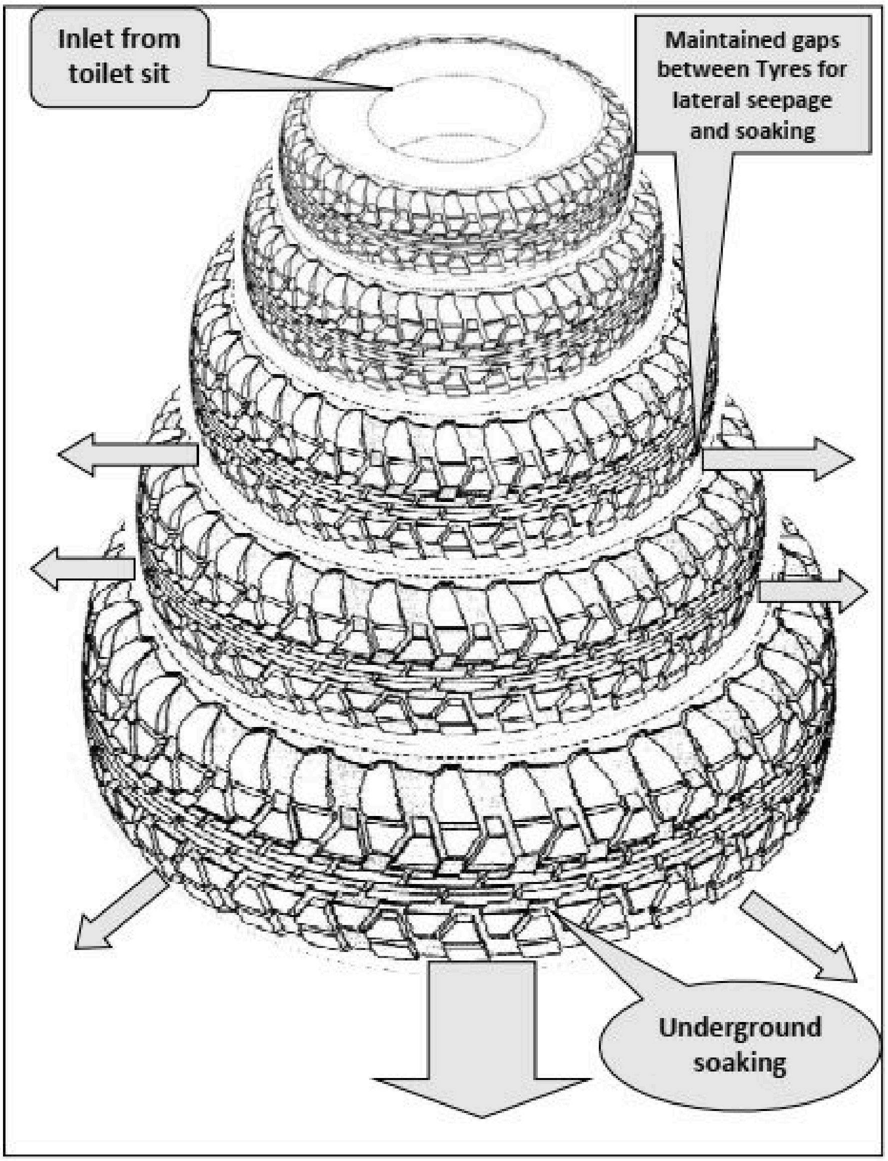


Table 25: *Details of MMC dumping site around Mokokochung town*

Sl. No.	Name of area	Distance* (km.)	Year of abandonment
1.	Kongtuba Tsuk, Ungma village	4	NA
2.	Nokchiyong, Mokokchung village	6	NA
3.	Minkong, Sungratsu village	8	1997
4.	Marepkong ward, Ungma village	5	2008
5.	Tsukjongkong, Ungma village	7	2016
6.	Sabangkaba Menchen, Mokokchung village	13	Ongoing

*Distance are approximate from town

(Source: MMC office)

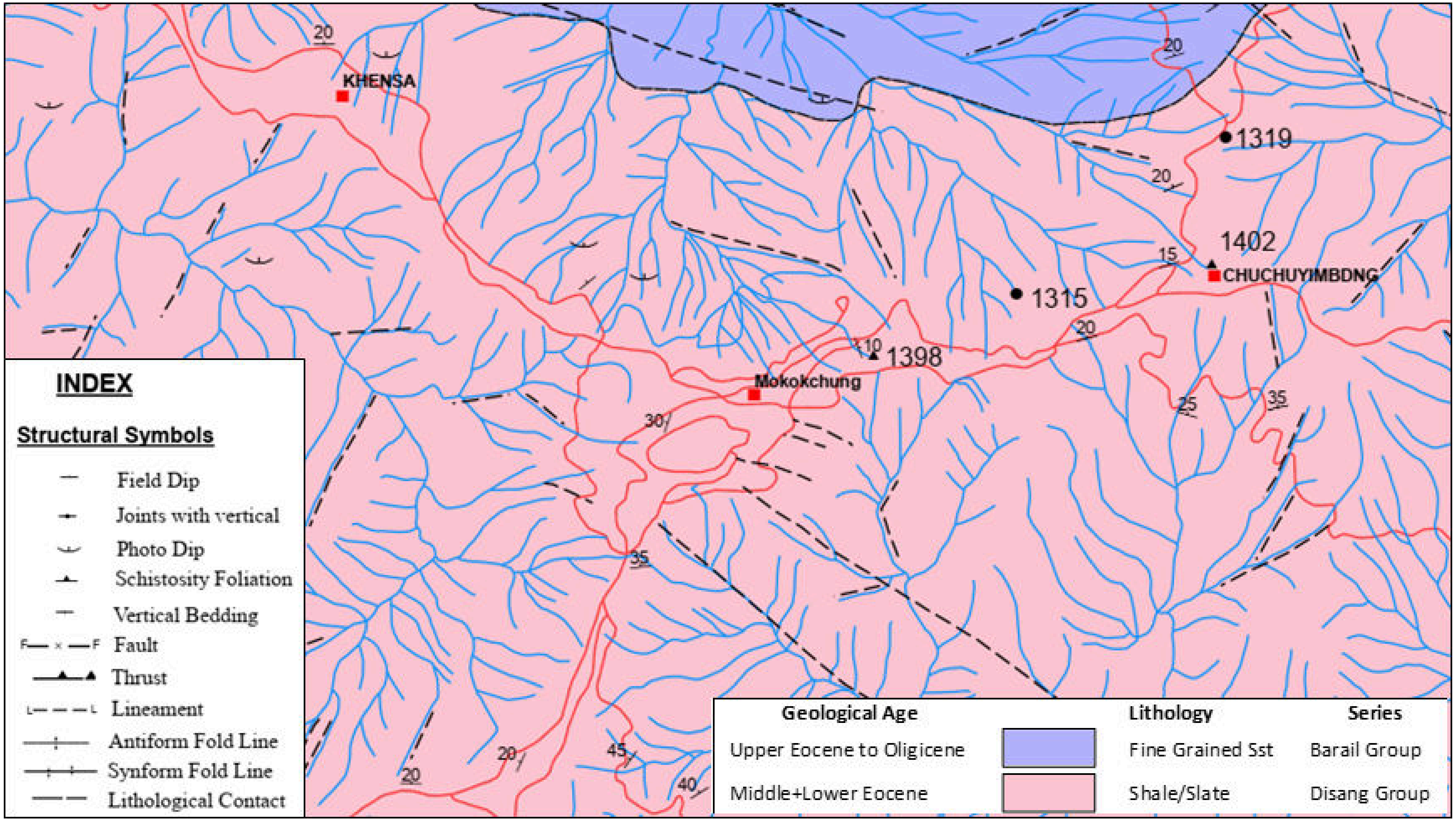
APPENDIX: B

Table 26: *Average monthly rainfall of Mokokchung, 2005-2014*

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Jan	7.6	0	0	27.9	0	2.3	40.9	74.8	0	19.1	17.3
Feb	10.3	0	60.9	7.5	0	13.1	6.4	0	18.7	21.7	13.9
Mar	65.8	34	5	91.2	38.8	146.3	57.2	38.8	85.5	33.6	59.6
Apr	66.5	177.4	187.8	84	99	182.9	121.2	240.4	118.9	41.3	131.9
May	210.8	205.5	167	250.9	181.5	263.8	341.9	109.7	570.2	67.7	236.9
Jun	174.1	168.5	224.3	707.1	267.1	601.8	592.6	284.3	349.5	174.7	354.4
Jul	327.3	564.9	330.1	602.2	775.2	453	445.3	484.1	411.9	327.1	472.1
Aug	487	145.9	260.7	367.3	473.3	362.4	441.9	431.2	316.2	326.8	361.3
Sep	93.7	310.9	333.7	262.2	310.7	293.3	396.9	319.7	123.4	311.7	275.6
Oct	63.8	69.9	174	116.9	81.6	341.7	126.4	146.5	76.8	49.4	124.7
Nov	0	45	41.5	0	23.6	0	11.2	9.4	0	2.2	13.3
Dec	0	5.3	3.4	1	0	14.5	0	0	12.4	0	3.7
Total	**1506.9**	**1727.3**	**1788.4**	**2518.2**	**2250.8**	**2675.1**	**2581.9**	**2138.9**	**2083.5**	**1375.3**	**2064.6**
Note: rainfall values are in millimetres											

Source: Soil and Water Conservation Department, Nagaland

Fig 52: *Map showing lithological structure around Mokokchung town*



(Source: Jha, 1982)

Table 27: *JMP service ladders for monitoring basic WASH services in health care facilities*

	WATER	SANITATION	HYGIENE	WASTE MANAGEMENT	ENVIRONMENTAL CLEANING
BASIC SERVICE	Water is available from an improved source[1] on the premises.	Improved sanitation facilities[2] are usable, with at least one toilet dedicated for staff, at least one sex-separated toilet with menstrual hygiene facilities, and at least one toilet accessible for people with limited mobility.	Functional hand hygiene facilities (with water and soap and/or alcohol-based hand rub) are available at points of care, and within five meters of toilets	Waste is safely segregated into at least three bins, and sharps and infectious waste are treated and disposed of safely.	Basic protocols for cleaning are available, and staff with cleaning responsibilities have all received training.
LIMITED SERVICE	An improved water source is within 500 meters of the premises, but not all requirements for basic service are met.	At least one improved sanitation facility is available, but not all requirements for basic service are met.	Functional hand hygiene facilities are available either at points of care or toilets but not both.	There is limited separation and/or treatment and disposal of sharps and infectious waste, but not all requirements for basic services are met.	There are cleaning protocols and/or at least some staff have received training on cleaning.
NO SERVICE	Water is taken from unprotected dug wells or springs, or surface water sources; or an improved source that is more than 500 meters from the premises; or there is no water source.	Toilet facilities are unimproved (e.g. pit latrines without a slab or platform, hanging latrines, bucket latrines) or there are no toilets	No functional hand hygiene facilities are available either at points of care or toilets.	There are no separate bins for sharps or infectious waste, and sharps and/or infectious waste are not treated/ disposed of safely.	No cleaning protocols are available and no staff have received training on cleaning.

(Source: JMP, 2019b)

[1] Improved water sources are those which by nature of their design and construction have the potential to deliver safe water. These include piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water

[2] Improved sanitation facilities are those designed to hygienically separate human excreta from human contact. These include wet sanitation technologies – such as flush and pour flush toilets connecting to sewers, septic tanks or pit latrines – and dry sanitation technologies – such as dry pit latrines with slabs, and composting toilets

Table 28: *Service indicator wise accessibility of water source evaluation*

Service indicator and problem	Rainwater	Tanker water	Dug-well water	PHED water	Boring water	Stream water	Porter (*Mutia*) Water
Quality	Safe (after first flush)	Safe (with good faith on vendor)	Safe (but pathogenic contaminates should be tested)	Safe	Safe but hard water	Unsafe due to possible contaminants	Under question
Quantity	Surplus during summer only	Should be purchased minimum 2 kl.	Limited during winter	Limited throughout the year	Limited in upper part of the town	Surplus during summer only	Limited
Coverage	Yes (but limited to available roof surface)	Yes (but limited to road condition and pipe length)	Topographically favourable locations with aquifer	Only 26% household of the town	Limited to few neighbours	Limited to only downhill areas near stream	Only in business area of town
Affordability	Small investment for collection system	Becomes costly for poor family	Digging is costly due to rocky layers	Connection is costly if distance increases from metre house	Costly investment	Investment for piping to the source	Costliest among all sources
Continuity / Availability	No (depends on storage volume)	Can be continuous on payment	Limited during winter	Not reliable	Can be continuous	Limited amount but continuous	On demand
Overall Problem	Storage and roof surface	Affordability and storage tank	Uncertain aquifer due to topographic factor	Frequent disruption due to landslide and technical snags	Costly and heavy machinery can't enter all areas due to topography	Not possible for upstream locations	Limited quantity and costly

(Compiled by author)

Table 29: *Ward wise area and population with PHED consumers of the town, 2017*

Sl. No.	**Ward name**	**Area* (sq. km.)**	**Population****	**Density (person/sq. km.)**	**Households** (H)**	**PHED Consumers** (C)**	**Ratio = C/H**
1.	Alempang	0.36875	2,025	5,492	603	219	36.32
2.	Alongmen	0.175375	2,500	14,255	500	96	19.20
3.	Aongza	0.28138	1,600	5,686	400	158	39.50
4.	Arkong	0.2263	3,012	13,310	502	291	**57.97**
5.	Artang	0.68985	2,016	2,922	567	146	25.75
6.	Dilong	0.2839	2,232	7,862	558	105	18.82
7.	Kichutip	0.20025	1,300	6,492	230	78	33.91
8.	Kumlong	0.31565	2,120	6,716	530	167	31.51
9.	Lijaba Lijen	0.1819	1,160	6,377	236	9	**3.81**
10.	Majakong	0.24485	1,450	5,922	337	113	33.53
11.	Marepkong	0.65646	824	1,255	206	14	6.80
12.	Mongsenbai	0.877875	2,020	2,301	404	85	21.04
13.	Penli	0.2139	2,024	9,462	506	67	13.24
14.	Salangtem	0.346	1,652	4,775	413	144	34.87
15.	Sangtemla	0.400	3,000	7,500	650	241	37.08
16.	Sungkomen	0.17062	2,026	11,874	500	46	9.20
17.	Tongdentsuyong	0.15435	1,420	9,200	355	79	22.25
18.	Yimyu	1.18767	2,015	1,697	475	-	-
	Total	**6.97508**	**34,396**	**4,931**	**7,972**	**2,062**	**25.87**
*Area data from LRSD; ** Population data differs from census 2011 due to different years; *** Consumers up to April 2017							

Compiled from PHED, LRSD and MMC, Mokokchung

Household sample survey questionnaire

Water accessibility and urban ecology of Mokokchung town
Nagaland University, Department of Geography

1. Identification of household:

H.H. No.	Date	GPS Location (optional):		Ward	House No	House type (occupied only): 1- Bamboo/ 2- AT/ 3- RCC-Tin/ 4- G± ________(Rooms)	Name of Head of the H.H./ Interviewee	Community/ Tribe
		N	E					

2. Demographic structure:

Sl. No.	Relationship with the household head	Age	Sex (M/F)	Education	Marital status	Occupation		
						Basic	Additional	Income (Rs)
1.	Head							
2.								
3.								
4.								
5.								
6.	Menial (if any)							

3. Household information:

Ownership Own/ Rental (since)	Belong to district	Yearly dependency % of water sources					Average power bill paid (Rs)/month	If any vehicle(s) owned: 2W/4W/6W (Number)	No of Pet animal					Vegetation type in the campus (Tree/ Bamboo/ Shrub)	% area covered by vegetation	Noticed wild species around town or sold in local market	Family members*				Yearly family Income (Rs) and occupation
		PHED	Rain	Dug-well	Boring well	Tanker			Cow	Pig	Goat	Dog	Other				Male	Female	Child<14	Total	

* Refer to demographic structure table

4. PHED water information:

Have connection since which year?	Connection cost (Rs)	Cost reasonable Y/N	Meter price paid at the time of connection Y/N	Observed any dirt/ odour in supplied water? Y/N	Used for drinking Y/N	Amount is adequate Y/N	Received amount (L/month)	Noticed any seasonal variation Y/N	Suspect any distribution discrimination? Y/N	Doubt any anomaly in meter count Y/N	Average delivery frequency in days	Average amount paid (Rs/month)	Tank capacity available (m^3)	Capacity can last for about how many days?	Expected delivery frequency	Expected delivery amount each time	Leakage noticed in the pipeline	Willing to pay higher rate if service is regular Y/N	Any disease suspects due to water?	Is there any common free point for public? Y/N	PHED Service satisfaction rating (1-5)

5. Private Dug well water information:

Since	Construction Cost (Rs)	Wall type: RCC/ Rock/ Earth	Drinkable Y/N	Adequate year round: Y/N	Depth: (ft.)	Yield: (L/Day)		Seasonal fluctuation (ft.)	Motor fitted: (HP)	Filter used if any	Sell water to vendor (Rs)/year	Remarks
						Sum	Win					

6. Rainwater harvesting information:

Since	Surface type (Concrete/ Tin) & area collected: (ft^2)	Storage wall type: 1-RCC/ 2-PVC/ 3-Poly/ 4-Metal	Storage capacity (m^3)	Installation & Construction Cost (Rs)	Drinkable Y/N	Adequate for: (Days/ Weeks)	Tank withdrawal by 1- Motor/ 2- Gravity/ 3- Manual	Filter used if any	Remarks

7. Community well water information:

Adequate year-round Y/N	Distance Up / Dn (metre)	Duration for single trip (min)		Amount allowed to collect (L)		Estimated cost for trip /day (Rs)		Carrying by: 1-hand/ 2-back/ 3-shoulder/ 4-vehicle/ 5-Mutia	Max Load to carry per trip: (L)	Family members involved M/W/C	Well type: 1- Rock 2-RCC 3-Earth	Maintenance cost to pay if any (Rs)/yr	Drinkable Y/N	Summer and winter fluctuation (ft.)
		Sum	Win	Sum	Win	Sum	Win							

8. Deep boring water information:

Since	Cost (Rs)	Drill depth (ft)	Motor depth (ft)	Ground Water depth (ft)	Water yield per day (L)	Quality 1- Soft/ 2- Mod/ 3- Hard	Washing can be done without filtering Y/N	Sale to tanker (Rs)/month	Sale to neighbour (Rs)/month	Buy boring water (Rs)/month	Remarks

9. Tanker water information:

Since	Buy water (Rs) X month(s)	Earn by Sale water (Rs) X month(s)*	Installation cost other than vehicle (Rs)	Load capacity (L)	Source of water stream/ boring/ dug-well/ other	Distance to source (km)	Maintenance cost per month (Rs)	Persons involved	Water quality 1- Soft/ 2- Mod/ 3- Hard	Any filter used	Remarks

*Having water vendor business

10. Mutia (Porter) fetched water information:

Since	Buy water through mutia (Rs) X month(s)	Earn by Sale water to mutia (Rs) X month(s)	Water requirement per day (L)	Carry per Load (L)	Source of water Stream/ Boring/ Dug well/ Other	Distance to source (m)	Water quality 1- Soft/ 2- Mod/ 3- Hard	Quality can be trusted Y/N	Any filter used	Remarks

11. Break up of estimated water requirement in the family:

Drinking (L/day)	Cooking (L/day)	Toilet flush (L/day)	Bathing (L/day)	Washing cloth (L/day)	Plantation (L/day)	Gardening (L/day)	Car washing (L/day)	Floor moping (L/day)	Utensils washing in kitchen (L/day)	Total requirement (L/day)	Food Habit Veg/ N-veg	Average cooking time Min/ meal

12. Miscellaneous information about hygiene:

Water filter type installed	Yield from filter (L/day)	Use of packaged M. water		Provide water to tenant Y/N	If so (L/Day)	Grey water produced (L/day)	Grey water use		Toilet pan type			Septic tank disposal system				
		Regular amount (L)	Occasional amount (L)				in summer	in winter	Type	Qty	Flush Y/N	Soak pit	Storm flush	MTC tank	Direct release	Other
									Indian							
									West^{n}							

13. Miscellaneous information about domestic energy:

LPG bottle using from agency & no.	Distance from agency (m)	Difficulty level to get refill cylinder (1-5)	Subsidy availed Y/N	Delivered by Agency/ Porter/ Self	Cylinder transport cost (Rs)	Fuel wood requirement (kg)/ month		Cost incurred in fuel wood (Rs)/year	Preferred species of fuel wood	Other cooking energy used				*Surveyor's observation*
						Summer	Winter			Electric	Charcoal	Kerosene	Coal	

14. Miscellaneous information about garbage disposal:

Waste produced per day (Kg)	Frequency of garbage disposal to outside HH in day(s)	Garbage disposal type: municipal dustbin/ throwing to stream/ other	Distance to disposal site (m)	Frequency of MTC collection if any	Fee paid for garbage collection `/month	No. of cleanliness drive in the ward per year	Alternative to solve garbage disposal problem	Sanitation problem faced for months/yr	Your options to solve water problem	Options you will take during very dry winter period	*Surveyor's observation*