POTENTIALS AND PRACTICES OF RAINWATER HARVESTING IN AIZAWL

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POTENTIALS AND PRACTICES OF RAINWATER HARVESTING IN AIZAWL

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CERTIFICATE

This is to certify that the thesis entitled ***"Potentials and Practices of Rainwater Harvesting in Aizawl"*** *by Mr.Zochhuanawma, (*MZU/Ph.D/857 Dt. 13.04.2016), *Ph.D Scholar*, *Department of Geography and RM, for the award of Doctor of Philosophy to the Department of Geography and Resource Management, has been written under my guidance.*

He has fulfilled all the requirements laid down in the Ph. D. regulations of the Mizoram University. The thesis is the result of his investigation into the subject. Neither the thesis as a whole nor any part of it was ever submitted to any other University for any research degree.

I also want to state here that all the experts' comments and suggestions have been incorporated in the Thesis.

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The : 6th Sept. 2021

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SEPTEMBER, 2021

DECLARATION

I, Zochhuanawma, hereby declared that the thesis entitled "**Potentials and Practices of Rainwater Harvesting in Aizawl**" is the record of work done by me, that the content of this thesis did not form basis of any previous awarded degree to me or to the best of my knowledge to anybody else's, and that the thesis has not been submitted by me for any research degree in any other university or Institution.

This is being submitted to the Mizoram University for the fulfilment of the degree of Doctor of Philosophy in the Department of Geography and Resource management.

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ABBREVIATIONS

AMC	Aizawl Municipal Corporation
G.I Sheet	Galvanised Iron Sheet
RCC	Reinforced Cement Concrete
HH	Household
PHE/D	Public Health Engineering/Department
JJM	Jal Jeevan Mission
CGWA	Central Ground Water Authority
NGO	Non-Governmental Organisation
GAWSS	Greater Aizawl Water Supply Scheme
MLD	Million Litres per Day
BPL	Below Poverty Line
RWH	Rain Water Harvesting
FAO	Food and Agricultural Organisation
GFW	Global Forest Watch
UN	United Nations
VDF	Very Dense Forest
MDF	Moderately Dense Forest
OF	Open Forest
MZU	Mizoram University
pH	Potential of Hydrogen
YMA	Young Mizo Association

CHAPTER–I

INTRODUCTION

1.1. General Introduction

This chapter introduces the whole thesis. It is much more appropriate to say that it is the blue print of the whole study. It discusses the scope of the study, its objectives, and deliberates about the study area and how study has been conducted on rainwater harvesting in different parts of the world, India and Mizoram. It is the general introduction of the overall condition of the study. It basically is the foundation of the research. By going through this chapter, one can learn the necessity, sustainability, reliability, efficacy, cost effectiveness and many other positive impacts of rainwater harvesting in various spots and regions of the globe.

Our earth is a watery planet wherein nearly 70% of it is covered by water. Water exists in all forms-solid, liquid and vapours. However, the water available to human beings in the fresh form such as lakes, rivers and ground is limited to about merely 0.3% of total water supply (Mohanty et al., 2010). Much of this fresh water is still too expensive to get or inaccessible and trapped in glaciers, under-grounds and snowfields. In the meantime, due to increasing population, development and high living standard, the demand for water become higher day by day while the sources of water are diminishing rapidly across the globe. This clearly shows the preciousness of our fresh water for human beings and all other living creations.

Rain and snow are an important attributes of water cycle on the earth, which is the basic foundation of all life on the earth's surface. Rainfall is the main way that the water in the skies comes down to earth, and it fills lakes and rivers with fresh water form; and also it recharges the underground water level, and provides waters to plants and animals for growth and survival. Water is one of the renewable natural resources which move in a cycle on the earth's surface and atmosphere with neither the beginning nor the end. Water vapor (evaporated from oceans, lakes, forest, fields, animals and plants) condenses and returns to earth as precipitation.

The word "Rainwater harvesting" may be describe as a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments and other man-made storage or catchment facilities using simple techniques such as jars and pots as well as more complex techniques such as underground dams or reservoirs. However, this research focuses particularly on rooftop rainwater harvesting in Aizawl city. Very simply, it is the capture, diversion, and storage of non-potable or potable water for later reuse. The technology is easy and simple which could be adopted and implemented by everyone. Rainwater harvesting is one of the most effective methods of water management and water conservation.

Rainwater harvesting, which is a simple, economical and eco-friendly method of water conservation, is an ideal solution to water crisis. In many areas, rainwater harvesting is a necessary, not a luxury. Many desert and arid areas have little to no fresh water resources. In those regions, people are bound to depend on rainwater for most of their water needs throughout the year.

Many countries in Africa, Middle-East and Asia faced a growing serious scarcity of water. This kind of water scarcity necessitates many nations to mandate the practice of rainwater harvesting as a law. Rainwater harvesting is being practiced in many countries around the globe to meet the demand of water supply. Bermuda and US Virginia Islands have a law which requires all the new houses to include rainwater harvesting system to meet the demand of water supply for the residents.

Some states in India have also done rainwater harvesting. During Cholas period, rainwater harvesting was practiced in Tamil Nadu. The same was also practiced in the states of Madhya Pradesh, Maharashtra and Chhattisgarh in the olden days. In recent years, many cities and states in India have mandatory law enacted in the legislation to practice rainwater harvesting. Accordingly, the uncertainty of today's and future's water condition of Aizawl city cannot be underestimated as well. This kind of water crisis needs to be anticipated in Mizoram as well due to rapid ground water depletion and urbanisation.

1.2. Statement of the problems

It is a natural phenomenon that the quality and quantity of water becomes lower and lower day by day due to the patterns of deforestation, industrialization and urbanization which is somewhat inevitable due to rapid growth of population. Similarly, it is the same case with the main source of water in Aizawl city. In the context of Aizawl city, the main source of water in the city is Tlawng river which is apparently not sufficient enough throughout the year for the city dwellers. Sometimes, during dry season, there is no sufficient water in the Tlawng river to feed onto. There used to be certain problems in pumping the water when the river channel is flooded during monsoon. Water scarcity or crisis happens in the city every year during lean season i.e. February to April. So, this is a high time to practice rainwater harvesting in Mizoram as a whole.

Further, one of the most important reasons to implement rainwater harvesting system is that most of the people residing around the periphery of Tlawng river in Aizawl area are mainly dependent upon agriculture which further needs clearing of the forest due to the practice of shifting cultivation. At the current rate of industrialization and population growth, the water condition of Aizawl city for the coming 10-20 years is quite disturbing for our next generation. The possibility of acute shortage of water in the near future needs to be anticipated by implementation of rainwater harvesting system in the regional level or local level.

Rainwater harvesting, especially roof-top water harvesting, is one of the most essential technology to meet the increasing demand of fresh water in Aizawl city, Mizoram. Today, our city has continued to grow at a rapid pace; undeveloped land has been replaced with impervious surfaces such as streets, buildings, pavements and parking lots. This process of urbanization leads to depletion of ground water level. The ground water potential is getting reduced due to urbanization and as a result most of the rivers and streams are getting dry-up very easily.

(Pic: Shallow water in some parts of Tlawng river during February)

Apparently, many of the residents in Aizawl city are in short supply of water, especially during dry spell of the year. Hence, a strategy to bridge the huge gap between water supply and water demand, in a major way needs to be launch with concerted efforts by various governmental and non-governmental agencies and public at large to make the rainwater harvesting a reliable and sustainable source for supplementing and supporting the water supply needs of the urban dwellers. This strategy has to be implemented at large by Village Panchayats/Municipalities/Municipal Corporation and other governmental departments with special efforts.

1.3. Scope of the study

The study of rainwater harvesting covers quite a wide range of weather attributes and part of population attributes as well, such as amount of rainfall, duration of rainfall in a year or month, population density of a region so studied etc. It covers mainly the study of water sustainability for a particular region. The proper balance between water demand and supply has become a critical matter these days and even for future as well because of water stress. This balance can be achieved by implementing alternative water sources.

As Aizawl city (Mizoram) is predominated and endowed by huge quantity of rainwater during the rainy seasons, among all other alternative water sources, rainwater harvesting system could be the most potential one for the state of Mizoram in general and Aizawl city in particular. The huge quantities of rainwater during the rainy season goes as run-off due to inefficient management of rainwater which further is closely associated with the occurrence of many landslides in the region. So, the study also, to some extent, includes natural disaster management.

As agriculture being the main stay of the economy, many forest cover are cleared every year for shifting cultivation. When these kinds of uncover lands are being washed and poured by huge amount of rainfall, the chance of landslides is quite high and intense. Many landslides occurring every year in the region may be attributed to the mismanagement of rainwater. The rate of deforestation for the past several years could have adverse impacts on the volume of water in many rivers of the region as well. So, the study also concern with the pattern of deforestation and precipitation in the state to some extent.

The study focuses on the amount of rainfall in Aizawl district, base on available rainfall data so as to understand, examine and assess the potential and practices of rainwater harvesting in the city. General observation shows that there exists an alarming water scarcity even within the capital city of Aizawl.

The study also attempts to find out the potentials of rainwater harvesting in Aizawl city. Instigating awareness to the general public about the essentiality and feasibility of rainwater harvesting is also one of the important scopes of the study. Participation of the local people is of great importance in fulfilling the strategy of rainwater harvesting because the study attempts at analyzing the roof water harvesting in particular. It also aims to educate the general public to practice roof water harvesting in the city because in Aizawl city the main catchment area of rainwater is the galvanized iron sheet (G.I sheet) and reinforced cement concrete (RCC) types of roofs, which are ideal for rooftop rainwater harvesting.

The buildings of the city are quite congested and there is very little open space. Apparently, most of the rainwater falls on the roof rather than open space. It is also interesting to observe that types of roof in Aizawl city are ideal for roof water harvesting as most of them are G.I sheet and concrete structures. The existing roof types are a potential for roof water harvesting without any extra effort. Moreover, Aizawl city is still free of air pollution to dilute the quality of rainwater. The problem so far is that people are not much aware of this potential and simply rely on Public Health Engineering (PHE) water supply.

1.4. Objectives

1. To identify roof types for potential rainwater harvest in Aizawl city
2. To examine rainwater harvesting practices in Aizawl city
3. To assess monthly rainwater quantity in Aizawl city
4. To suggest measures for optimum use of rainwater harvesting

1.5. Chapterisation

Chapter I - Introduction

Chapter II - Methodology

Chapter III - Water supply scenario in Aizawl city

Chapter IV - Patterns of deforestation and quantity of rainfall in Aizawl city

Chapter V - Types of roof and their potentials for rainwater harvesting in Aizawl city

Chapter VI - Practices of rooftop water harvesting in Aizawl city

Chapter VII - Attributes of rainwater harvesting in Aizawl city

Chapter VIII – Conclusion

1.6. Review of literature

The construction and use of cisterns to store rainwater can be traced back to the Neolithic age, when waterproof lime plaster cisterns were constructed in the floors of houses in the village of the Levant, some areas in South-west Asia, south of the Taurus mountains, bound by the Arabian desert in the south, the Mediterranean sea in the west, and Mesopotamia in the east. By around 4000 BC, cisterns were an effective and convenient component of water management techniques utilized for farming in the arid regions.

Many ancient water tanks or cisterns were unearthed and discovered in some parts of Jerusalem and the entire Land of Israel. A large cistern dating back to as early as 2500 BC was discovered at the place which is believed to be the biblical city of Ai. This large cistern had a capacity of almost 1,700 m^3. It was made out of a solid rock and sealed with clay to prevent the leakage of water.

The island of Crete which is located in Greece is also popular for its use of large cisterns for collection of rainwater and for storage facility during the Minoan period from around 2,500 BC to 1,000 BC. Four large cisterns were also discovered at Myrtos-Pyrgos, Archanes, and Zakro each. The cistern found at Myrtos-Pyrgos had a capacity of more than 80 m^3 and it dates back to around 1700 BC.

Rainwater harvesting is a technique dating back to the Greek and Roman empires as well, where sophisticated methods of collection and storage systems were employed to capture rainwater for various domestic and agricultural uses. The techniques of rainwater harvesting which are usually found in Asia and Africa are the continuation of the same techniques practiced and employed by ancient civilizations within these regions. The techniques still serve as a major source of drinking water supply in many rural areas. During the third century BC, people of the farming communities in

Balochistan (now located in Pakistan, Afghanistan and Iran), Kutch in India, used the harvested rainwater for agriculture and many other purposes.

Even though it is not very popularly known, the city of Venice had been depended on rainwater harvesting for generations. The lakes and seas that surround the city are brackish or non-potable water which is not fit for drinking purposes. Thus the ancient people in the Venice city implemented a systematic method of rainwater collection using man-made storage facility or well in the city. The well was designed in such a way that it has a layer that filtered the water. The water that percolates into the well was collected at the bottom of the well after being filtered by a layer of stone and sand. When Venice achieved the status of territories, it started to import water from various rivers. But still, the wells in the city were well maintained and used as they were very important during the time of war when import of water from the mainland could be disrupted and blocked by an enemy.

Rooftop rainwater harvesting is being practiced in many parts of Argentina, China and Brazil for various domestic uses such as livestock, irrigation, farming, etc. The provinces of Gansu in China and semi-arid areas of northeast Brazil have one of the largest rooftop rainwater harvesting projects. Some housing societies are using rainwater for their main water sources after proper treatment for different domestic uses in Beijing.

Rainwater harvesting is very affective and reliable that large proportion of population (around 40%) living in rural areas of Thailand are still relying on it. Rainwater harvesting was insisted and promoted heavily by the government of Thailand during the 1980s and even funding for storage facilities were provided by the government. During the 1990s, when government funds for the collection tanks and storage facility had come to an end, the private players stepped in to provide several million tanks to many private households. This is one of the largest examples of self-supply of water worldwide.

In Bermuda, there is a law that requires the practice of rainwater harvesting for all the newly constructed buildings and the rainwater harvesting must also be adequate for all the residents of the house as well. In Senegal and Guinea-Bissau, the people of Diola frequently practiced rainwater collection using traditional homebrew rainwater harvesters which are made from local organic materials.

Along the Irrawaddy river of Myanmar, as the groundwater is saline and not suitable for drinking, the communities around it depend on rainwater which accumulates in the ponds to meet the needs of water during the dry season. These ponds are treated with great respect as they are as old as centuries.

Contrastingly in the United States, until 2009 in Colorado, water rights laws almost completely restricted rainwater harvesting; a property owner who captured rainwater was considered and regarded as stealing it from those who have the rights to take water from the watershed. The water right laws considered the rainwater to be accumulate first in the watershed of the region so as to be collectable by everyone equally at a same time.

Construction of rainwater catchment facility is mandatory for all new dwellings in Santa Fe, New Mexico. An interesting practice is that Texas even offers a sales tax exemption for those who purchase rainwater harvesting equipments. Both the states of Texas and Ohio allow the practice even for potable purposes. Oklahoma passed the Water for 2060 Act in 2012, to promote pilot projects for rainwater and gray water use among other water-saving techniques.

The systematic study on potential of rainwater harvesting in Mizoram was conducted by Lalmalsawmzauva (2015), which reveals that the average annual rainfall for the last 19 years (1990-2012) was 2538.31 mm. The study also indicated that rainwater harvesting alone can meet almost half the requirement of water demand in Mizoram.

The type of roof material, flat or slopes determines the total quantity of rainwater that can be harvested in a particular area. It also determines the system that would be appropriate for efficiently harvesting this amount of rainwater. The total volume of rainwater available from any rooftop surface is a product of total rainfall and the surface area of collection. A runoff coefficient is usually calculated and applied to account for infiltration, evaporation and other losses and it varies from 0.8 to 0.95. And in order to estimate the average annual monsoon runoff from rooftop area in any given area, the amount of annual mean rainfall for the location need to be applied (Lalmalsawmzauva, 2015). It appears from the above literatures that rainwater harvesting is extremely important to meet increasing demand of water in Mizoram.

Besides its importance in agriculture, water is also important in many industrial processes, and is used to remove waste. Climate change is affecting the global pattern of rainfall, which can lead to even higher temperatures and lower rainfall in tropical areas (Kumar, 2006).

In Israel, the Southwest center for the study of Hospital and Healthcare Systems in cooperation with Rotary International is sponsoring rainwater harvesting model program across the country. The first rainwater harvesting system was constructed and installed at an elementary school in Lod, Israel and the project had expanded to Haifa in its third phase. The Southwest Center has also partnered with the Water Resources Action Project of Washington, DC, which also has rainwater harvesting projects in the West Bank. In order to spread awareness about the water conservation principles, rainwater harvesting systems are being practiced and constructed in local schools. It is considered and hoped to bridge the divides between people of different religious and ethnic backgrounds, while addressing the water scarcity issue that the Middle East faces at the same time.

New Zealand has an abundant rainfall in the western and southern parts of the country and rainwater harvesting is the normal practice for most rural housing, using roof water directed by spouting into covered, 1000 liters storage tanks, and is encouraged by most council.

For many households of rural areas in Sri Lanka, rainwater harvesting has become a popular method of accessing and obtaining water for agriculture, drinking and other domestic purposes. Through the Urban Development Authority (Amendment) Act, No. 36 of 2007, rules and regulation to promote rainwater harvesting was enacted in the legislation. Lanka rainwater harvesting forum is leading all the initiatives to promote the same in the country.

In the United Kingdom, the practice of rainwater harvesting is getting much more important. It is a traditional and revived technique of the olden days for collection of water for various domestic uses. The harvested rainwater is generally used for non-hygienic purposes such as watering gardens, toilets, washing, etc. It is claimed and considered that in the South East of England the share of water per head is less than that of the same in many Mediterranean countries.

In UK, rainwater is almost always collected strictly from the roof, and then heavily filtered using different kinds of filtering methods that are placed in an underground tank. Many households in UK using rainwater harvesting system can reduce their water usage from main supply by over 50%. In some parts of UK, mains water delivery and equivalent waste water and sewerage processing costs about £2 per cubic metre. Reducing mains-water metered volumes also reduces the sewerage and sewage disposal costs in the same proportion, because water-company billing assumes that all water taken into the house is discharged into the sewers.

Harvesting of rainwater is an ancient technology that is now being reinvented in several countries as a water supply solution. The latest rainwater harvesting techniques involve improved collection, storage and hygiene. Sometimes even very old cisterns, tanks and other such structures can be incorporated into modern rainwater collection systems (Kumar, 2006).

Kumar (2006) stated that as per the report by UN in 2003, world water reserves are drying up fast and booming populations, increasing population and global warming will join up to cut the average person's water supply by a third in the next 20 years. This report ranked 122 countries on the quality of their water provision. Belgium is being figured at the bottom of the list, below India and Rwanda. By 2050, it is estimated that water scarcity will affect a population between 2 billion and 7 billion.

Rautela (2000) observed that water has been harvested in India since antiquity. Ancient texts, inscriptions, local traditions and archaeological remains provide the evidence for this tradition. Rig Veda mentioned a lot about the rational and judicious use of water from different sources.

Water has been considered an everlasting free resource that can be acquired naturally. Meanwhile, the demand for recycled and refined supply water is growing higher due to an ever increasing population. Such an increasing demand for water has to be met in one way or the other. Systematic, judicious and sustainable use of water could bridge a gap between water demand and supply. And rainwater harvesting is the most traditional and sustainable method, which could be easily used for potable and non-potable purposes in both residential and commercial buildings to tackle the growing demand of water (Rahman, 2014).

Rainwater harvesting is an ancient technique which is actually revived and became popular nowadays due to its quality and interest in reducing the consumption of processed water. Rainwater is most valued and wanted for its pure form. It has nearly a neutral pH, and is generally free from disinfection by-products, salts, minerals, and other natural and man-made contaminants. Plants also grow well under irrigation with harvested and stored rainwater. Colley (2005) stated that appliances last longer when free from the corrosive or scale effects of hard water. Users with potable systems prefer the superior taste and cleansing properties of rainwater.

Rainwater harvesting technique has become a popular supplement for potable water to reduce the demand on the conventional water supplies particularly in cities where the surface water is polluted with urban waste and the groundwater is over-tapped due to rapid increase in population due to urbanisation. The cost of rainwater collection tends to be quite small but the costliest economic expense is the initial capital cost to construct the collection facility and system (Rebecca, 2013).

Globally, water scarcity is being experienced in almost every continent. The demand of water has been growing day by day globally along with the pattern of population growth. Many water-scarcity regions and arid areas are facing problems of water even for sustainable or subsistence basis livelihood. Many areas in the world face water shortage such as southern Italy, Spain, Greece, most of Arab states, India, Taiwan, Japan, Western Australia, North-western and south-eastern Africa coast, etc. (Mohanty et al., 2010).

As per the global water institute in 2013, about 700 million people worldwide could be displaced by intense water scarcity by 2030. Almost half of the world's population is 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. About 73% of the affected people live in Asia (Burek et al., 2016).

According to the data released by International Development Enterprises of India (IDEI) in 2016, India is also facing a freshwater crisis. As much as 16% of the world's population lives in India and it possesses only around 4% of the global fresh water. As per the reports of UNICEF in 2017, even though India has spent millions of rupees on water through various schemes under Ministry of Drinking Water and Sanitation or Jal Shakti, less than 50% of the population in India has access to safely managed drinking water.

In India, rainwater was utilized enormously before the British India government supplied the country with a centralized drinking water supply system. The Centre for Science and Environment (CSE), an independent organization which supports and promotes rainwater utilization in India through several measures, offers courses continuously in different regions of India (Lalmalsawmzauva, 2015).

In India, according to Ministry of environment, forest and climate change (MoEF & CC), there are separate legislations for RWH in different states. Some of the legislations in Indian states are mentioned below.

Tamil Nadu is the first state to make rainwater harvesting compulsory for every building to prevent and avoid groundwater depletion. Launched and introduced in the year 2001, the project has been implemented in all rural areas of the state. Posters all over Tamil Nadu including rural areas created awareness about the efficacy and environmental friendliness of harvesting rainwater. Subsequently, it earned amazing and excellent results within five years, and slowly every state used it as a role model. Since its implementation, Chennai had a 50% rise in water level in five years and the water quality significantly improved in the region.

In Gujarat in 2002, Ahmedabad Urban Development Authority (AUDA) had made rainwater harvesting compulsory for all buildings measuring an area of over 1,500 m2. According to the rule, for a cover area of over 1,500 m2, one percolation well is mandatory to ensure ground water recharge. For every additional 4,000 m2 cover area, another well needs to be built.

In order to conserve water and to enhance the quantity of ground water in Bangalore, the Karnataka government in February, 2009 gave an order that all the buildings constructed in the city will have to compulsorily adopt rainwater harvesting system. Residential sites, which are more than an area of 40 x 60 feet, shall create rainwater harvesting facility as per the new law in the city.

In Chennai, Tamil Nadu, rainwater harvesting has been made mandatory in three storied buildings, irrespective of the size of the rooftop area. All new water and sewer connections are provided only after the proper implementation and installation of rainwater harvesting systems.

In Gujarat, the state roads and buildings department have made rainwater harvesting mandatory for all government buildings.

Haryana Urban Development Authority (HUDA) has made rainwater harvesting mandatory in all new buildings irrespective of the roof area in the state. In the notified areas in Gurugram town and adjoining industrial areas, the Central Ground Water Authority asked and insisted all the institutions and residential colonies to adopt rainwater harvesting.

There is also a regulation in Himachal Pradesh that all commercial and institutional buildings, tourist and industrial complexes, hotels etc., existing or coming up and having a plinth area of more than 1000 m2 will have rainwater storage facilities commensurate with the size of roof area. No-objection certificate, which is required under different regulation and statutory, will not be issued to the owners of the buildings, until and unless, they produce satisfactory proof of implementation of rainwater harvesting facility. It has been recommended that the buildings will have rainwater storage facility in line with the size of roof in the open and set back area of the plot at the rate of 0.24 cubic feet per m2 of the roof area.

In Hyderabad (Andhra Pradesh), rainwater harvesting has been made mandatory in all new buildings with an area of 300 m2 or more.

In Indore, Madhya Pradesh, rainwater harvesting is made compulsory and mandatory for all the new buildings with an area of more than 250 m2.

Kanpur (Uttar Pradesh) also has a regulation that mandate the implementation of rainwater harvesting facility in all new buildings with an area of 1000 m2 or more.

The Kerala Municipality Building Rules, 1999 was amended in the year 2004 by the Government of Kerala to include rainwater harvesting structures in all new construction in the state.

In Mumbai (Maharashtra), the state government has made rainwater harvesting mandatory for all buildings that are being constructed on plots that are more than 1,000 m2 in size.

In New Delhi since June 2001, the Ministry of Urban Affairs and Poverty Alleviation has made rainwater harvesting mandatory in all new building construction with a roof area of over 100 m2 and in all plots with an area of more than 1000 m2 that are being developed. The Central Ground Water Authority (CGWA) has made the implementation of rainwater harvesting mandatory in all institutions and residential colonies in notified areas such as South and south-west Delhi and adjoining areas like Faridabad, Gurugram, and Ghaziabad.

However, it has been observed that there is no uniformity with respect to the rainwater harvesting system approved by Central Ground Water Authority / Delhi Jal Board (DJB). So, National Green Tribunal (NGT) had directed the CGWA, DJB, and the Delhi Pollution Control Committee to convene a meeting to fix common and uniform procedure and also for prescribing a format as well as proper design for the rainwater harvesting system to be installed by the hotels, hospitals and malls in and around Delhi.

In 2007, Port Blair Municipal Council (PBMC), Andaman & Nicobar Islands, directed all the persons related and concerned with construction work to provide a proper tank for the collection of rainwater to be utilized for various domestic purposes other than drinking. As per the existing building by-laws 1999, the slab or roof of the building would have to be constructed with a proper pipe or gutter for collection of rainwater, which would benefited the residents of the municipal area during water crisis. The PBMC advised all the owners of buildings in the municipal area to abide and comply with the provisions within four months. And failing to comply so will be punishable by the Council.

In Rajasthan, the state government has made rainwater harvesting mandatory for all public and commercial establishments and all properties in plots covering more than 500 m2 in urban areas.

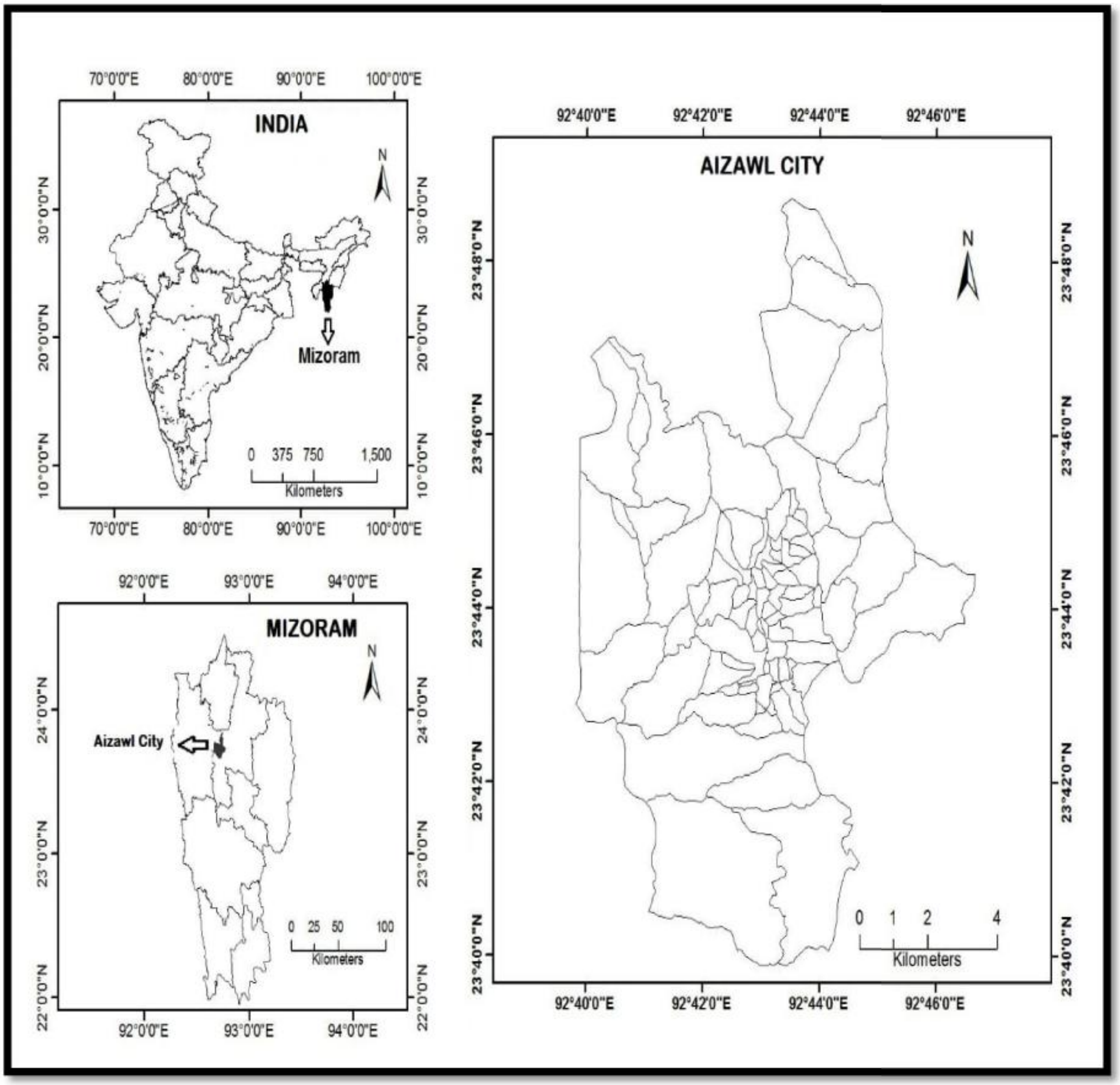
1.7. Study Area

The study area is Aizawl city, Mizoram, the capital city of the state, which is located north of the tropic of Cancer in the northern part of Mizoram. It is situated on a ridge of 1132 meters (3715 ft) above sea level, with the Tlawng river valley to its west and the Tuirial river valley to its east. The geographical coordinates of the city are 23°43´38´´ N and 92°43´04´´ E. Its total area is 457 km2 with a total population of 293,416 as per 2011 census. And the density of the population is 234 persons per square kilometre. The city is one of the most urbanised cities even in India.

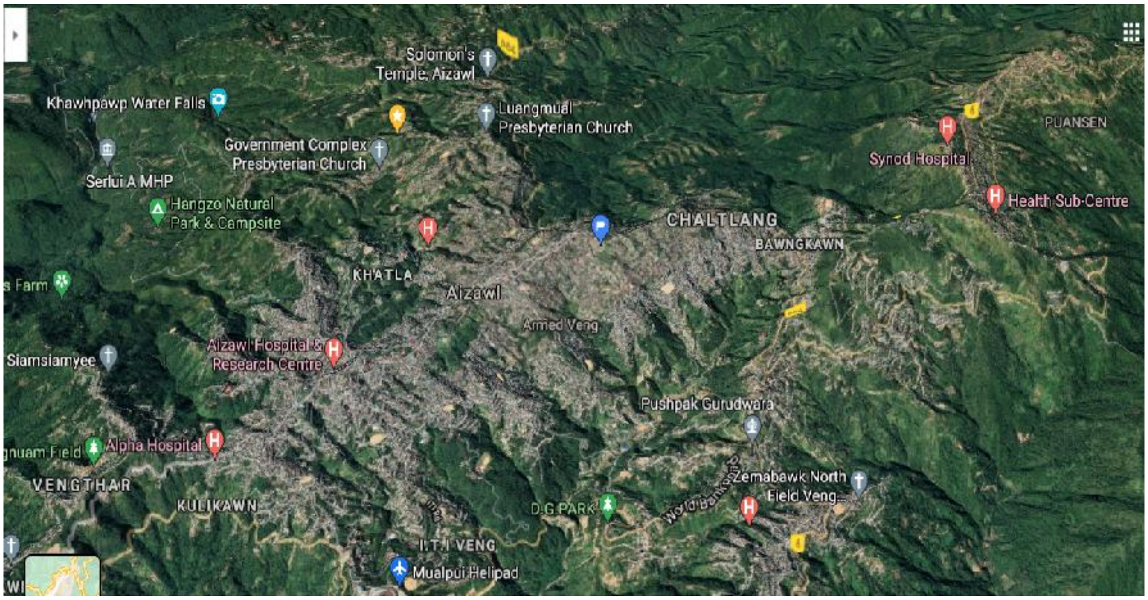
In detail, within the study area, Aizawl city, also, the research gives major thrust on 19 different selected localities from 19 Aizawl Municipal Corporation (AMC) wards. Out of the total 19 AMC wards within the city, 19 local councils are selected from each AMC wards for household to household field survey so as to cover the study area in its entirety. As shown in the following map: 1.1, the study area is Aizawl city and it includes the area covered by Aizawl Municipal Corporation.

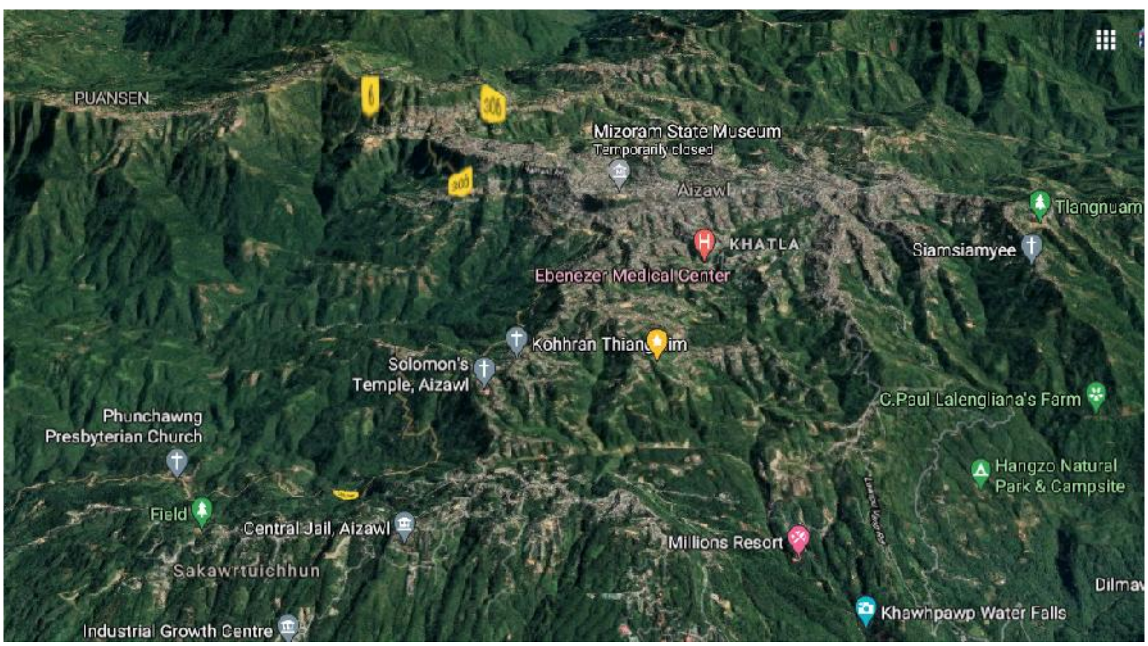
Map: 1.1

Map of the Study Area.



Google view of Aizawl city.





CHAPTER-II

METHODOLOGY

This chapter stresses upon the method of the present research, how it has been conducted, what types of methods and procedures are followed to examine rainwater harvesting potentials and practices in Aizawl city, Mizoram. It is discussed here in this chapter how sample has been designed, how data have been collected and how questionnaire has been prepared and employed. Methodology is one of the most important deciding factors that determines the efficacy and reliability of the research.

2.1. Sample Design

The scarcity of water in Aizawl city is the perception of the city dwellers during the dry season almost every year for about the past several years. Thus, in order to get the ground reality of the problem in the city, household to household field survey is conducted using questionnaire on water connection status, sources of water, frequency of water supply, etc. in the city. These household's water related conditions are considered to be the real images of the ground reality.

Firstly, Aizawl city comes under the maintenance and jurisdiction of Aizawl Municipal Corporation (AMC). Aizawl city is categorized into 19 AMC wards and each ward consists of 3-7 localities. From all the 19 AMC wards, one locality each is selected for field survey which means that 19 localities are selected for field survey. Basically, there are 83 localities in the city out of which 19 localities (22.89%) are firstly selected for household level field survey. And the selection of locality from each ward is based on the number of households in the locality. It is selected in such a way that it covers the whole locality as well as the whole Aizawl city comprehensively and impartially.

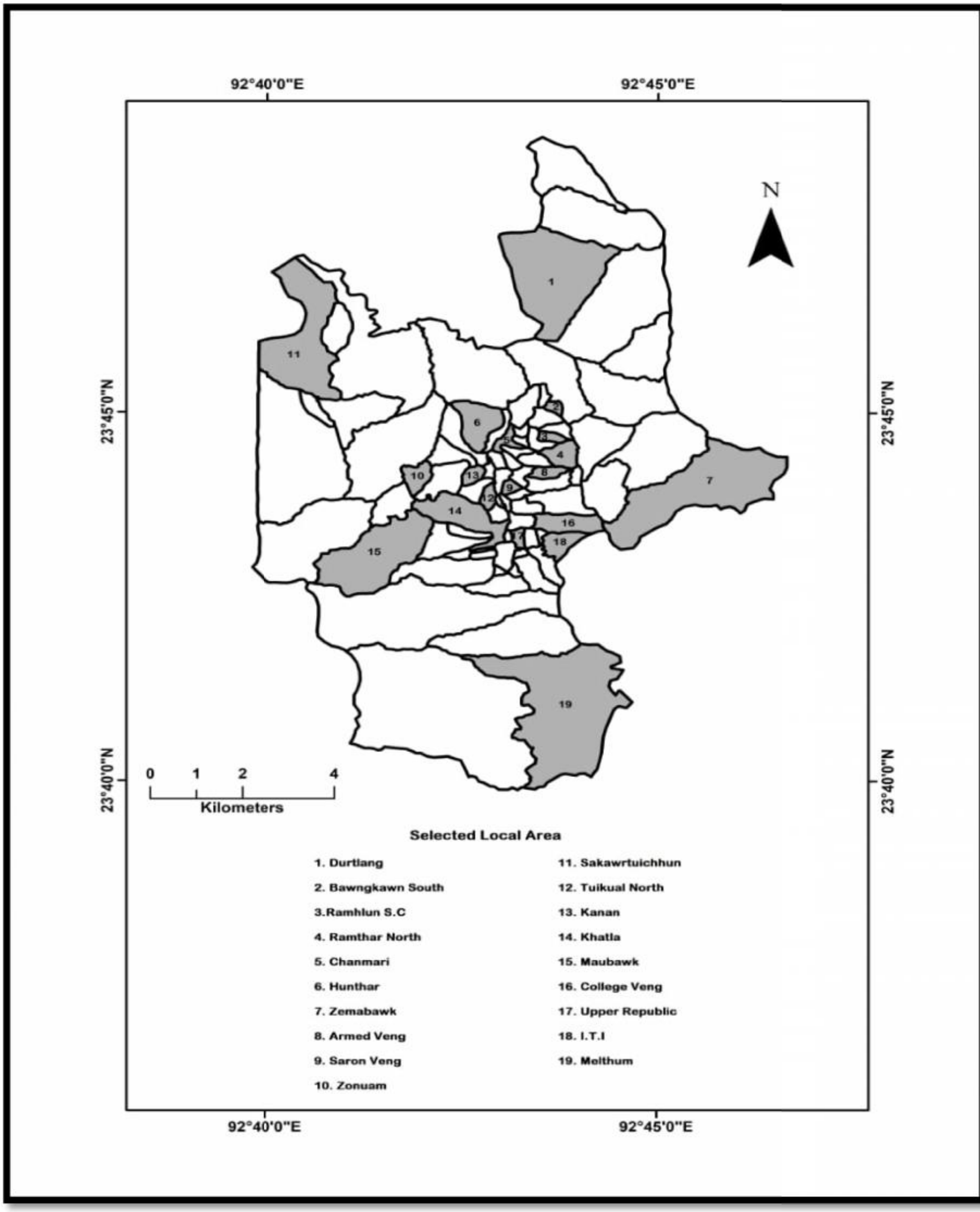
The following table-2.1 shows the names of selected localities and total number of households in each locality.

Table-2.1.	Selected localities with total number of Households	
Sl. No.	**Localities**	**Total Households**
1	Durtlang	812
2	Bawngkawn South	468
3	Ramhlun S.C.	210
4	Ramthar North	375
5	Chanmari	1262
6	Hunthar	564
7	Zemabawk	2022
8	Armed Veng	833
9	Saron	675
10	Zonuam	556
11	Sakawrtuichhun	284
12	Tuikual North	983
13	Kanan	713
14	Khatla	1491
15	Maubawk	815
16	College	611
17	Upper Republic	544
18	ITI	899
19	Melthum	241
Total	**19**	**14358**
Source: Household Census of India 2011		

The following map of the study area shows the spatial location of 19 different localities selected for field survey in the city. The numbers 1-19 represent the selected

19 localities and the names of the localities are indicated against each numbers below the map.

Map: 2.1



2.2. Method on selection of number of samples from selected localities

The total household from 19 selected localities from each AMC ward is 14,358 households or families. Firstly, 10% of the samples (1,435 families or samples) are selected for household level field survey. But, as per the census of India 2011, only the number of household is listed for each locality in Aizawl city instead of the number of houses or buildings due to which number of building is not selected. So, 10% of the sample is further divided by 2 because most of the buildings or houses in the city are occupied by 2 or 3 families or tenants. Subsequently, the final number of samples for household level field survey comes to 722 families.

Similarly, from each locality, 10 % of the households are selected for the household level surveys. And 10% is further divided by 2 because in Aizawl city most of the houses or buildings are occupied by 2 or 3 families. In certain cases, some houses are occupied by 5 or more households and some household are having separate water connection while in some cases there are no separate water connections for 3 or 4 families living under the same one roof. Thus, dividing 10% of the sample by 2 is justified as shown in the below table.

Table-2.2	**Method on selection of number of samples from selected localities (2011 census)**			
Sl. No.	**Name of localities**	**Total HH**	**Sample size (10% from HH)**	**10% divided by 2. (Number of HH selected)**
1	Kanan	713	71	36
2	Tuikual North	983	98	49
3	Bawngkawn South	468	47	25
4	Chanmari	1262	126	63
5	Armed Veng	833	83	43
6	College	611	61	31
7	Durtlang	812	81	41

8	Hunthar	564	56	28
9	I.T.I	899	90	45
10	Khatla	1491	149	75
11	Ramhlun S.C	210	21	11
12	Ramthar north	375	38	19
13	Zemabawk	2022	202	101
14	Saron	675	68	34
15	Zonuam	556	56	28
16	Sakawrtuichhun	284	28	14
17	Maubawk	815	82	41
18	Upper republic	544	54	27
19	Melthum	241	24	12
	Total	**14,358**	**1,435**	**722**

As shown above, the total household from the selected localities is 14,358 and the number of household selected for field survey is 722 which are only 5% of the sample. This seems to be quite less. However, it is justified from the data of 2020-2021 as depicted in the following table.

Table-2.3	**Method on selection of number of samples from selected localities (2020-21 Data)**							
Sl. No.	**Name of localities**	**Total HH (as on 2020)**	**Sample size (10% from THH)**	**10% divided by 2. or Number of HH Selected**	**Total Building (TB) as on 2021**	**% of TB divided by NHHS**	**THH divided by TB or No. of HH in 1 building**	**Actual size of sample in %**
1	Kanan	1018	101	51	352	6.9%	2.89	**10.35%**
2	Tuikual North	1204	120	60	491	8.18%	2.45	8.18%

3	Bawngkawn South	400	40	20	220	11%	1.81	11%
4	Chanmari	1260	126	63	597	9.47%	2.11	9.47%
5	Armed Veng	1010	101	51	431	8.45%	2.34	8.45%
6	College	413	41	21	391	18.61%	1.05	**9.53%**
7	Durtlang	906	90	45	766	17.02%	1.18	**8.51%**
8	Hunthar	786	78	39	443	11.35%	1.77	11.35%
9	I.T.I	1326	132	66	700	10.60%	1.89	10.60%
10	Khatla	1721	172	86	433	5.03%	3.97	**10.06%**
11	Ramhlun S.C	1325	132	66	162	2.45%	8.17	**9.52%**
12	Ramthar North	515	51	26	286	11%	1.8	11%
13	Zemabawk	2300	230	115	1525	13.26%	1.5	13.26%
14	Saron	721	72	36	252	7%	2.86	**10.5%**
15	Zonuam	785	78	39	464	11.89%	1.69	11.89%
16	Sakawrtuichhun	538	53	27	351	13%	1.53	13%
17	Maubawk	1252	125	63	621	9.85%	2.01	9.85%
18	Upper Republic	650	65	33	266	7.38%	2.44	7.38%
19	Melthum	294	29	15	275	18.33%	1.06	**9.48%**
Total		**18,424**	**1,836**	**922**	**9,026**			**Av=10.18%**

As shown in the above table as per 2020-2021 data from Aizawl Municipal Corporation (AMC), the number of household in the selected locality has increased to 18,424 and the number of selected locality for field survey has to be 922 as per the current methodology. And 922 divided by 18,424 is only 5% of the sample. At the same time, the number of building has also increased to 9,026. Since only one sample from one building is taken, the total sample (922 households) means 922 buildings. Thus, dividing 9,026 buildings by 922 buildings becomes 10%. The methodology is primarily based on the number of buildings instead of number of households, because the study focuses particularly on rainwater harvesting from rooftop.

Even though the above data is of 2020-2021, it is assumed that this kind of pattern (number of building and number of household in one building) has been existed in the city for the past several years. Since data on number of building is not available for the year 2011, it is assumed that the data from 2011 census on number of household and number of building will be in a similar pattern with data from 2020-2021.

2.3. Questionnaire

Household questionnaire is prepared and survey is being conducted from 19 localities or wards of Aizawl Municipal Corporation. At least one locality each is selected for conducting field survey so as to cover all the 19 wards of the city. This questionnaire mainly tries to assess rooftop water harvesting practice and potentials, opinions and observations of the people as well as problems relating to water.

It also tries to analyze the different obstacles and hurdles on water issues being confronted by the city dwellers such as water tank, PHE water connection, reasons for water insufficiency, etc. Other composition of the questionnaire consist like frequency of water supply, sources of water, type of roof, annual expenditure on water, etc. Using this questionnaire, household survey is conducted from 722 samples or households in Aizawl city. Apart from secondary data, the primary data obtained through field survey is one of the parameter used for making the decision on water issues in Aizawl city.

2.4. Selection of households for field survey

Simple Purposive method is used for selection of the households for field survey. But, when only 10% of the sample is selected for field survey, there is a chance to easily complete the survey from only one portion of the locality by selecting a group of households from a particular part of the locality. However, this survey is done in such a way that it covers the whole area. North, South, East and West parts of the locality are covered so as to make the survey inclusive and genuine. Generally during the field survey, households are selected on 3-5 buildings-apart-bases to make the data more efficient and comprehensive.

2.5. Methods of Data Collection

There are two ways of data collection in this research which are primary data collection and secondary data collection which are explained below.

2.5.1. Primary Data

Primary data are collected from field survey through household questionnaire that was prepared. The first method involved the collection of rainfall data using rain gauges such as digital rain gauge and manual rain gauge. For this, rain gauges were set up at different location within Aizawl city base on – (1) elevation of the city, such as low, medium and high elevations and (2) space or spatial, such as north, south, and east and west parts of the city to cover potential variation of rainfall within the city.

For rainwater quality, only potential of hydrogen (pH) is assessed assuming that rainfall is pure especially in Aizawl city where there is no much pollution due to lack of industries and other polluters. Thus, roof rainwater is collected from different types of roof, such as G.I sheet, cement etc and the quality of rainwater is tested using *pH Meter80* portable device to compare water quality variations. Rainwater quality is tested at least once each a month to compare monthly quality. Apart from roof type based, direct rainfall quality is also tested.

Selection of sites for collection of rain water quality is based on the assumption that some sites/localities might be more polluted than other areas. For example main city areas like Zarkawt, Chanmari and main market areas might be more polluted than localities like Tlangnuam, Durtlang and ITI situated in the outer fringes of the city.

Moreover, household questionnaire is prepared and survey is being conducted from 19 wards of Aizawl Municipality. At least one locality each is selected for conducting field survey so as to cover all the 19 wards of the city. From each locality 10 % houses are selected for household survey. These questionnaires mainly tried to assess roof water harvesting practice and potential, opinion of the people and their observation as well as problems relating to water.

The main compositions of the questionnaire are size of households, types of roof, size of the buildings, quantity of household's daily water consumption, PHE water connection status, frequency of water supply from PHE, sources of water, capacity of water tank, families practicing or not practicing rooftop water harvesting, household buying or not buying water from commercial sources, etc. Primary data on these issues are collected from field survey.

2.5.2. Secondary Data

Secondary data are collected through published and unpublished records of various agencies like Department of Economics and Statistics, Government of Mizoram, Department of Agriculture, govt. of Mizoram, Department of Public Health Engineering, Directorate of Science and technology, Department of Forest, Pushpak, Thuampui, Central Water Commission, Mizoram University, etc. These data are mainly related with pattern of rainfall and deforestation, types of roof, materials of roof, number of households, number of government's buildings, etc.

Data from NGO's and local communities are also collected. Participatory observation is adopted to collect village level information on rainwater harvesting and number of family practicing rainwater harvesting. Opinions of the local residents on various rainwater harvesting system related issues are also obtained from field survey.

CHAPTER-III

WATER SUPPLY SCENARIO IN AIZAWL CITY

3.1. Introduction

In order to implement the practices of RWH in Aizawl city, the water condition of the city needs to be understood firstly. So, this chapter reveals the ground reality of water conditions in Aizawl city which is analyzed under different sub-headings. This section covers the entire scenario and condition of water supply in Aizawl city under the sub-headings of (1) Problems and vulnerability of Water in Aizawl city, (2) Greater Aizawl Water Supply Schemes (GAWSS) Phases – I, II & III, (3) Household's PHE water connection status in Aizawl city, (4) Spatial distribution of PHED zonal tanks in Aizawl city and, (5) Daily water supply scenario in Aizawl city during lean seasons.

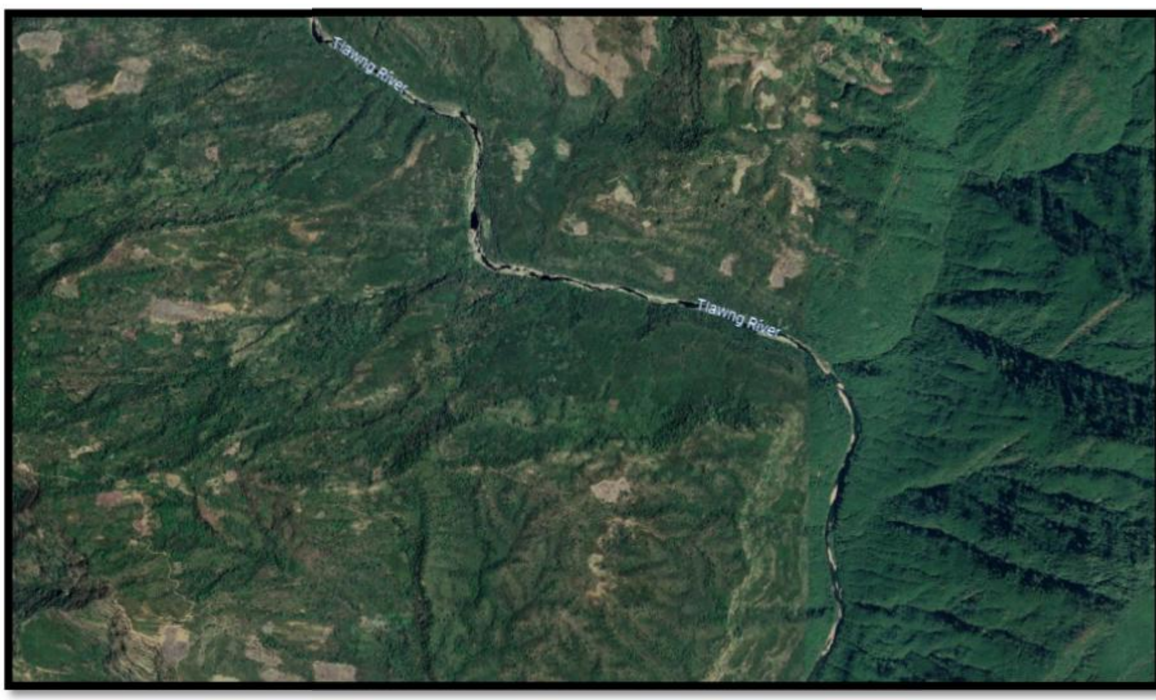
Almost every year during the dry season there is an acute shortage of water in the city. Even though the city possesses two phases of GAWSS, the water supply seems to be insufficient for the citizens. The reasons behind this are being revealed here in this chapter by analyzing the household's water connection status of the city, spatial location of water zonal tanks, and the frequency and quantity of water supply from the PHE department.

Generally, in Mizoram, the main sources of water are surface water, groundwater and rainwater out of which surface water and rainwater could be the most utilized waters for various uses in the state. Due to a variety of reasons, groundwater has not yet been tapped in the state as compared to the formers. As such, water from rivers is the main source for different domestic and agricultural uses in the region.

The major rivers in Mizoram are Tlawng, Chhimtuipui and Khawthlangtuipui rivers. The main source of water in Aizawl city is Tlawng and Serlui rivers as of now. It is also being used by people in many villages in other districts of the state. The Tlawng river originates at an elevation of 4587 feet in Zopui hill in Lunglei district and it flows for a distance of 234 km. The important tributaries are Tut, Teirei and Serlui rivers.

Apparently Tlawng river water is not sufficient enough throughout the year for Aizawl city dwellers. Sometimes, during the dry season, there is no sufficient water in the Tlawng river to feed onto, even though technological up-gradation of water pumping machines takes place several times. There used to be certain problems in pumping the water when the river channel is flooded during monsoon. Besides, most of the people residing around the periphery of the Tlawng river in Aizawl area are mainly dependent upon agriculture, which further needs clearing of the forest due to the practice of shifting cultivation which could decrease the volume of water in the river.

Aerial or Google view of Tlawng river near Aizawl city.



3.2. Problems and vulnerability of water in Aizawl city

Do water crisis and scarcity really happens and exists in Aizawl city? The ground reality could be found and seen from the upcoming analysis in this chapter. It is a natural phenomenon that the quality and quantity of water source become decrease day by day due to deforestation, urbanization and other human activities in and around rivers. In the context of Aizawl, the main source of water in the city is Tlawng river, which is now insufficient for the city. Tlawng river originates at an elevation of 4587 feet in Zopui hill in Lunglei district and it flows for a distance of 234 km or 186 km (straight line). The important tributaries are Tut, Teirei and Serlui rivers.

Pic: Tlawng river near Sairang locality during February

The Tlawng river water supply system used to confront three major problems: (1) one is insufficient water in the Tlawng river to pump up the water to the main reservoir at Tuikhuahtlang, (2) the problem of siltation during monsoon season due to flood of the river that cause lots of filtration problem and other man-made damages at the riverbank, (3) Further, most of the people residing around the periphery of the Tlawng river practice shifting cultivation by clearing forest resources, which further aggravates the problems as one need to cut down the riverside forest as well as for settlement due to the rapid increase of urbanization. If the current rate of deforestation of the riverside forest goes on with whatsoever the reasons may be, the magnitude of water scarcity for Aizawl city in the coming 10-20 years is quite disturbing.

(Pic: Tlawng river near Sairang locality during February)

According to the household's data obtained from the field survey, many of the residents in Aizawl city are in short supply of water and water crisis is the ground reality in the city especially during the dry season of the year. Hence, a strategy to bridge the huge gap between water supply and water demand is an urgent necessity to be addressed with concerted efforts by various stakeholders, whether governmental, non-governmental agencies and general public at large. The present research, therefore, tries to uncover the bleak reality of water supply condition in Aizawl city with a hope to give more awareness and encourage stakeholders to come forward and rescue the lifeline of Aizawl city immediately.

3.3. Greater Aizawl Water Supply Schemes (GAWSS) Phases – I, II & III

The Greater Aizawl Water Supply Scheme (GAWSS) is a state government's initiative which is implemented to supply sufficient water to the general public of Aizawl city in particular and Aizawl area in general. There are two phases of GAWSS under the Department of Public Health Engineering, Government of Mizoram. The third phase is still in progress which is expected to be completed soon. As of now, phase-I & II are the main sources of water in the city.

Firstly, water is being recycled and refined at Tlawng river refinery centre, after which the clean water is again pump to the main reservoir at Tuikhuahtlang locality located at around an altitude of 1300m in the heart of Aizawl city from where water for all the localities within the city are distributed with gravity through pipelines. There are different 55 zonal tanks spatially located in different localities. Usually, these zonal tanks receive water from the main reservoir on a daily basis. And then, water is again redistributed from these zonal tanks to the general public. The details of phases I & II of GAWSS are given in the following table.

Main water reservoir of Aizawl city located at Tuikhuahtlang locality from where water is being distributed to 83 different PHE zonal tanks in the city.

Table-3.1	Profile of Greater Aizawl Water Supply Scheme (GAWSS)	
GAWSS	**Phase-I**	**Phase-II**
Location	Aizawl	Aizawl
Nature	Pumping	Pumping
Initial stage	57,890 ltrs	90,453 ltrs
Intermediate stage	74,493 ltrs	1,95,800 ltrs
Ultimate stage	80,000 ltrs	3,10,000 ltrs
Total quantity of water produced		
Initial stage	7.82 mld	7.05 mld
Intermediate stage	10.05 mld	15.27 mld
Ultimate stage	***10.80 mld***	***24.18 mld***
Rate of supply as per norms	135 lpcd	78 lpcd
Present rate of supply	***30 lpcd***	***45 lpcd***
Source	Tlawng	Tlawng
Estimate cost	Rs. 18,00,00,000	Rs. 1,13,47,00,000
Per capita cost	Rs.2,250	Rs. 3,660
Year of commencement	1984	1999

Year of completion	1988	N/A
Funding pattern	100% state	75:25 Doner & State
Agency	PHE	PHE
Source: www.phedmizoram.in, May, 2021		

The data obtained from the PHE department's website in May 2021 reveals that the capacity of water pumping during the peak period is 10.80 million litres per day for GAWSS Phase-I and 24.18 million litres per day for GAWSS Phase-II respectively. The work of GAWSS Phase-III is still in progress due to which data is not available. According to the Deputy Chief Minister of the state during Assembly Session held during March 2021, GAWSS Phase-III will have the capacity of pumping 37 million litres of water per day, which is going to be more than the previous two phases of 34.98 mld. As shown in the above table-3.1 the present rate of water supply from phase-I & II is 30 and 45 litres per capita per day respectively which is now not sufficient for the Aizawl city, especially during the lean season when the full capacity of the pumping is not feasible due to insufficient water in the Tlawng river.

3.4. Household's water connection status in Aizawl city

As mentioned earlier Public Health Engineering Department (PHED) is the nodal department to deal with water supply and distribution in Aizawl city. The present research collects information from 722 households within the city about water supply connection provided by PHED in the city, sources of water supply and frequency of water supply in the city.

Table-3.2	**Household's water connection status in Aizawl city**		
Particulars		**Household**	**Percentage**
Connection		659	91.27%
No Connection		63	8.72%
Water	Once a week	574	79.50%

supply frequency	Twice a week	9	1.2%
	Once in two weeks	56	7.75%
	Thrice a month	20	2.77%
Source of drinking water	Only PHE	539	74.65%
	Only Public well	31	4.29%
	PHE & Public well	8	1.10%
	PHE & Tanker	14	1.93%
	Rainwater & PHE	94	13.01%
	Rainwater & tanker	8	1.10%
	Only rainwater	1	0.13%
	Public well & rainwater	14	1.93%
	BPL & PHE	3	0.41%
	BPL* & rain water	1	0.13%
	Only BPL	4	0.55%
	PHE & Sihtui	1	0.13%
	Sihtui**	4	0.55%
Total household		722	
Source: Field survey 2018			
*Below poverty line; **Spring; "Potentials and practices of rainwater harvesting in Aizawl city"			

Table-3.2 uncovered that out of 722 samples, 659 (91.27%) possess PHE water connection while 63 (8.72%) of the samples do not possess the same which is quite unfortunate as Aizawl is the capital city of Mizoram where living standard is comparatively higher than other towns and villages within Mizoram. It is also noticed that as many as 574 (79.50%) household receives water supply once in a week while just 9 (1.2%) of them receives twice in a week and 56 (7.75%) household receives once in two weeks which could be the reasons for water deficiency for such households and 2.77% of the samples receive water thrice in a month.

The source of water in the city also varies from family to family. As many as 539 (74.65%) of them rely fully on PHE water supply, 31 (4.29%) of them rely only on Public well which could be a menace to them; just 8 (1.10%) rely on PHE and Public well; 14 (1.93%) households rely on PHE and Tanker; 94 (13.01%) of them rely on Rainwater and PHE; 8 (1.10%) families rely on Rainwater and Tanker; merely 1 (0.13%) family relies solely on rainwater; and 1.93% of them rely on Public well and rainwater.

It could be asserted from the above data that about 25% of the samples do not get sufficient water from PHE which necessitates them to rely on some other sources of water such as public well, commercial water, BPL, spring (Sihtui) etc. as well. BPL is a kind of water connection in which a private household possesses a good source of water and distribute it to different families with lower cost. It is also very unfortunate to learn that there are some families who still rely only on spring nearby.

3.5. Spatial distribution of PHED zonal tanks in Aizawl city

In Aizawl city, there are 55 zonal tanks spatially distributed in different localities from which water is being supplied to the general public. These zonal tanks receive water from the main reservoir in Tuikhuahtlang on a daily basis. And out of 83 localities within Aizawl Municipal Corporation, there are only 55 zonal tanks which seem insufficient when looking from a spatial perspective. This means that one zonal tank is shared by around 1.5 localities each in the AMC area.

These zonal tanks are very crucial as they are the reservoir of water for all the localities in the city. The capacities of these tanks differ from locality to locality. The capacity is measured according to the depth of the tank only as data on the length and breadth of the tanks is not available. The deepest zonal tanks are 20 feet each located in 7th Day Tlang and Laipuitlang while the shallowest tank is 5.6 feet located in Falkawn (MCON). As a whole, the average depth of these zonal tanks is 12.76 feet. These zonal tanks are highlighted in the following table-3.3.

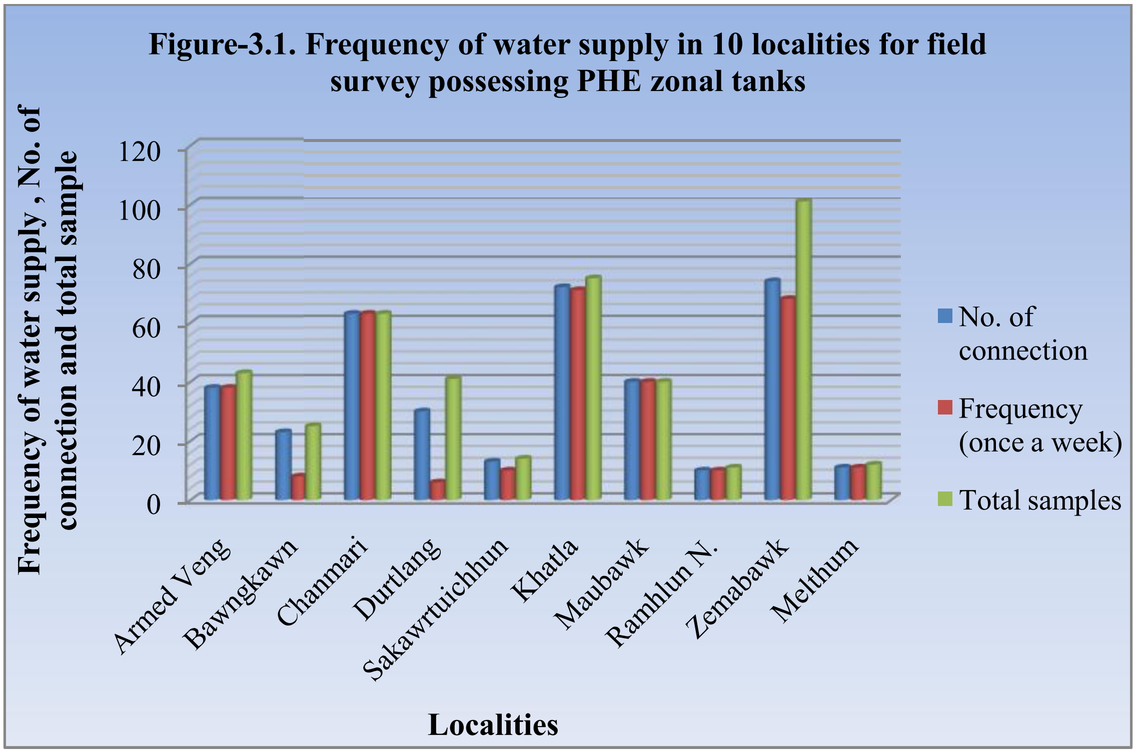
Table-3.3	Names and spatial location of 55 PHED zonal tanks in Aizawl city				
Sl.No	**Name of zonal tank**	**S.No**	**Name of zonal tank**	**Sl.No**	**Name of zonal tank**
1	7th Day Tlang	20	Laipuitlang	39	Melthum
2	Armed Veng	21	Luangmual	40	Hualngohmun
3	Babutlang	22	Maubawk	41	Melriat-1 (Circular)
4	Bawngkawn	23	Lawipu BSUP	42	Melriat-2 (Square)
5	Bethlehem	24	MC Hill	43	Kelsih
6	Chaltlang	25	Mission Veng	44	Muallungthu (Circular)
7	Chanmari West	26	Mission VT	45	Muallungthu (VC Tanky)
8	Edenthar	27	New Sec Comp.	46	Samtlang
9	Chhinga Veng	28	Ramhlun North	47	North Lungleng
10	D.Vengthar (AR)	29	Thakthing Tlang	48	Lungleng
11	D.Vengthar (Direct)	30	Mualpui	49	Falkawn
12	Durtlang	31	TKT-1	50	Falkawn (ZMC)
13	Govt. Complex	32	Zemsen	51	Falkawn (ZMC)
14	Central Jail	33	TKT-2	52	Falkawn (MCON)
15	Tanhril	34	Tlangnuam	53	Falkawn (MCON)
16	Tuivamit	35	Zemabawk D	54	Falkawn (Dr.Quarter)
17	Sakawrtuichhun	36	Zemabawk TB	55	Falkawn (Dr.Quarter)
18	Rangvamual	37	Zemabawk TV		
19	Khatla Tlang-1	38	Hlimen		
Source: Public Health Engineering Department, Government of Mizoram.					

The above table-3.3 highlights the localities possessing PHE zonal water tanks in the city. Out of these 55 zonal tank possessing localities, there are 10 localities selected for field survey. The number of PHE water connections, frequency of water supply and the total number of samples in these 10 localities selected for field survey is elaborated and interpreted as given below in figure-3.1.

The below picture is one of the 83 PHE zonal tanks located in Laipuitlang locality.

PHE Zonal tanks located in Ramhlun Venglai and Sakawrtuichhun localities

The following diagram shows the frequency (once a week) of water supply in 10 localities where PHE zonal tanks are located in the areas. Water supply once every week is the most regular and frequent pattern in the city. However, some localities and households receive water supply once in two weeks or three times a month, etc.



As shown in the above figure-3.1, there are 10 localities out of 19 localities selected for the field survey, possessing PHE zonal tanks. These 10 localities, except Bawngkawn and Durtlang localities, have a very regular water supply from PHE as evident from the above data. Out of 43 samples in Armed Veng locality, 38 households have water connection and all of them receive water once every week. Meanwhile, Bawngkawn and Durtlang localities have only 8 and 6 households respectively, who receive PHE water supply once a week out of 25 and 41 total families respectively. As per the above data, out of the total households possessing PHE water connection, apart from Bawngkawn and Durtlang localities, all the other localities frequency of PHE water supply range from 77%-100%, once in a week.

Table-3.4	Locality-wise Frequency of Water Supply in Aizawl city		
Sl No	**Locality**	**Frequency (Once a week) in number & percentage (%)**	**Total sample**
1	**Armed Veng**	38 (88.37%)	43
2	**Bawngkawn South**	8 (32%)	25
3	**Chanmari**	63 (100%)	63
4	**College Veng**	27 (87.09%)	31
5	**Durtlang**	6 (14.63%)	41
6	**Hunthar**	15 (53.57%)	28
7	**I.T.I**	45 (100%)	45
8	**Kanan**	36 (100%)	36
9	**Khatla**	71 (94.66%)	75
10	**Maubawk**	40 (100%)	40
11	**Melthum**	11 (91.66%)	12
12	**Ramhlun S.C**	10 (90.9%)	11
13	**Ramthar North**	18 (94.73%)	19
14	**Sakawrtuichhun**	10 (71.42%)	14
15	**Saron**	34 (100%)	34
16	**Tuikual North**	44 (89.79%)	49
17	**Upper Republic**	25 (92.59%)	27
18	**Zemabawk**	68 (67.32%)	101
19	**Zonuam**	5 (17.85%)	28
	Total locality = 19	**Average Frequency = 79.50%**	**722**
Source: Public Health Engineering Department, Government of Mizoram.			

Apparently, there exists a perception that localities possessing zonal tanks receive water supply more frequently and regularly than localities not having the same. But the study found that such perception is not the actual case. As evident from the above table-3.4, the localities with green fonts signify the localities possessing PHE zonal tanks. Accordingly, even though Bawngkawn South and Durtlang localities possess zonal tanks, only 32% and 14.63% of the households receive water supply once a week respectively. At the same time, some other localities not possessing PHE zonal tanks receive water supply very regularly like I.T.I and Kanan localities as shown in the above table.

Thus, it could be inferred that possession of PHE zonal tanks by any localities does not have any effect on the frequency of water supply, especially during the lean season; rather it seems that is it more of the spatial locational effects of the locality.

3.6. PHE daily water supply scenario in Aizawl city during lean season (January & February, 2021)

This section focuses on the most recent water supply condition of Aizawl city, especially during the lean season when there is not much water available in the Tlawng river. As shown in table-3.5 and table-3.6, water is being pumped from the Tlawng river to Tuikhuahtlang reservoir every day. It is learnt that the water pumped every day is distributed to zonal tanks on a daily basis. And apart from other columns in table-3.5, **70% efficiency** signifies that the total volume of water pumped from the Tlawng river through phase-I & II has some errors sometimes due to obstacles and problems in water pipelines, water pumping machine, power, etc, which further means that the total amount of water pumped through phase-I & II is slightly incorrect or less. So, it is assumed that 70% of the total water pumped actually reaches the main reservoir. Thus, even though the total water pumped from phase-I and II for the month of January 2021 is 907.93 million litres, the actual or 70% efficiency total amount is 635.55 million litres as shown in table-3.5. Another column ***Zonal Tank Water Received/Released*** is also the main indicator of the actual amount of water received, or distributed, because this is the point or water tank from where the distribution of water to the public starts. The actual amount of water distributed to 55 zonal tanks from the main reservoir for the month of January 2021 is 538.65 million litres.

The performance of the water pump house of GAWSS phase-I&II have been reflected in this table-3.5 and 3.6. It is revealed that the efficiency level of water pumping machine located at Tlawng river bank is down to 70%, which apparently shows that we could not get the full potential of water that is available in the Tlawng river.

Table-3.5	**Daily Water Pumping Report & Water Released (in million litres), January 2021**					
Date	**Phase-I**	**Phase-II**	**Total**	**70% Efficiency**	**Zonal Tank Water Received/Released**	**Difference**
01-01-2021	10.40	18.12	28.52	19.96	5.07	14.89
02-01-2021	9.81	11.68	21.50	15.05	15.89	-0.85
03-01-2021	11.42	19.23	30.65	21.45	12.45	9.01
04-01-2021	11.36	19.23	30.59	21.41	22.70	-1.28
05-01-2021	11.51	19.23	30.74	21.52	21.27	0.25
06-01-2021	11.54	19.23	30.77	21.54	20.26	1.28
07-01-2021	11.57	19.23	30.80	21.56	20.43	1.13
08-01-2021	11.63	19.23	30.86	21.60	19.69	1.91
09-01-2021	11.04	17.37	28.41	19.89	19.54	0.35
10-01-2021	11.84	19.23	31.07	21.75	13.85	7.90
11-01-2021	10.13	19.23	29.36	20.55	22.61	-2.06
12-01-2021	7.33	19.23	26.56	18.59	17.57	1.02
13-01-2021	9.84	19.23	29.07	20.35	18.15	2.20
14-01-2021	10.29	19.13	29.42	20.59	16.85	3.74
15-01-2021	10.08	19.23	29.31	20.52	16.86	3.66
16-01-2021	10.11	19.23	29.34	20.54	16.10	4.43
17-01-2021	11.01	19.23	30.24	21.17	12.13	9.04
18-01-2021	10.57	19.82	30.39	21.28	21.59	-0.31
19-01-2021	9.89	19.23	29.12	20.39	20.15	0.24
20-01-2021	10.26	20.18	30.44	21.31	19.21	2.10
21-01-2021	10.68	16.18	26.86	18.80	17.50	1.29
22-01-2021	9.87	19.23	29.10	20.37	18.91	1.46

23-01-2021	9.46	19.23	28.69	20.08	20.14	-0.06
24-01-2021	10.97	19.23	30.20	21.14	10.49	10.65
25-01-2021	9.72	19.60	29.32	20.52	22.36	-1.84
26-01-2021	9.66	20.05	29.71	20.80	10.27	10.53
27-01-2021	9.72	19.12	28.84	20.19	22.63	-2.44
28-01-2021	10.19	19.23	29.42	20.59	17.61	2.99
29-01-2021	10.36	19.82	30.18	21.13	16.33	4.79
30-01-2021	9.71	19.23	28.94	20.26	19.51	0.75
31-01-2021	10.30	19.23	29.53	20.67	10.54	10.13
Total	**322.27**	**585.67**	**907.93**	**635.55**	**538.65**	**96.91**
Daily Average	**10.40**	**18.89**	**29.29**	**20.50**	**17.38**	**3.13**
Source: Public Health Engineering Department, Government of Mizoram, Tuikhuahtlang						

The daily average water pumping from GAWSS phase-I and II are 10.40 million litres per day and 18.89 million litres per day respectively in the month of January 2021. Together Aizawl city received 29.29 million litres per day during the lean season of January 2021. At the same time, the total amount of water that actually reached the main reservoir in Tuikhuahtlang is calculated as per 70% efficiency, which is 20.50 million litres because the total pumping capacity from phase-I & II is not the exact water quantity that reaches the main reservoir. Subsequently, what is even more important is the *actual daily average amount of water received by zonal tanks which is 17.38 million litres* because this is the point from where this amount of water is redistributed to the general public.

Table-3.6	**Daily Water Pumping Report & Water Released (in million litres), February 2021**					
Date	**Phase-I**	**Phase-II**	**Total**	**70% Efficiency**	**Zonal Tank Water Received/Released**	**Difference**
01-02-2021	10.17	19.23	29.41	20.58	23.17	-2.59
02-02-2021	9.95	19.23	29.18	20.43	18.43	2.00

03-02-2021	9.17	19.23	28.41	19.88	18.45	1.43
04-02-2021	9.91	19.23	29.14	20.40	18.57	1.83
05-02-2021	10.82	19.23	30.05	21.03	19.39	1.64
06-02-2021	10.83	19.23	30.06	21.04	20.64	0.40
07-02-2021	9.89	19.00	28.89	20.22	11.46	8.77
08-02-2021	9.86	19.12	28.97	20.28	21.12	-0.84
09-02-2021	10.55	18.40	28.95	20.27	18.42	1.85
10-02-2021	11.38	19.12	30.50	21.35	17.56	3.79
11-02-2021	9.24	16.94	26.18	18.32	19.65	-1.33
12-02-2021	10.29	15.39	25.68	17.98	11.08	6.89
13-02-2021	11.02	19.23	30.25	21.17	20.00	1.18
14-02-2021	11.44	19.23	30.67	21.47	8.94	12.53
15-02-2021	10.38	19.23	29.61	20.73	22.53	-1.81
16-02-2021	11.92	17.51	29.44	20.60	15.15	5.45
17-02-2021	11.20	19.23	30.43	21.30	19.19	2.11
18-02-2021	11.33	19.43	30.76	21.53	19.05	2.48
19-02-2021	11.07	19.23	30.30	21.21	21.07	0.14
20-02-2021	10.91	14.93	25.84	18.08	17.93	0.15
21-02-2021	11.42	19.23	30.66	21.46	7.23	14.23
22-02-2021	11.68	19.23	30.91	21.64	22.77	-1.13
23-02-2021	11.33	16.69	28.02	19.61	18.28	1.34
24-02-2021	11.25	14.92	26.18	18.32	16.51	1.81
25-02-2021	9.78	16.40	26.19	18.33	17.22	1.11
26-02-2021	10.91	15.43	26.34	18.44	15.35	3.09
27-02-2021	10.46	15.63	26.09	18.26	18.36	-0.10
28-02-2021	10.95	12.15	23.10	16.17	5.93	10.24
Total	**299.12**	**501.05**	**800.17**	**560.12**	**483.47**	**76.65**
Daily Average	**10.68**	**17.89**	**28.58**	**20.00**	**17.27**	**2.74**
Sources: Public Health Engineering Department, Government of Mizoram, Tuikhuahtlang						

During February 2021, the amount of water pumped from the Tlawng river has been declining in both GAWSS-I&II. As shown in table-3.6, the water pumped out from the Tlawng river to the main reservoir is 10.68 million litre per day and 17.89 million litre per day in phase-I and phase –II respectively. Together it is 28.58 million litre per day, which means the water pumped in February become lesser compared with the water pumped in January i.e. 29.29 million litre per day.

It is also revealed that the daily average water pumped from phase-I & II, obtained at 28.58 million litres, is getting reduced to 20 million litres as per 70% efficiency. The ultimate correct amount of water received by zonal tanks is lessened to 17.27 million litres. This pattern of water distribution is also seen in table-3.5 for the month of January 2021. Thus, even in laymen's calculation, ***the share of water per head per day during the dry season in Aizawl city*** (during February) could be calculated as follows:

Amount of daily average water received at zonal tanks or distributed to public = 17.27 million litres,

Population of Aizawl city = 2, 93,000 (2011 census) or 3, 78,000 (present or April, 2021),

Therefore, **1,72,70,000 / 3,78,000 = 45.68 litres per head per day**.

Or,

Amount of daily average water as per 70% efficiency or received at main reservoir at Tuikhuahtlang = 20 million litres,

2,00,00,000 / 3,78,000 = 52.91 litres per head per day.

But, it has to be remembered that 17.38 or 17.27 million litres of water is not the constant and regular daily average quantity of water received by zonal tank in the city. Sometimes it is more or even less. Consequently, the amount of daily average water differs from one day to another, and the share of water might be rounded up to 40 – 60 litres per head per day, which is not sufficient for Aizawl city and far below the standard norms for Indian cities with a population of more than 1 lakhs. As per the Bureau of Indian Standards, IS: 1172-1993, a minimum water supply of 200 litres per capita per day (lpcd) should be provided for domestic consumption in cities with full flushing systems.

According to one of the most subscribed printed newspaper in Mizoram, the Vanglaini daily newspaper published on 26th April, 2021, the Deputy Chief Minister is quoted as saying that GAWSS phase-I is capable of pumping 10 million litres of water in a day (MLD) and phase-II is capable of pumping 24.8 million litres in a day during lean season or as on March 2021 which comes to a total of 34.8 million litres in a day (installed capacity).

Then, ***the share of water per head per day according to 34.8 MLD would be,***

Population of Aizawl city = 2, 93,000 (2011 census) or 3, 78,000 (present or April, 2021),

Therefore, **3,48,00,000 / 3,78,000 = 92.06 litres per head per day.** This is yet below Bureau of Indian Standards, IS: 1172-1993.

But it has to be kept in mind that the quantity or volume of water installed capacity seldom actually reached the main reservoir due to power supply, inefficiency of the pumping machine, water pipelines, etc. Thus calculation of the share of water per head per day from the total installed capacity is erroneous. And the calculation of share of water per head per day in this section is based only on the quantity of water during lean season (January and February, 2021).

3.7. Conclusion

The research found out that the Tlawng river, the main source of water supply for Aizawl city is becoming insufficient due to increasing demand of population as well as the declining efficiency of the water pump house as time goes by.

It is also revealed that as many as 91% of families have water connections provided by Public Health Engineering Department (PHED) while 74.65% of the families in Aizawl city is depending solely on the Water supply provided by (PHED).

Regarding the frequency of water supply, it is noticed that as many as 574 (79.50%) household receives water supply once in a week while just 9 (1.2%) of them *receives twice in a week and 56 (7.75%) household receives once in two weeks which could be the reasons for water deficiency for such households and 2.77% of the samples receive water thrice in a month.*

With regards to the quantity of water supply from Tlawng river to Tuikhuahtlang, it has to be kept in mind that the quantity or volume of water installed capacity seldom actually reached the main reservoir due to power supply, the inefficiency of the pumping machine, distribution loss due to leakages of water pipelines, etc. Thus, the calculation of the share of water per head per day from the total installed capacity is erroneous.

Thus, a conclusion could be made from the quantity of daily average water supply during the lean season in January and February 2021 that the average share of water per head per day in Aizawl city ranges from 40 – 60 litres approximately, which seems to be very insufficient for the city.

It is also observed that water crisis does not happen during January or February; rather it happened in the month of March and April. This is maybe due to the long dry period of this year i.e.2021. This indicates that the month of January and February 2021 can be somehow manageable as it drew water from the remnant of the last monsoon seeping out from the catchment forest cover area of Tlawng river.

Taking together, it can be concluded that the Tlawng river is not sufficient for Aizawl city due to both increasing demand and diminishing Tlawng water volume due to deforestation and other human activities happening in the catchment area of Tlawng river, which needs an urgent response from all the stakeholders of Aizawl. Lastly, stringent and efficient policy of the government of the state has to be implemented to control various causes of deforestation.

CHAPTER-IV

PATTERNS OF DEFORESTATION AND QUANTITY OF RAINFALL IN AIZAWL CITY

4.1. Introductory Literature

This chapter discusses about the possible correlation between deforestation and rainfall in general. Since there is no separate data on deforestation in Aizawl city, Mizoram data as a whole is used for deforestation, which is much more appropriate as the source of water supply of Aizawl city 'Tlawng river' passes through more than half of the length of the state starting from Zopui hills near Lunglei town toward the north and end up in Barak valley. The catchment area is large and more suitable to represent the whole state when it comes to deforestation instead of just taking deforestation in and around Aizawl city alone.

This chapter also analyzes in detail the pattern and quantity of monthly and annual rainfall of Aizawl city. As the main thrust of the study relates to rainwater harvesting, the correlation between deforestation and rainfall is of utmost importance due to which patterns of deforestation and rainfall are examined in this chapter. In fact, they are the main attributes or components of RWH directly or indirectly. Precipitation is the main source of water in Mizoram as all the rivers are rain fed in the region. As the major rivers of Mizoram are rain-fed, the volume of water of these rivers depends, to a great extent, upon the quantity of rainfall which further again is highly depending upon the forests cover of the region. It is well known that deforestation affects the pattern of rainfall as well.

Forest has been an important source of water since the evolution of mankind without which many biotic organisms could not survive. Forest plays an important role in the circulation of water in different stages. It recycles water vapour and moisture in the air through the process of transpiration. Vast forested catchment areas produce moisture and water vapour into the atmosphere which falls on earth as precipitation after different stages of processes.

According to Fred Pearce (a freelance journalist in the U.K) in his article "*Rivers in the Sky: How Deforestation Is Affecting Global Water Cycles*", due to the destruction of tropical forests around the globe, the movements of water cycle in the atmosphere are disrupted on a vast scale. This affects the patterns and quantity of rainfall which could lead to floods and droughts in many areas in India, U.S and China. Each and every tree in the forest absorbs water from the under-ground through its roots for growth and subsequently, it releases water vapour into the atmosphere that contributes to the amount of water circulation in the air.

The impact of deforestation is not limited only to rainfall. It affects the occurrence of natural calamities such as floods, landslides, avalanche, etc. Many developed countries are busy in finding the way to control global warming which is to a great extent affected by deforestation around the globe. Cutting the amount of carbon dioxide emission by a country is also one measure to tackle global warming. Meanwhile trees in the forest are absorbing large quantity of $CO2$ from our atmosphere and releases oxygen instead thus involving actively in the tackling of global warming as well. However, its impact on the pattern and quantity of rainfall could be the most important phenomenon.

Doug Sheil of the Norwegian University of Life Sciences rightly remarked and criticized the traditional perception that some areas like Congo and the Amazon receive high precipitation because these areas are located in the region where rainfall is usually high as always. But, he opined and stressed that this high rainfall are caused by the thick and intact forests in the region without which the interior parts of these regions would be deserts; and thus emphasized the effects of deforestation on rainfall around the globe.

According to UN Food and Agricultural Organisation (FAO) report, 2020, even though forests are not equally distributed across the world, the total forest cover area is about 4 billion hectares. There are some particular regions where most of the forests of the world are concentrated. Around half of the world's forests which are 66% are found in Russian federation, U.S.A, China, Canada and Brazil. About two third of the world's forests are found in other 10 countries of the world. Deforestation keeps on increasing around the globe especially in the countries such as Myanmar, Congo, Paraguay, Brazil, Indonesia, Cambodia, etc. The pattern of deforestation in the tropical countries affects the climate and rainfall of the world to some extent.

The Global Forest Watch (GFW) is released by World Resources Institute (WRI) which analyzes the data of forest cover area around the globe. GFW reported that India has lost as much as over 1.5 million hectares of forest cover area since 2001 to 2018. It is estimated that the north eastern states of Nagaland, Tripura, Mizoram, Meghalaya and Manipur were to a great extent the cause for the loss of more than 50% of forest cover area in India during 2001-2018. The main economy of the north eastern states is agriculture which needs clearing of forest due to the practice of shifting cultivation which further leads to the alarming rate of forest degradation in the region. GFW estimated that around 172 metric tonnes of carbon is emitted in India during the same period due to the loss of tree and forest cover in different parts of the region. However, the forest cover area of 12% in the year 2000 is reduced to only 8.9% in the year 2010 in India.

The rate of deforestation and forest degradation continue to grow at an alarming pace across the globe. It disrupts the natural processes of ecology and biodiversity of many regions in the world. According to an estimate, due to various changes in land use pattern since 1990, around 400 million hectares of forest cover areas have been degraded and lost. However, the rate of deforestation has declined from 16 million hectares per year in the year 1990 to around 10 million hectares per year in the year 2020. The intact or virgin forest cover area of the world is estimated to be declined by about 80 million hectares over the last 3-4 decades.

Subsequently, Aizawl city has also continued to grow at a rapid pace; undeveloped land has been replaced with impervious surfaces such as streets, buildings, pavements and parking lots. The ground water potential is getting reduced due to industrialisation, urbanization and deforestation; and as a result most of the rivers and streams are getting dry-up very easily.

4.2. Patterns of Deforestation in Mizoram

Mizoram is one of the eight states of North-East India sharing an international boundary with Myanmar and Bangladesh. As a hilly region, different heights of peaks run across the state. As tropic of cancer passes through Mizoram, the state is blessed with tropical semi-evergreen, tropical moist deciduous and subtropical mountain or alpine forests. Bamboo is one of the most common vegetation found in the region.

Deforestation and forest degradation are the common phenomena since the olden days due mainly to urbanisation and the practice of shifting cultivation in the region. Due to the increase in population’s year on year, the forest cover area of the region also changes. One of the driving factors for changes in forest cover area is wild-fire which takes place almost every year.

Pics: Google view of shifting cultivation near Tlawng river

Pic: Google view of shifting cultivation near Tlawng river

(Pics: Slash and burn practices in Lunglei district)

(Pics: Slash and burn practices in Aizawl district)

(Pics: Shifting cultivation near Tlawng river in Aizawl district)

Table-4.1 below shows the trend of changes in forest cover area in the state from 2005-2019.

Table-4.1		Changes in forests cover of Mizoram during 2005-2019 (in km2)						
Year	**VDF ***	**Change**	**MDF ****	**Change**	**OF*****	**Change**	**Total**	**Change**
2005	133	-	6,173	-	12,378	-	18,684	-
2009	134	1	6,251	78	12,855	477	19,240	556
2011	134	0	6,086	-165	12,897	42	19,117	-123
2013	138	4	5,900	-186	13,016	119	19,054	-63
2015	138	0	5,858	-42	12,752	-264	18,748	-306
2017	131	-7	5,861	3	12,194	-558	18,186	-562
2019	157	26	5,801	-60	12,048	-146	18,006	-180
VDF=Very Dense Forest ; **MDF=Moderately Dense Forest; ***OF= Open Forest								
Source: ISFR 2005- 2019								

According to Indian State of Forest Report shown in the above table, forests are categorized into Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF). The total geographical area of the state is 21,081 square kilometres out of which as evident, 18,684 square km (88.6%) is forest area in the year 2005. By the year 2019, the total forests cover area decrease to 18,006 square km (85%).

There are slight changes in VDF area from 2005 to 2017, but 26 square kilometres increase is observed in the year 2019. Only 0.74% of the region is under VDF as on 2019.

With regards to MDF, there is 78 square kilometres increase in forests cover in 2009 after which huge decrease in forest cover area is witnessed almost every biennial. The total MDF cover area decreased by 372 square kilometres since 2005 till 2019. As on 2005, the MDF cover area was 29% of the total geographical area which decrease to 27% in the year 2019.

Open forest cover area highly increased during the years 2005 to 2013. But a huge decrease in its cover area is noticed during the years 2015 to 2019. A total loss of 330 square kilometres is observed for Open forests since 2005 to 2019. As evident, open forest occupies the largest area in the region as 58.7% of the total area comes under it as on 2005 which decrease to 57% in 2019.

Figure-4.1. Pattern of Changes in Total Forests Cover Area of Mizoram during 2005-2019 (in km2)

The above figure-4.1 shows the total forest cover area of Mizoram as a whole during 2005-2019. The total forest cover area of Mizoram increased only in the year 2009 only by 556 square kilometres. Since 2011 there is disturbing decrease in total forest cover area may be due to varying reasons. The total forests cover area of Mizoram decreased by 1,234 square kilometres during 2009 to 2019. A total loss of Mizoram forests cover area by 678 square kilometres is witnessed during the year 2005 – 2019.

As a whole, the forest cover areas of the region decrease almost every biennial. Only the cover area of VDF increases noticeably in the year 2019. The total forest cover area decreased from 19,240 square km in 2009 to 18,006 square km in 2019. If this pattern of decrease in forests cover area continues for the next 10-20 years, then, it could simply be assumed that the forest resources in the region will be much lesser than the present condition which will adversely affect the amount of river water and rainfall.

4.3. Introduction to Patterns of Rainfall in Mizoram

To fully understand the potential of rainwater harvesting in any area, the amount of rainfall receive by that particular area is extremely important, inter alia, types of roof and catchment area. But, the amount of rainfall is not equally distributed across the state or even across the globe due to various factors. The amount of rainfall in some parts of the world may be lesser than even 1 inch per year while some other parts of the world may receive even more than 1,000 inches in a year. One of the driest places on earth is Atacama, and it receives less than 1 millimeter of rainfall each year, and some areas of Atacama have not receive any rainfall for more than 500 years. On the contrary, the wettest place in the world, Mawsynram, India, receives over 10,000 millimeters of rain in a year.

The India Meteorological Department (IMD) designates four climatological seasons: Winter, occurring from December to February; summer lasting from March to May; Monsoon season from June to September; and autumn, lasting from October to November. However, the rainfall usually starts as early as from the month of May and generally retreats by the month of October.

Apparently during the olden days, especially in Mizoram, rainy season normally lasts from May to August and the months of September to November are the period of happiness specifically due to the awesome weather condition during this period as there were no more rainfalls and storms. But the irregularity and sporadicity of the present pattern of monthly and annual rainfall in Aizawl city is witness almost every monsoon now.

4.4. Patterns of Rainfall in Aizawl city: 2005 - 2020

This section reveals that the quantity of rainfall in Aizawl city changes every year which usually range from around 150 centimeters to over 350 centimeters of rainfall annually. The amount and pattern of rainfall in Aizawl city varies year on year due to varying reasons. Particularly, it also analyzes in detail the monthly pattern of rainfall of four different stations in the city for the last five years i.e. 2015-2019.

The secondary rainfall data from 2015-2019 are obtained from Department of Geography & Resource Management, Mizoram University (MZU), Directorate of Agriculture, Tuikual 'A', Directorate of Science and Technology, New Capital Complex and Pushpak, Thuampui. These rainfall data from four different stations are analyzed and compared for the year 2015-2019 in particular.

The quantity of rainfall differs from department to department and location to location even within Aizawl city as well. The geographical location of MZU is in the western fringe of the study area (Tanhril locality) whereas the Pushpak is located in the eastern part of the study area (Thuampui locality), and Directorate of science and technology and directorate of agriculture are located in the central part of the city (New capital complex and Tuikual 'A' localities). The distance between MZU and the central part (Directorate of science and technology and directorate of agriculture) is around 13 kilometers; and the distance between central part and Pushpak is around 8 kilometers. It is observed that the quantity of rainfall differs even within the length and breadth of study area which is around 457 km2.

This chapter also analyzes and compares the pattern and quantity of monthly rainfall of four rainfall centres in the city. Rainfall data of all the centres are examined separately year after year for better understanding. A comprehensive analysis of rainfall from the available data produces the mean annual rainfall for the year 2015 – 2019.

4.4.1. Monthly rainfall in Mizoram University: 2015

Figure-4.4.1 shows the pattern of rainfall in Mizoram University in the year 2015. MZU is located in Tanhril locality which is at the western tip of the study area.

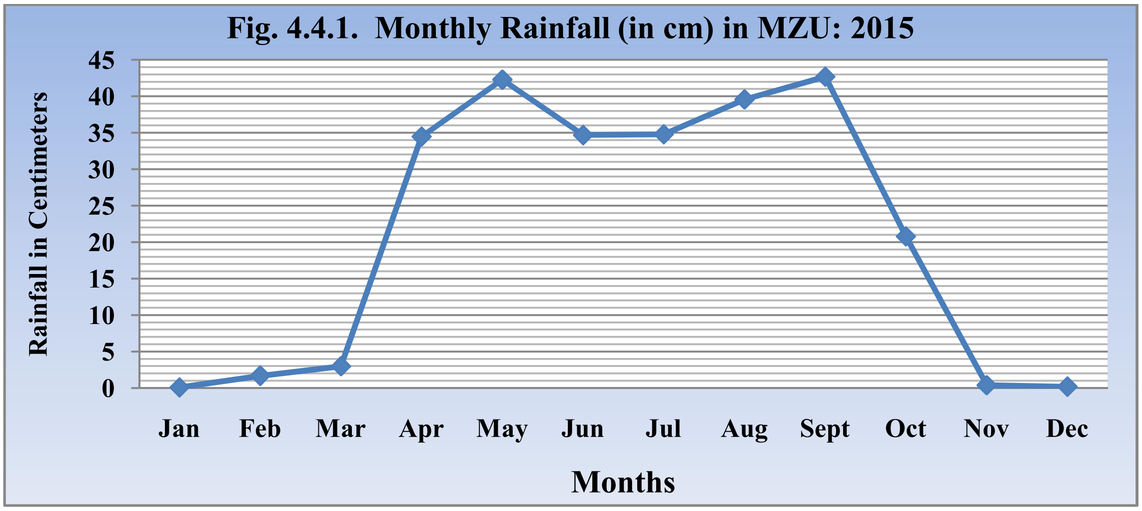


Fig. 4.4.1. Monthly Rainfall (in cm) in MZU: 2015

As shown in the above diagram, the rainfall in MZU starts as early as January and continues till the month of December. Every month of the year experienced certain amount of rainfall. The maximum rainfall occurs between the months of April to October in the year 2015. The month of September receives the highest rainfall which is 42.7 centimetres. The average monthly rainfall is 21.23 centimeters and the total annual rainfall is 254.8 centimeters.

4.4.2. Monthly rainfall in Directorate of Agriculture: 2015

Directorate of agriculture, government of Mizoram is located in Tuikual 'A' and it is at the central part of the city. It is one of the centers where daily rainfall data are recorded regularly.

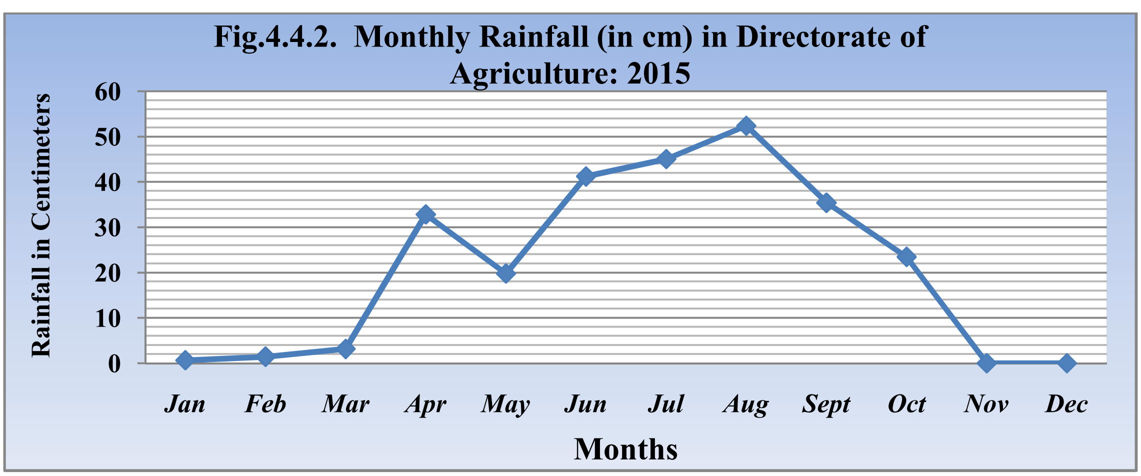


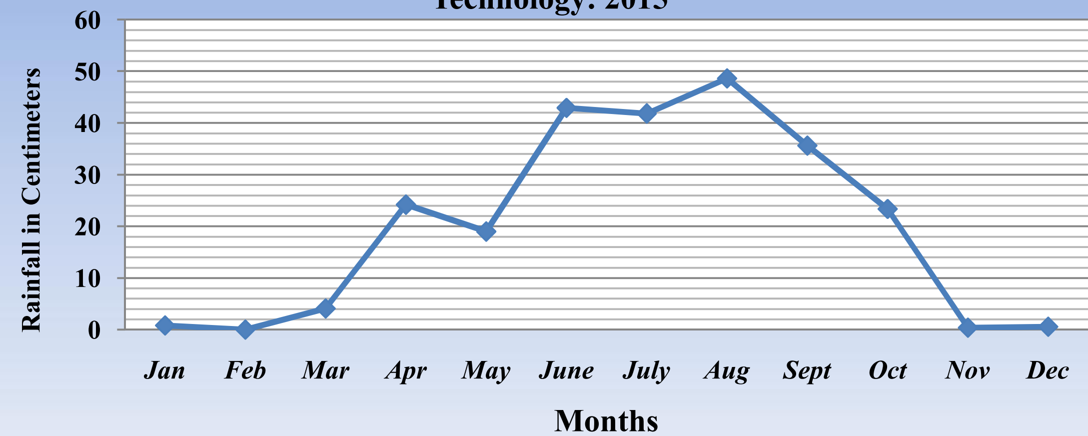
Fig.4.4.2. Monthly Rainfall (in cm) in Directorate of Agriculture: 2015

The above diagram represents the rainfall data recorded by directorate of agriculture in Tuikual locality in which the month of August receives the highest rainfall which is as much as 52.33 centimeters. Unlike the rainfall data in MZU, all months of the year do not receive rainfall in this year. The months of November and December do not experienced any rainfall. Majority of rainfalls occur from the month of April to October. The average monthly rainfall is 21.26 centimeters and the total annual rainfall is 255.13 centimeters.

4.4.3. Monthly rainfall in Directorate of Science and Technology: 2015

The below diagram represents the monthly quantity of rainfall in Aizawl city recorded in Directorate of Science and Technology for the year 2015.

Fig.4.4.3. Monthly Rainfall (in cm) in Directorate of Science & Technology: 2015

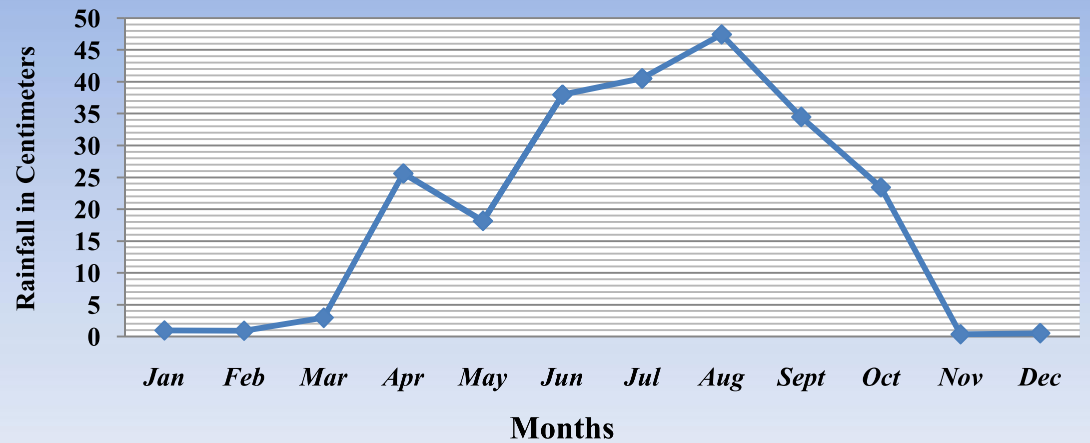


As evident from figure-4.4.3, the onset of monsoon starts from the month of April and it retreats from October. During this period, the city gets most of the rain water. The months from June to August are the period during which the rainfall is highest as the city gets rainfall of 43, 42 and 49 centimeters respectively. Unlike other locations, the month of February does not receive any amount of rainfall. The total annual rainfall of the year is 241.23 centimeters. The mean monthly rainfall is 20.1 centimeters.

4.4.4. Monthly rainfall in Pushpak: 2015

Pushpak comes under the central government and it is located in the eastern fringe of the city at Thuampui locality. The below data are the rainfall data recorded for the year 2015.

Fig.4.4.4. Monthly Rainfall (in cm) in Pushpak: 2015



The rainfall data recorded in Pushpak is also more or less the same with other centers. Here also, most of the high and intense rainfall occurs between the months of April to October. The highest rainfall is received in the month of August which is 47.47 centimeters. All the months of the year receive certain amount of rainfall. The total annual rainfall for the year is 233.61 cm and the mean monthly rainfall is 19.46 cm.

4.4.5. Graphical comparison of monthly rainfall of four different stations: 2015

The following diagram shows the rainfall patterns of four different stations such as MZU, Directorate of Agriculture, Directorate of Science & Technology and Pushpak for the year 2015.

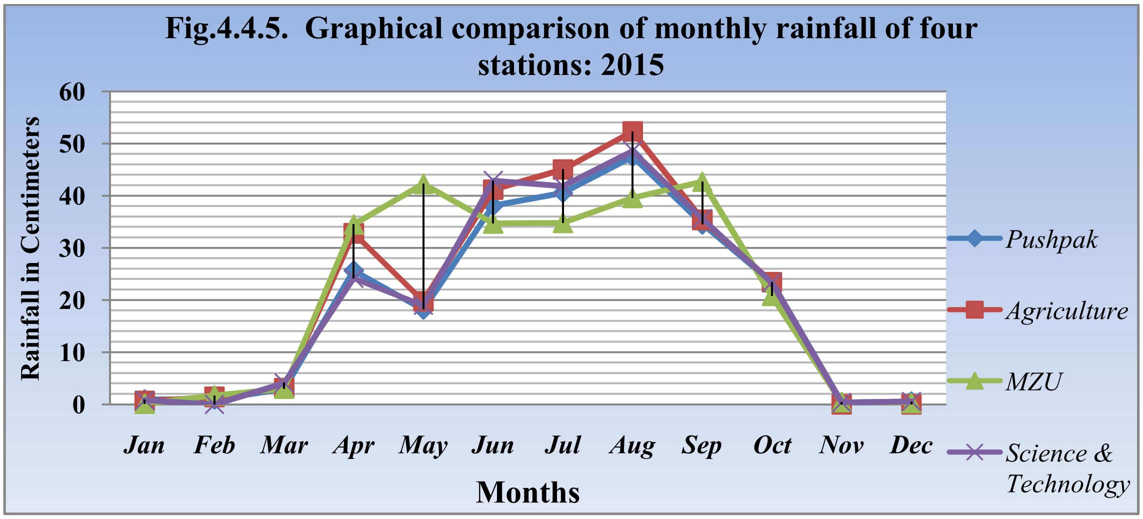


Figure-4.4.5 shows the pattern of monthly rainfall in four different stations in Aizawl city for the year 2015. Even though there are slight differences in the quantity of monthly rainfall for all the centers, the patterns of rainfalls are more or less the same throughout the year. However, the quantity of monthly rainfall recorded in MZU sharply differs from other centers for the month of May, 2015. It can be seen from the diagram that the imaginary lines of Science & technology and Pushpak centers are very close or same throughout the whole year when compared with that of MZU and directorate of agriculture.

4.4.6. Comparison of Quantity of Monthly Rainfall of four different geographical locations in Aizawl city: 2015

Table-4.2 below shows the monthly rainfall data of four different stations in Aizawl city such as stations of MZU, Agriculture, Science and technology and Pushpak.

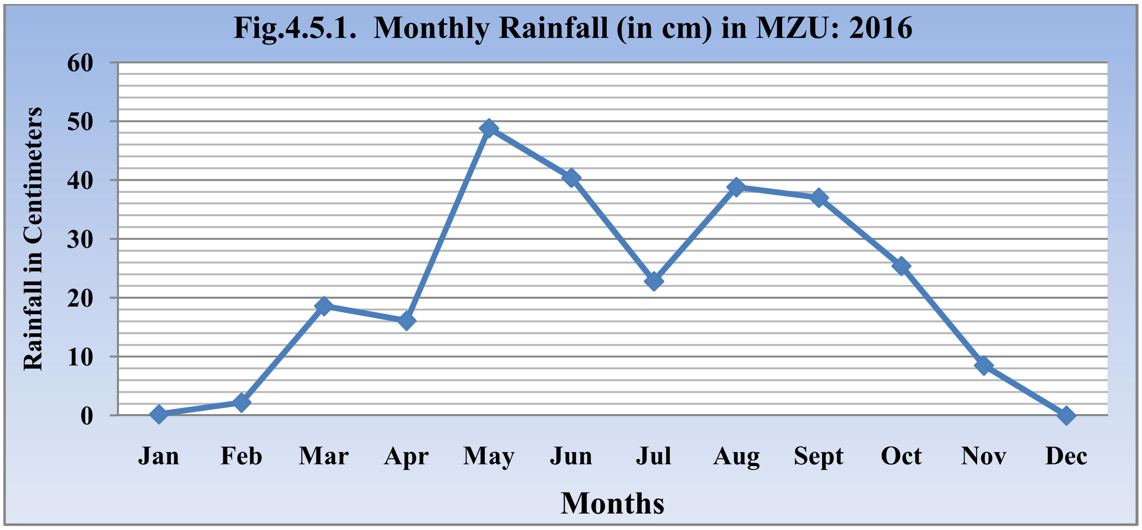
Table-4.2	Comparison of Quantity of monthly Rainfall (in cm) of four different geographical locations in Aizawl city: 2015			
Month	**Mizoram University**	**Directorate of Agriculture**	**Directorate of Science & Technology**	**Pushpak**

Jan	0.1	0.64	0.8	0.96
Feb	1.7	1.43	0	0.92
Mar	3	3.14	4.08	2.96
Apr	34.5	32.8	24.18	25.63
May	42.3	19.76	18.98	18.18
Jun	34.7	41.17	42.91	38.06
Jul	34.8	45.05	41.82	40.56
Aug	39.6	52.33	48.6	47.47
Sep	42.7	35.37	35.61	34.52
Oct	20.8	23.44	23.34	23.44
Nov	0.4	0	0.37	0.37
Dec	0.2	0	0.54	0.54
Average	**21.23**	**21.26**	**20.1**	**19.46**
Total	**254.8**	**255.13**	**241.23**	**233.61**
Total Annual Mean Rainfall of 4 stations: 2015			**246.19**	

As shown above in table-4.2, the rainfall data obtained from the above mentioned centers for the year 2015 differ from location to location. The highest annual rainfall which is 255.13 centimeters is recorded in directorate of agriculture followed by the rainfall in MZU which is 254.8 centimeters in the year 2015. Science & Technology center recorded the third highest annual rainfall which is 241.23 centimeters and Pushpak receives the lowest rainfall which is 233.61 centimeters in the year 2015. The differences in the amount of rainfall could be due to certain factors such as spatial location, types of rain gauge, etc. It is evident that there exists spatial variation in the quantity of rainfall even within 457 km2 of the study area. In general, it could be concluded that the annual rainfall in Aizawl city for the year 2015 ranges from around 230 – 260 centimetres. The mean monthly rainfall of all the stations is 20.51 centimetres and the mean annual rainfall from all the centres is 246.19 centimeters in the year 2015.

4.5.1. Monthly rainfall in Mizoram University: 2016

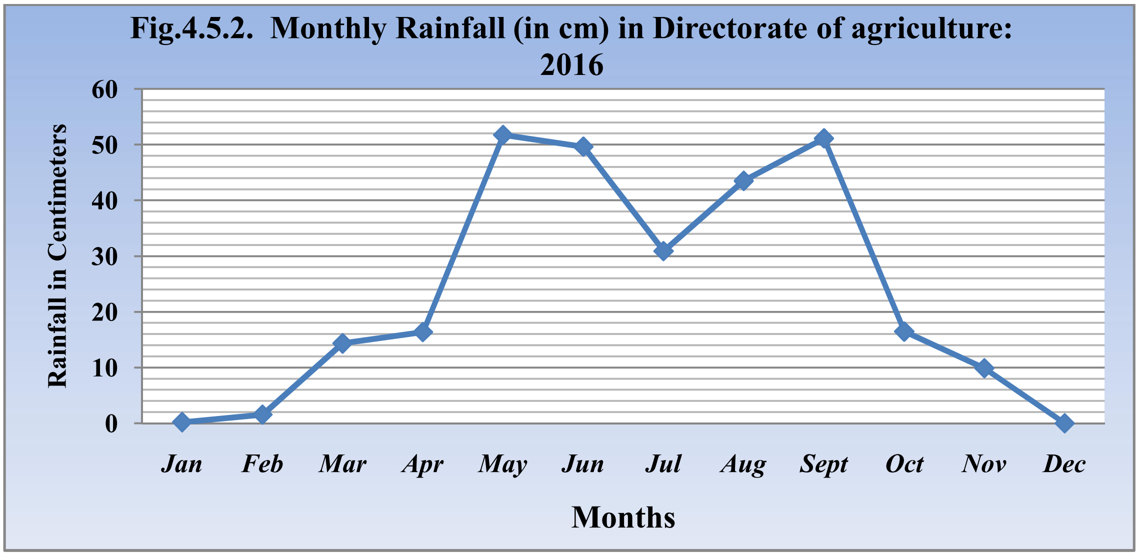
The below figure shows the quantity of monthly rainfall recorded in Mizoram University, Tanhril, for the year 2016.



It could be observe from the above figure that the onset of monsoon in the year 2016 is as early as March and continued to rain quite intensively till the month of October, 2016. The months of May, June, August and September are the period during which rainfall is highest in the year. The month of May receives the highest rainfall with 48.8 centimeters followed by the months of June and August in MZU center. December is the only month without any drop of rain the whole year.

4.5.2. Monthly Rainfall in Directorate of agriculture: 2016

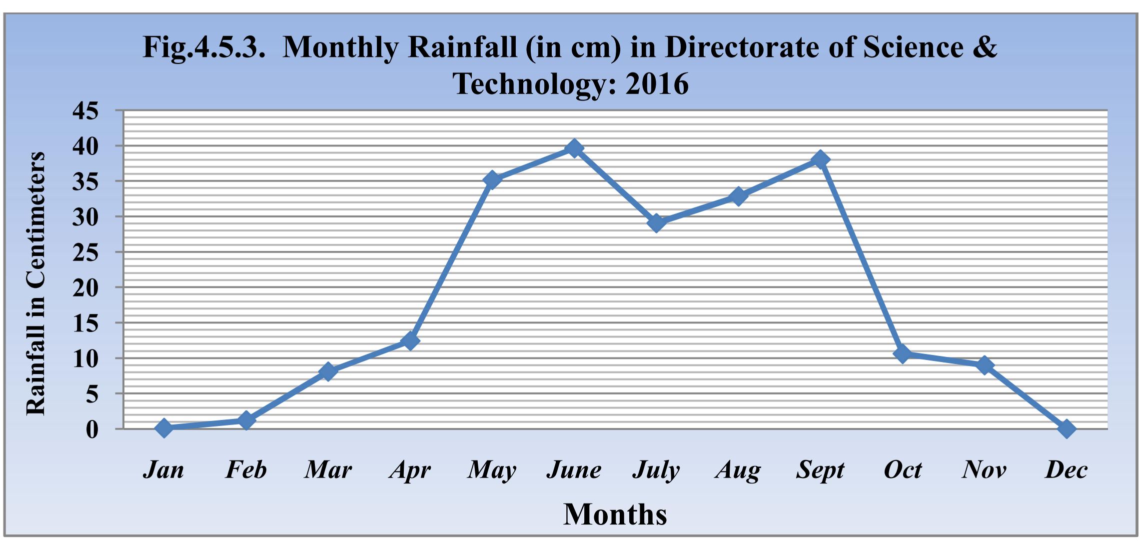
The below diagram represents the monthly rainfall data recorded in Directorate of Agriculture for the year 2016.



Directorate of agriculture recorded a very high rainfall in the year 2016. As much as 51.73 and 51.12 centimeters of rainfalls are recorded in the months of May and September respectively. The months of June and August also receive a high rainfall of 49.63 and 43.5 centimeters respectively. Like MZU, this center also does not receive any precipitation during the month of December in a year.

4.5.3. Monthly Rainfall in Directorate of Science & Technology: 2016

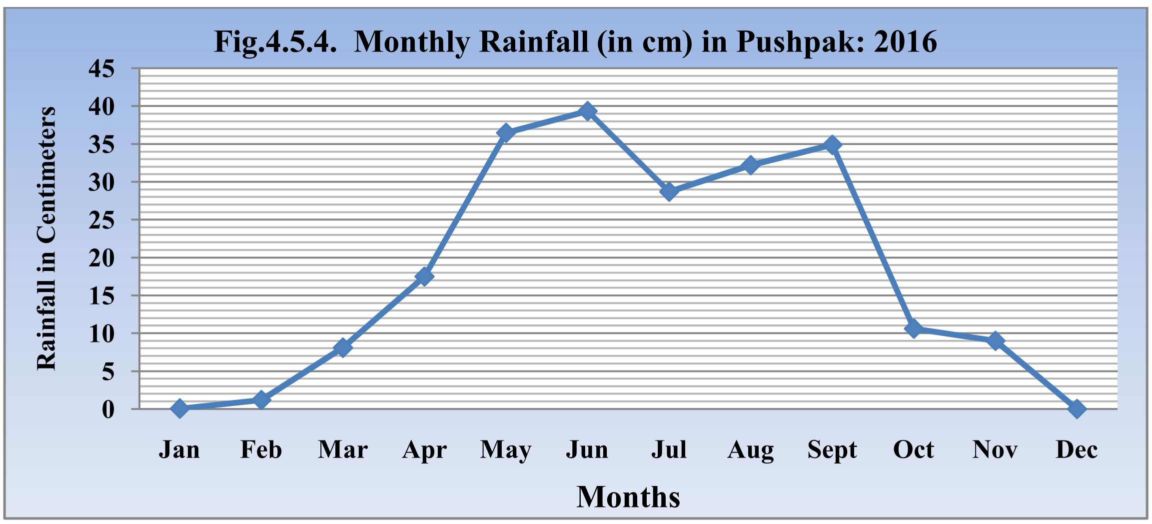
The below diagram shows the quantity of monthly rainfall recorded in Directorate of Science and technology for the year 2016.



As shown in the above diagram, the maximum rainfall is received during the month of May to September in the year 2016. The highest rainfall is received in the month of June which is 39.63 centimeters. The total annual rainfall of the year is 216.11 centimeters. Again, December is the only month in the entire year during which rain did not fall in this center.

4.5.4. Monthly rainfall in Pushpak: 2016

Pushpak is one of the most reliable centers that recorded the daily rainfall in the study area. Below is the monthly rainfall data of Pushpak for the year 2016.



Pushpak center also recorded more or less the same amount of rainfall with other centers. The highest amount of rainfall occurs in the month of June which is 39.33 centimeters in 2016. The months from May to September experienced high rainfall ranging from 28.68 to 39.33 centimeters. December is the only month without rainfall throughout the year.

4.5.5. Graphical comparison of monthly rainfall of four different stations: 2016

Below is the pattern of monthly rainfall of four different stations in the study area for the year 2016.

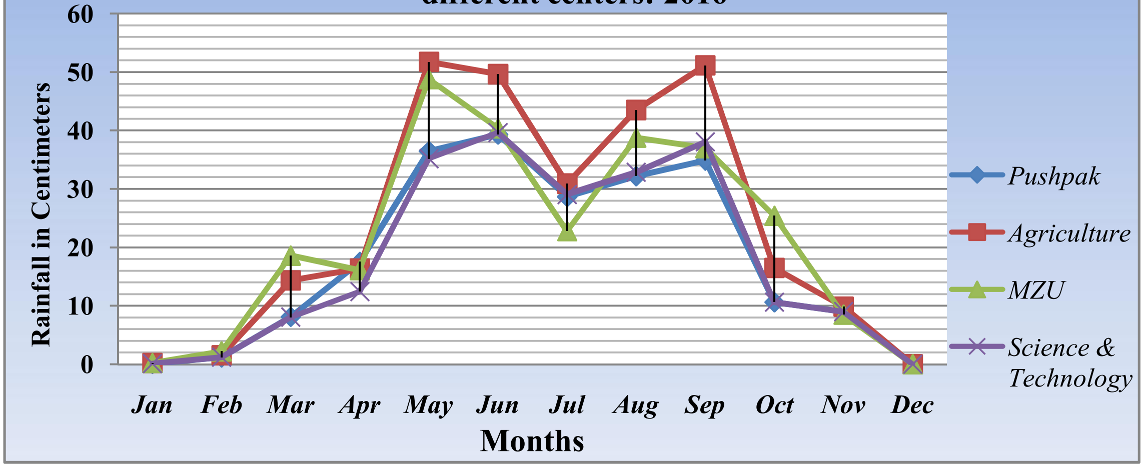


Fig.4.5.5. Graphical comparison of monthly rainfall of four different centers: 2016

As evident from the above line graph, even though the patterns of rainfall in all the centers are more or less similar, it could be seen that the pattern of rainfall in Pushpak and Science centers are almost the same throughout the year. A slight difference is seen in the months of April, May and September between the two centers. The amount of rainfall is quite high in MZU and Agriculture centers and the patterns are also more or less the same when compared to the other two centers. The amount of rainfall in Agriculture station during the months of June and September is comparatively higher than other stations.

4.5.6. Comparison of Quantity of Rainfall of four different geographical locations in Aizawl city: 2016

The following table-4.3 highlights the quantity of monthly rainfall in four different rainfall stations in the study area for the year 2016.

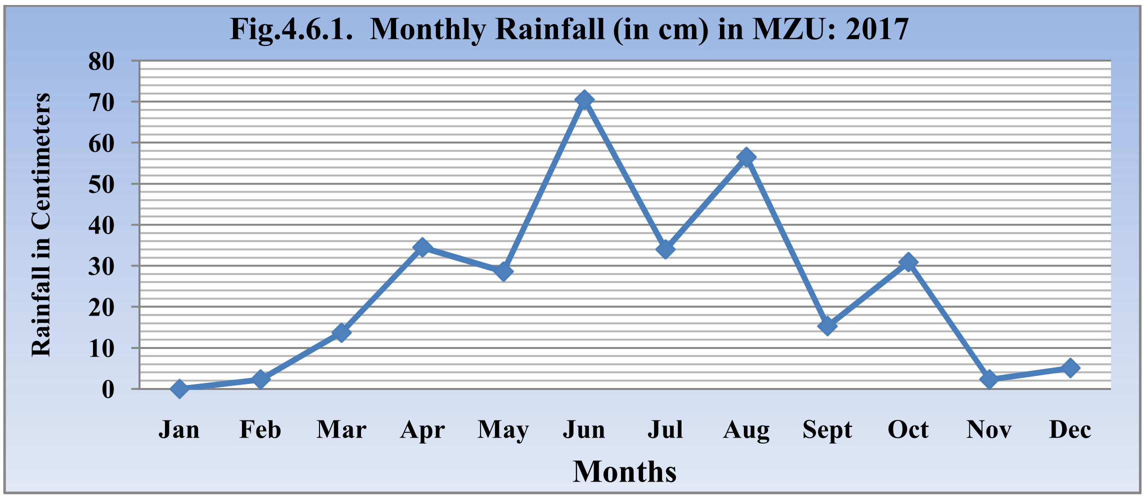
Table-4.3	**Comparison of Quantity of monthly Rainfall (cm) of four different geographical locations in Aizawl city: 2016**			
Month	**Mizoram University**	**Directorate of Agriculture**	**Directorate of Science & Technology**	**Pushpak**

Jan	0.2	0.2	0.1	0.05
Feb	2.2	1.53	1.18	1.18
Mar	18.6	14.33	8.06	8.09
Apr	16.1	16.37	12.43	17.49
May	48.8	51.73	35.17	36.47
Jun	40.4	49.63	39.63	39.33
Jul	22.8	30.9	29.05	28.68
Aug	38.8	43.5	32.84	32.2
Sep	37	51.12	38.06	34.88
Oct	25.4	16.46	10.6	10.61
Nov	8.5	9.86	8.99	8.99
Dec	0	0	0	0
Average	**21.56**	**23.8**	**18**	**18.16**
Total	**258.8**	**285.63**	**216.11**	**217.97**
Total Annual Mean Rainfall of 4 stations: 2016			**244.62**	

The year 2016 experienced a wide range of unequal distribution of rainfall in the study area. The centers of MZU and Directorate of Agriculture receive high annual rainfall which is 258.8 and 285.63 centimeters respectively. Meanwhile the other two centers of Science & Technology and Pushpak receive lesser amount of annual rainfall of 216.11 and 217.97 centimeters each respectively in the same year. Accordingly, the average monthly rainfall for all the centers also varies. It could be rounded up that the total annual rainfall in the city ranges from about 210 – 290 centimeters. The average annual rainfall of all the centers is 244.62 centimeters in the year 2016, and the mean monthly rainfall of all the stations is 20.38 cm.

4.6.1. Monthly rainfall in Mizoram University: 2017

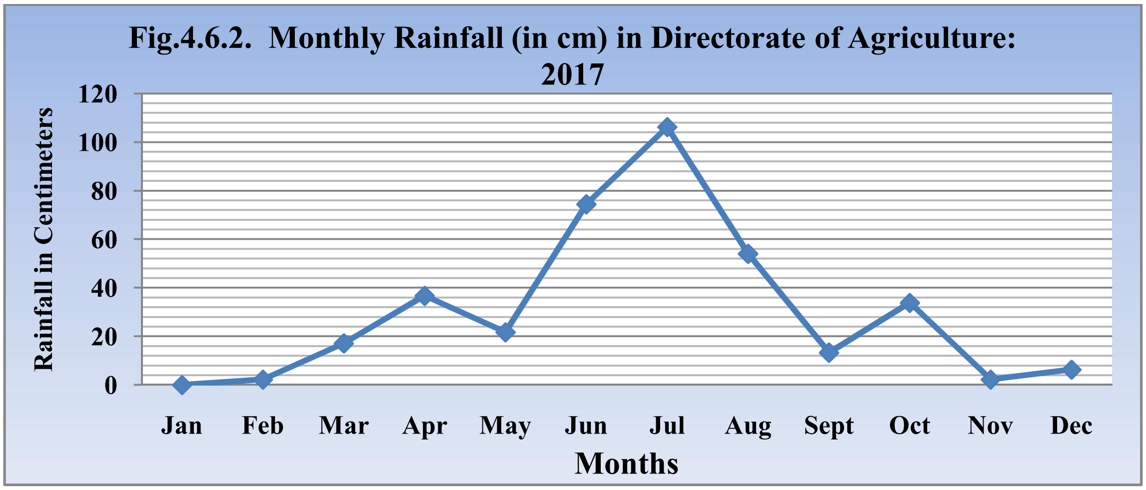
Below is the quantity of monthly rainfall received at MZU station in the year 2017. It is recorded and maintained by the department of Geography and Resources management.



As evident from the above rainfall diagram, the pattern of rainfall is irregular and fluctuated month on month throughout the year. The intensity of rainfall fluctuated every alternate months all through the year. The onset of monsoon starts in April and retreats by October. The highest rainfall which is as much as 70.5 centimeters is received during the month of June. January is the only month without any precipitation throughout the year. The mean monthly rainfall is 24.47 cm and the total annual rainfall in the station is 293.7 centimeters.

4.6.2. Monthly Rainfall in Directorate of agriculture: 2017

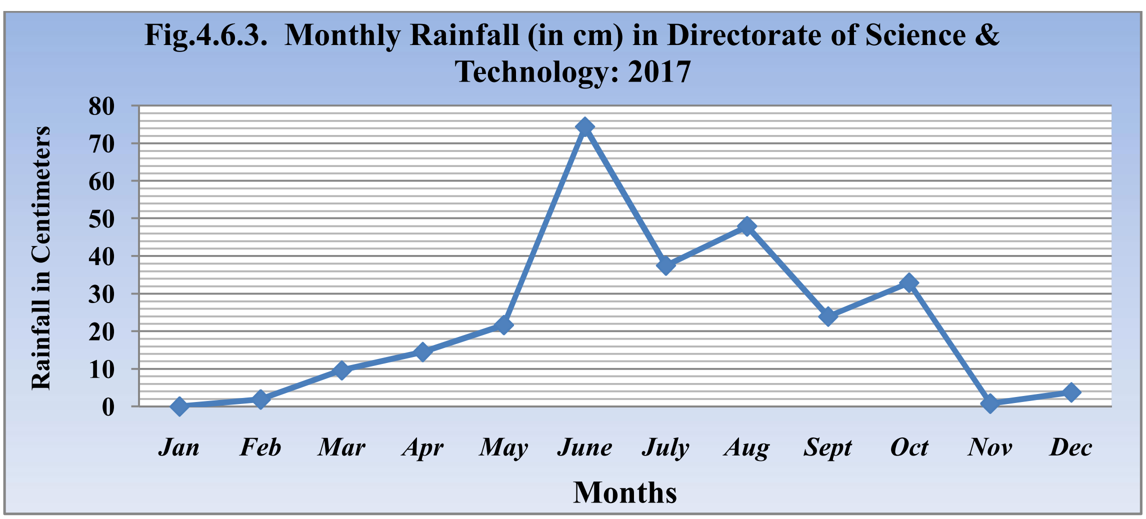
The below diagram shows the monthly rainfall data recorded by the center of Directorate of Agriculture for the year 2017. The data of this station is available till 2017 only; henceforth it will not be shown in the upcoming analysis.



The pattern of monthly rainfall for this center is also quite similar with that of MZU except for the month of July. Unlike MZU, the highest rainfall which is a whooping 106.16 centimeters is received during the month of July. The pattern of fluctuation of the intensity of rainfall is similar with that of MZU to a great extent. The months from June to August alone received rainfall of as much as 234.56 centimeters. Here in this center also, the month of January is the only month when there is no rainfall.

4.6.3. Monthly Rainfall in Directorate of Science & Technology: 2017

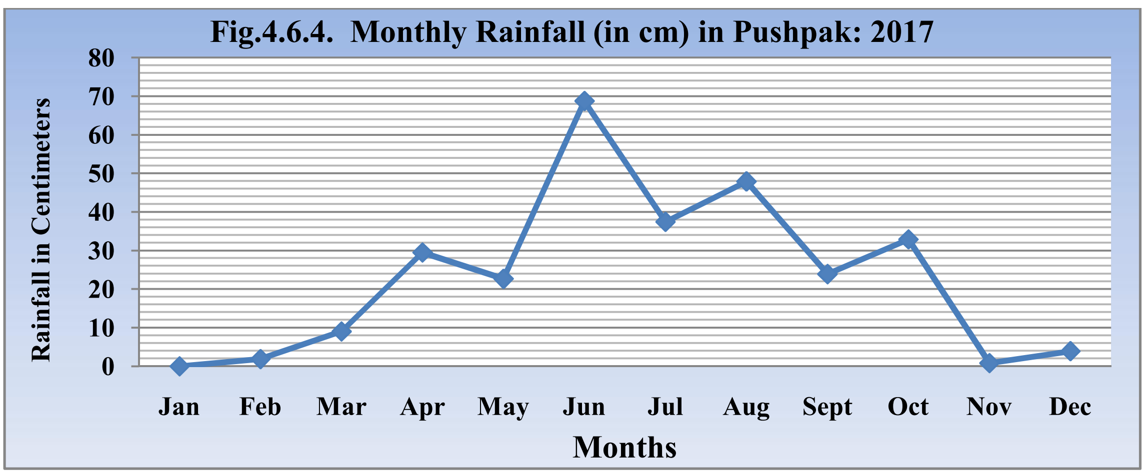
The following diagram highlights the amount of monthly rainfall received at the center of Directorate of Science and Technology in the year 2017.



As shown above, the total amount of rainfall is highest in this year during 2015 to 2019. The month of June marked as much rainfall as 74.35 centimetres in the year 2017. The maximum rainfall occurs during June to August. The total annual rainfall of the year is 268.67 centimeters. It might be stated that the pattern of rainfall is kind of sporadic and irregular in this year compare to the previous years. Like other centers, January is the only month during which there is not a drop of precipitation through the year.

4.6.4. Monthly rainfall in Pushpak: 2017

The below rainfall data is recorded in the year 2017 at Pushpak center which is located in the eastern part of Aizawl city.

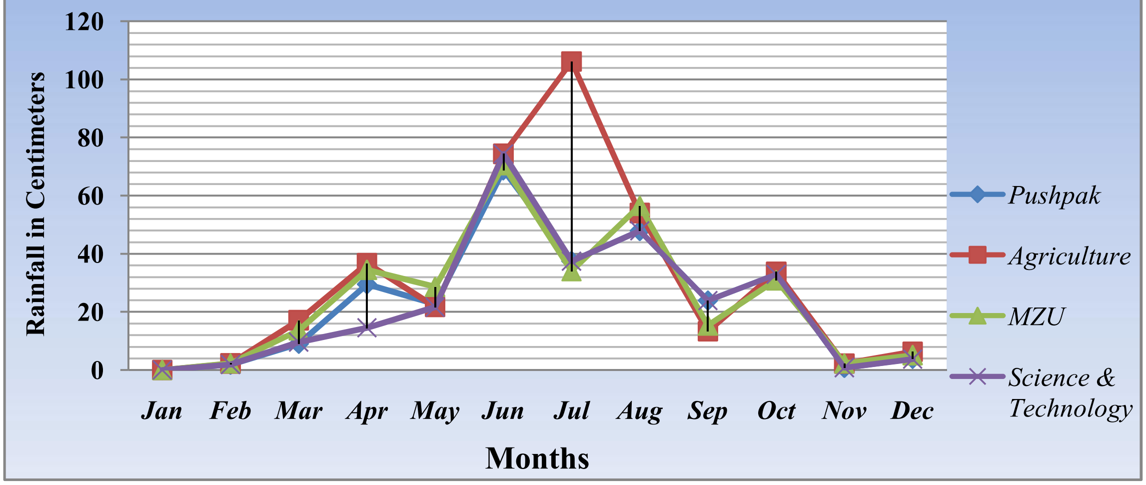


The pattern of fluctuation in monthly rainfall in this center is similar to that of other centers in the city. The intensity of monthly rainfall varies month on month throughout the entire year. In this center also, the onset of monsoon starts in April and it retreats by the month of October. The highest monthly rainfall is received in the month of June which is 68.75 centimeters. The months of June and August received comparatively higher amount of rainfall. This center also did not record any precipitation during the month of January, 2017.

4.6.5. Graphical comparison of monthly rainfall of four different stations: 2017

The below diagram indicates the pattern of rainfall of four different stations in Aizawl city for the year 2017.

Fig.4.6.5. Graphical comparison of monthly rainfall of four different stations: 2017



As evident from the above diagram, except for a few months, there is a common and similarity pattern of rainfall among all the centers such as MZU, Directorate of Agriculture, Directorate of Science and Technology and Pushpak. It could be seen from the graph that the pattern of rainfall for Science and Technology station is the odd one during the month of April while it is the Agriculture station which is totally odded out for the month of July. Apart from these, the pattern of rainfall for most of months is more or less the same throughout the year.

4.6.6. Comparison of Quantity of Rainfall of four different geographical locations in Aizawl city: 2017

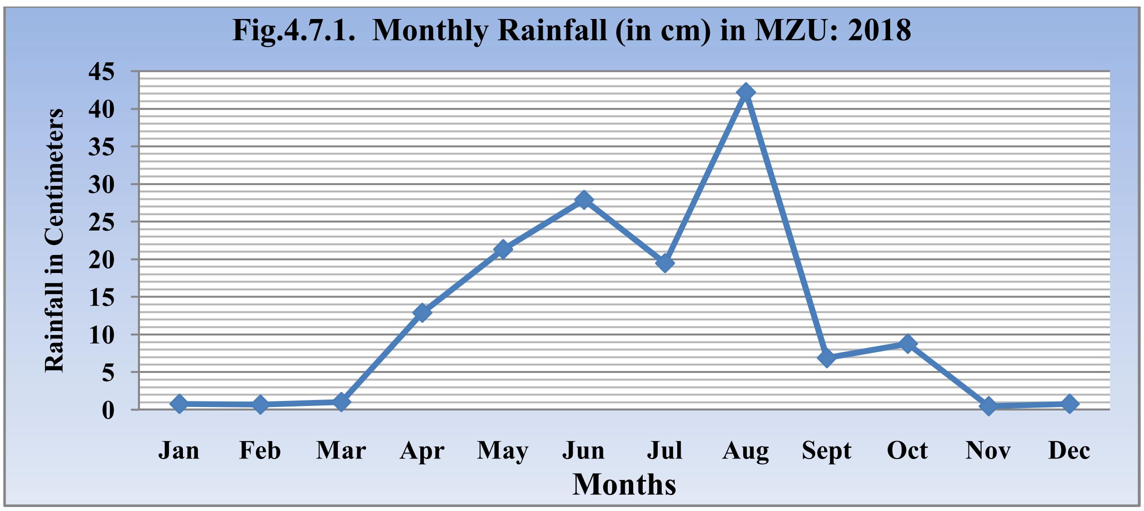
The following table shows the differences and similarities of the quantity of rainfall among all the centers in the study area for the year 2017.

Table-4.4	Comparison of Quantity of monthly Rainfall (cm) of four different geographical locations in Aizawl city: 2017			
Month	Mizoram University	Directorate of Agriculture	Directorate of Science & Technoloy	Pushpak
Jan	0	0	0	0
Feb	2.3	2.24	1.87	1.87
Mar	13.7	17.12	9.59	9.01
Apr	34.5	36.72	14.5	29.5
May	28.6	21.68	21.65	22.67
Jun	70.5	74.4	74.35	68.75
Jul	34	106.16	37.45	37.45
Aug	56.5	54.01	47.9	47.9
Sep	15.3	13.3	23.9	23.9
Oct	30.9	33.79	32.9	32.9
Nov	2.3	2.22	0.8	0.8
Dec	5.1	6.29	3.76	3.9
Average	**24.47**	**30.66**	**22.38**	**23.22**
Total	**293.7**	**367.93**	**268.67**	**278.65**
Total Annual Mean Rainfall of 4 stations: 2017			**302.23**	

As could be seen from the above table, the month of January is dry and without any precipitation for all the centers. Except for the center of Agriculture, all other centers have certain level of similarities in the quantity of rainfall. Center of Agriculture has a comparatively higher annual rainfall of 367.93 centimeters while the remaining centers have less than 300 centimeters of annual rainfall in the year 2017. As per the table, the total annual rainfalls for the three centers are 293.7, 268.67 and 278.65 centimeters respectively. As a whole, the total amount of annual rainfall for the year 2017 ranges from around 260 to 370 centimeters in the study area. And the average annual rainfall of all the four centers is 302.23 centimeters and the mean monthly rainfall is 25.18 cm. The period from the months of June to August is the time during which quantity of rainfall is much higher than other months of the year.

4.7.1. Monthly rainfall in Mizoram University: 2018

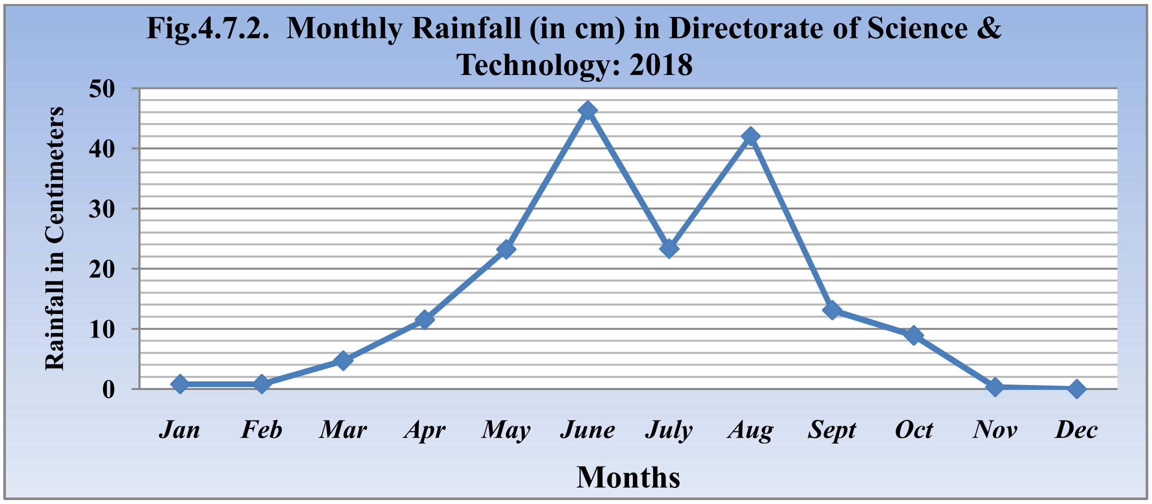
Below is the quantity of monthly rainfall data recorded in the centre of Mizoram University for the year 2018.



As seen in the above diagram, the onset of monsoon starts from the month of April and it retreats by the month of August. Generally in Mizoram, the period from the month of September to March seldom experiences a huge amount of rainfall almost every year. High intensity rainfall occurs from the month of May to August in the year 2018. The highest monthly rainfall is received during the month of August which is 42.2 centimeters. Rain falls throughout all the months of the year 2018. The total annual rainfall for the year in MZU is 143.41 centimeters.

4.7.2. Monthly Rainfall in Directorate of Science & Technology: 2018

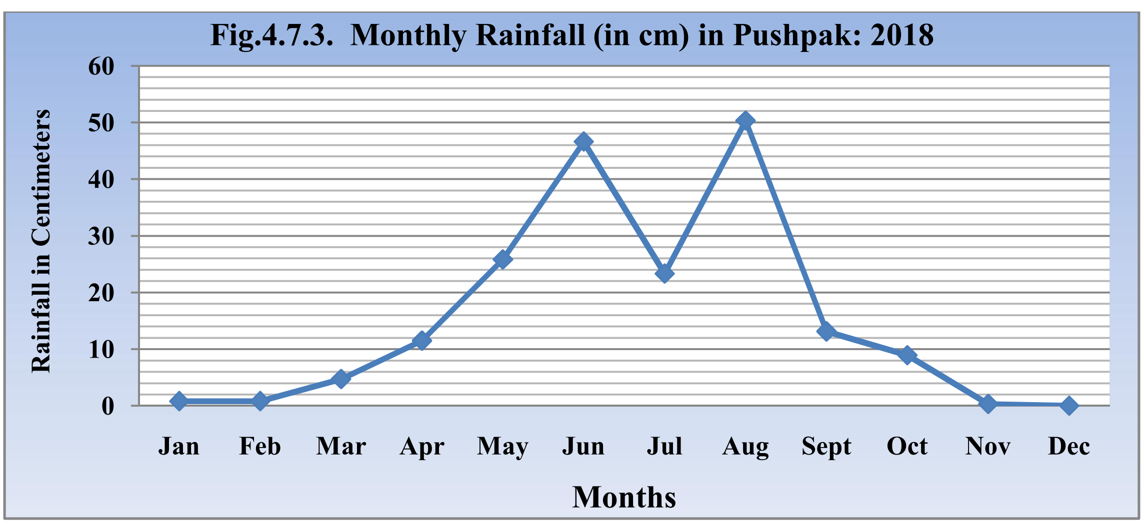
The following diagram represents the quantity of monthly rainfall recorded in Directorate of Science and Technology for the year 2018.



As depicted in the above diagram, the maximum rainfall occurs between the months of May to August in the year 2018. The pattern of month-wise rainfall is more or less sporadic and occasional as well in this year. The highest rainfall is received in the month of June which is 46.3 centimetres. The total annual rainfall of the year is 174.9 centimeters. Unlike the pattern of rainfall in MZU, the month of December does not receive any precipitation in this center in 2018.

4.7.3. Monthly rainfall in Pushpak: 2018

The following diagram shows the rainfall data of Pushpak station for the year 2018.



As evident from the above data, this station receives varying amount of rainfall in all the months except December. The highest quantity of rainfall occurs in the month of August which is 50.3 centimeters. The months from May to July also receives a good amount of rainfall. The total annual rainfall is 186 centimeters.

4.7.4. Graphical comparison of monthly rainfall of three different stations: 2018

The following graph compares the monthly rainfall of MZU, Science & Technology centers and Pushpak only due to the unavailability of the same data from Directorate of Agriculture for the year 2018-2019. However, the data from these three centers is one of the most reliable sources in the city. Henceforth, data from only these three centers will be reflected.

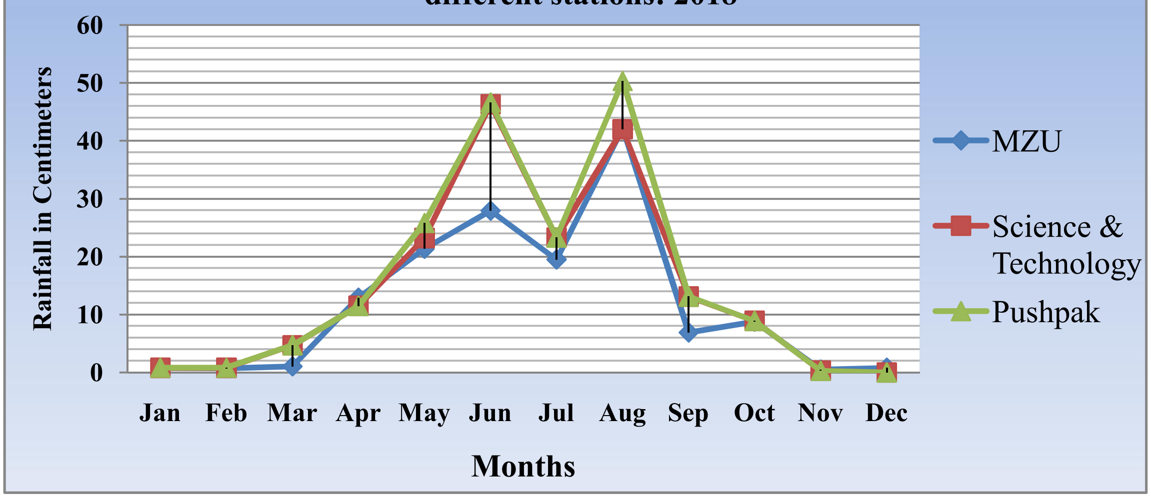


Fig.4.7.4. Graphical comparison of monthly rainfall of three different stations: 2018

The above graph shows a few differences in the pattern of rainfall among the three stations in the city. The major differences in the amount of rainfall are observed in the months of March, June, July, August and September. The highest difference occurs in the month of June during which the monthly rainfall in MZU is much lower than the other two stations. The rainfall in Science & Technology and Pushpak centers are quite similar throughout the year except in the month of August when the rainfall in Pushpak is higher than that of Science and Technology. The remaining months of the year receives more or less the same quantity of rainfall throughout the year 2018.

4.7.5. Comparison of Quantity of Rainfall of three different geographical locations in Aizawl city: 2018

The following table compares the quantity of monthly rainfall of three different geographical rainfall centers, i.e. Mizoram University, Directorate of Science & Technology and Pushpak, in the city for the year 2018.

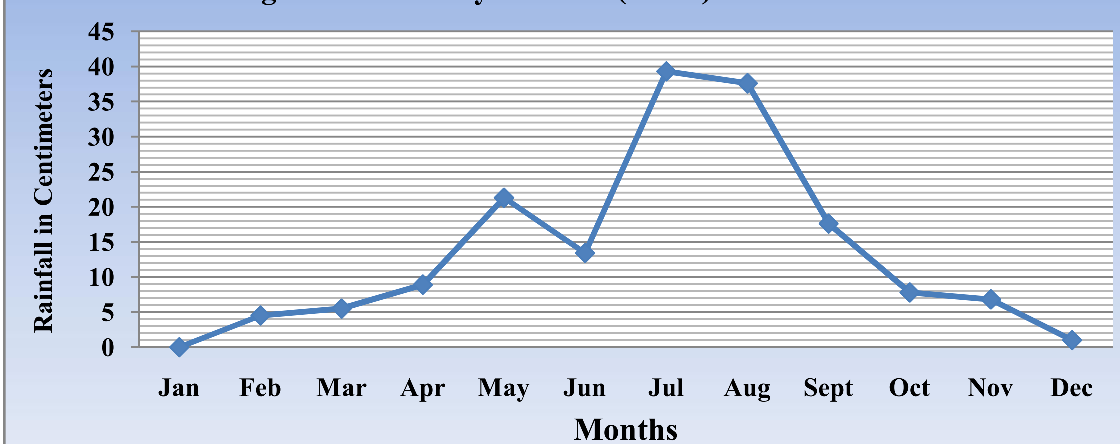
Table-4.5	**Comparison of Quantity of monthly Rainfall (cm) of three different geographical locations in Aizawl city: 2018**		
Month	**Mizoram University**	**Directorate of Science & Technology**	**Pushpak**
Jan	0.8	0.8	0.8
Feb	0.71	0.8	0.8
Mar	1.04	4.7	4.7
Apr	12.91	11.5	11.47
May	21.34	23.2	25.8
Jun	27.91	46.3	46.6
Jul	19.5	23.3	23.3
Aug	42.2	42	50.3
Sep	6.9	13.1	13.1
Oct	8.8	8.9	8.9
Nov	0.5	0.3	0.3
Dec	0.8	0	0
Average	**11.95**	**14.57**	**15.50**
Total	**143.41**	**174.9**	**186.07**
Total Annual Mean Rainfall of 3 stations: 2018			**168.12**

As seen the above table-4.5, even though the amount of rainfall of the three centers differs in most of the months, the differences are very minor except during the month of June. When MZU center receives rainfall of 0.8 centimeter in the month of December, Directorate of Science & Technology and Pushpak stations do not receives any rainfall during the same period. The total annual rainfall in MZU center is 143.41 centimeters while it is 174.9 centimeters in Science and Technology center for the same year, and Pushpak station receives the highest which is 186.07 centimeters. The mean monthly rainfall for the three stations is 14 centimeters and the total annual mean rainfall is 168.12 centimeters for the year 2018.

4.8.1. Monthly rainfall in Mizoram University: 2019

The following monthly rainfall data represents the pattern of rainfall in Mizoram University for the year 2019.

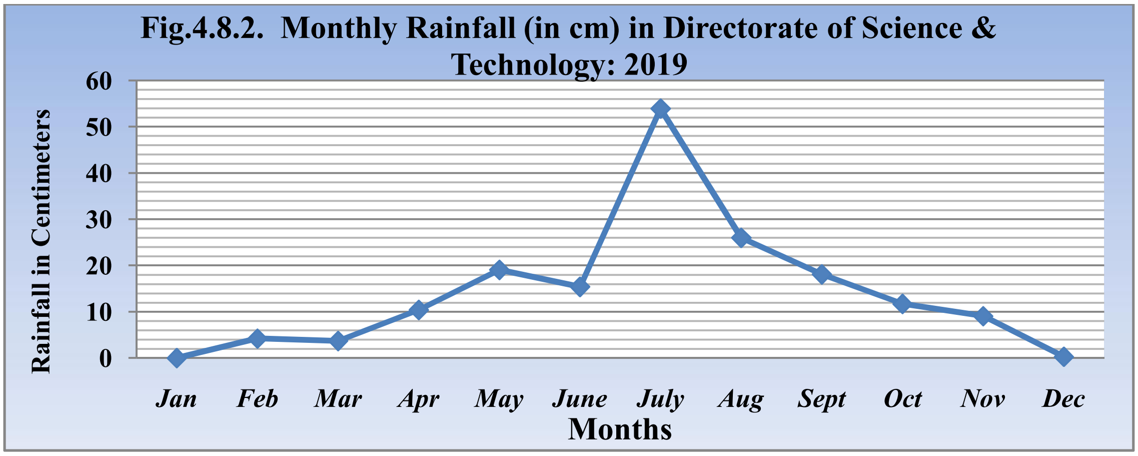
Fig.4.8.1. Monthly Rainfall (in cm) in MZU: 2019



As evident from the above diagram, the maximum rainfall occurs between the months of May to August in the year 2019. The highest rainfall is recorded in the month of July which is 39.3 centimeters followed by the month of August which is 37.6 centimeters. The total annual rainfall of the year is 163.7 centimeters. The month of January is the only month without any rainfall throughout the year.

4.8.2. Monthly Rainfall in Directorate of Science & Technology: 2019

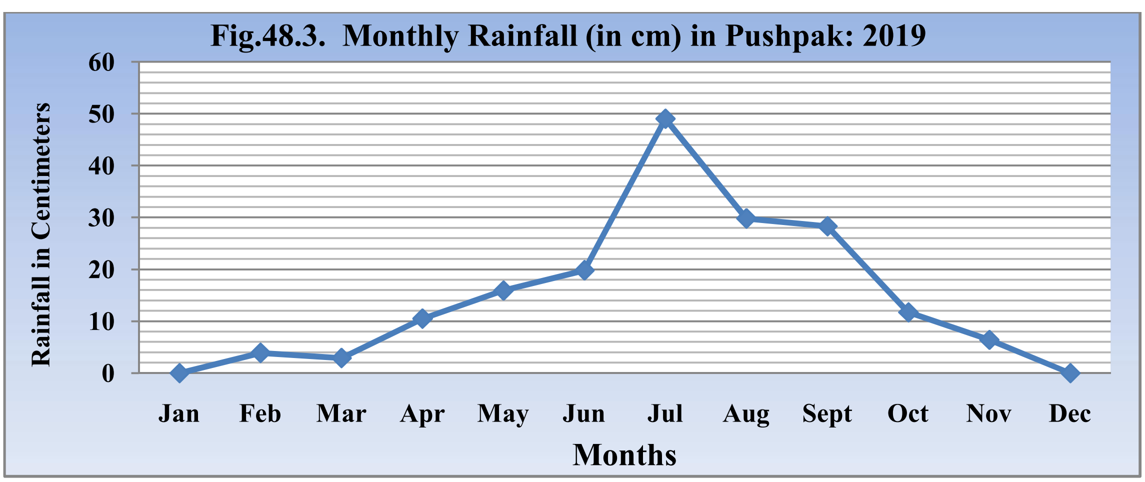
The following rainfall diagram of 2019 represents the pattern of rainfall recorded in the center of Directorate of Science & Technology.



Here in this center as well, the month of January does not receive any rainfall. In the year 2019, maximum rainfall occurs from the month of April to November which is pretty unusual and quite a long duration compare to the previous years. But the quantity of rainfall is low except for the month of July which is the highest month-wise rainfall in the year. The total amount of annual rainfall is 171.81 centimeters in the year 2019.

4.8.3. Monthly Rainfall in Pushpak: 2019

Below is the amount of monthly rainfall in Pushpak station for the year 2019.

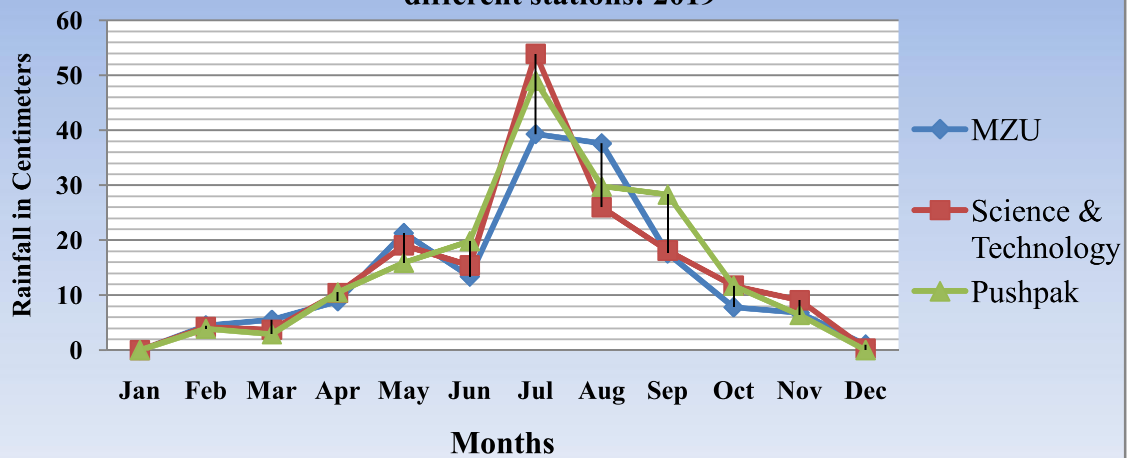


As seen in the above rainfall data, the months of January and December do not receive any amount of rainfall while the rest of the months in the year receive certain amount of rainfall. The highest rainfall which is 49 centimeters is received in the month of July, followed by the months of August and September which are 29.8 and 28.3 centimeters respectively. The total annual rainfall in the year is 178.2 centimeters.

4.8.4. Graphical comparison of monthly rainfall of three different stations: 2019

The following graph shows the differences of the monthly rainfall quantity among three different geographical rainfall centers in the city for the year 2019.

Fig.4.8.4. Graphical comparison of monthly rainfall of three different stations: 2019



As seen in the above diagram, high difference in the amount of rainfall among the three centers is found in the months of July, August and September. This reveals that the amount of rainfall differs within a distance of only around 13 kilometers also. Apart from these three months, the amount of rainfall is more or less the same in all other months of the year 2019. The patterns are also similar throughout the year.

4.8.5. Comparison of Quantity of Rainfall of three different geographical locations in Aizawl city: 2019

The following table-4.6 compares the amount of monthly rainfall between MZU, Directorate of Science & Technology and Pushpak for the year 2019 in the city.

Table-4.6	**Comparison of Quantity of monthly Rainfall (cm) of three different geographical locations in Aizawl city: 2019**		
	Mizoram University, Tanhril	**Directorate of Science & Technology, New Capital Complex**	**Pushpak, Thuampui**
Jan	0	0	0
Feb	4.5	4.2	3.9
Mar	5.5	3.7	2.9
Apr	8.9	10.4	10.5
May	21.3	19.07	15.9
Jun	13.4	15.4	19.8
Jul	39.3	53.9	49
Aug	37.6	26	29.8
Sep	17.6	18.1	28.3
Oct	7.8	11.71	11.7
Nov	6.8	9.05	6.4
Dec	1	0.28	0
Average	**13.64**	**14.31**	**14.85**
Total	**163.7**	**171.81**	**178.2**
Total Annual Mean Rainfall of 3 stations: 2019			**171.23**

As evident from the above data, the month of January do not receives any rainfall in all the centers. The highest difference in the amount of rainfall is observed during the month of July. Except for the month of January, the quantity of rainfall is different in all other months of the year. The amount of rainfall in Science & Technology center which is 171.81 centimeters is higher than that of MZU which is 163.7 centimeters in the year 2019; and the highest rainfall is experienced in the station of Pushpak which is 178.2 centimeters. Overall, the total annual and monthly mean rainfall in 2019 is obtained at 171.23 and 14.26 centimeters respectively.

4.9. Total Annual Mean Rainfall in Aizawl city: 2015-2019

Figure-4.9 below shows the total annual mean rainfall in Aizawl city from the year 2015-2019. This data is obtained from the analysis and comparison of the quantity of monthly rainfall in four different geographical rainfall centres in the city such as Mizoram University, Directorate of Agriculture, Directorate of Science & Technology and Pushpak.

Fig.4.9. Total Annual Mean Rainfall (in cm) in Aizawl city: 2015-2019

The major rivers of Mizoram are rain-fed and thus the volume of water of these rivers depends, to a great extent, upon the quantity of rainfall. As evident from the above diagram, even though the region still receives a good amount of precipitation, the pattern of precipitation in the city during the year 2015-2019 is, more or less, in a diminishing or decreasing pattern. From a rainfall of 246 centimetres in the year 2015, it decreased to 244 centimetres of rainfall in the year 2016. But there is an increase in the quantity of rainfall in the year 2017 which is 302 centimetres and it is the highest rainfall during the same period. Again, the following years i.e. 2018 and 2019, have a decrease in the quantity of rainfall at 168 and 171 respectively.

It could be asserted from the above diagram that the quantity and severity of decrease in rainfall is higher and more extreme than that of increase in rainfall during the last five years in Aizawl city. However, as per the comparison and analysis of four different rainfall stations in the city, the average annual rainfall of the city for the past five years (2015-2019) is 226.478 centimetres. The amount of rainfall in the area is sufficient enough for various domestic purposes. But, unfortunately, it appears that huge amount of rainfall goes wasted as run off. The year 2017 marked the highest precipitation during the years 2015-2019 which is 302 centimetres.

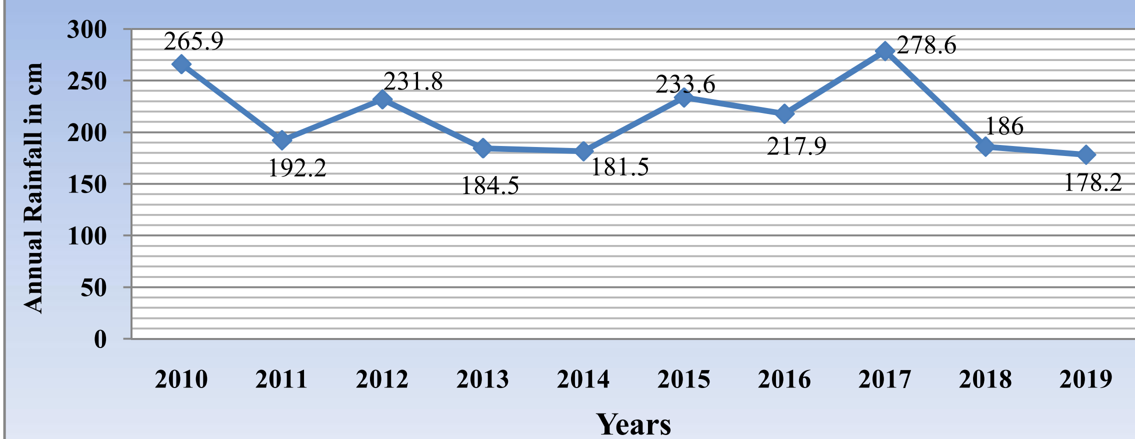
4.10. Total Annual Mean Rainfall (cm) in Aizawl city: 2005-2020

The following figure 4.10.1 and 4.10.2 shows the total annual rainfall of Aizawl city from the year 2005-2020 and 2010-2019, recorded in the stations of Directorate of Science and Technology, New Secretariat and Pushpak, Thuampui, respectively.

Fig.4.10.1. Total Annual Rainfall (cm) in Directorate of Science & Technology: 2005-2020

As evident from the above diagrams, the quantity of rainfall in Aizawl city for the last 16 years is quite sporadic and it is in a diminishing pattern. The city receives a varying amount of rainfall almost every alternate year. Moreover, the last 3 consecutive years (2018-2020) receive pretty less amount of rainfall. The quantity of annual rainfall ranges from around 154 to 268 centimetres during the same period. The year 2017 marked the highest rainfall while the year 2008 received the lowest rainfall. However, the average annual rainfall of the city as per the data of Directorate of Science and Technology for the past sixteen years (2005-2020) is 203.325 centimetres.

Fig.4.10.2. Total Annual Rainfall (cm) in Pushpak: 2010-2019



The pattern and quantity of rainfall in Pushpak station during 2010-2019 is more or less similar to that of Directorate of Science and technology. The year of 2017 receives the highest rainfall which is 278.6 centimetres while the year 2019 marked the lowest amount of rainfall which is 178.2 centimetres during the same period. The mean annual rainfall as per the above data for the last 10 years is 215.02 centimetres.

4.11. Graphical Comparison of Annual Rainfall of Directorate of Science and Technology, New Secretariat and Pushpak, Thuampui from the year 2005-2020.

The following figure-4.11 graphically compares the quantity of annual rainfall between the stations of Directorate of Science and Technology, New Secretariat and Pushpak, Thuampui. The following diagram shows the quantity and pattern of rainfall in Aizawl city as per the data recorded in two rainfall stations for the past 16 years as indicated below. But, the rainfall data from Pushpak is available from the year 2010-

2019 only while the same from Directorate of Science & Technology is from 2005-2020. So, taking the mean from 2005-2020 could be erroneous. Thus, the mean annual rainfall of the last 10 years is calculated from 2010-2019 as the data from both the stations are available which is obtained at 215.22 centimetres. The amount of rainfall is more or less the same only in both the stations during 2010-2019. However, it could also be assume that the quantity of rainfall for the remaining years will be, to certain extent, the same only.

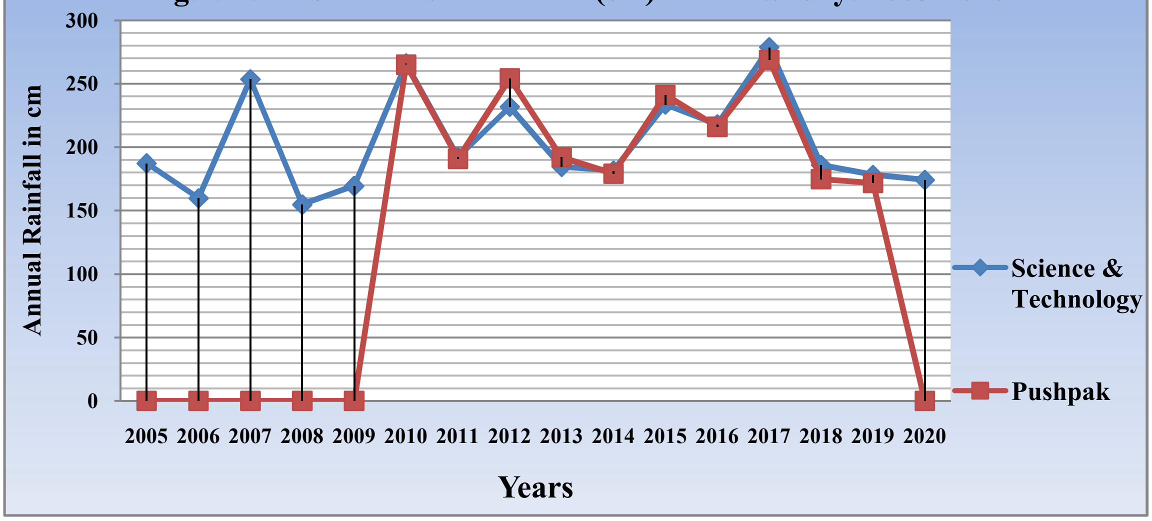


Fig.4.11. Total Annual Rainfall (cm) in Aizawl city: 2005-2020

4.12. Conclusion

It is evident from figure-4.1 and figure-4.10.1 that the correlation between deforestation and quantity of rainfall is minimal or negative for the last 16 years (2005-2020) particularly in the state of Mizoram. The total forest cover area of the state in 2005 was 18,684 square kilometres which increased to 19,240 square km in 2009. Since the year 2009, the total forest cover area of the state decreased gradually every biennial till the year 2019. The total forest cover area of the state in 2019 was only 18,006 square kilometres which is 6.41% decreased from the year 2009. There is a loss of 678 square kilometres forest cover area in the state within a span of 15 years (2005-2019).

On the other hand, even though the pattern of rainfall for the last 16 years (2005-2020) is irregular and sporadic, the quantity of rainfall is more or less the same except for the last three years (2018-2020). The quantity of rainfall in the state decreased or increased almost every alternate year. The rainfall in 2005 was 187.3 cm which decreased to 159.8 cm in the next years, i.e. 2006; it again increased to 253.5 cm in the year 2007. This pattern of alternate decrease and increase in the quantity of rainfall is experienced throughout the same period except during the years 2008-2009, 2013-2014 and 2018-2020.

Thus, it could be inferred that the pattern of deforestation in the state of Mizoram still does not have large scale immediate impacts on the quantity of rainfall for the last 16 years (2005-2020). This might be attributed to the fact that the quantity of rainfall of a particular region does not increase or decrease due to deforestation of such region or state or country. Rather it seems to change noticeably due to deforestation of a much larger scale such as continental or global scale; or possibly, may be only 16 years of deforestation or rainfall is too short to notice the effects as well.

Manual rain gauge at Directorate of Agriculture, Tuikual

Digital rain gauge at Directorate of Science & Technology, New Secretariat

CHAPTER-V

TYPES OF ROOF AND THEIR POTENTIALS FOR RAINWATER HARVESTING IN AIZAWL CITY

5.1. Introduction

This chapter deals with the types of roof in the state in general and in the study area in particular. Broadly, the types of roof are categorised into two types which are harvestable roofs and not harvestable roofs. Depending upon the design and purposes, some of the roofs which are made of mud, brick, bamboo, etc. may not be suitable for harvesting rainwater while some roofs which are made of galvanized iron (G.I), metal, plastic, concrete, etc may be more convenient for the same. So, this chapter shows the roofs suitable and not suitable for rainwater harvesting in the state as well as in the study area in particular.

Types of the roof are one of the most vital components to practice rainwater harvesting as it is the first place or site where the rain falls. Thus, the size of the catchment area and the type of the catchment area cannot be underestimated. The type of roof in Mizoram varies from district to district, locality to locality and so on. This chapter highlights the inter-districts variation of roof types in Mizoram, materials of roof types in percentage in Mizoram and types of roof in Aizawl city.

Since G.I roof is considered to be the most potential type of roof for rainwater harvesting, it is used as the basis for categorizing the study area into High, Medium, and Low potential localities to practice rainwater harvesting in the city. Thus, 722 households from 19 localities in each AMC ward are grouped into three categories on the basis of types of roof (G.I roof). The types of roof in all the localities are analyzed and interpreted so as to obtain the potentiality of any locality for rainwater harvesting.

Basically, this chapter emphasises the overall scenario of types of roof and their potentials for rainwater harvesting in various districts of Mizoram where data are available. It also gives a major thrust, in detail, on the types of roof and their potentials for rainwater harvesting in different selected localities in the study area, Aizawl city.

On the basis of types of roof found in different localities in the city, the study area is divided into three categories under the heading of: **1). Types of roof in High potential localities, 2). Types of roof in Medium potential localities, and 3). Types of roof in Low potential localities**. As the name itself suggests, the localities in the high potential category possess a type of roof that is mostly suitable for rainwater harvesting and so on and so forth for the remaining categories as well.

5.2. Types of roof in Mizoram: Inter-District variation

Table-5.1 below shows the types of roof which are harvestable and not harvestable in Mizoram.

Table-5.1	**Types of roof in Mizoram: Inter-District variation**		
State/District	**Total Occupied house**	**Not harvestable roof***	**Harvestable roof****
Mizoram	**2,57,581**	**41,002**	**2,16,579**
Mamit	19,883	5,929	13,954
Kolasib	20,238	3,887	16,351
Aizawl	**96,615**	**4,287**	**92,328**
Champhai	29,902	2,260	27,642
Serchhip	14,697	602	14,095
Lunglei	37,554	8,304	29,250
Lawngtlai	26,313	13,529	12,784
Saiha	12,379	2,204	10,175
*Roof made of Thatch/Bamboo/Mud; **Roof made of Metal/Concrete, Brick, Tile, Plastic etc			
Source: Household Census of India-2011			

As mentioned in the above table, roofs made of thatch/Bamboo/Mud etc, are considered to be not harvestable while roofs made of Metal/Concrete/Brick/Tile/Plastic etc, are considered to be harvestable. Generally, as roof is the first catchment area of rainwater, the type and material determine the capability to harvest the rainwater.

The total occupied house in the state is 2,57,581 as on 2011 census out of which 2,16,579 houses (84%) are harvestable while 41,002 houses (15.9%) are not harvestable. In Aizawl district, the total occupied houses is 96,615; and 4,287 houses (4.43%) are inconvenient for rainwater harvesting while as much as 92,328 houses (95.5%) are harvestable.

Mamit district has a total occupied houses of 19,883 and 5,929 houses (29.8%) are not harvestable while 13,954 houses (70.1%) are harvestable. Kolasib district has 20,238 occupied houses from which 3,887 (19.20%) are not harvestable while the remaining 16,351 houses (80.79%) are suitable for rainwater harvesting. Champhai district has total occupied houses of 29,902 out of which 2,260 houses (7.5%) are not harvestable while 27,642 houses (92.4%) are harvestable.

Serchhip district has 14,697 occupied houses, and 602 houses (4.09%) are not harvestable while 14,095 houses (95.9%) are harvestable. Lunglei district has total occupied houses of 37,554; and 8,304 houses (22.1%) are not harvestable while 29,250 house (77.88%) are harvestable. Lawngtlai district is with 26,313 occupied houses; and as much as 13,529 houses (51.4%) are not harvestable while 12,784 houses (48.5%) are harvestable. Saiha district has 12,379 occupied houses out of which 2,204 houses (17.8%) are not harvestable and 10,175 houses (82.1%) are harvestable.

It is evident from the analysis of table-5.1 that, except for Lawngtlai district, the majority of the houses and roofs in all other districts are harvestable which range from 70% - 95%. The study district (Aizawl city) as a whole has as much as 95.5% of roofs or houses which are harvestable. This shows the potentiality of practicing rainwater harvesting not only in Aizawl city but also in the whole state on the basis of roof type. But, in Lawngtlai district, 51.4% are not suitable for rainwater harvesting while a mere 48.5% are convenient for the same which is quite typical compared to other districts.

5.3. Materials of Roof in Mizoram in percentage (%)

The following table-5.2 represents the materials of the roof in Mizoram as a whole.

Table-5.2	Materials of Roof in Mizoram in percentage (%)								
District	**Grass/ Thatch/ Bamboo/ Wood/ Mud etc.**	**Plastic/ Polythene**	**Hand-made Tiles**	**Machine made Tiles**	**Burnt Brick**	**Stone/ Slate**	**G.I./ Metal/ Asbestos sheets**	**Concrete**	**Any other material**
Aizawl	4.9	0.3	0.1	0.1	0.2	1.3	**65.2**	**27.9**	0.1
Champhai	8.3	0.3	0	0.1	0.1	1.2	86.1	3.8	0
Kolasib	20.6	2.2	0.2	0.2	0.2	1.6	63.9	11	0.1
Lawngtlai	55.7	0.3	0	0.1	0.1	0.5	40.4	2.9	0
Lunglei	24.7	0.3	0.1	0.1	0.1	0.5	67.7	6.2	0.4
Mamit	33.2	1.2	0	0	0	0.3	62.7	2.4	0.1
Saiha	19.9	0.3	0.1	0.6	0.1	0.3	72.5	6.3	0
Serchhip	4.1	0.4	0.1	0	0.1	0.7	89.3	5.2	0
Mizoram	**21.42**	**0.66**	**0.075**	**0.15**	**0.11**	**0.8**	**68.47**	**8.21**	**0.08**
Source: Household Census of India-2011									

Generally, G.I sheet is the most common type of roof in all the districts except Lawngtlai where 55.7% of the roofs are of grass/thatch/bamboo/wood etc while G.I sheet accounts for 40.4% only. In Aizawl district, 65.2% of the roofs are of G.I sheet while 27.9% are of concrete roof.

In Champhai district, 86.1% of the roofs are G.I sheet while 8.3% are of grass/thatch/bamboo/wood etc. In Kolasib district, G.I sheet accounts for 63.9%; concrete roof accounts for 11%; and grass/thatch/bamboo/wood etc account for 20.6%.

In Lunglei district, 67.7% is of G.I sheet while grass/thatch/bamboo/wood etc account for 24.7%. In Mamit district, 62.7% is of G.I sheet while 33.2% is of grass/thatch/bamboo/wood etc. In Saiha district, 72.5% of the roofs are G.I sheet while 19.9% are of grass/thatch/bamboo/wood etc. In Serchhip district, 89.3% are of G.I sheet; concrete accounts for 5.2%; and grass/thatch/bamboo/wood etc account for 4.1%.

As a whole, G.I sheets account for 68.47% of the roofs; grass/thatch/bamboo/wood etc account for 21.42%; and concrete accounts for 8.21% of the roofs in Mizoram. Thus, most of the roof in the state is of G.I sheet (68.47%) which is considered to be very suitable for practicing rainwater harvesting.

5.4. Types of roof in Aizawl city

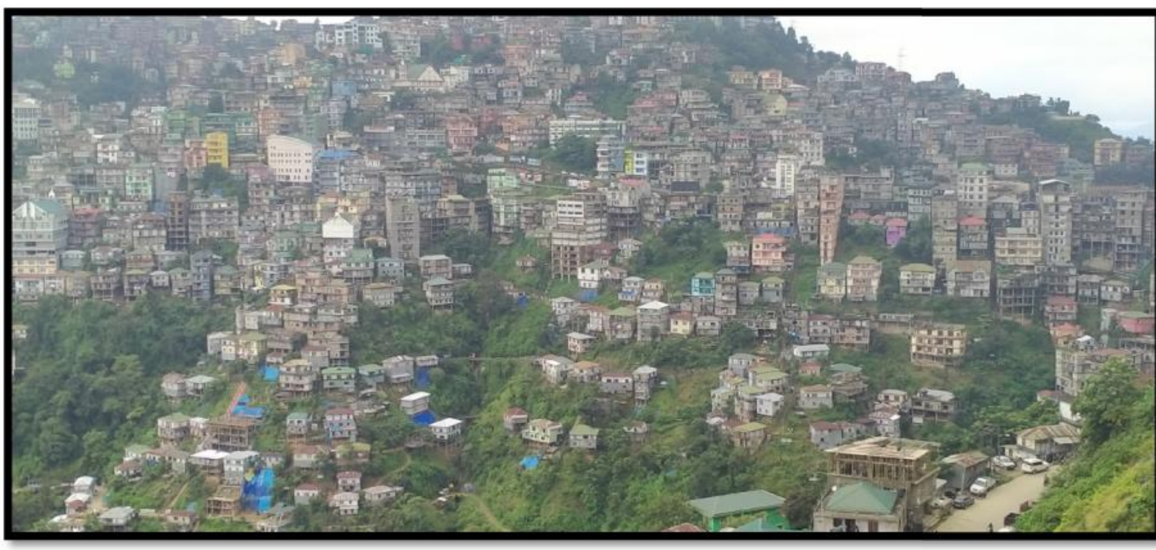
Household survey was conducted in 19 selected localities from 19 different Aizawl Municipal Corporation (A.M.C) wards using questionnaire on different issues pertaining to the potentials and practices of rainwater harvesting in Aizawl city, especially on the issue of type of roofs.

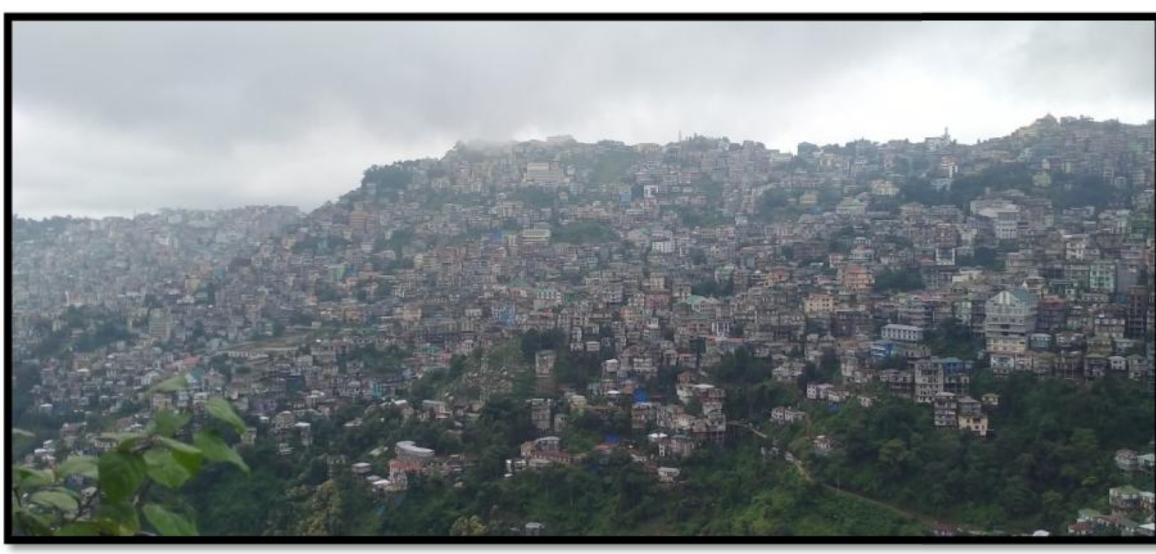
Table-5.3	**Types of roof in Aizawl city**	
Types	Number of roof	Percentage
Concrete roof	277	38.36%
G.I roof	417	57.75%
Tiles/others	28	3.87%
Total roofs	722	
Source: Field survey, 2018		

The above table shows the type of roofs in the city as a whole. As shown in table 5.3, 38.36% of the roofs in the city are concrete; 57.75% of the roofs are G.I sheet and 3.87% of the same are tiles/bricks/etc. But the results and data so obtained differ from house to house and locality to locality which are interpreted locality-wise below.

In Aizawl city, roof with G.I sheet is considered to be the most potential type for rooftop rainwater harvesting, followed by roofs made of RCC. Accordingly, the study area which includes 19 localities from each AMC ward is divided into ***high, medium and low potential localities*** based on the types of roof which is interpreted below. The types of roof determine the potentiality of practicing RWH as it is the surface where the rain falls first. Therefore, the potentiality of practicing RWH in a locality is also based on it.

Types of roof in eastern slope of Aizawl city ridge





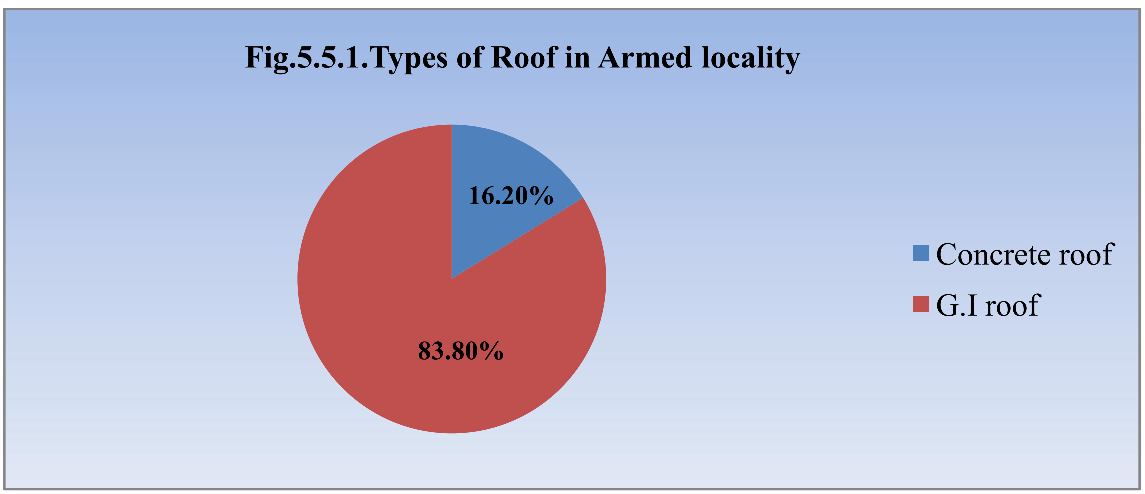
Types of roof in some parts of western slope of Aizawl city ridge

5.5. Types of roof in High potential localities in Aizawl city

The below localities possess high potentialities to practice rainwater harvesting in Aizawl city on the basis of type of roofs. High potential localities on the basis of G.I roof type include Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Armed, College, Zonuam, I.T.I and Khatla which are interpreted in the following. These localities are categorised as high potential localities because the types of roof found in the area are mostly G.I sheet which is the most convenient type to practice rooftop rainwater harvesting.

5.5.1. Armed locality

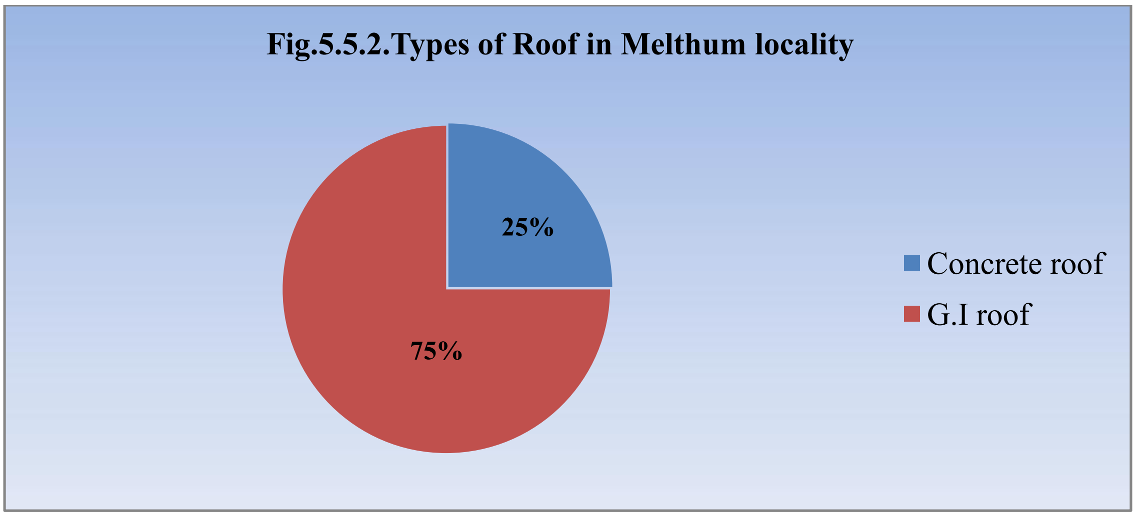
The below diagram represents the type of roof in Armed Veng locality in which it is evident that most of the roofs found in the area is with G.I roof.



As shown in the above fig.5.5.1, house to house survey on the type of roof was conducted for 43 different buildings in Armed Veng locality. It is noticed that there are 7 buildings with concrete roof which is 16.2 percent out of the total sample in Armed Veng locality. There are 36 buildings with G.I (galvanized iron) roof which is 83.8 percent. Generally, as building with G.I sheet roof is more convenient and suitable for practicing rainwater harvesting, Armed Veng locality has a good opportunity to practice rainwater harvesting based on the type of roof found in the area.

5.5.2. Melthum locality

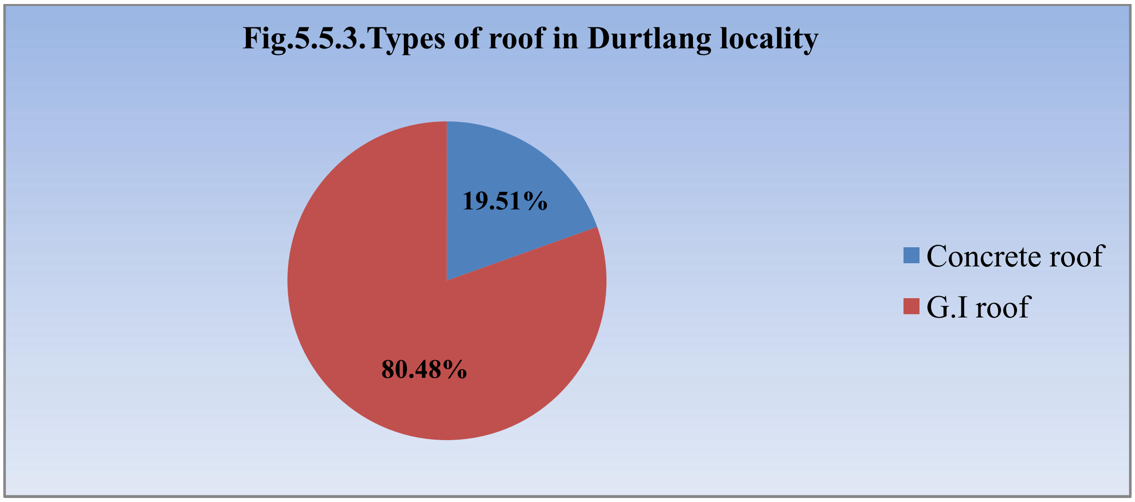
Figure 5.5.2 shows the type of roof notified in Melthum locality and it is observed that most of the buildings are of G.I roof.



Survey was conducted on the types of roof in the area in which it was found that 25% of the samples were concrete roof and the remaining 75% of the samples were G.I roof. From the above data, it could be concluded that the potentiality to practice rainwater harvesting in the locality is very high on the basis of type of roof.

5.5.3. Durtlang locality

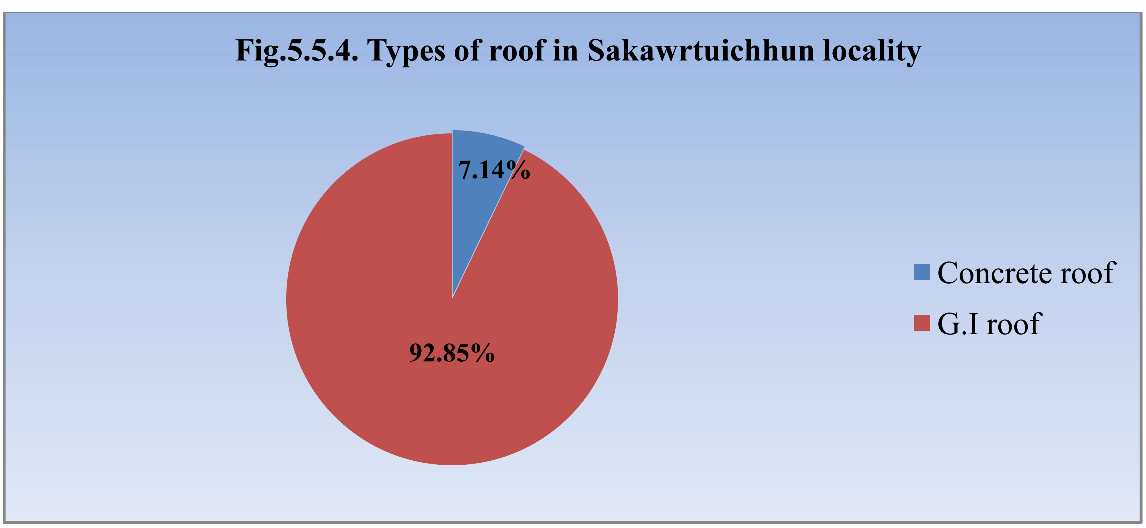
The below diagram represents the types of roof found in Durtlang locality. This locality is located in the northern most part of the study area and it is one of the highest elevation areas in the city where the PHE water connection is implemented or launched only about 4-5 years back due apparently to its spatial altitude. Due to the scarcity of water in the area, most of the households practice proper and efficient rainwater harvesting system.



As per the field data shown in the above fig.5.5.3, there are 8 concrete roofs in the locality which account for 19.51%. Meanwhile, 80.48% of the roofs are G.I roof which indicate the high potentiality of practicing rainwater harvesting in the locality. This locality has the highest number of households practicing full-fledge rainwater harvesting in the city.

5.5.4. Sakawrtuichhun locality

Fig.5.5.4 represents the types of roof noticed in Sakawrtuichhun locality and it is observed that majority of the roofs are with G.I sheet in the area. This locality is located in the western fringe of the city.

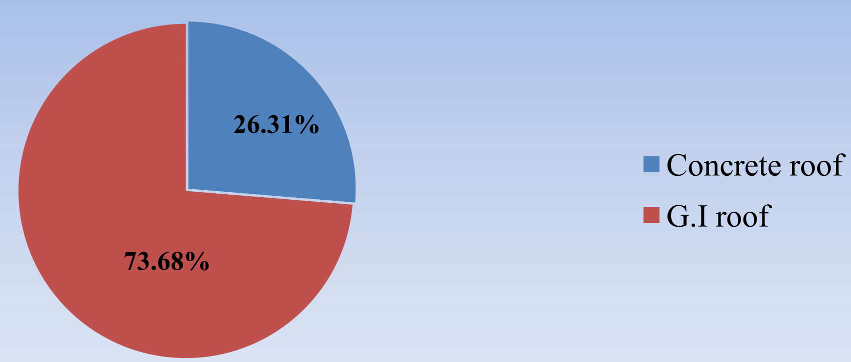


The above Fig.5.5.4 indicates the type of roof found in the locality. As shown above, 7.14% of the samples are concrete roof while 92.85% of the samples are G.I roof. Given the importance of type of roof, it could be asserted from the given data that the potentiality of practicing rainwater harvesting is high in the area.

5.5.5. Ramthar North locality

The below chart indicates the types of roof prevalent in Ramthar North locality. The following fig.5.5.5 shows the types of roof found in the locality.

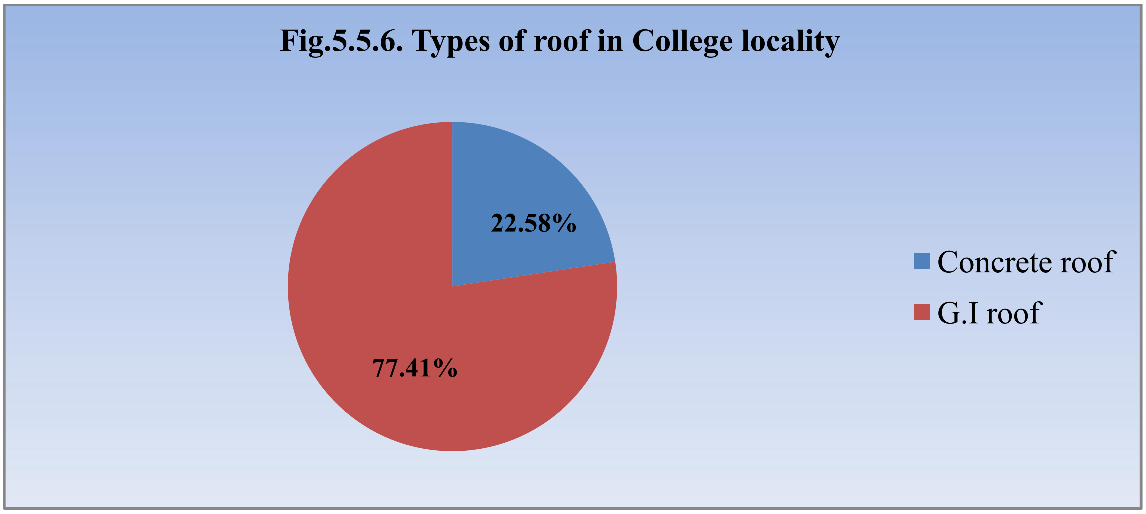
Fig.5.5.5. Types of roof in Ramthar North locality



Out of 19 samples there are 5 concrete roofs which account for 26.31% in the area and there are 14 G.I roofs which account for 73.68% of the samples. It could be asserted that the potentiality and conveniences of practicing rainwater harvesting in the area is quite promising on the basis of type of roof.

5.5.6. College locality

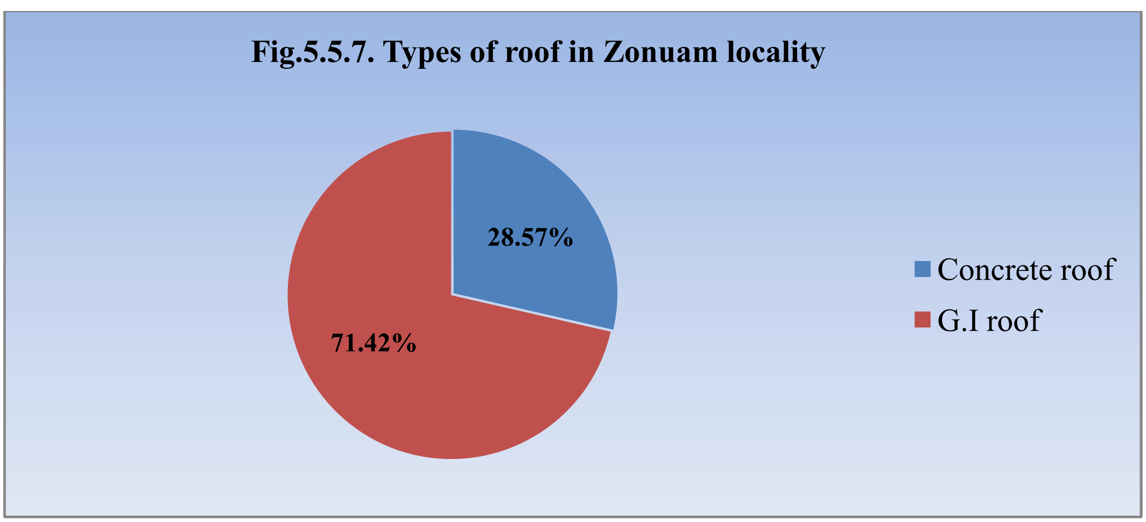
Types of roof, to certain extent, determine the potentiality of rainwater harvesting. Generally, in Mizoram, the roofs with G.I sheet are more potential than any other types of roof as it is convenient and the most prevalent type of roof in rural areas as well as in urban areas also.



The above fig.5.5.6 shows the types of roof found in College locality. There are 7 concrete roofs which account for 22.58% and there are 24 G.I roofs which is 77.41%. Considering the number of G.I roof found in the area, it could well be asserted that the potentiality of practicing rainwater harvesting is high in the locality.

5.5.7. Zonuam locality

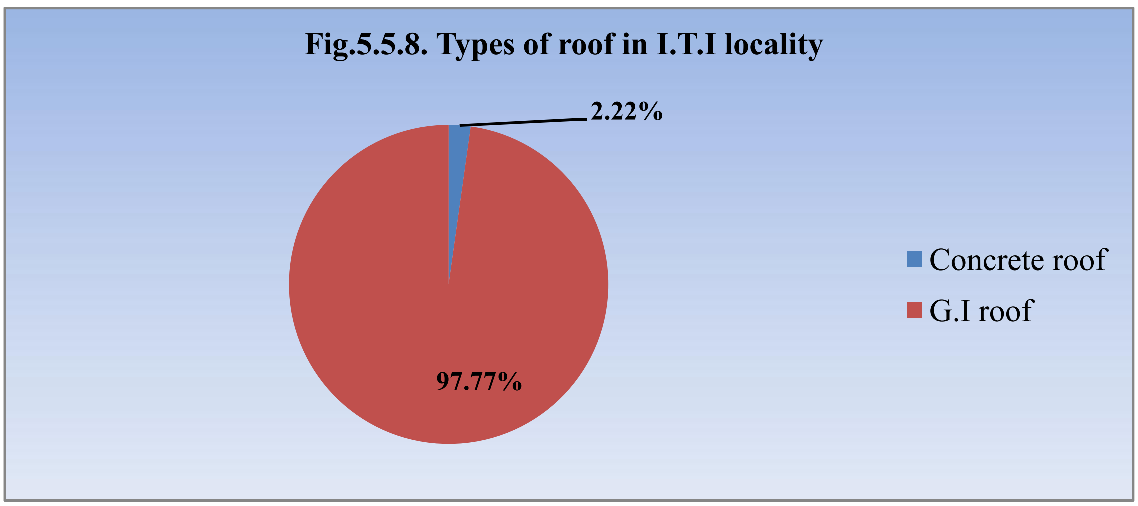
Zonuam locality is also one of the most potentials localities to practice rainwater harvesting.



As per the field data depicted in the above fig.5.5.7, there are 8 concrete roofs in the locality which account for 28.57%. Meanwhile, 71.42% of the roofs are G.I roof which indicate the high potentiality of practicing rainwater harvesting in the area. In Zonuam locality, it is observed that there are some households practicing full-fledge rainwater harvesting. It is learnt that these households do not used water supply from PHE and they rather used the harvested rainwater throughout the year. Even though they possess PHE water connection, they let their tenants used it.

5.5.8. I.T.I locality

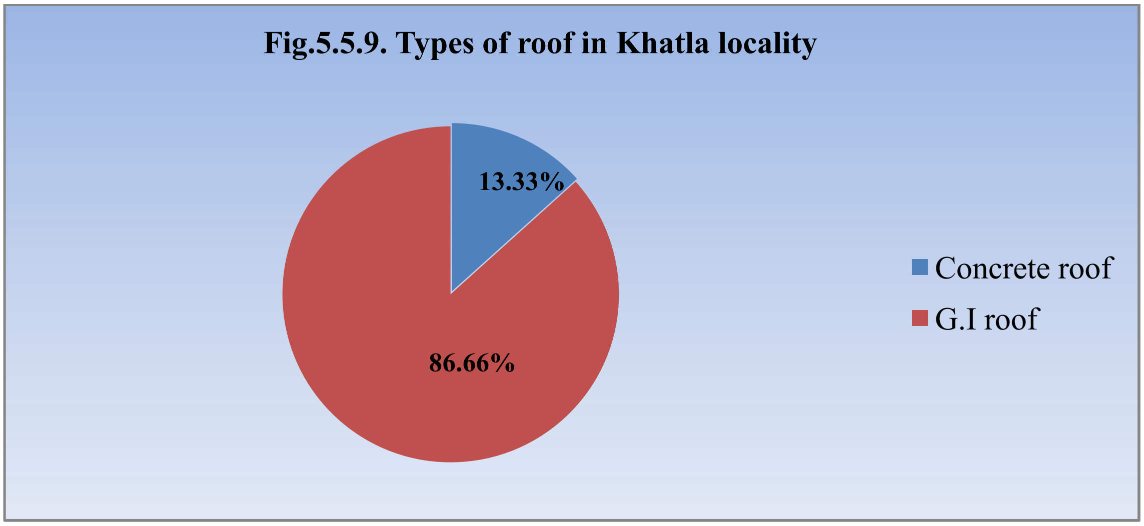
I.T.I locality has a great potential on the basis of types of roof as depicted below.



The above fig.5.5.8 shows the types of roof found in the locality. There is only 1 concrete roof in the area out of 45 samples while there are 44 G.I roofs which account for almost 98% from the samples. It could be asserted that the potentiality and conveniences of practicing rainwater harvesting in the area is very promising.

5.5.9. Khatla locality

Given the importance of type of roof, Khatla locality, situated in the central part of the city, is another high potential locality for practicing rainwater harvesting as shown in fig.5.5.9 below.

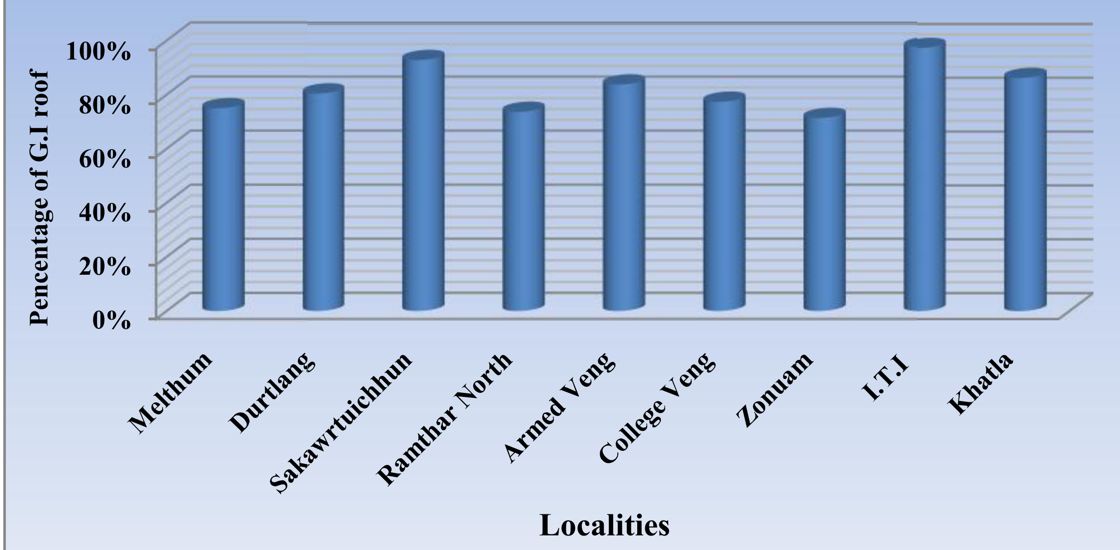


The above fig.5.5.9 shows the types of roof found in the locality. There are 10 concrete roofs which account for 13.33% out of 75 samples while there are 65 G.I roofs which account for almost 86.66% from the samples in the area. It is cleared from the above data that the potentiality and conveniences of practicing rainwater harvesting in the area is very high.

5.6. High potential localities to practice RWH

As whole, the following fig.5.6 shows the percentage of G.I roof found in different highly potential localities on the basis of types of roof (G.I roof). As depicted below, I.T.I locality has the highest number of roof with G.I sheet which is 97.77% of the samples, followed by Sakawrtuichhun locality with G.I roof of 92.85%. Khatla, Armed and Durtlang localities have G.I type of roof with 86.66%, 83.80% and 80.48% respectively. The remaining localities have more or less the same number of percentage. College locality with 77.41%, Melthum locality with 75%, Ramthar North locality with 73.68% and Zonuam locality with 71.42% are also very potential for practicing rainwater harvesting in the city.

Fig.5.6. Percentage of G.I roof in High potential localities to practice RWH



Thus, it is found that out of 19 Aizawl Municipal Corporation (AMC) wards, 9 localities possess a very promising potential on the basis of types of roof. The average percentage of G.I roof in these highly potential localities to practice RWH, on the basis of roof type, is 82% while the remaining 18% is of concrete roof as a whole. Even if only these localities practice regular and full-fledge rainwater harvesting in the city, the scarcity and problems of water in the city could be mitigated to certain extent.

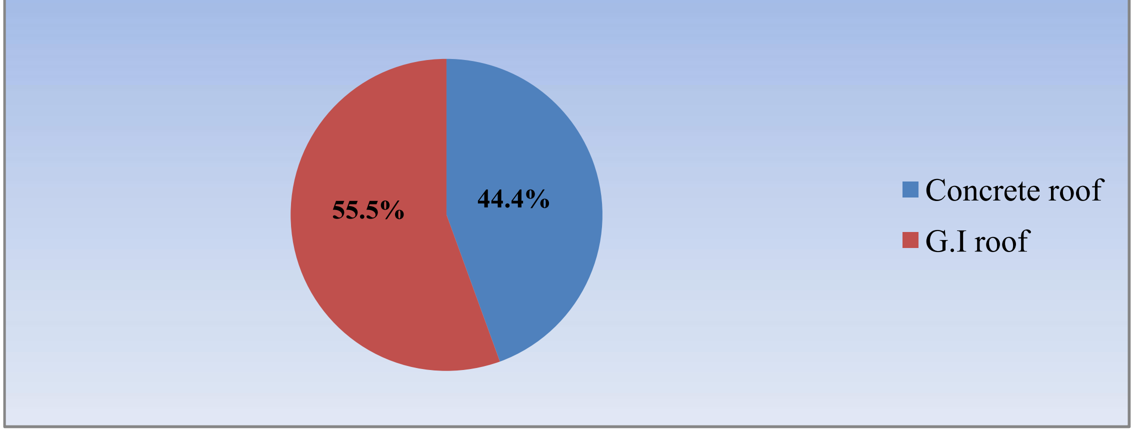
5.7. Types of roof in Medium potential localities in Aizawl city

During the survey, it is found that there are five localities where the number of G.I roof and concrete roof are more or less the same. These localities are Kanan, Zemabawk North, Hunthar, Upper Republic and Ramhlun Sport Complex localities. The types and numbers of roofs for each locality are interpreted below.

5.7.1. Kanan locality

Kanan locality could be categorized as a medium potential locality for practicing rainwater harvesting due to the types of roof found in the area.

Fig.5.7.1. Types of roof in Kanan locality

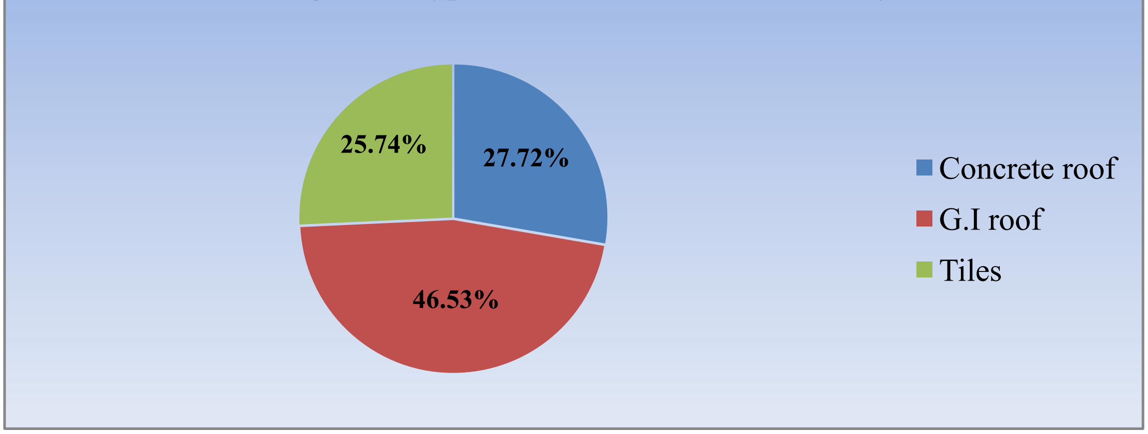


The above fig.5.7.1 shows that Kanan locality has a good opportunity to practice rainwater harvesting, because 55.5% of roofs is G.I roof which is very suitable for practicing rainwater harvesting. It is learnt that even if 55.5% of the family practices full-fledge rainwater harvesting, the scarcity of water in the area will be resolved to a great extent. Generally, to some extent, the types of roof affect the possibility of practicing rainwater harvesting. Out of 44.4%, some buildings with concrete roof are also still suitable for practicing rainwater harvesting.

5.7.2. Zemabawk locality

Zemabawk locality is also one of the five medium potential localities to practice rainwater harvesting in Aizawl city.

Fig.5.7.2. Types of roof in Zemabawk locality

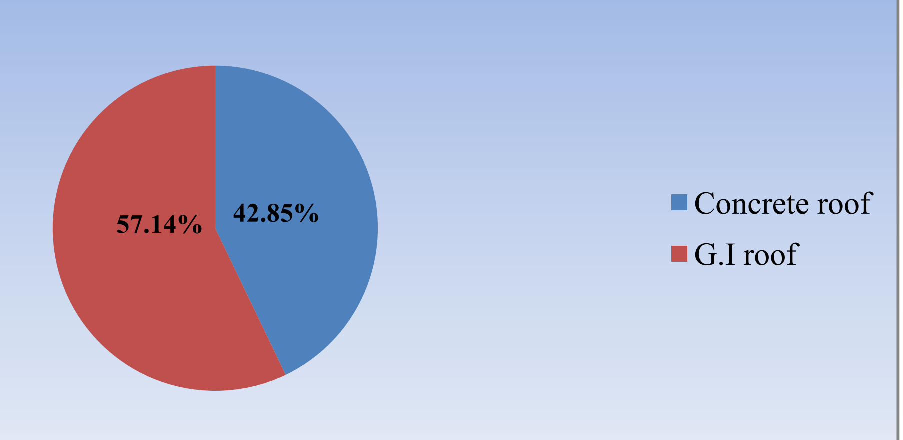


As per the field data shown in the above fig.5.7.2, there are 28 concrete roofs in the locality which account for 27.72% of the samples. Meanwhile, 47 roofs are of G.I roof which account for 46.53% of the samples which indicate the high potentiality of practicing rainwater harvesting in the locality. Also, there are 26 roofs with tiles which account for 25.74% of the samples.

5.7.3. Hunthar locality

Hunthar locality is also one of the five medium localities to practice rainwater harvesting in the city.

Fig.5.7.3. Types of roof in Hunthar locality

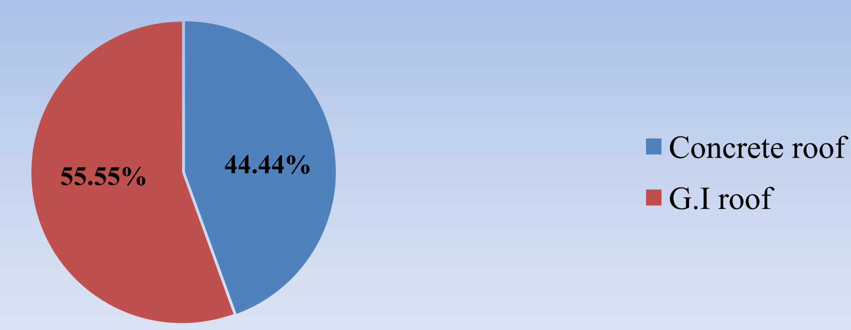


Hunthar locality is also one of the low lying areas in the north western part of the city. As per the field data shown in the above fig.5.7.3, there are 12 concrete roofs in the locality which account for 42.85%. Meanwhile, 16 roofs are of G.I roof which account for 57.14% which indicate the high potentiality of practicing rainwater harvesting in the locality.

5.7.4. Upper Republic locality

Upper Republic locality, situated in the central part of the city, is also a medium potential locality as the types of roofs (G.I and RCC roofs) found in the area are almost equivalent as depicted below.

Fig.5.7.4. Types of roof in Upper Republic locality

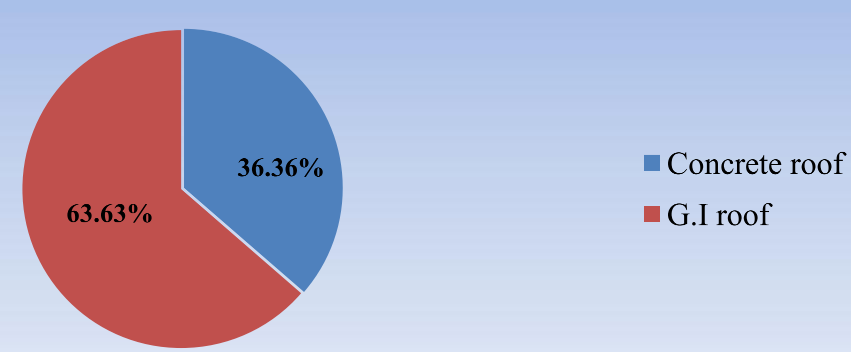


The above fig.5.7.4 shows that Upper Republic locality also has a good opportunity to practice rainwater harvesting, because 55.55% of roofs is G.I roof which is very suitable for practicing rainwater harvesting. It is assumed that even if 55.55% of the family practices full-fledge rainwater harvesting, the deficiency of water in the area will be resolved to a great extent. Generally, the types of roof affect the possibility of practicing rainwater harvesting. Out of 44.44%, some buildings with concrete roof are also still suitable for practicing rainwater harvesting.

5.7.5. Ramhlun Sport Complex locality

The following figure 5.7.5 highlights the type of roof found in Ramhlun sport complex locality.

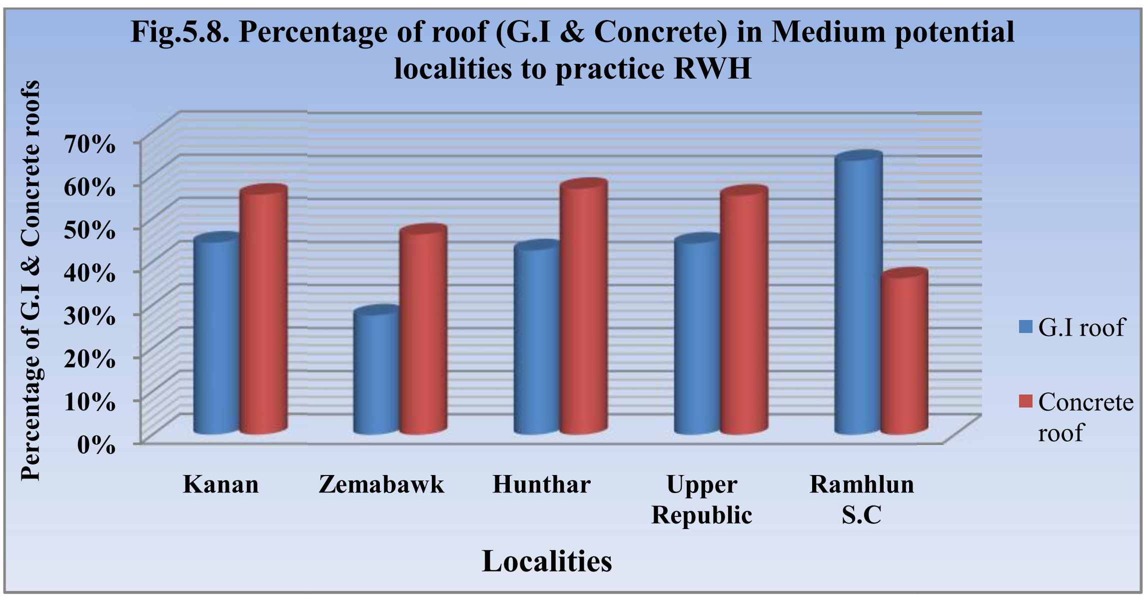
Fig.5.7.5. Types of roof in Ramhlun S.C locality



Out of 11 samples in the area, it is observed that 36.36% of the roofs in Ramhlun sport complex locality are concrete roof while the remaining 63.63% of the roofs are of G.I roof. It is evident from the type of roof here in the area that there is higher chance of practicing rainwater harvesting. If all the samples practice full-fledge rainwater harvesting method, the water condition in the area will be sufficient for majority of the area.

5.8. Medium potential localities to practice RWH

The following figure-5.8 shows the percentage of G.I and Concrete roof in five medium potential localities in Aizawl city.



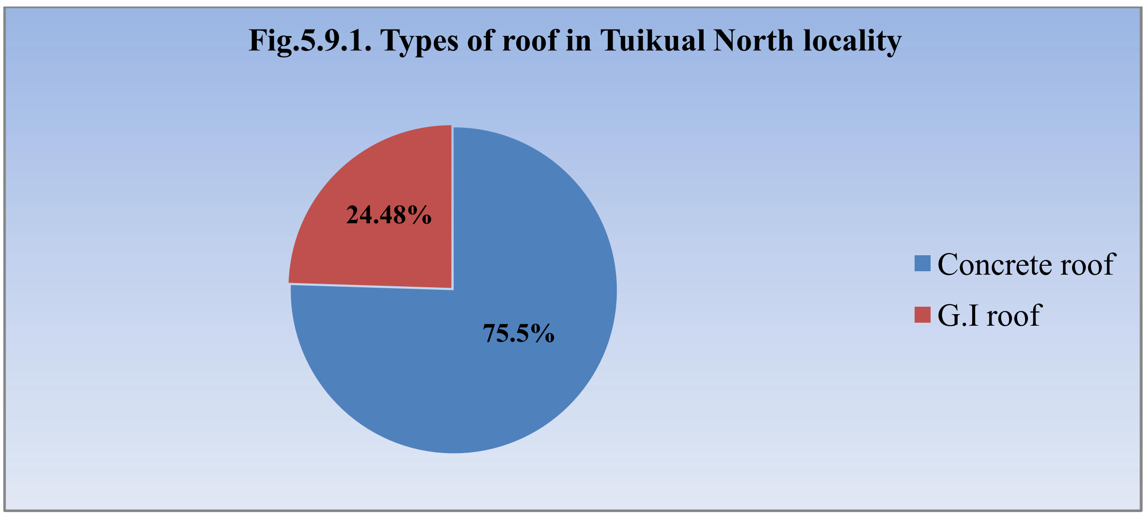
As evident from figure-5.8, the medium potential localities on the basis of roof type (G.I & Concrete roof) are Kanan, Zemabawk, Hunthar, Upper Republic and Ramhlun S.C localities in the city as the main types of roof are more or less equal. The average percentage of G.I roof in these moderately potential localities to practice RWH, on the basis of roof type, is 44.60% while the majority 50.21% is of concrete roof and another negligible 3% is tiles/bricks/others as a whole. Basically, the harvestable roofs and not harvestable roofs found in the area are almost equivalent due to which these localities fall under medium category.

5.9. Types of roof in Low potential localities in Aizawl city

This group includes the localities with high number of concrete roof which is not generally suitable and convenient to practice rainwater harvesting. It also has to be remembered that due to the design and purposes, some concrete roofs are suitable or unsuitable for rainwater harvesting. These localities are Tuikual North, Bawngkawn South, Maubawk, Chanmari and Saron which are interpreted below.

5.9.1. Tuikual North locality

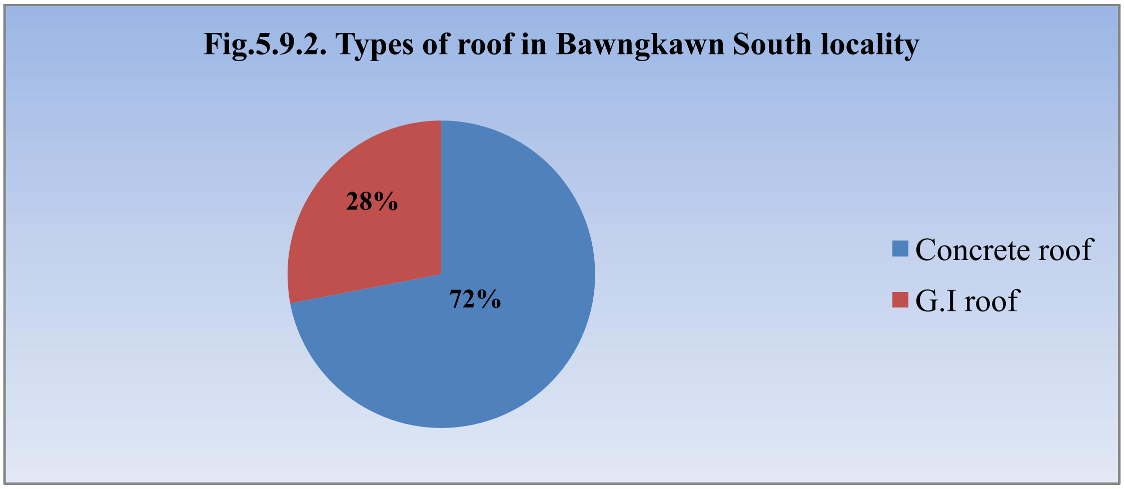
The following figure 5.9.1 indicates the types of roof found in Tuikual North locality.



As shown in the above figure 5.9.1, 75.5% of the samples are concrete roof while 24.48% of the samples are G.I roof. Keeping in mind the importance of type of roof, it could be asserted from the given data that the potentiality of practicing rainwater harvesting is low on the basis of roof type in the area.

5.9.2. Bawngkawn South locality

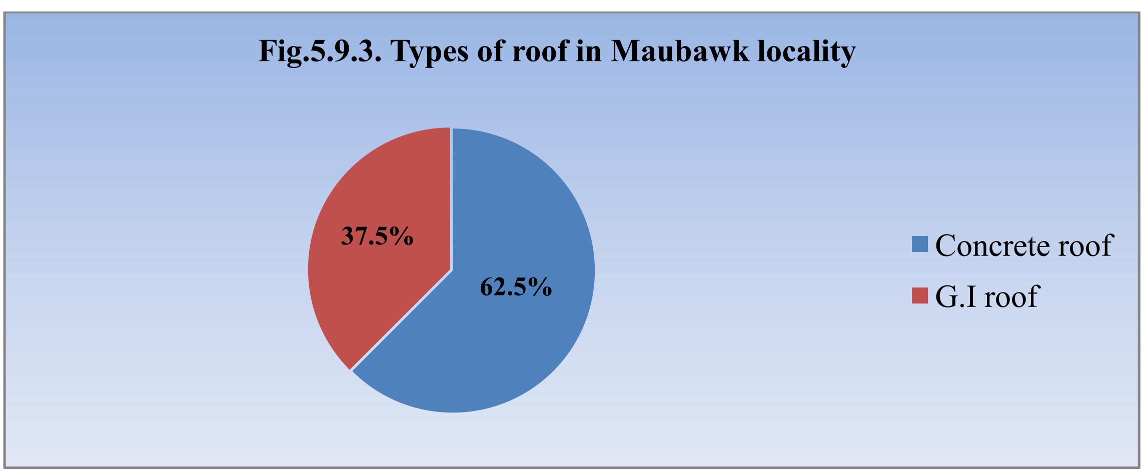
Figure 5.9.2 represents the types of roof found in Bawngkawn South locality situated in the northern part of the study area.



Out of 25 samples in the area, it is found that 72% of the roofs in Bawngkawn South locality are concrete roof and the remaining 28% of roofs are G.I roof. As per the type of roof in the area, there is lesser chance or only 28% of practicing rainwater harvesting. Even though most of the concrete roofs are not suitable for practicing rainwater harvesting, some concrete roofs, i.e. 28%, are still found to be convenient for practicing rainwater harvesting in the locality.

5.9.3. Maubawk locality

The following diagram represents the types of roof found in Maubawk locality.

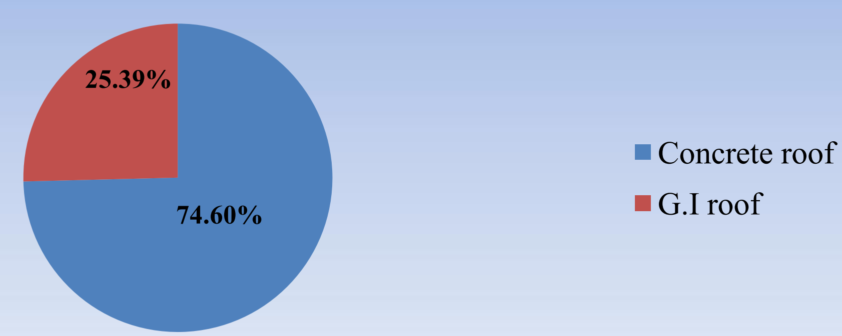


As shown in the above data, out of 40 samples, the number of concrete roof in the locality is 25 which account for 62.5% while the remaining 37.5% is G.I roof. As evident, the potentiality of practicing rainwater harvesting in the area is low on the basis of type of roof.

5.9.4. Chanmari locality

The above table-5.9.4 shows the type of roof in Chanmari locality which is located in the central part of the study area.

Fig.5.9.4. Types of roof in Chanmari locality

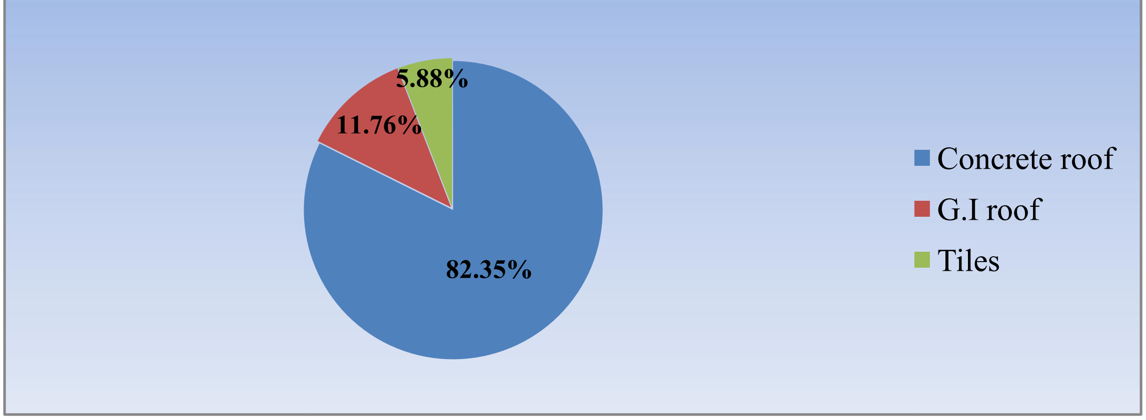


There are 47 concrete roofs which are 74.60% and there are 16 G.I roofs which account for 25.39% in the area. As most of the concrete roofs are less suitable for rainwater harvesting, the possibility and potentiality of practicing rainwater harvesting in the area could be less. This locality is also one of the central business district areas where the buildings are constructed very close to each other due to congestion. And spaces for constructing water storage facilities could be a major challenge in the area.

5.9.5. Saron locality

The following pie chart shows the types of roof found in Saron locality. This locality is also located in the central business district area of the city where there are very less open spaces due to congestion. Like few other localities situated in the main business area, the potentiality of practicing rainwater harvesting may be less in this area as well.

Fig.5.9.5. Types of roof in Saron locality

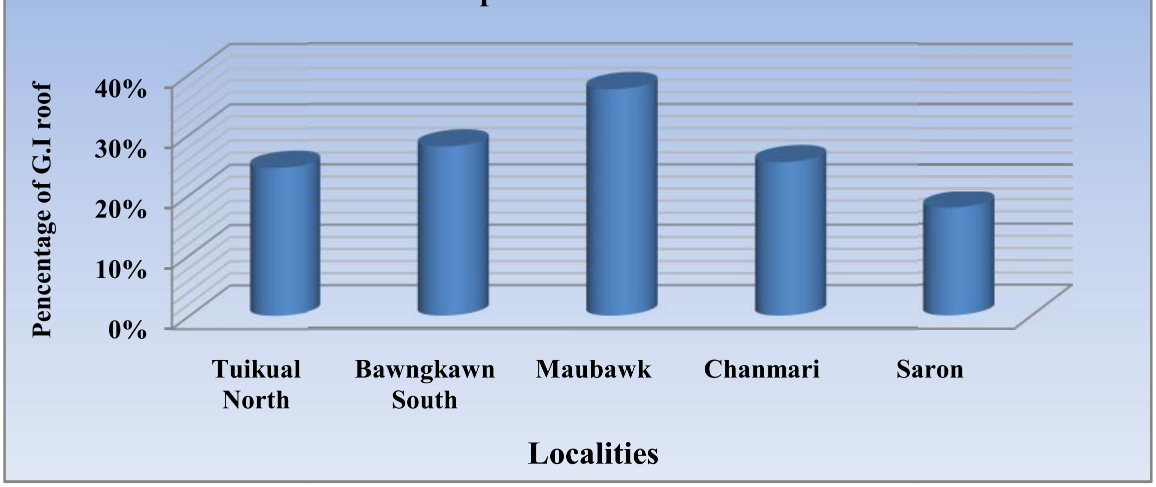


There are 28 concrete roofs which account for 82.35% out of 34 samples while there are 4 G.I roofs which account for 11.76% of the samples in the area. And 5.88% of the roofs are tiles in the locality. It is cleared from the above data that the potentiality and conveniences of practicing rainwater harvesting in the area is low considering the types of roof.

5.10. Low potential localities to practice RWH

The following figure 5.10 highlights the percentage of G.I roof in five different low potential localities to practice RWH in the city.

Fig.5.10. Percentage of G.I roof in Low potential localities to practice RWH



As seen in fig.5.10, the low potential localities on the basis of roof type (G.I roof) includes Tuikual North, Bawngkawn South, Maubawk, Chanmari and Saron localities as majority of the roofs are made of concrete roof which is considered to be less convenient for practicing rainwater harvesting when compare to that of G.I roof.

5.11. Conclusion

It is evident from the analysis of table-5.1 that, except for Lawngtlai district, majority of the houses and roofs in all other districts are harvestable which range from 70% - 95%. The study district (Aizawl city) as a whole has as much as 95.5% of roofs or houses which are harvestable. This shows the potentiality of practicing rainwater harvesting not only in Aizawl city, but also in the whole state on the basis of roof type. But, in Lawngtlai district, 51.4% are not suitable for rainwater harvesting while a mere 48.5% are convenient for the same which is quite typical compared to other districts.

As a whole, G.I sheets account for 47% of the roofs; grass/thatch/bamboo/wood etc account for 21.42%; and concrete accounts for 8.21% of the roofs in Mizoram. Thus, most of the roof in the state is of G.I sheet (68.47%) which is considered to be very suitable for practicing rainwater harvesting.

It is found that out of 19 Aizawl Municipal Corporation (AMC) wards, 9 localities possess a very promising potential on the basis of types of roof. The average percentage of G.I roof in these highly potential localities to practice RWH, on the basis of roof type, is 82% while the remaining 18% is of concrete roof as a whole. Even if only these localities practice regular and full-fledge rainwater harvesting in the city, the scarcity and problems of water in the city could be mitigated to certain extent.

As evident from figure-5.8, the medium potential localities on the basis of roof type (G.I & Concrete roof) are Kanan, Zemabawk, Hunthar, Upper Republic and Ramhlun S.C localities in the city as the main types of roof are more or less equal. The average percentage of G.I roof in these moderately potential localities to practice RWH, on the basis of roof type, is 44.60% while the majority 50.21% is of concrete roof and another negligible 3% is tiles/bricks as a whole.

The low potential localities on the basis of roof type (G.I roof) includes Tuikual North, Bawngkawn South, Maubawk, Chanmari and Saron localities as majority of the roofs are made of concrete roof which is considered to be less convenient for practicing rainwater harvesting. The percentage of G.I roof ranges from 17 – 37% in these low potential localities area.

As a whole, 9 localities (Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Armed Veng, College, Zonuam, I.T.I and Khatla) have a very high and ideal condition for practicing rainwater harvesting in the city while five localities such as Kanan, Zemabawk North, Hunthar, Upper Republic and Ramhlun Sport Complex localities possess medium potential to practice the same. Lastly, five localities such as Tuikual North, Bawngkawn South, Maubawk, Chanmari and Saron possess poor or low potential to practice rainwater harvesting in the city.

CHAPTER – VI

PRACTICES OF ROOFTOP WATER HARVESTING IN AIZAWL CITY

6.1. Introduction

The practices of rainwater harvesting could be said as the traditional practices and habits of our ancestors back in the olden days. The history of the Mizos is closely knitted with RWH to a certain extent as the types of the roof during the ancestral period were mostly kind of grass which was quite convenient for harvesting rainwater. Big jars or containers were placed near the windows or the door of the house where the rain falls or pours from the roof. This water was used for various domestic purposes such as food, drinking, bathing, etc. during the rainy season.

Till now in Mizoram, especially during the monsoon, most of the households store or harvest rainwater from their rooftop for various domestic uses due to abundant and fresh rainwater in the state as of now. This chapter highlights the households practicing and not practicing rooftop water harvesting in different localities during monsoon season. Accordingly, 19 localities of the study area are categorized into three groups, viz. **1). High RWH practicing localities, 2). Medium RWH practicing localities, 3). Low RWH practicing localities,** on the basis of the practices of rooftop water harvesting or simply households storing or not storing rainwater from rooftop; and it is not based on households practicing full-fledge rainwater harvesting system.

This chapter also highlights the number of families practicing full-fledged rainwater harvesting systems in the city. A full-fledge rainwater harvesting system differs from simple rainwater collection during monsoon in such a way that the former involves quite a systematic planning and method. The data of rooftop water harvesting in this chapter are obtained from house to house field survey and it represents the ground reality of the city on the practice of rooftop water harvesting. As already mentioned in the previous chapter about the types of roof in the state and in the city, it is also observed from the field survey that there are many houses and roofs which are not harvestable.

***Pics: Rooftop rainwater harvesting in Aizawl city*.**

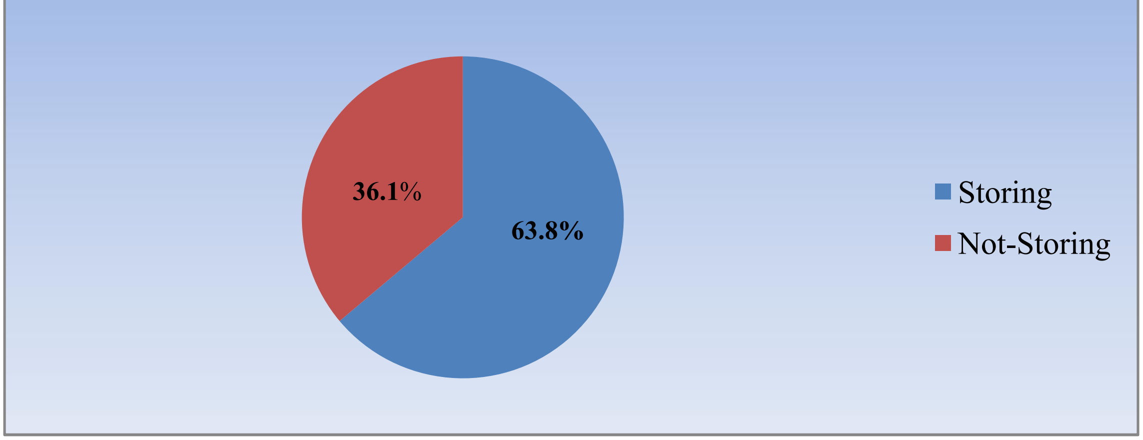
6.2. High RWH practicing localities in Aizawl city

This group includes Kanan, Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Zonuam and I.T.I localities where rooftop water harvesting is very common and prevalent. Majority of the households in this category practice rainwater harvesting in one way or the other.

6.2.1. Kanan locality

Figure 6.2.1 below shows the percentage of household storing and not storing rainwater from roof top in Kanan locality.

Fig.6.2.1. Practices of RWH in Kanan locality

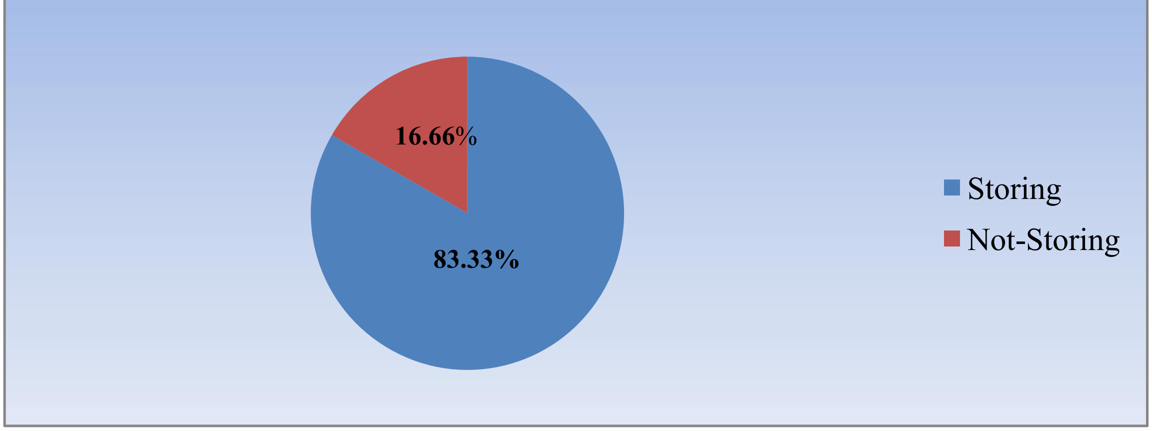


It is evident from the above table-6.2.1 that 63.8% of the families store rainwater from roof during rainy season while 36.1% of the families do not store the same due to the type of roof, storage facility and other inconveniences. Apparently, all the families storing rainwater do not practice full-fledge rainwater harvesting as they do not possess a sufficient storage facility due to varying reasons, and as a result, the rainwater is being stored and used on a daily basis during rainy season only. Thus, the extent of water scarcity during dry season remains the same.

6.2.2. Melthum locality

Fig.6.2.2 shows the number of household storing or not storing rainwater from roof in the area.

Fig.6.2.2. Practices of RWH in Melthum locality



It is evident that majority of the samples, i.e. 83.33%, store rainwater while the remaining 16.66% do not store the same. This shows that if the families storing rainwater practice full-fledge RWH system, the locality will be self sufficient in water to a great extent.

6.2.3. Durtlang locality

Below is the pattern of rainwater harvesting or rooftop rainwater collection in the locality.

Fig.6.2.3. Practices of RWH in Durtlang locality

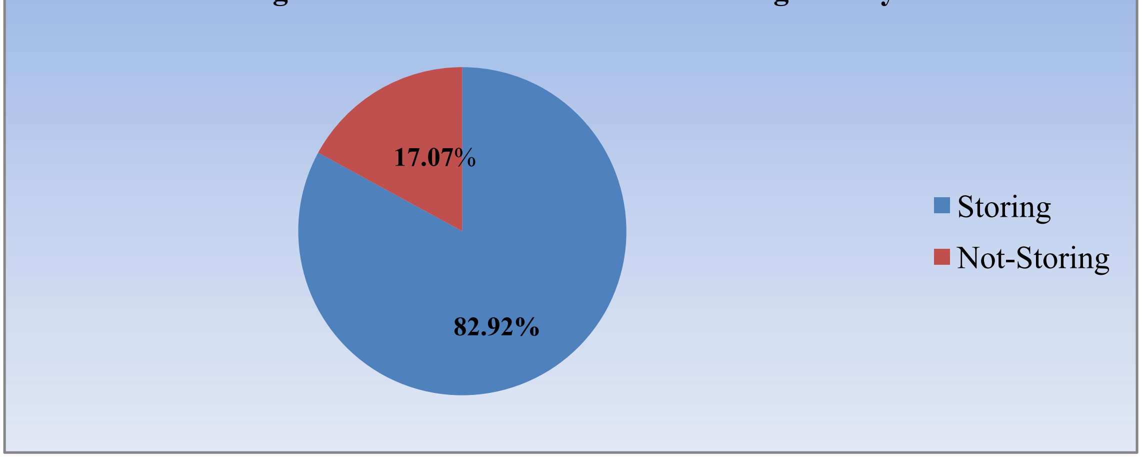
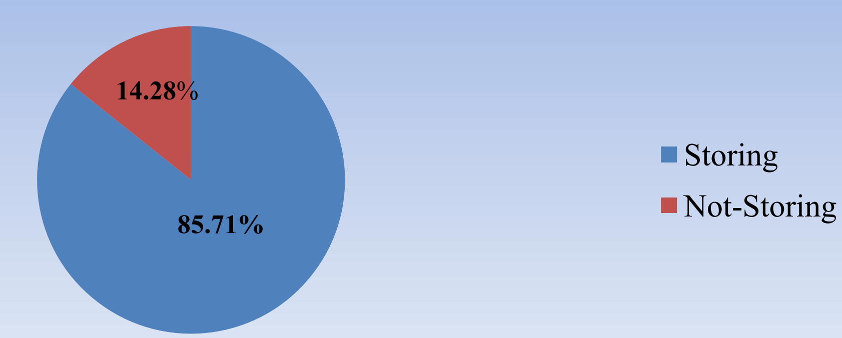


Fig.6.2.3 above reveals that 34 families that account for 82.92% store rainwater from their rooftop; and there are 7 families accounting for 17.07% who do not store the same. It is also noteworthy to mention that it was found from the field survey that out of 34 families who store rainwater from rooftop, many other families also practice rainwater harvesting in the area.

6.2.4. Sakawrtuichhun locality

The given pie chart below depicts the households storing or not-storing rainwater from roof in the locality.

Fig.6.2.4. Practices of RWH in Sakawrtuichhun locality



As seen above, it was noticed that a huge 85.71% of the samples store rainwater from roof while a mere 14.28% of the samples do not store the same. It is very appreciative to see such a remarkable practice in the area. Somehow, except few families, many of the samples practice only day to day rainwater harvesting system in the area apparently.

6.2.5. Ramthar North locality

The following figure 6.2.5 represents the percentage of families storing and not storing rainwater from their rooftop in Ramthar North locality.

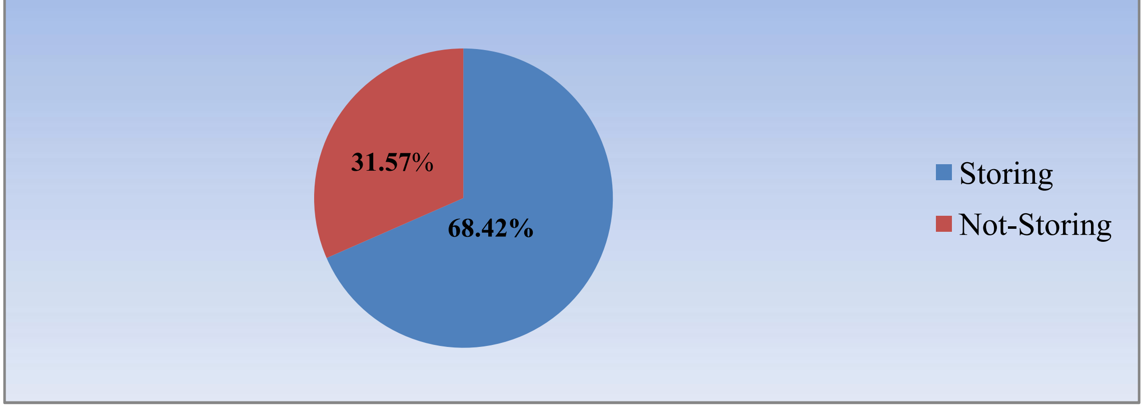


Fig.6.2.5. Practices of RWH in Ramthar North locality

As shown in fig.6.2.5, it was found from the field survey that 68.42% of the samples store rainwater from their rooftop in the locality whereas 31.57% do not store the same. It is unfortunate to find that there is no family who practice a full-fledge rainwater harvesting method in the locality. Apparently, even though majority of the samples store rainwater from their rooftop, it is only for daily purposes.

6.2.6. Zonuam locality

This locality is located in the western part of the city wherein some families practice full-fledge rainwater harvesting in the area. The following figure 6.2.6 shows the number and percentage of those who store and do not store rainwater from their rooftop in the area.

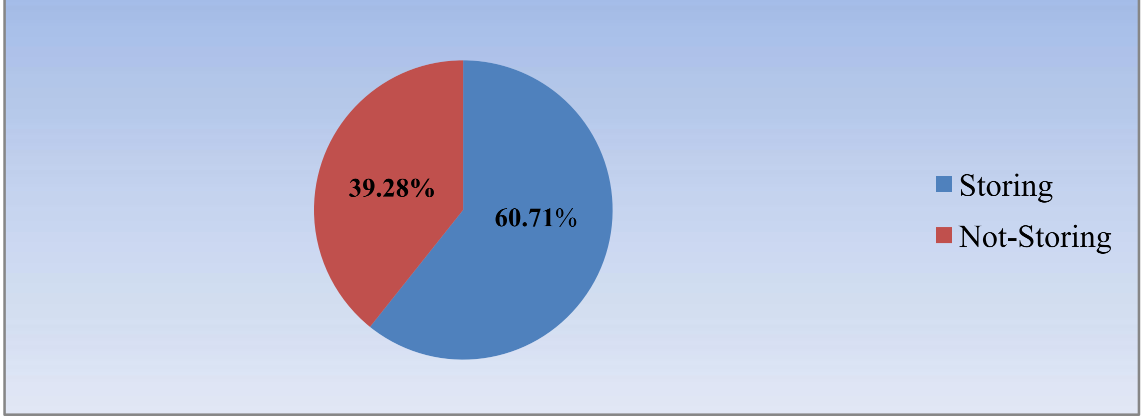


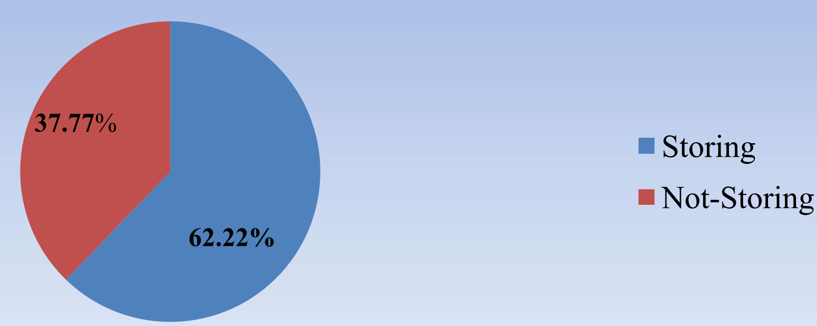
Fig.6.2.6. Practices of RWH in Zonuam locality

It was also appreciable to find during the survey that 17 families that account for 60.71% store rainwater from their rooftop; and there are 11 families accounting for 39.28% who do not store the same. It is also noteworthy that it was found from the field survey that out of 17 families who store rainwater from rooftop, few other families also practice rainwater harvesting in the area.

6.2.7. I.T.I locality

Figure 6.2.7 highlights the percentage and number of households storing and not storing rainwater from their roof top in the locality.

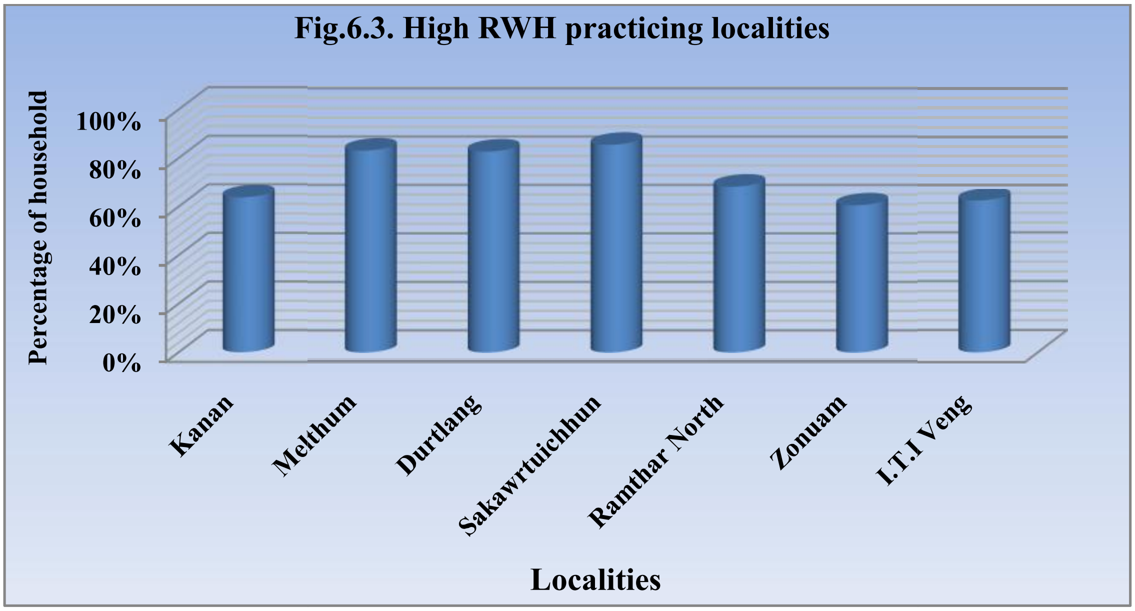
Fig.6.2.7. Practices of RWH in I.T.I locality



When field survey was conducted on different selected questionnaire, it was found that 62.22% of the samples store rainwater from their rooftop in the locality whereas 37.77% do not store the same. It is unfortunate to found that there is no family who practice a full-fledge rainwater harvesting method in the locality. Apparently, even though majority of the samples store rainwater from their rooftop, it was only for daily uses.

6.3. Localities with high number of families practicing rooftop water harvesting

The following diagram shows the percentage of households collecting or storing rainwater from their roof top in seven localities in the city.



Localities with high number of families practicing rooftop water harvesting includes Kanan, Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Zonuam and I.T.I localities and the percentage of practicing rooftop water harvesting from these localities range from 60.71% to 85.71%. Had this much of percentage practiced proper system of rainwater harvesting method in the area, the scarcity of water could be mitigated to certain extent.

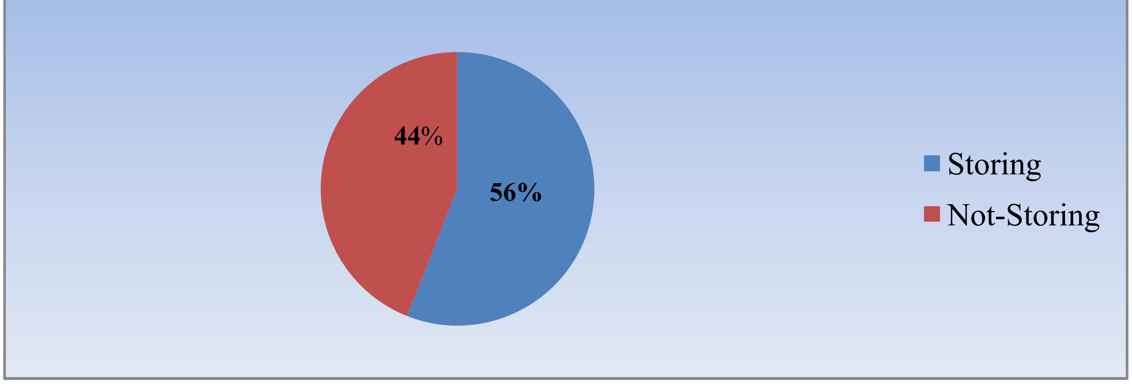
6.4. Medium RWH practicing localities in Aizawl city

As already mentioned in the previous chapter, the grouping of this group is also based on the number of families practicing rooftop water harvesting in the city. The number of families practicing rooftop water harvesting in this group is moderate and medium which is interpreted below for each locality. The Medium RWH practicing localities are Bawngkawn South, Maubawk, Chanmari, Zemabawk, Hunthar, Ramhlun Sport Complex, Khatla and Saron localities where the number of families practicing rooftop water harvesting are more or less the same with the number of families who do not practice the same.

6.4.1. Bawngkawn South locality

Bawngkawn South locality comes under the category of medium RWH practicing localities and the percentage of families storing and not storing are given below.

Fig.6.4.1. Practices of RWH in Bawngkawn South locality

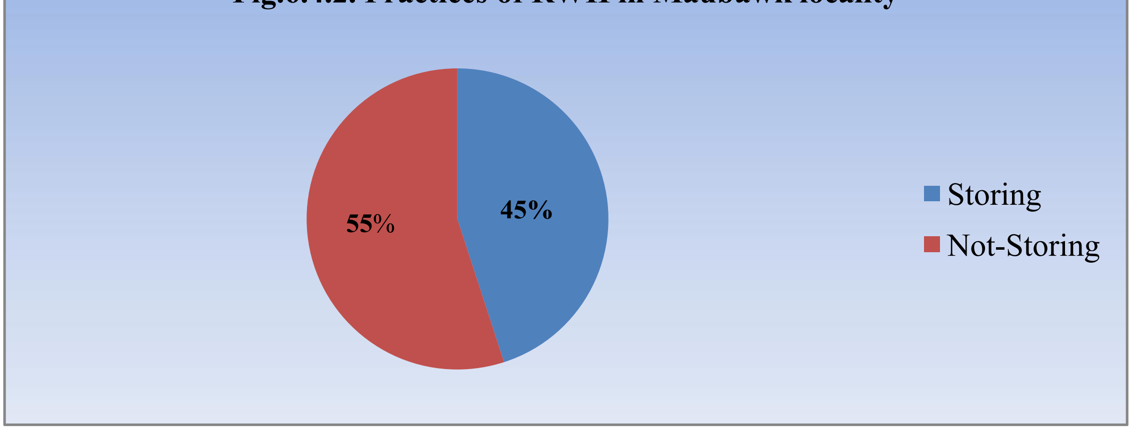


As evident from the above figure-6.4.1, 56% of the families store rainwater from roof for various domestic purposes in the locality while 44% of the families do not store the same. It is learnt that there are no family who practice full-fledge rainwater harvesting method in the area because of different inconveniences. Apparently, the rainwater stored by families in the area is only for daily uses during rainy season.

6.4.2. Maubawk locality

Figure 6.4.2 shows the households storing and not storing rainwater from their rooftop in the locality.

Fig.6.4.2. Practices of RWH in Maubawk locality

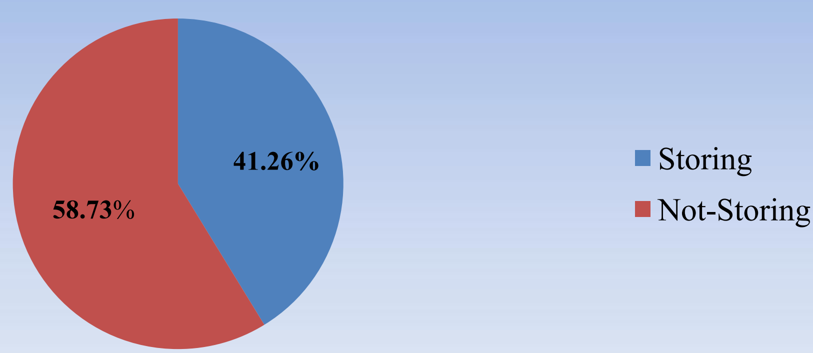


From the above fig.6.4.2, it is cleared that 45% of the samples store rainwater from their rooftop while 55% do not store the same. It is unfortunate to found from the survey that there are no families who practice a full-fledge rainwater harvesting method in the area. Those families who store rainwater from their rooftop also just did it for daily uses only.

6.4.3. Chanmari locality

Figure 6.4.3 given below shows the percentage of households practicing RWH in Chanmari locality.

Fig.6.4.3. Practices of RWH in Chanmari locality

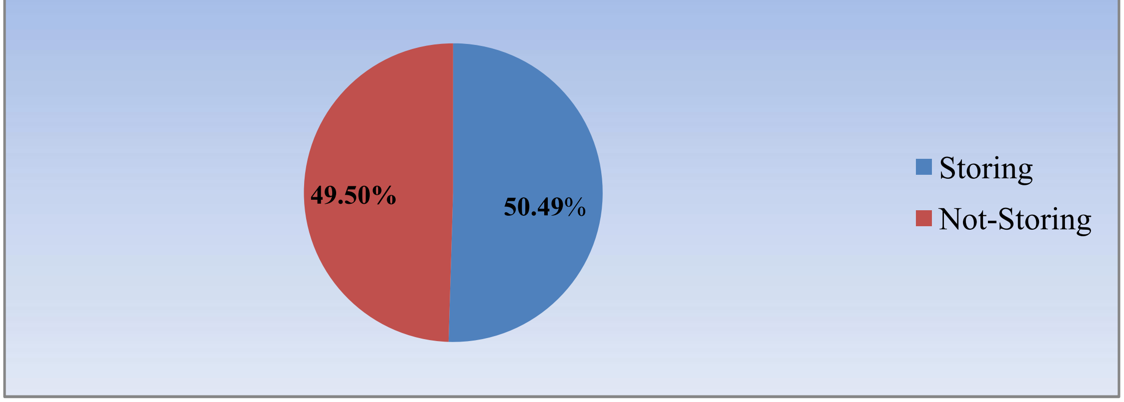


Out of 63 families, 26 families which accounts for 41.26% store rainwater from their rooftop while 37 families, i.e. 58.73% do not store the same. Even though rainwater harvesting is practiced here in the area, systematic and full-fledge rainwater harvesting is not prevalent. It is only during the monsoon period.

6.4.4. Zemabawk locality

The following fig.6.4.4 shows the families storing and not storing rainwater from rooftop in the locality. Zemabawk locality has the highest number of samples which is 101 samples or households among 19 selected localities for field survey.

Fig.6.4.4. Practices of RWH in Zemabawk locality

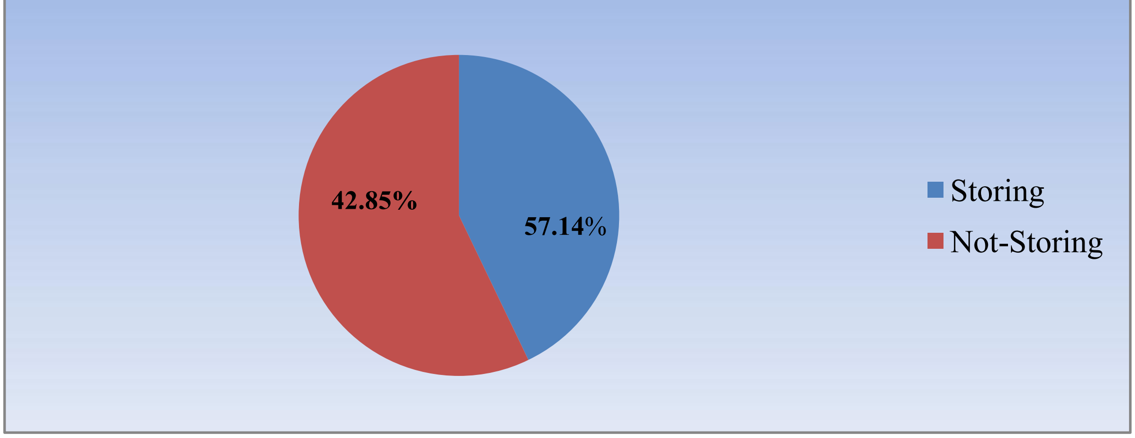


It is also appreciable to find during the survey that 51 families that account for 50.49% store rainwater from their rooftop; and there are 50 families accounting for 49.50% who do not store the same. But unfortunately it was found from the field survey that out of 51 families who store rainwater from rooftop, there are no family from the samples who practice a proper rainwater harvesting method in the area.

6.4.5. Hunthar locality

Hunthar locality is also one of the medium RWH practicing localities in the city which is located in the north western part of the study area. The following diagram shows the families storing and not storing rainwater from their roof top in the area.

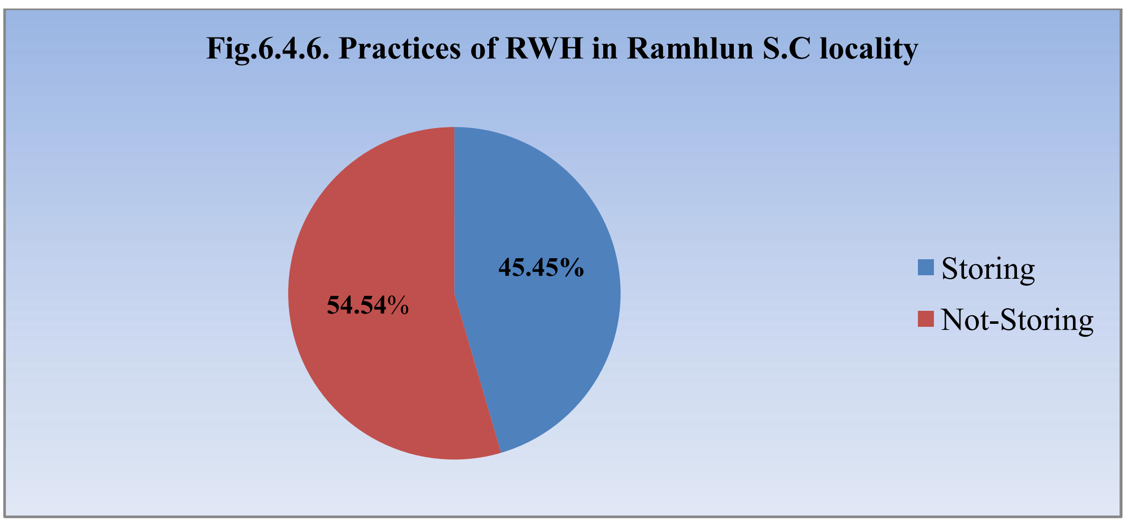
Fig.6.4.5. Practices of RWH in Hunthar locality



It is also appreciable to find during the survey that 16 families that account for 57.14% store rainwater from their rooftop; and there are 12 families accounting for 42.85% who do not store the same. But unfortunately it is found from the field survey that out of 16 families who store rainwater from rooftop, only 1 family practices a proper rainwater harvesting method in the area.

6.4.6. Ramhlun Sport Complex locality

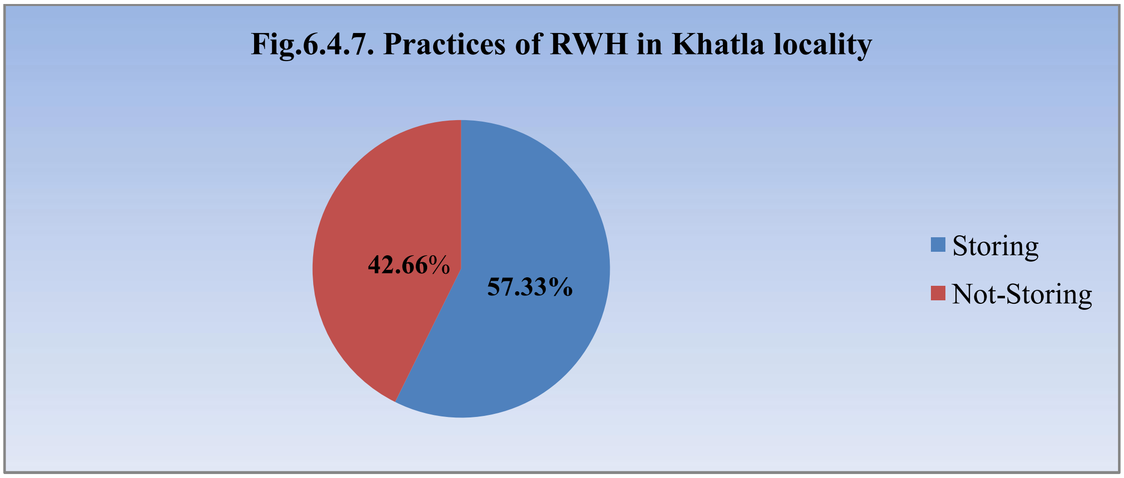
Figure 6.4.6 represents the pattern of rainwater storage in Ramhlun Sport Complex locality. The locality is categorized into medium RWH practicing locality as the households storing and not storing rainwater from rooftop are more or less the same as shown below.



As evident from the above fig.6.4.6, 45.45% of the families store rainwater from roof for various domestic purposes in the locality while the remaining 54.54% of the families do not store the same. It is learnt that most of the families do not practice proper rainwater harvesting method in the area because of different inconveniences.

6.4.7. Khatla locality

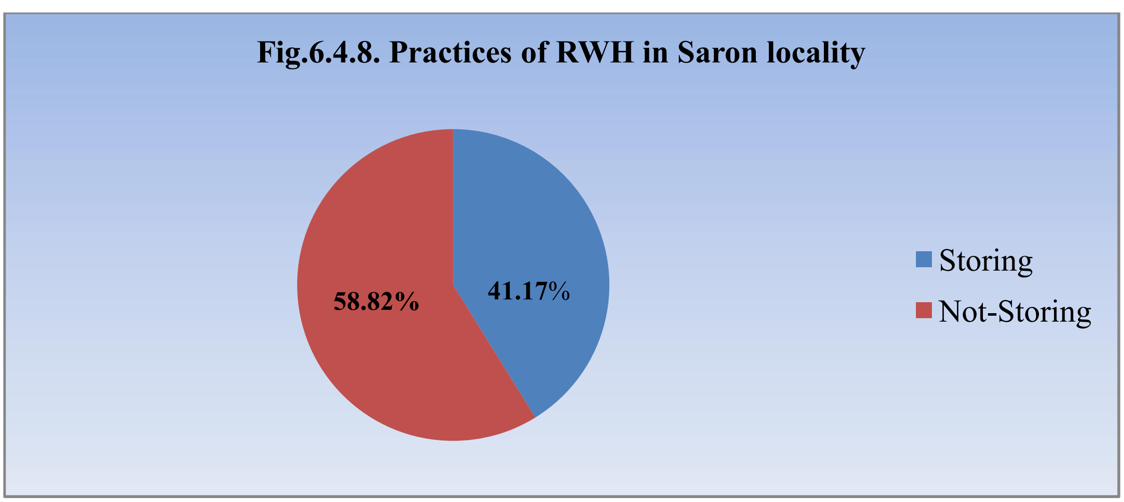
The following figure 6.4.7 represents the practices of RWH in Khatla locality.



During field survey on different selected questionnaire, it is found that 57.33% of the samples store rainwater from their rooftop in the locality whereas the remaining 42.66% do not store rain water. It was unfortunate to find that there is no family who practice a full-fledge rainwater harvesting method in the locality. Apparently, even though majority of the households store rainwater from their rooftop, it is only for the period of monsoon on a daily basis and not for dry seasons.

6.4.8. Saron locality

Saron locality is located in the central part of the city and it is also one of the medium RWH practicing localities. The households storing and not storing rainwater from their roof top are more or less the same as highlighted below.



During field survey on this particular item, it is found that 41.17% of the samples store rainwater from their rooftop in the locality whereas the remaining 58.82% of the samples do not store rain water. It is unfortunate to found that there is no family who practice a full-fledge rainwater harvesting method in the locality.

Apparently, even though almost half of the households store rainwater from their rooftop, it is only for the period of monsoon on a daily basis and not for the dry spells. Saron locality is located in the inner part of the city where the roads, buildings and spaces are quite congested which could be one of the reasons behind the absence of practices of full-fledge RWH system in the area. Construction or spaces for water storage facilities occupies some portions of the area which could be quite problematic where space itself is very congested.

6.5. Localities with moderate number of families practicing rooftop water harvesting

There are eight localities in medium potential category to practice RWH in the city as shown below.

Fig.6.5. Medium RWH practicing localities

Moderate or medium potential localities to practice rainwater harvesting on the basis of households storing and not storing rooftop water includes Bawngkawn South, Maubawk, Chanmari, Zemabawk, Hunthar, Ramhlun S.C, Khatla and Saron localities. The common percentage of storing and not storing rooftop water ranges from 41% to 59% in this group. As shown in the above diagram, the households storing and not storing rainwater from rooftop are more or less the same.

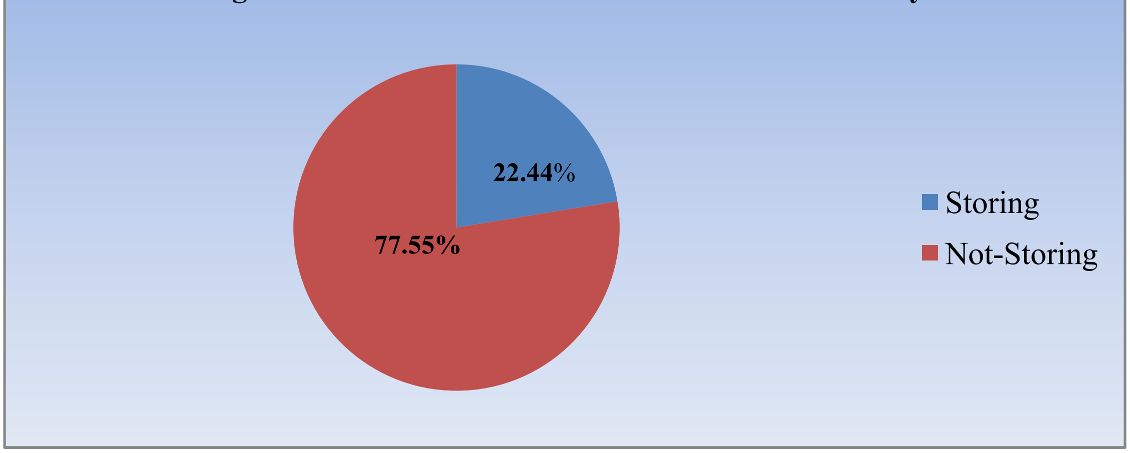
6.6. Low RWH practicing localities in Aizawl city

This group includes Tuikual North, Armed Veng, College and Upper Republic localities in which the families practicing rooftop water harvesting are very less compared to other groups. The percentage of rooftop water harvesting in this group ranges from 22 – 25% as interpreted below. Thus it is assumed that the potentiality of rainwater harvesting in these localities is low on the basis of practices when compared to other localities in the city.

6.6.1. Tuikual North locality

Tuikual North locality is one of the localities wherein the collection of rainwater from rooftop is not quite prevalent as shown in the following diagram.

Fig.6.6.1. Practices of RWH in Tuikual North locality

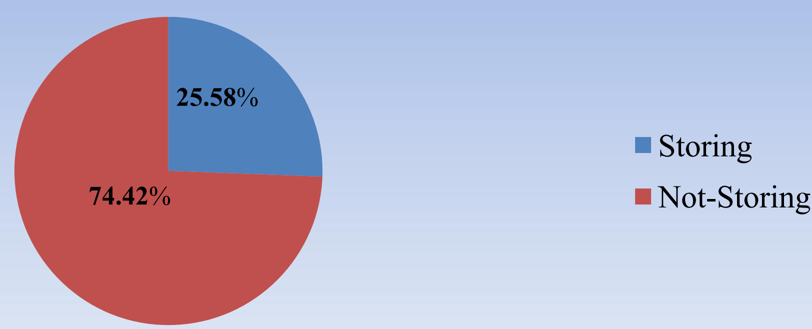


When field survey was conducted on different selected questionnaire, it is found that 22.44% of the samples store rainwater from their rooftop in the locality whereas 77.55% do not store the same. It is also found that there is no family who practice a full-fledge rainwater harvesting method in the locality. Apparently, even though 22.44% of the samples store rainwater from their rooftop, it is only for daily basis.

6.6.2. Armed Veng locality

The following figure 6.6.2 shows the number of households practicing RWH in Armed Veng locality.

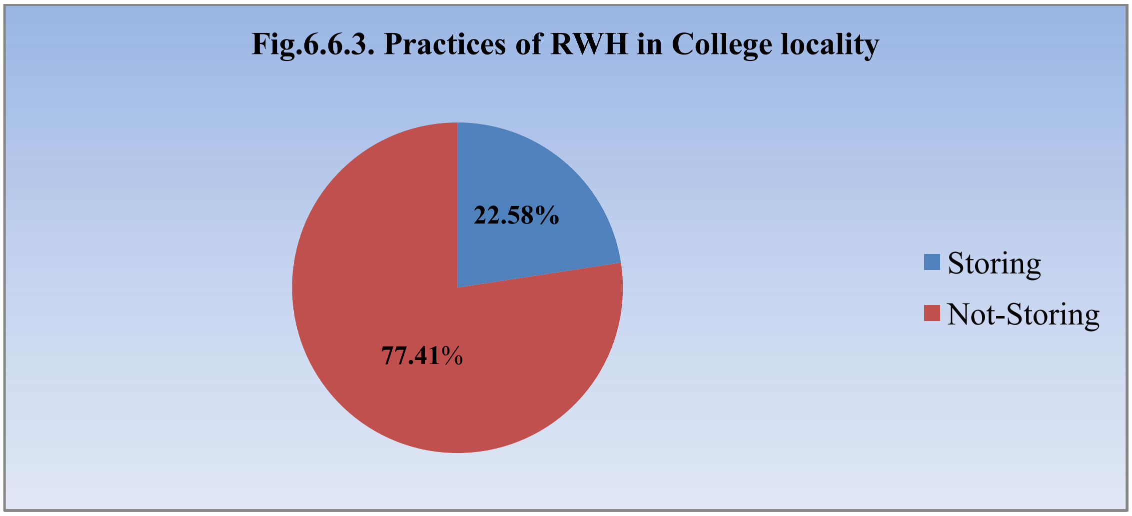
Fig.6.6.2. Practices of RWH in Armed Veng locality



The above fig.6.6.2 shows that 25.58% of the families from the sample store rainwater from roof while 74.42% of the families do not store the same due to varying reasons in Armed Veng locality. It is unfortunate to learned from the samples that the families who store rainwater from roof also do not practice a full-fledge rainwater harvesting method in the area.

6.6.3. College locality

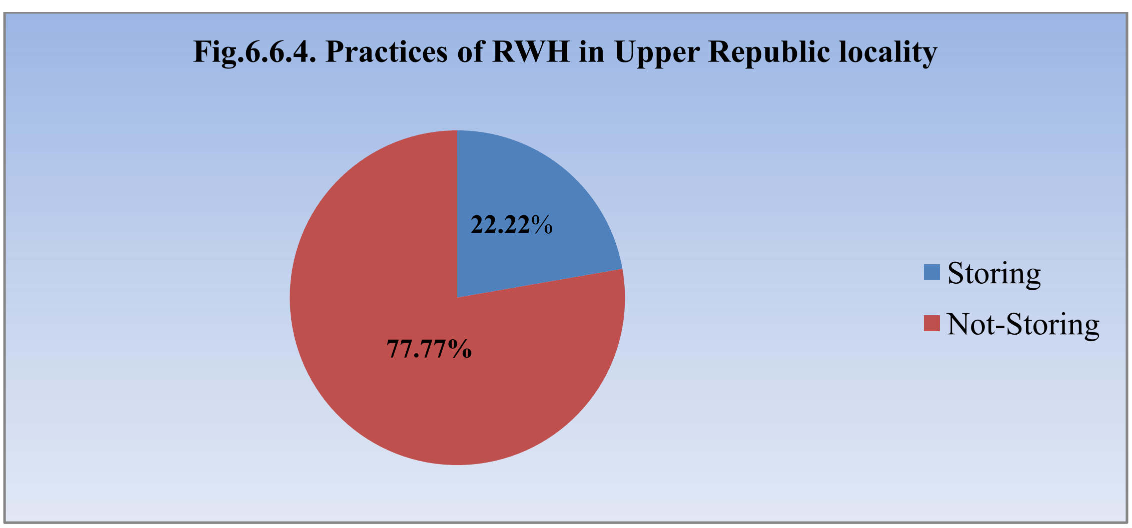
College locality is also one of the low RWH practicing localities in the city as shown below.



From the above figure 6.6.3, it is cleared that 22.58% of the samples store rainwater from their rooftop while 77.41% do not store the same. It is found from the survey that there are no families who practice a full-fledge rainwater harvesting method in the area. Those families who store rainwater from their rooftop also just did it for daily uses only.

6.6.4. Upper Republic locality

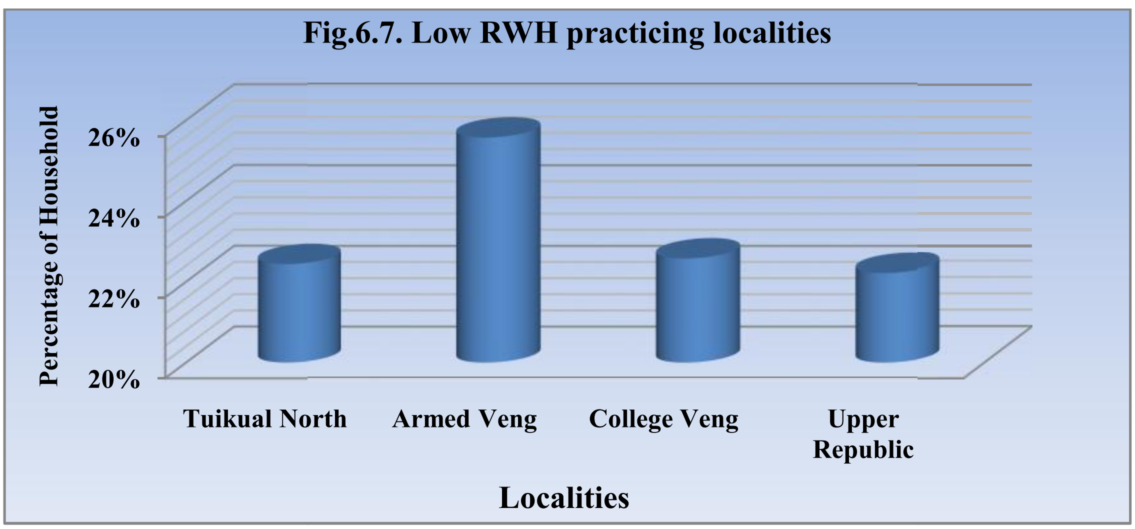
The percentage of families storing and not storing rainwater from rooftop in the locality is given below.



The above chart shows the households storing or not storing rain water. It is found during the survey that 6 families that account for 22.22% store rainwater from their rooftop; and there are 21 families accounting for 77.77% who do not store the same. But unfortunately it is also found from the field survey that out of 6 families who store rainwater from rooftop, no family practices a proper rainwater harvesting method in the area.

6.7. Localities with low number of families practicing rooftop water harvesting

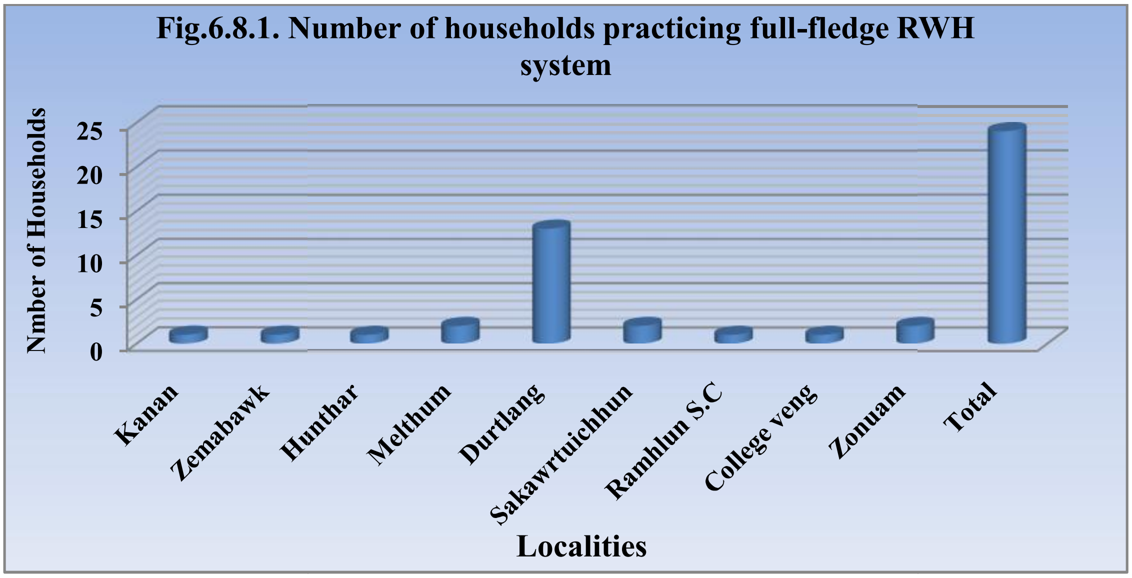
The following figure 6.7 shows four localities in the city where the percentage of RWH or storing and not storing rainwater from roof top is very low as seen below.



The localities of low potentials on the basis of rooftop water harvesting include Tuikual North, Armed Veng, College and Upper Republic localities in which the percentage of practices of rooftop water harvesting range from only 22-25%. Majority of the households do not practice and harvests rainwater due to various inconveniences.

6.8. Practices of full-fledge rainwater harvesting system in Aizawl city

The following figure 6.8.1 shows the number of families practicing full-fledge RWH in Aizawl city. There are a few number of families who practice a full-fledge RWH in the city.



It is found during the survey that out of 722 households from the samples, only 24 families practices a full-fledge rainwater harvesting method. However, it is interesting to learn from these families that water scarcity is not a problem for them. They have sufficient water for the whole year. These localities are Kanan, Zemabawk, Hunthar, Melthum, Durtlang, Sakawrtuichhun, Ramhlun Sport Complex, College and Zonuam localities. As shown in figure 6.8.1 above, one family each from 5 localities have sufficient water; two families each from 3 localities; and 13 families from Durtlang locality have abundant water.

As already shown in table-3.4 (chapter-iii), Durtlang locality has a very irregular and sporadic water supply frequency, i.e. only 14.63% of the families receive water supply once a week, nonetheless, as much as 31.7% of the families are self sufficient in water due to the practices of full-fledge rainwater harvesting method in the area.

6.9. Hypothesis or Correlation on Frequency of water supply, Practice of RWH and Roof-type in Aizawl city

One of the objectives of the study is to find out the correlation between frequency of water supply from PHE, practices of RWH and type of roof in the city, if there is any. The following table-6.1 highlights the details of the same for all the localities in the study area.

Table-6.1	**Correlation between Frequency of water supply, Practice of RWH and Roof-type in Aizawl city**				
Sl. No.	**Locality**	**Water Supply Frequency (Once a week)**	**Practices of RWH**	**Roof type (G.I sheet)**	**No. of Practicing Full-fledge RWH**
1	Armed Veng	88.37%	25.58%	83.80%	0
2	Bawngkawn South	32%	56%	28%	0
3	Chanmari	100%	41.26%	25.40%	0
4	College Veng	87.09%	22.58%	77.41%	1
5	Durtlang	14.63%	82.92%	80.48%	13
6	Hunthar	53.57%	57.14%	42.85%	1
7	I.T.I	100%	62.22%	97.77%	0
8	Kanan	100%	63.80%	44.40%	1
9	Khatla	94.66%	57.33%	86.66%	0
10	Maubawk	100%	45%	37.50%	0
11	Melthum	91.66%	83.33%	75%	2
12	Ramhlun S.C	90.9%	45.45%	63.63%	1
13	Ramthar North	94.73%	68.42%	73.68%	0
14	Sakawrtuichhun	71.42%	85.71%	92.85%	2
15	Saron	100%	41.17%	17.65%	0
16	Tuikual North	89.79%	22.44%	24.50%	0
17	Upper Republic	92.59%	22.22%	44.44%	0
18	Zemabawk	67.32%	50.49%	27.72%	1
19	Zonuam	17.85%	60.71%	71.42%	2

As evident from the above table, Durtlang locality has a very irregular supply of water (only 14.63% of the households receive water supply once in a week) due to which the practices of RWH is prevalent (82.92%) in the area; and it could also be assumed that the prevalence of RWH in the area is due to the type of roof (80.48% G.I roof) which is very convenient to do the same in the locality as well. This indicates that there is a positive correlation among the three phenomena in Durtlang area.

Accordingly, there are six localities such as Bawngkawn South, Durtlang, Hunthar, Sakawrtuichhun, Zemabawk and Zonuam where the frequency of water supply from PHE is quite irregular or below 70% including Sakawrtuichhun locality (71.42%). Out of these six localities, the same pattern of positive correlation is found in all the localities with varying degrees of correlation. The percentage of households practicing RWH in these localities is above 50%. Bawngkawn South and Zemabawk localities have lower percentage of households practicing RWH which is 56% and 50.49% respectively because of the fact the percentage of G.I roof in these areas is very low which is 28% and 27.72% respectively. Considering the low percentage of G.I roof in these two localities, the percentage of households practicing RWH is comparatively high. Thus, this clearly reveals that the area where the frequency of water supply is sporadic and irregular, the number of households practicing RWH is generally high.

The remaining 13 localities have a frequent and regular supply of water where more than 87% of the households receive water supply once every week. In five localities 100% of the households receive water supply once every week. Thus the percentage of household practicing RWH in these 13 localities is generally low due to the abundant supply of water. However, it is also evident from these 13 localities that the number of G.I roof certainly influences the number of households practicing RWH except for the localities of Armed Veng and College Veng. Even though 11 localities, out of 13 localities, receive a frequent supply of water, the practice of RWH is still prevalent due to high number of G.I roof in these areas.

Lastly, the localities with green fonts indicate that there is PHE zonal tank in the area where water supply is believed to be more frequent. And the data in yellow rows represents a possible negative correlation; whereas the data in green rows represent a possible positive correlation. Subsequently, it is clear from the above data analysis that there is a positive correlation among frequency of water supply, practices of RWH and type of roof in the city. The frequency of water supply and type of roof impact the practices of RWH in Aizawl city.

6.10. Conclusion

The localities with high number of families practicing rooftop water harvesting includes Kanan, Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Zonuam and I.T.I localities as the percentage of practices rooftop water harvesting from these localities range from 60.71% to 85.71%.

Moderate or medium potential localities to practice rainwater harvesting on the basis of households storing and not storing rooftop water includes Bawngkawn South, Maubawk, Chanmari, Zemabawk, Hunthar, Ramhlun S.C, Khatla and Saron localities. The common percentage of storing and not storing rooftop rainwater ranges from 41% to 59% in this group.

The localities of low potentials on the basis of rooftop water harvesting include Tuikual North, Armed Veng, College and Upper Republic localities in which the percentage of practices range from 22-25%.

Meanwhile, inferences could be drawn from the number of households practicing full-fledge RWH system in the city from the samples that Rainwater harvesting is one of the best techniques to supplement the water scarcity in the Aizawl city as of now. Even though Durtlang locality has very irregular water supply frequency (once a week) which is only 14.63%, almost half of the samples are self-sufficient in water. Had the pattern of full-fledged rainwater harvesting practices in all the localities is as prevalent and efficient as it is in Durtlang locality, the present scenario of water scarcity in the city could have been avoided and the financial expenses of the government of Mizoram on water could have been lessened to a great extent.

It is found from the analysis of table-6.1 that there is a positive correlation between frequency of water supply, practices of RWH and type of roof in the city. The frequency of water supply and type of roof impact the practices of RWH in Aizawl city. The area where the frequency of water supply is sporadic and irregular, and where G.I roof is prevalent, the number of households practicing RWH is generally high.

CHAPTER-VII

ATTRIBUTES OF RAINWATER HARVESTING IN AIZAWL CITY

7.1. Introduction

This chapter highlights the general overview of water conditions and related issues and challenges in Aizawl city based on field survey. Household survey was conducted in 19 localities from 19 Aizawl Municipal Corporation (AMC) wards to acquire the real water related conditions of the city. The study under observation includes size of household, quantity of household's water consumption per day, household's water tank capacity, duration of water tank sustainability, reasons for water insufficiency, families buying and not buying water from other sources, perceptions of local residents on water related issues, etc. These conditions of the ground reality depict the actual problems confronted by the city dwellers.

The above mentioned households issues reflect the water condition in the city. Firstly, the quantity of consumption of water is determined by the size of the household. The quantity of water consumption in a day by a household clearly shows the availability of water for household consumption. The capacity of water tank influences the duration of water tank sustainability by a household that reveals the main factor for water sufficiency or scarcity. Simply, the sufficiency or insufficiency of the quantity of water supply could be obtained from these two conditions.

Similarly, the pattern of water buying or not buying could indicate the sufficiency of water supply from PHE in the city as well. The ideas and opinions of the local residents on rainwater harvesting system in the city were also obtained during field survey. It is believed that their perceptions on the rainwater harvesting system for the city as well as their locality would be the best supplementary source of water. Basically, this chapter tries to find the evidences of the general perception that water scarcity prevails in the city, by analyzing various water related conditions of the households in the city.

To understand few socio-economic attributes of the state, the following table-7.1 highlights the number of households in Aizawl district and also for Mizoram as a whole. As per census of India, number of households or families is listed for each locality in Aizawl city instead of number of houses or buildings.

Table-7.1	**Number of Households in Aizawl district and Mizoram**		
Name	**Total Rural Urban**	**No. of Households**	**Total Population**
Mizoram	Total	2,22,853	10,97,206
Mizoram	Rural	1,05,812	5,25,435
Mizoram	Urban	1,17,041	5,71,771
Aizawl	Total	82,524	4,00,309
Aizawl	Rural	17,328	85,555
Aizawl	**Urban**	**65,196**	**3,14,754**
Source: Department of Economics and Statistics, 2011.			

As seen in table-7.1 above, the total household in Mizoram according to 2011 census is 2,22,853, out of which 47.48% are in rural areas while 52.52% are in urban areas. There are 82,524 households in Aizawl district out of which 20.99% are in rural areas while as much as 79.11% are living in urban area of Aizawl district. As the capital city of Mizoram, the process of urbanisation also has its full swing in the area which leads to a rapid increase in population year on year due to migration and other factors.

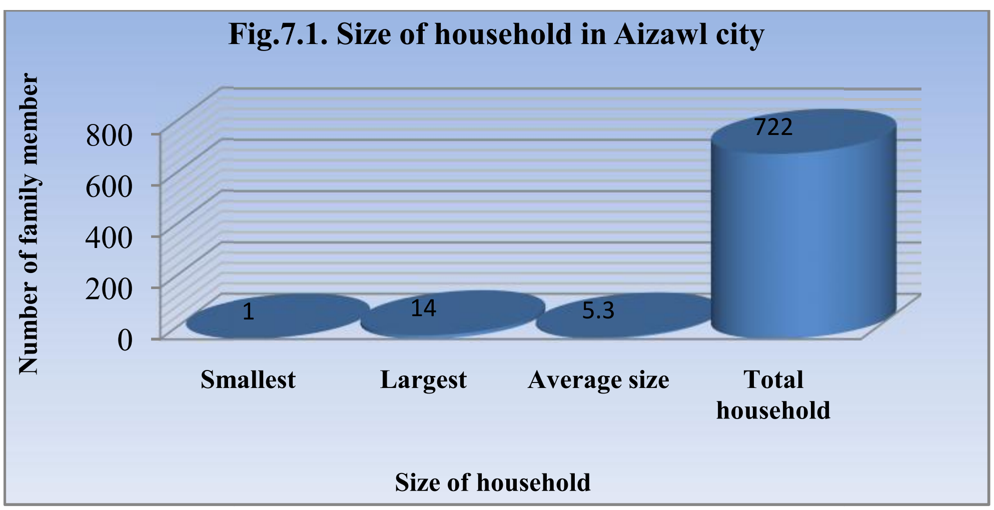
Table-7.2	**Decadal Growth Rate of Population in Mizoram: 1921-2011**				
Census Year	**Total population**	**Decadal variation in %**	**Census Year**	**Total population**	**Decadal variation in %**
1921	98,406	-	1971	3,32,390	24.93
1931	1,24,404	26.42	1981	4,93,757	48.55
1941	1,52,786	22.81	1991	6,89,756	39.70
1951	1,96,202	28.42	2001	8,88,573	28.82
1961	2,66,063	35.61	2011	10,97,206	23.47

Source: National Informatics Centre, Ministry of Communication & Information Technology

As shown in the above table 7.2, the decadal growth rate of Mizoram during 1921-2011 ranges from about 22% to 39%. The average decadal growth rate of population in the state is 30.97% during the same period. The highest growth rate is observed in the year 1991 which is 39.70% and the lowest is 22.81% in the year 1941. It could be assumed and inferred that when the population of the state increased as a whole, the share of population in the capital city also increased in more or less similar trend.

7.2. Size of household in Aizawl city from the samples

In order to implement any kind of policy, understanding of the demographic attributes is one of the vital primary measures as it is the people who are concerned and affected ultimately in any type of state.

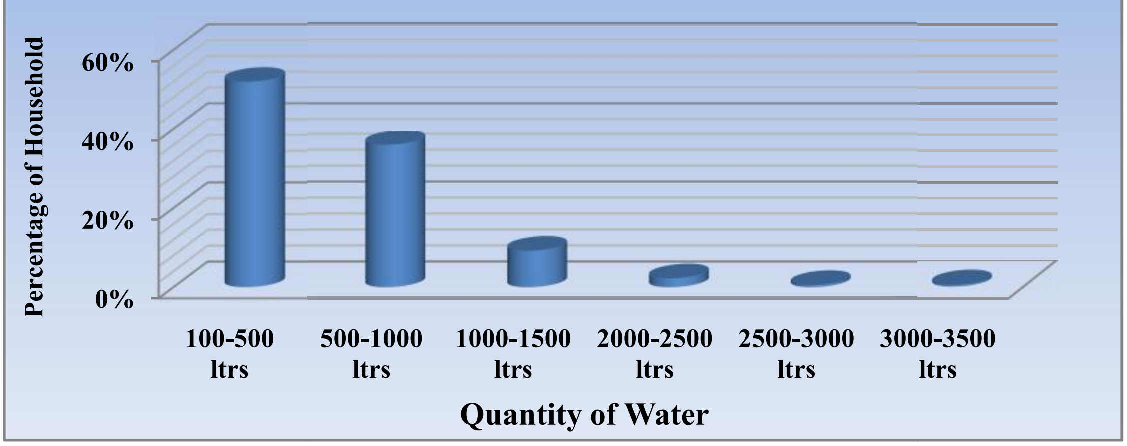


As already mentioned in the methodology, the number of samples selected for field survey is 722 households. The above diagram represents the size of the households from the samples in Aizawl Municipal Corporation. The smallest household is of one family member while the largest family consists of 14 members in the city. The average household size is 5.3 family members in the city. According to 2011 census, there are 2,93,000 persons living in Aizawl city, which rose to 3,78,000 persons in April, 2021.

7.3. Quantity of household's water consumption per day (in litre) in Aizawl city

The following figure shows the average quantity of household's water consumption per day in Aizawl city.

Fig.7.2. Average quantity of household's water consumption per day (in litre) in Aizawl city



The water used in the city is not very high as represents in the above data. Majority of the samples which is 375 families that account for 51.93% consumed 250 litres of water for daily purposes approximately or in an average. And almost half of the samples, i.e. 35.73% of the samples, used 500-1,000 litres of water in a day for different domestic purposes. Another 9.14% of the samples consumed water of 1,000-1,500 litres in a day. The remaining 3.21% of the sample used the same of 2,000-3,500 litres in a day. And the average daily water consumption by a household in the city is arrived at 575.13 litres.

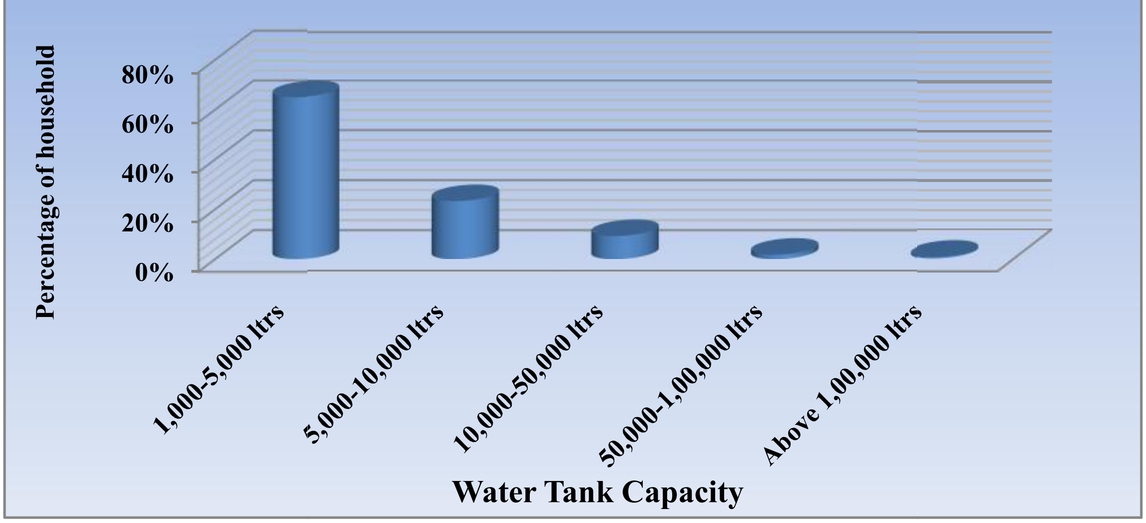
Considering the lowest household's water consumption per day, as evident from the above data interpretation, at least 500 litres of water per day per household is the minimum requirement of the city. Even then also, it might be still insufficient or less due to the average size of family in the city as per the sample which is 5.3 members per household.

As mentioned in chapter-III, as per water supply from PHE, the share of water per head per day ranges from 40-60 litres. When 60 litres is multiplied by average household size of 5.3 members, it comes to 318 litres. The outcome is much lesser than the real quantity of household's daily water consumption (575.13 litres). Inference could be made from this result that due to insufficiency of water supply, many families buy or manage water from other sources.

7.4. Household's water tank capacity (in litre) in Aizawl city

The following diagram depicts the water tank capacity of families in Aizawl city. The volume of water tank determines the duration of time that a household can rely on water. It is one of the most important compositions of RWH.

Fig.7.3. Household's water tank capacity (in litre) in Aizawl city



Water tank is one of the most vital components of rainwater harvesting as the amount of water to be store depends on it. As shown above, 64.95% of the samples have water tank of 1,000-5,000 litres capacity which is very small for practicing full-fledge rainwater harvesting for long period. And 23.26% of the samples possess 5,000-10,000 litres of water tank; 9.27% of the samples possess 10,000-50,000 litres of water tank;

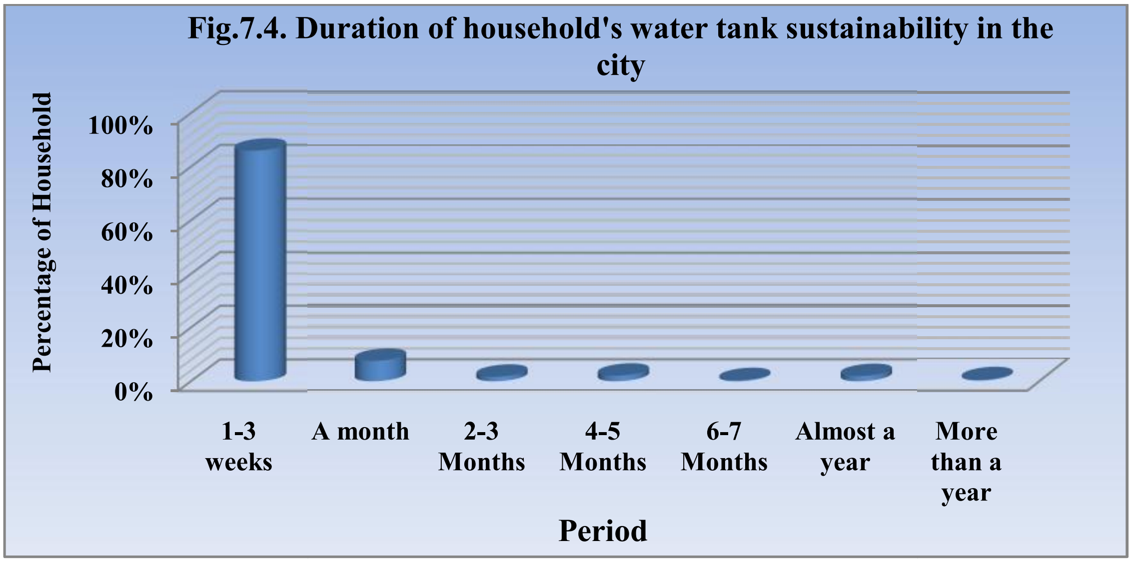
1.80% of the samples possess water tank of 50,000-1,00,000 litres which is normal and better for practicing full-fledge rainwater harvesting; and lastly, only 0.55% of the samples possess 1,00,000 & above litres of water tank in the city. The capacity of water tank is grouped into 5 categories like 1,000-5,000, 5,000-10,000, etc. So, in order to obtain the average household's water tank in the city, the median is obtained from all the groupings; and the average capacity of household's water tank is arrived at 7,689 litres.

It might not be wrong to assume that at least 50,000 and above litres of water tank is the ideal capacity for practicing better and efficient rainwater harvesting in the city. But unfortunately about 65% of the families possess water tank of 1,000-5,000 litres capacity only. However, the efficacy of water tank capacity depends on the number of people to be served. From the above data, inferences could be made in such a way that one of the main problems for insufficiency of water in the city is the storage facility for water as almost 65% of the sample's water tank capacity is limited to 5,000 litres only. The quantity of water is of no use when the facility for storing the same is inadequate.

RCC water tank, constructed on the ground in Ramhlun locality.

7.5. Duration of water tank sustainability in the city

The below diagram shows the period the family can rely and use the water from their water tank when it gets full.



As presented above, 621 households which account for 86.01% of the samples can use for a period of only 1-3 weeks which is quite a short period of time. And 55 families which is 7.61% of the samples can use it for a month; 12 families which is 1.66% of the samples can utilize for 2-3 months; 15 families which account for 2.07% of the samples can rely on it for a period of 4-5 months; 3 families which comes to 0.41% of the samples can use for a period of 6-7 months; 14 families which is 1.93% of the samples can utilize it for almost a year; and 2 families which is 0.27% of the samples can use it for a period of more than a year which proved that some families practice real rainwater harvesting system in the city.

The facts and figures presented in the above diagram clearly revealed that when 86.01% of the samples can rely on their water tank just for a period of 1-3 weeks, it is obvious that the storage facility is not enough for most of the households in the city. Had the amount of water supply even been sufficient also, it is the storage facility which is the main problem confronted by the citizens to a great extent.

7.6. Reasons for insufficiency of water and not possessing sufficient water storage tank in Aizawl city

The general perception of the city dwellers to certain extent is the problems and scarcity of water in Aizawl city, especially during lean season. So, field survey was conducted to find the reasons behind such water problems and scarcity in the city. Even though the water supply is regular and sufficient sometimes in some localities, some families still cannot afford sufficient water. The following table shows some of the many reasons for household's water inadequacy and it is more of a personal or family problems.

Table-7.3	**Reasons for insufficiency of water in Aizawl city.**	
Reasons	**No. of Household**	**Percentage**
Water tank is too small	325	45.01%
No proper water storage tank	373	51.66%
Sufficient	24	3.32%
Total household	722	
Reasons for not possessing sufficient water storage tank in Aizawl city.		
Reasons	**No. of Household**	**Percentage**
No space	37	5.12%
Both of space and financial problems	546	75.62%
Financial problem	100	13.85%
Negligence	15	2.07%
Sufficient/No problem	24	3.32%
Total household	722	
Source: Field survey, 2018		

The above table-7.3 shows different reasons for water insufficiency and the obstacles behind not possessing enough water storage facilities. As shown above, 45.01% of the samples do not have enough water storage tanks to store more water. Due to varying inconveniences, 51.66% of the samples do not possess even a proper water storage tank. Meanwhile, 3.32% of the samples found themselves comfortable enough in water issue.

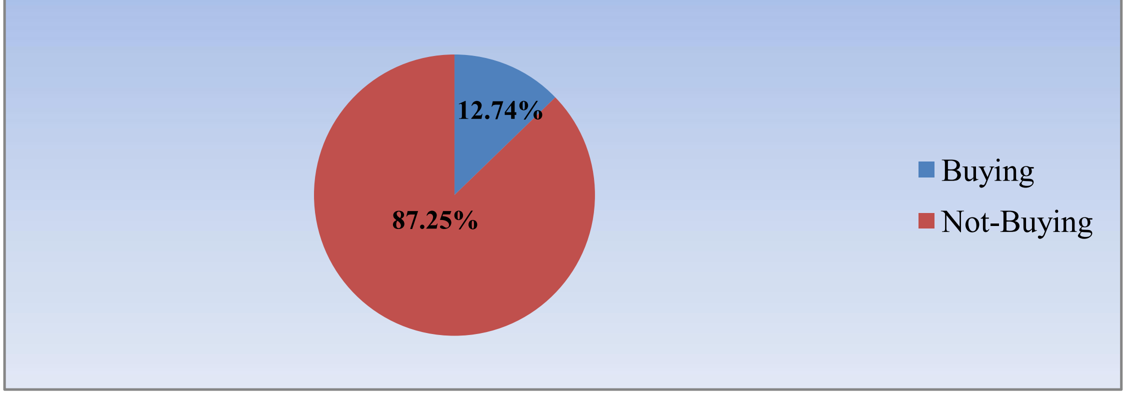
Truth be told, Aizawl city has developed without any concrete or systematic city or town planning, which leads to various difficulties that needs to be confronted rationally. As depicted in the above table, 5.12% of the families do not have space for constructing water storage facilities; 75.62% of the families have both of space and financial problems to do the same; And 13.85% of the samples have financial problems to acquire enough water storage facilities; and there are some people who still neglect what they need also due to traditional ideas as 2.07% of the samples just neglect it.

As evident from the above data, 45% of the samples possess insufficient water storage facility while about 52% do not even have proper storage facility in the city from which conclusion could be made that storage facility is the main concern. Space and financial constraints are the main problems of the people from the samples to acquire sufficient water storage facilities.

7.7. Families buying and not buying water from other sources in the city

Figure-7.5 shows that the number of households purchasing and not purchasing water from other sources in the city. Apart from PHE water supply, some households still buy water from commercial water suppliers as presented below.

Fig.7.5. Families buying and not buying water from other sources in the city



There are many private players involving in selling of water in Aizawl city and they are thriving and blooming which is a good development in business for themselves and the can-buy-riches. This, on the other hand, proved the insufficiency of water from a PHE department in the city. But what about the poor, the Below Poverty Line (BPL) families and the have-not people who cannot effort to buy water and still not having and getting enough water for daily uses? As shown in the above chart, 92 families which account for 12.74% of the samples still buy commercial water while 630 families which is 87.25% of the samples do not need to buy the same. This shows that majority of the households do not buy commercial water in the city.

The above analysis shows the ground reality of water scarcity from the samples in the city. As many as 12.74% of the samples which account for 92 families from the samples still buy commercial water with costlier price, which reveals the inadequacy of water from PHE department, for many families in the city.

7.8. Quality of Rainwater in Aizawl city

In order to understand the quality of rainwater in the city, samples of rainwater from rooftop and open rainwater (direct rainfall) were collected from four different stations in the city such as I.T.I, Nursery, Kanan and Durtlang localities. The samples of rainwater were tested using at least pH Meter80 portable device as more sophisticated and specific testing was not convenient due to pandemic.

Map: 7.1

Following is the map showing the geographical location of four rainwater collection stations in the city.

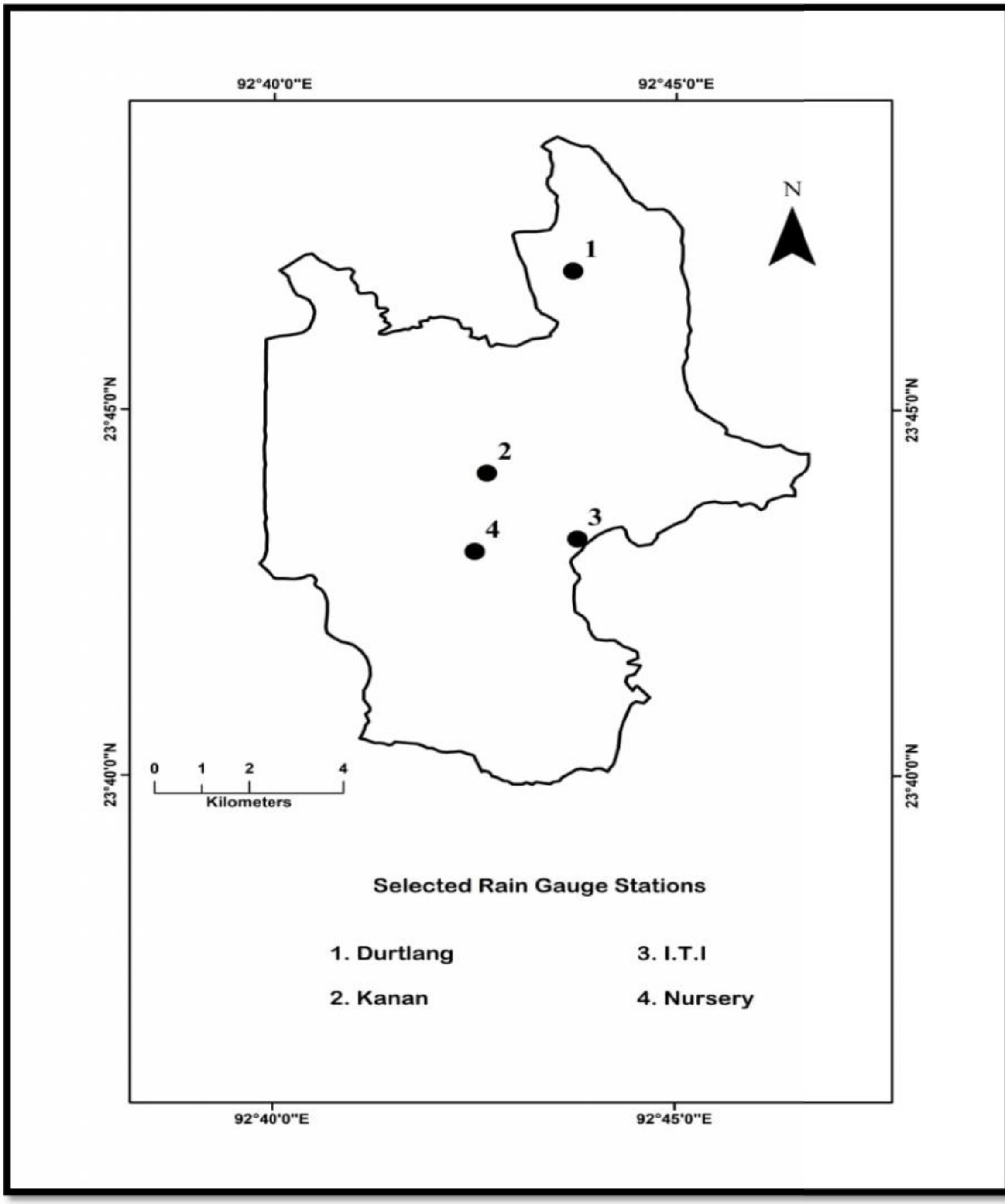


Table-7.4	pH values of Open or Direct and Rooftop rainwater from four stations in Aizawl city, 2016.				
Open rainwater or Direct rainfall quality			**Open rainwater or Direct rainfall quality**		
Station-1	**Date**	**pH value**	**Station-2**	**Date**	**pH value**
I.T.I	06-17.03.2016	9.1	**Kanan**	17.03.2016	9
	21-31.03.2016	8.6		21.03.2016	8.9
	01-16.04.2016	8.9		28.03.2016	7
	17-28.04.2016	8.7		01-16.04.2016	8.7
	04-13.05.2016	8.4		01-18.05.2016	8.7
	18-25.05.2016	8.3		19-25.05.2016	8.5
	03-07.06.2016	8.2			
	08-13.06.2016	8.1			
Open rainwater or Direct rainfall quality			**Roof rainwater quality (GI Sheet)**		
Station-3	**Date**	**pH value**	**Station-4**	**Date**	**pH value**
Durtlang	17.04.2016	7.2	**Nursery**	02.03.2016	8.1
	22.04.2016	7.6		21.03.2016	7.5
	25.04.2016	7		23.03.2016	7.5
	26.04.2016	7.5		16.04.2016	8.8
	28.04.2016	7.5		18.04.2016	8.1
	02.05.2016	7.7		25.04.2016	8.5
	13.05.2016	7.3		27.04.2016	8.7
	18.05.2016	7.8		12.05.2016	8.2
	21.05.2016	7.9		17.05.2016	8.5
	29.05.2016	8.1		10.06.2016	7.6
	02.06.2016	7		16.06.2016	8
	04.06.2016	7.2		25.06.2016	7.8
Source: Field survey 2016					

As depicted in the above table-7.4, the quality of open and direct rainwater is tested in three stations like I.T.I, Kanan and Durtlang localities while rainwater from rooftop is tested in one station, i.e. Nursery locality. The quality of rainwater was tested from the month of March to June, 2016 as a whole. In general, the values of pH Meter80 range from 1-10, and the higher the value, the more saline is the rainwater and the lower the value, the more acidic is the rainwater. When the value is lower than 5, it is acidic and unfit for drinking. The pH value of acid rain normally ranges from 3-4. pH value of 7 is neutral and is pure water and uncontaminated form. Basically, the pH value of water needs to be over 7 in order to be fit for drinking. When it is more than 7, it is more saline but still fit for drinking.

The pH value of open rainwater in I.T.I, station-1 was tested from 6th March to 4th June, 2016. During this period, pH value of 8 open rainwater samples were obtained in which the highest value is as high as 9.1 whereas the lowest is 8.1. The pH value of open rainwater was tested in station-2 (Kanan) during 17th March to 25th May, 2016. It was found that the pH value of open rainwater in the station ranges from 7-9; the lowest being on 28.03.2016 and the highest on 17th March. In Durtlang station also quality of open rainwater was tested during 17th April to 4th June, 2016. The pH value of the station-3 ranges from 7-8.1 which is clean enough for drinking.

The roof rainwater quality was also tested in station-4, Nursery, during 2nd March to 25th June, 2016, to compare the pH value of open and roof rainwater. However, it is found that the rainwater pouring down from the G.I roof in station-4 also has more or less similar pH value as could be seen above. The pH value of rainwater in station-4 ranges from 7.5-8.8 which are pure and fit for drinking.

Thus, as evident from the above data analysis, it could be inferred that the natural rainwater receive in Mizoram, especially in Aizawl city, is fit for drinking even without any more purification. The lowest pH value is 7 which is neutral value and pure water while the highest value is 9.1, characterized by more alkaline in the study area. As a whole, it could be concluded that the rainwater in the study area is more alkaline, but still fit for drinking and other domestic uses. The rainwater characterized by acidic is not found in any part of the study area as of now.

7.9. Approximate number of Non-Residential public buildings and their average catchment area (in Sq. feet) in Aizawl city

The following table shows the approximate number of non-residential public buildings in the city which are considered to be potential for RWH. There are many unoccupied and non-residential public buildings in the city which could be very useful for RWH.

Table-7.5 **Potential of non-residential building for rainwater harvesting in Aizawl city**

Buildings	Number	Average Size
Gov't offices	35	30x38
YMA hall	10	39x46
YMA library	10	19x24
Church	27	40x50
Total Building	**82**	**32x39.5**

Source: Field survey, 2018

Resource is not a resource if it is not being utilized. Petroleum was not useful in the olden days to our forefathers due to absence of vehicles and others. Systematic use of the resources that are handy and feasible is one of the best and convenient approaches for the development of Aizawl city in all spheres today. How hard could it be to practice rainwater harvesting in the city?

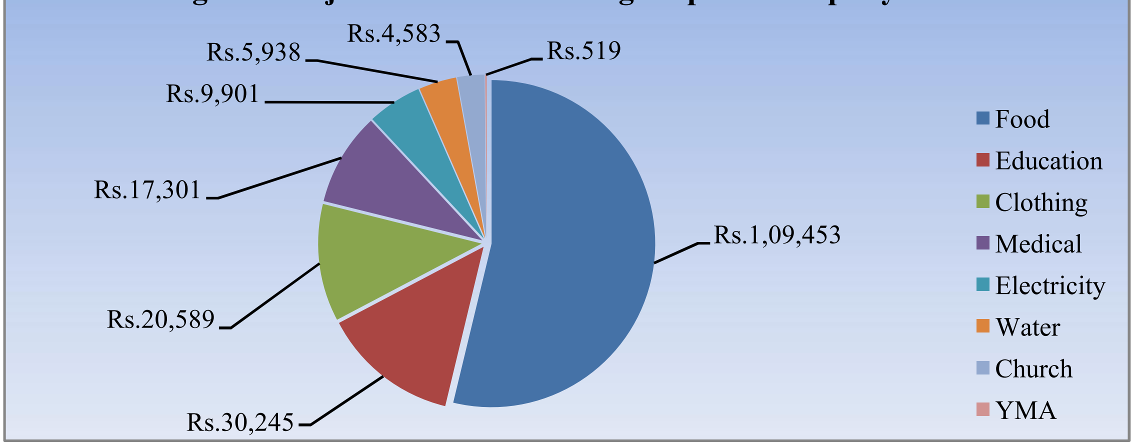
As shown above, there are as much as 82 non-residential public buildings in the study area, these buildings could have been very potential sites for rainwater harvesting; these 82 unoccupied buildings could have turned into the source of supplementing the shortage of water in the city if rational and systematic approaches were being implemented. If proper legislation were enacted to mandate all the buildings in the city to practice RWH system, these non-residential buildings would have turned into a huge rainwater reservoir which could supplement to a great extent the water need of the people during lean season of the year.

These kinds of new buildings keep coming up in the city as urbanisation has its full swing to every society like globalization has. This has to be anticipated so as to avoid any unwanted circumstances in future. It would be highly appreciated if Buildings construction regulatory board or Aizawl Municipal Corporation implemented certain rules and regulations so as to improve and enhance the water conditions of the city.

7.10. Major household's expenditure heads per year in Aizawl city

The main intention of this section is to understand the pattern of household's annual expenditure in the city in general and the expenditure incurred on water for self reliant in particular.

Fig. 7.6. Major household's average expenditure per year



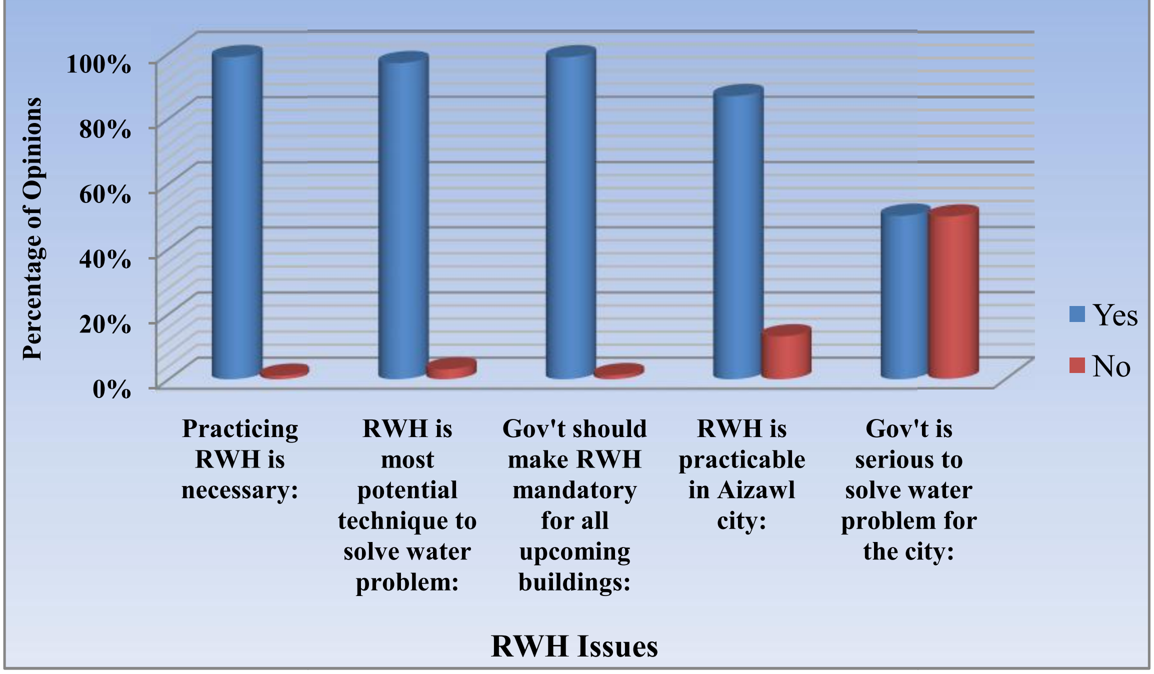
The above pie chart represents the major house's average expenditure annually in Aizawl city. The annual expenditure on food is comparatively very high followed by expenditure on education, clothing and medical. The annual expense on electricity is Rs.9,901 and the expense on water is Rs.5,938 which is pretty costly considering the basic water connection cost. The expenditure on water is just 5.42% of the expenditure incurred on food; 19.6% of education; 28.8% of clothing, etc.

Thus the expenditure on water is quite less compared to the expenditure on other items except the expenditure on church and YMA. In order to be a self reliant household on water throughout the year without the water supply from PHE, the household's expenditure incurred on water is negligible.

7.11. Perception/Opinion of Aizawl citizens on practices of Rainwater harvesting in the city

With regards to RWH, the following diagram represents the personal opinions of the citizens.

Fig.7.7. Perception of Aizawl citizens on RWH in the city



People's mindset and awareness is the key to make anything happen in a democratic society like Mizoram. If the mind's of the people are not prepared and oriented to adapt to new things, whatever good it might be, cannot be introduce successfully.

As evident from figure-7.7 above, 714 residents of the city which is 98.89% of the samples feel the need to practice rainwater harvesting in the city while only 1.10% of the samples do not see the necessity to do the same. And 700 city dwellers which account for 96.95% of the samples believe that rainwater harvesting is one of the most potential techniques to solve problem of water scarcity in Aizawl city whereas a mere 3.04% of the samples do not believe the same.

When asked about whether the government should take initiative to mandate the practice of rainwater harvesting for every new construction of buildings in Aizawl city or not, 98.75% of the samples agreed the proposal while only 1.24% of the samples are against the proposal. Also, 86.84% of the samples believe in the feasibility and possibility of practicing rainwater harvesting the city while 13.15% of the samples opined that it would not be practicable in the city due to varying reasons. Lastly, 50.13% of the samples agreed that government is serious to solve water problem for the city while 49.86% of the samples do not see the zeal and effort from the government to solve the problems of water scarcity in the city.

As a whole, as a state of democracy, the opinion of the people could be regarded as the most important measure for the success of any government. Here in Aizawl city also, as seen in figure 8.7, the necessity of practicing RWH and its potentiality is highly appreciated by the citizens. Almost 99% of the citizens want the government to mandate implementation RWH for every upcoming building in the city. When any kind of new vehicle comes with insurance, why not a building with RWH? 86.8% of the citizens opined that RWH is practicable in the city as well. People of the city would like to see their voice capitalised into reality.

7.12. Assessment of Application of RWH in Aizawl city

Methods of RWH can be classified into two types such as surface RWH and rooftop RWH. Surface RWH signifies the accumulation of rainwater in the land surface whereas rooftop RWH refers to the collection of rainwater through the roof; and the latter will be given the main thrust in this section for Aizawl city.

7.12.1. Components of rooftop RWH in Aizawl city

Firstly, the major components of rooftop RWH in the study area are:

1. Number of people to be served

2. Type of roof
3. Size of catchment area
4. Quantity and quality of rainfall
5. Average quantity of household's water consumption
6. Storage facility, etc.

In order to harvest rainwater, the above mentioned attributes has to be considered systematically in the city. The number of people to be served need to be calculated in order to understand the amount of rainwater that needs to be harvested in any particular area or household. As already mentioned, the average size of household in the city is 5.3 members.

The type of roof and the size of catchment area or roof determine the runoff coefficient and potential quantity of rainwater that could be harvested respectively. As highlighted in chapter-v, only 4.43% of the roofs are inconvenient for rainwater harvesting while as much as 95.5% are harvestable in Aizawl district. In Aizawl city, 38.36% of the roofs are concrete and 57.75% are G.I sheet. The runoff coefficient of corrugated metal sheet (G.I and Concrete roofs) ranges from **0.8-0.9** as per Bureau of Indian Standards, IS: 15797: 2008. The average size of non-residential public building is obtained at **32*39.5 square feet** in the city. However, the size of roof varies from household to household.

The quantity and quality of rainfall are of immense importance as they are the foundation of RWH. As mentioned in annual mean rainfall (chapter-iv), the mean annual rainfall for the past 5 years (2015-2019) is **223.988 centimetres** in Aizawl city. And the pH value of rainwater of the city recorded in the year 2016 ranges from 7-9.1 which is clean and fit for drinking. There is no point in harvesting rainwater when the pH value is below 5.

And the pattern of household's water consumption and storage facility also play crucial part. The average daily water consumption by a household in the city is arrived at 575.13 litres. And 64.95% of the samples in the study area have water tank of 1000-5000 litres capacity only and taking the median would make the capacity of water tank becomes 2500 litres. The capacity and volume of water tank needs to be estimated and constructed on the basis of the number of people to be served.

As per Central Pollution Control Board, the formula for calculation of quantity of rainwater harvesting in an area is,

Rainwater harvesting potential of a site = Rainfall (mm) * Area of catchment (m2) * Runoff coefficient of the catchment surface

Therefore, example for Rainwater harvesting potential of Aizawl city = 223.988 cm (2239.88 mm) x 32*39.5 sq. ft. (9.7*12 sq. m) x 0.8

= 2239.88 mm * 116.4 sq. m * 0.8

= 208,577.62 litres in a year.

This means that a roof of 116.4 sq. metres, where annual mean rainfall is 2239.88 mm, can harness rainwater of around 208,577 litres in a year.

7.12.2. Water Demand and Ideal Water Tank Capacity in Aizawl City

The present amount of water demand in the city is more or less similar to the average quantity of daily water consumption of a household in the city which is 575.13 litres approximately. This implies that a household with **5.3** family members needs water of 575.13*7 litres in a week and 575.13*30 litres in a month which is 4025.91 litres and 17,253.9 litres respectively. It signifies that one family member consumes around **108.5** litres per day. On the other hand, the average capacity of household's water tank in the city is 7,689 litres only which is not even able to contain the amount of two weeks water requirement of a household. Furthermore, around 65% of the samples or households possess water tank capacity of only 1000-5000 litres. And as seen from the rainfall data, the driest period of the year could be assumed as around **90** days (the months of January to March).

Thus, the bare minimum capacity of water tank for a household to last and sustain the dry season of a year could be computed as: - **5.3*108.5*90 = 51,754** litres.

Consequently, one or more water tanks of around 50,000 litres capacity is the ideal or minimum water tank capacity for a household in the city to suffice the minimum requirement of water during dry season of the year (months of January to March). This is also the ideal capacity to practice efficient and reliable rainwater harvesting in the city presently.

7.13. Conclusion

The average household size is 5.3 family members in the city. According to the 2011 census, there are 2,93,000 persons living in Aizawl city, which rose to 3,78,000 persons in April, 2021.

As already mention in chapter-III, the share of water per head per day ranges from 40-60 litres in the city. When 60 litres are multiplied by the average household size of 5 members, it comes to 318 litres. The outcome is much lesser than the real or maximum quantity of a household’s daily water consumption (500 litres).

From the above data, inferences could be made in such a way that one of the main problems for insufficiency of water in the city is the storage facility for water as almost 65% of the sample’s water tank capacity is limited to 5000 litres only. The quantity of water is of no use when the facility for storing the same is inadequate.

It is clearly revealed that when 86.01% of the samples can rely on their water tank just for a period of 1-3 weeks, it is obvious that the storage facility is not enough for most of the households in the city.

45% of the samples possess insufficient water storage facility while about 52% do not even have a proper storage facility in the city from which conclusion could be made that storage facility is the main concern. Space and financial constraints are the main problems of the people from the samples to acquire sufficient water storage facilities.

As many as 12.74% of the samples which account for 92 families from the samples still buy commercial water with costlier prices, which reveals the inadequacy of water from PHE department, for many families in the city.

There are as much as 82 unoccupied buildings in the study area, these buildings could have been very potential sites for rainwater harvesting; these 82 unoccupied buildings could have turned into the source of supplementing the shortage of water in the city if rational and systematic approaches were being implemented.

Almost 99% of the citizens want the government to mandate implementation RWH for every upcoming building in the city. 86.8% of the citizens opined that RWH is practicable in the city as well. The people of the city would like to see their voice capitalised into reality.

Presently, one or more water tanks of around 50,000 litres capacity is the ideal water tank capacity for a household in the city to suffice the minimum requirement of water during dry season of the year (months of January to March). This is also the ideal capacity to practice efficient and reliable rainwater harvesting in the city presently.

CHAPTER-VIII

CONCLUSION

This chapter is devoted for the overall assessment and major findings of the research entitled: "**Potentials and practices of rainwater harvesting in Aizawl city".** As already mentioned in the earlier chapter, the main objectives of the research are to identify roof types in Aizawl city for potential rainwater harvest; to examine rainwater harvesting practices in Aizawl city; to assess monthly rainwater quantity in Aizawl city and to suggest measures for optimum use of rainwater harvesting. Apart from these main objectives, the water supply condition of the city and pattern of deforestation are also one of the major thrusts of the study as well.

The research found that there exist water scarcities in the city especially during lean seasons (February, March & April) almost every year. As per the average amount of daily water distribution from the main water reservoir of PHE to different 55 zonal tanks in the city for the month of February, 2021, the share of water per head per day could be calculated as follows.

Amount of daily average water received at zonal tanks or distributed to public = 17.27 million litres,

Population of Aizawl city = 2, 93,000 (2011 census) or 3, 78,000 (present or April, 2021),

Therefore, **1,72,70,000 / 3,78,000 = 45.68 litres per head per day**.

Or,

Amount of daily average water as per 70% efficiency or received at main reservoir at Tuikhuahtlang = 20.50 million litres,

2,05,00,000 / 3,78,000 = 54.23 litres per head per day.

The above calculation shows the scarcity and insufficiency of water in the city. As per the Bureau of Indian Standards, IS: 1172-1993, a minimum water supply of 200 litres per capita per day (lpcd) should be provided for domestic consumption in cities. But the current quantity of water share per head per day during lean season is way below the norms of Bureau of Indian Standards, IS: 1172-1993. This condition of acute shortage of water in the city necessitates catering for the supplementary technique to mitigate the same which is RWH indeed.

In India, many states such as Tamil Nadu, Rajasthan, Gujarat, Karnataka, Haryana, Himachal Pradesh, etc. and many cities in the country mandate the implementation of rainwater harvesting system as a law. Municipal corporations of Ahmedabad, Bengaluru, Chennai, Hyderabad, Mumbai, etc. are the cities that made RWH compulsory in their respective areas. It is learnt from these states and cities that many households have an access to sufficient water due to the legislation that mandate RWH in their localities.

In Mizoram, there is no legislation that mandate rainwater harvesting for any kinds of buildings yet. But still, there are many households who practice rainwater harvesting in the state due to varying reasons. Type of roofs and freshness or quality of rainwater could be attributed to the reasons behind the practices of rainwater harvesting in the states.

As much as 68.47% of the roofs of the buildings in the state are of G.I sheet which is very convenient for RWH. Another 21.42% of the roofs are of grass/thatch/bamboo which is also the traditional type of roof that is very convenient for RWH since the olden days.

In Aizawl district, as much as 65.2% of the roofs are of G.I sheet; 27.9% of the roofs are concrete and 4.9% of the roofs are grass/thatch/bamboo.

In Aizawl city, the research found that 57.75% of the roofs are G.I roofs; 38.36% of the roofs are concrete and 3.87% of the roofs are made of tiles/wood/etc. from the samples. This clearly shows that more than half of the buildings in the city are very convenient for practices of RWH.

As G.I sheet is considered to be much more convenient than other types of roof for practices of RWH, the study area, Aizawl city is divided into three categories, on the basis of roof type (G.I sheet) which are Highly potential localities, Moderately potential localities and Low potential localities (Chapter-V).

The research found that out of 722 samples, 49.72% of the households store rainwater from their rooftop for various domestic uses. Meanwhile, 50.27% of the samples do not store the same due to varying inconveniences in the city. Even though there is no legislation to mandate RWH in the city, as much as 359 families still practice casual or normal rooftop rainwater harvesting.

It is found during the survey that out of 722 households from the samples, only 24 families practices full-fledge rainwater harvesting method. But, it is interesting to learn from these families that water scarcity is not a problem for them. As shown in figure 6.8.1, one family each from 5 localities have sufficient water; two families each from 3 localities; and 13 families from Durtlang locality have abundant water. They have sufficient water for the whole year. The water condition of these 24 families from different localities clearly revealed the reliability and efficacy of practicing RWH to tackle the menace of acute water shortage during lean season every year in Aizawl city.

With regards to the quantity of rainfall in the city, it is also observed from the secondary data that the quantity and pattern of decrease in rainfall is higher and more extreme than that of an increase in rainfall during the last six years in Aizawl city. However, the average annual rainfall of the city as per the data of Directorate of Science and Technology for the past sixteen years (2005-2020) is 203.325 centimetres. The amount of rainfall in the area is still sufficient enough for various domestic purposes of the city. But, unfortunately, it appears that huge amount of rainfall goes wasted as run off due to lack of management for this precious and free natural resource.

Major findings of the research

1). It is noticed that the Tlawng river, the main source of water supply for Aizawl city is becoming insufficient due to increasing demand of population as well as the declining efficiency of the water pump house with time goes by.

2). It is revealed that as many as 91% families have water connection provided by Public Health Engineering Department (PHED) out of which 74.65% of the families in Aizawl city are depending solely on Water supply provided by PHED.

3). *Regarding the frequency of water supply, it is found that as many as 574 (79.50%) household receives water supply once in a week while just 9 (1.2%) of them receives twice in a week and 56 (7.75%) household receives once in two weeks which could be the reasons for water deficiency for such households and 2.77% of the samples receive water thrice in a month.*

4). With regards to the quantity of water supply from PHE, it has to be kept in mind that the quantity or volume of water installed capacity seldom actually reached the main reservoir due to disruption of power supply, inefficiency of the pumping machine, distribution loss due to leakages of water pipelines, etc. Thus, it differs from locality to locality and also month on month. And the calculation of share of water per head per day from the total installed capacity is erroneous.

5). The research also found from the quantity of daily average water supply during the lean season of January and February, 2021 that the average share of water per head per day in Aizawl city ranges from 40 – 60 litres approximately, which seems to be very insufficient for the city.

6). It is also observed that water crisis does not happen during January or February; rather it happened in the month of March and April. This is may be due to the long dry period of this year i.e.2021. This indicates that the month of January and February, 2021 can be somehow manageable as it drawn water from the remnant of the last monsoon seeping out from the catchment forest cover area of Tlawng river.

7). As evident from the annual rainfall diagrams, the pattern of precipitation in the city during the year 2005-2020 is, more or less, in a diminishing or decreasing pattern. However, the average annual rainfall of the city as per the data of Directorate of Science and Technology for the past sixteen years (2005-2020) is 203.325 centimetres *which has to be utilised in the most efficient way. The year 2017 marked the highest precipitation during the years 2005-2020 which is as much as 268.7 centimetres. Meanwhile the year 2008 received the lowest rainfall during the same period which is 154.8 centimetres. Therefore, a scientific method needs to be evolved to anticipate the future water scarcity for, not only Aizawl city, but also for Mizoram, and also to make use of rainfall resource which is free of cost to cut the massive expenditure incurred by the state on water.*

8). It is also found from the study that the correlation between deforestation and quantity of rainfall is minimal or negative for the last 16 years (2005-2020) particularly in the state of Mizoram. The pattern of deforestation in the state of Mizoram still does not have large scale immediate impacts on the quantity of rainfall for the last 16 years (2005-2020). This might be attributed to the fact that the quantity of rainfall of a particular region does not increase or decrease due to deforestation of such region or state or country. Rather it seems to change noticeably due to deforestation of a much larger scale such as continental or global scale; or possibly, may be only 16 years of deforestation or rainfall is too short to notice the effects as well.

9). Altogether, it can be inferred that the Tlawng river is not sufficient for Aizawl city due to both increasing demand and diminishing Tlawng water volume due to deforestation and other human activities that happened in the catchment area of Tlawng river, which need urgent response from all the stakeholders of Aizawl city. Stringent and efficient policy from the government of the state has to be implemented to control various causes of deforestation.

10). With regards to types of roof as a whole, G.I sheets account for 68.47% of the roofs; grass/thatch/bamboo/wood etc account for 21.42%; and concrete accounts for 8.21% of the roofs in Mizoram. Thus, most of the roof in the state is of G.I sheet (68.47%) which is considered to be very suitable for practicing rainwater harvesting.

11). It is found that out of 19 Aizawl Municipal Corporation (AMC) wards, 9 localities (Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Armed Veng, College, Zonuam, I.T.I and Khatla) possess a very promising potential to practice RWH, on the basis of types of roof. The average percentage of G.I roof in these highly potential localities to practice RWH, on the basis of roof type, is 82% while the remaining 18% is of concrete roof as a whole. Even if only these localities practice regular and full-fledge rainwater harvesting in the city, the scarcity and problems of water in the city could be mitigated to certain extent.

12). The medium potential localities on the basis of roof type (G.I & Concrete roof) are Kanan, Zemabawk, Hunthar, Upper Republic and Ramhlun S.C localities in the city as the main types of roof are more or less equal. The average percentage of G.I roof in these moderately potential localities to practice RWH, on the basis of roof type, is 44.60% while the majority 50.21% is of concrete roof and another negligible 3% is tiles/bricks as a whole.

13). The low potential localities on the basis of roof type (G.I roof) includes Tuikual North, Bawngkawn South, Maubawk, Chanmari and Saron localities as majority of the roofs are made of concrete roof which is considered to be less convenient for practicing rainwater harvesting. The percentage of G.I roof ranges from 17 – 37% in these low potential localities area.

14). Localities with high number of families practicing rooftop water harvesting includes Kanan, Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Zonuam and I.T.I localities as the percentage of practicing rooftop water harvesting from these localities range from 60.71% to 85.71%.

15). Moderate or medium potential localities to practice rainwater harvesting on the basis of households storing and not storing rooftop water includes Bawngkawn South, Maubawk, Chanmari, Zemabawk, Hunthar, Ramhlun S.C, Khatla and Saron localities.

The common percentage of storing and not storing rooftop water ranges from 41% to 59% in this group.

16). Localities of low potentials on the basis of rooftop water harvesting include Tuikual North, Armed Veng, College and Upper Republic localities in which the percentage of practices range from 22-25%.

17). It is found during the survey that out of 722 households from the samples, only 24 families practices full-fledge rainwater harvesting method. These localities are Kanan, Zemabawk, Hunthar, Melthum, Durtlang, Sakawrtuichhun, Ramhlun Sport Complex, College and Zonuam localities. As shown in figure 6.8.1, one family each from 5 localities have sufficient water; two families each from 3 localities; and 13 families from Durtlang locality have abundant water. They have sufficient water for the whole year.

18). Inferences could be drawn from the number of households practicing full-fledge RWH system in the city from the samples that Rainwater harvesting is one of the best techniques to supplement the water scarcity in the city as of now. Even though Durtlang locality has very irregular water supply frequency (once a week) which is only 14.63%, almost half of the samples are self-sufficient in water. Had the pattern of full-fledge rainwater harvesting practices in all the localities is as prevalent as it is in Durtlang locality, the present scenario of water scarcity in the city could have been avoided and the financial expenses of the government of Mizoram on water could have been lessened to a great extent.

19). It is found from the analysis of table-6.1 that there is a positive correlation among frequency of water supply, practices of RWH and type of roof in the city. The frequency of water supply and type of roof impact the practices of RWH in Aizawl city. The area where the frequency of water supply is sporadic and irregular, and where G.I roof is prevalent, the number of households practicing RWH is generally high.

20). It is found that the average quantity of household's daily water consumption is 575.13 liters in the city. Considering the lowest household's water consumption per day, *at least 500 litres of water per day per household is the minimum requirement of the city. Even then also, it might be still insufficient or less due to the average size of family in the city as per the sample which is 5.3 members per household.*

As mentioned in chapter-III, the share of water per head per day ranges from 40-60 litres. When 60 litres is multiplied by average household size of 5 members, it comes to 318 litres. The outcome is much lesser than the real quantity of household's daily water consumption (575.13 litres). Inference could be made from this result that due to insufficiency of water supply, many families buy or manage water from other sources.

21). Inference could be made from the study in such a way that one of the main problems for insufficiency of water in the city is the storage facility for water as almost 65% of the sample's water tank capacity is limited to 5,000 litres only.

22). The facts and figures obtained from the field clearly revealed that when 86.01% of the samples can rely on their water tank just for a period of 1-3 weeks, it is obvious that the storage facility is not enough for most of the households in the city. Had the amount of water supply even been sufficient also, it is the storage facility which is the main problem confronted by the citizens.

23). It is observed that, 45% of the samples possess insufficient water storage facility while about 52% do not even have proper storage facility in the city from which conclusion could be made that storage facility is the main concern. Space and financial constraints are the main problems of the people from the samples to acquire sufficient water storage facilities.

24). As many as 12.74% of the samples which account for 92 families from the samples still buy commercial water with costlier prices which reveals the inadequacy of water from PHE department, government of Mizoram, for many families in the city.

25). It is found that the natural rainwater receive in Mizoram, especially in Aizawl city, is fit for drinking even without any purification. The lowest pH value is 7 which is neutral value and pure water while the highest value is 9.1, characterized by more *alkaline in the study area. As a whole, it could be concluded that the rainwater in the study area is more alkaline, but still fit for drinking and other domestic uses.*

26). It is noticed that 714 residents of the city which is 98.89% of the samples feel the need to practice rainwater harvesting in the city while only 1.10% of the samples do not see the necessity to do the same.

27). 700 city dwellers which account for 96.95% of the samples believe that rainwater harvesting is one of the most potential techniques to solve problem of water scarcity in Aizawl city whereas a mere 3.04% of the samples do not believe the same.

28). When asked about whether the government should take initiative to mandate the practice of rainwater harvesting for every new construction of buildings in Aizawl city or not, 98.75% of the samples agreed the proposal while only 1.24% of the samples are against the proposal.

29). Also, 86.84% of the samples believe in the feasibility and possibility of practicing rainwater harvesting the city while 13.15% of the samples opined that it would not be practicable in the city due to varying reasons.

30). 50.13% of the samples agreed that government is serious to solve water problem for the city while 49.86% of the samples do not see the zeal and effort from the government to solve the problems of water scarcity in the city.

*31). The bare minimum capacity of water tank for a household to last and sustain the dry season is computed as: - 5.3 * 108.5 * 90 = 51,754 litres. So, one or more water tanks of around 50,000 litres capacity is the ideal water tank capacity for a household in the city to suffice the minimum requirement of water during dry season of the year. This is also the ideal capacity to practice efficient and reliable rainwater harvesting in the city presently.*

Suggestions

First of all, the average annual growth rate of population in Aizawl city for the past 5 years (2017-2021) is 2.44% which in an actual figure comes to approximately 10,000 persons per year. The demand of population for water, like all other kinds of resources, keeps on increasing in all urban cities. This kind of urbanization has to be dealt with efficient and systematic approach to anticipate the uncertain circumstances in future for the city and the state as well.

1). Keeping in mind the pattern of population growth in the city, the existing GAWSS phase I and II condition of PHED needs to be enhanced and the upcoming phase-III needs to be constructed to be capable of using its full capacity. Presently, the quantity or share of water per capita per day during the lean season usually ranges from 40-60 litres which are insufficient.

2). As revealed from the field survey within the samples, there are many households who still do not possess PHE water connection in the city. Planning and effort from the government needs to be taken, one way or the other, to provide water connection to all the households of the city.

3). Out of 83 localities within Aizawl Municipal Corporation, there are only 55 zonal tanks which seem insufficient while looking from spatial perspective. If the number of zonal tanks equals the number of localities in the city, then the scarcity of water will be mitigated to a great extent.

4). Forest and water are interdependent and goes hand in hand; so stringent policy needs to be evolve to protect the forest cover of the state. The processes of deforestation and forest degradation have to be mitigated as far as sustainable development goal is concerned.

5). Like many other states and cities in the country, there needs to be separate legislation from the government or AMC to mandate the practice of full-fledge RWH at *least for every upcoming new building in the city. This will reduce the massive expenditure incurred by the state government on water while it will tackle the water scarcity menace in the region as well. When any kind of motor vehicle comes with insurance, why not RWH for all the new buildings which actually is a benefit for the owner of the building him/her-self?*

6). Public and private new buildings keep coming up in the city as urbanisation has its full swing to every society like globalization has. This has to be anticipated so as to avoid any unwanted circumstances in future. It would be highly appreciated if Buildings construction regulatory board or Aizawl Municipal Corporation implemented certain rules and regulations so as to improve and enhance the water conditions of the city.

7). Planning on implementation of RWH system should be done and prepared by dovetailing all available resources by convergence of different programmes such as MGNREGS, Swachh Bharat Mission, Grants to PRIs, Compensatory Afforestation Fund Management and Planning Authority (CAMPA) funds, District Mineral Development Fund, Local Area Development Funds, etc.

8). Especially, programme of Jal Jeevan Mission, government of India, which aims to provide potable drinking water to every rural household through Functional Household Tap Connections (FHTCs) by 2024, needs to be utilised and implemented in its full potential and converge it along with RWH in the state so as to make RWH practicable and feasible to all.

9). Widespread awareness needs to be given from government, NGOs, institutions and individual on the reliability, sustainability and efficacy of RWH at village level, regional level and state level.

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APPENDIX-1: Questionnaire

Questionnaire on Potentials and practices of rainwater harvesting in Aizawl city.

Questionnaire No..........

Date:..........

Name of Ph.D Scholar *: Mr. Zochhuanawma*

Name of Supervisor *: Dr. K.C. Lalmalsawmzauva*

Department of Geography & Resource Management, Mizoram University

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I. Household

1. Name of Locality: ....and Ward No..........................

2. Household No.………

3. Name of the household head……………………………………., Sex: M/F ....

4. Household size...............

II. Type of Roofs

5. Type of House Roof...... (1) Corrugated Metal Sheets / G.I. Sheet (2) Tiles

(3) Concrete

6. Size of house /building roof......................$feet^2$

III. Water Source & Consumptions

7. What is the average daily water consumption of the family?

(a) Types.....(1) Cooking..........litres (2) Bathing........... litres

(3) Drinking.........litres (4) Washing...........litres (5) Toilet.........litres (6) Flowering.........litres (7) Domesticated animals ....litres (8) Washing cars/scooty etc...........litres (9) Others, specify...litres

(b) Quantity..........(1)<100 litres ; (2) 100-500 litres (3) 500-1000 (4) 1000-1500 (5) 2000-2500 (6) 2500-3000 (7) 3000-35000 (8) >3500 litres

8. Do you have P.H.E water connection? ....(1) Yes (2) No

If yes, how many times do you get water supply from P.H.E:.......... (1) Once a week

(2) 2 times a week (3) 3 times a week (4) Once in 2 weeks

(5) Once in 3 weeks (6) Once a month (7) Any other....................................

9. Source of drinking water...(1) Rain water stored from roof (2) PHE

(3) Hand pump (4) Both rain water and tanker truck (5) Public well

(6) Buy from tanker truck (7) Both PHE and tanker truck

(8) Any other...

10. From the above sources, which **one** is main source: (1) Rain water stored from roof

(2) Buy from tanker truck (3) Hand pump (4) Public well

11. Do you have water tank...........(1) Yes (2) No

12. If you have, how many litres it can contains :...(1) <1000 (2) >1000-5000

(3) 5000-10000 (4) 10000-50000 (5) 50000 -100000 (6) 100000 &above

13. Do you store rainwater from roof...... (1) Yes; (2) No

14. Any other roofs like -toilet, pig shed etc.....(1) Yes; (2) No

15. If yes, do you utilize for rainwater harvesting?...... (1) Yes (2) No

16. If you store rainwater, is it sufficient for your family....... (1) Yes; (2) No

17. How long your water tank(s) can sustain your family:....(1) 1-3 weeks (2) A month (3) 2-3 months (4) 4-5 months (5) 6-7 months (6) Almost a year

(7) More than a year

18. If, it is not sufficient, why?...(1) No proper storage water tank (2) Water tank is /are too small (3) Any others ....

19. If water tank is too small, why don't you construct a bigger one?..(1) No Space

(2) Financial problem (2) Both of Space & Financial problems

(3) Neglect (4) Any other...

20. Do you buy water from tanker truck or from other source..... (1) Yes (2) No

21. If yes, what is the average annual expenditure ...(1) Rs 1000-5000 (2); 6,000-10,000

(3) 10,000-50,000 (4) 50,000-100,000 (5)100,000 & above

22. Do you buy water during rainy seasons.... (1) Yes (2) No

23. Method of purification of Drinking water… (1) Water filter (2) Boiling

(3) Boil + Filter (4) Nothing (5) Other………………………………

IV. Other Buildings/ Ask Local Council or Prominent Citizen of the locality

24. How many Government Offices are there in your locality:.............; or I don't know.......

Please Name them whatever you know:...
....
....
....
....

(a) How many GI Roof................Please guess average size of all GI roof(s) around..............$feet^2$

(b) How many Concrete Roofs................Please guess average size of all concrete roof(s)...........$feet^2$

25. How many YMA Hall/Indoor stadium are there in your locality:.........

(a) How many GI Roof................Please guess average size of all Hall roof(s)..............$feet^2$

26. How many separate YMA Library are there in your locality:.........

(a) Please guess average size of all Library's roof(s)..............$feet^2$

27. How many Churches are there in your locality :...........(Including -Pres. Baptist, U.P.C etc)/ or I don't know

Name them whatever you know:

....
....
....
....

(a) How many GI Roof.................Please guess average size of all GI roof(s) around...............$feet^2$

(b) How many Concrete Roofs.................Please guess average size of all concrete roof(s)...........$feet^2$

V. Major Head of Expenditure

28. Monthly Household expenditure on food per year (Rice,Veg.Oil etc) Rs..............................

29. Education expenditure (school fees etc) per year Rs...

30. Expenditure on clothes per year Rs..

31. Expenditure on medical/healthcare per year Rs...

32. Expenditure on electric bills per year Rs..

33. Expenditure on water bills per year Rs..

34. Expenditure on Church related (excluding 1/10) per year Rs................................

35. Expenditure on YMA/Games & Sport etc (NGO) Rs..

VI. Personnel Opinion

36. Do you think harvesting rainwater is necessary.....(1) Yes (2) No

37. Do you think that rainwater harvesting is one of the most potential techniques to solve problem of water scarcity in Aizawl city....... .....(1) Yes (2) No

38. Do you think that government should take initiative to mandate the practice of rainwater harvesting for every new construction of buildings in Aizawl city....(1) Yes (2) No

39. Do think rainwater harvesting is practicable in Aizawl city ....(1) Yes (2) No

40. Do you think govt is serious to solve water problem for your locality.....(1) Yes (2)No

41. Any suggestions/comment for water sufficiency in this locality/Mizoram...
....
....
....
....
....
....
....
....

Date & Signature of Research Scholar

BIO-DATA OF THE CANDIDATE

Name	**: Zochhuanawma**
Father's Name	**: Thanchuta (L)**
Date of Birth	**: 23rd September 1983**
Sex	**: Male**
Marital Status	**: Married**
Nationality	**: Indian**
Educational Qualification	**: M.Sc (Geography)**
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PARTICULARS OF THE CANDIDATE

NAME OF CANDIDATE	: ZOCHHUANAWMA
DEGREE	: Ph.D
DEPARTMENT	: Dept. Of Geography & RM
TITLE OF THE THESIS	: Potentials and practices of rainwater harvesting in Aizawl city.
DATE OF ADMISSION	: 31.08.2015
APPROVAL OF RESEARCH PROPOSAL	
1. BOS	: 07.04.2016
2. SCHOOL BOARD	: 13.04.2016
MZU REGISTRATION NO	: 2671 of 2003-04
PH.D REGISTRATION NO. & DATE	: MZU/Ph.D/857 of 13.04.2016
EXTENSION IF ANY	: 2 years

(PROF. P.RINAWMA)

Head

Department of Geography & RM

POTENTIALS AND PRACTICES OF RAINWATER HARVESTING IN AIZAWL

By

Zochhuanawma

Research Scholar,
Geography & Resource Management

Supervisor,

Dr. KC. Lalmalsawmzauva

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Submitted in partial fulfilment of the requirement of the Degree of Doctor of Philosophy in the Department of Geography & Resource Management in Mizoram University, Aizawl, Mizoram.

ABSTRACT

Introduction

Our earth is a watery planet wherein nearly 70% of it is covered by water. Water exists in all forms-solid, liquid and vapours. However, the water available to human beings in the fresh form such as lakes, rivers and ground is limited to about merely 0.3% of total water supply (Mohanty et al., 2010). Much of this fresh water is still too expensive to get or inaccessible and trapped in glaciers, under-grounds and snowfields. In the meantime, due to increasing population, development and high living standard, the demand for water become higher day by day while the sources of water are diminishing rapidly across the globe. This clearly shows the preciousness of our fresh water for human beings and all other living creations.

The word “Rainwater harvesting” may be described as a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments and other man-made storage or catchment facilities using simple techniques such as jars and pots as well as more complex techniques such as underground dams or reservoirs. However, this research focuses particularly on rooftop rainwater harvesting in Aizawl city. Very simply, it is the capture, diversion, and storage of non-potable or potable water for later re-use. The technology is easy and simple which could be adopt and implement by everyone. Rainwater harvesting is one of the most effective methods of water management and water conservation.

The study focuses on the amount of rainfall and water condition in Aizawl district based on available rainfall data so as to understand, examine and assess the potential and practices of rainwater harvesting in the city. General observation shows that there exists an alarming water scarcity even within the capital city of Aizawl. The study also attempts to find out the potentials of rainwater harvesting in Aizawl city. Implementing awareness to the general public about the essentiality and feasibility of rainwater harvesting is also one of the important scopes of the study. Participation of the local people is of great importance in fulfilling the strategy of rainwater harvesting

because the study attempts at analyzing the roof water harvesting in particular. It also aims to educate the general public to practice roof water harvesting in the city because in Aizawl city the main catchment area of rainwater is the galvanized iron sheet (G.I sheet) and reinforced cement concrete (RCC) types of roofs, which are ideal for rooftop rainwater harvesting.

The buildings of the city are quite congested and there is very little open space. Apparently, most of the rainwater falls on the roof rather than open space. It is also interesting to observe that types of roof in Aizawl city are ideal for roof water harvesting as most of them are G.I sheet and concrete structures. The existing roof types are a potential for roof water harvesting without any extra effort. Moreover, Aizawl is still free of air pollution to dilute the quality of rainwater. The problem so far is that people are not much aware of this potential and simply rely on Public Health Engineering (PHE) water supply.

Statement of the problems

It is a natural phenomenon that the quality and quantity of water becomes lower and lower day by day due to the patterns of deforestation, industrialization and urbanization which is somewhat inevitable due to rapid growth of population. Similarly, it is the same case with the main source of water in Aizawl city. In the context of Aizawl city, the main source of water in the city is Tlawng river which is apparently not sufficient enough throughout the year for the city dwellers. Sometimes, during dry season, there is no sufficient water in the Tlawng river to feed onto. There used to be certain problems in pumping the water when the river channel is flooded during monsoon. So, this is a high time to practice rainwater harvesting in Mizoram as a whole.

Further, one of the most important reasons to implement rainwater harvesting system is that most of the people residing around the periphery of Tlawng river in Aizawl area are mainly dependent upon agriculture which further needs clearing of the forest due to the practice of shifting cultivation. At the current rate of industrialization and population growth, the water condition of Aizawl city for the coming 10-20 years is quite disturbing for our next generation. The possibility of acute shortage of water in the near future needs to be anticipated by implementation of rainwater harvesting system in the regional level or local level.

Rainwater harvesting, especially roof-top water harvesting, is one of the most essential technology to meet the increasing demand of fresh water in Aizawl city, Mizoram. Today, our city has continued to grow at a rapid pace; undeveloped land has been replaced with impervious surfaces such as streets, buildings, pavements and parking lots. This process of urbanization leads to depletion of ground water level. The ground water potential is getting reduced due to urbanization and as a result most of the rivers and streams are getting dry-up very easily.

Apparently, many of the residents in Aizawl city are in short supply of water, especially during dry spell of the year. Hence, a strategy to bridge the huge gap between water supply and water demand, in a major way needs to be launch with concerted efforts by various governmental and non-governmental agencies and public at large to make the rainwater harvesting a reliable and sustainable source for supplementing and supporting the water supply needs of the urban dwellers. This strategy has to be implemented at large by Village Panchayats or Municipalities or Municipal Corporation and other governmental departments with special efforts.

Study Area

The study area is Aizawl city, Mizoram, the capital city of the state, which is located north of the tropic of Cancer in the northern part of Mizoram. It is situated on a ridge of 1132 meters (3715 ft) above sea level, with the Tlawng river valley to its west and the Tuirial river valley to its east. The geographical coordinates of the city are 23°43´38´´ N and 92°43´04´´ E. Its total area is 457 km2 with a total population of 293,416 as per 2011 census. And the density of the population is 234 persons per square kilometre. The city is one of the most urbanised cities even in India. In detail, within the study area, Aizawl city, also, the research gives major thrust on 19 different selected localities from 19 Aizawl Municipal Corporation (AMC) wards. Out of the total 19

AMC wards within the city, 19 local councils are selected from each AMC wards for the study and household to household field survey so as to cover the study area in its entirety. The study area is Aizawl city and it includes the area covered by Aizawl Municipal Corporation.

Objectives

- To identify roof types for potential rainwater harvest
- To examine rainwater harvesting practices in Aizawl city
- To assess monthly rainwater quantity in Aizawl city
- To suggest measures for optimum use of rainwater harvesting

Methodology

Firstly, Aizawl city comes under the maintenance and jurisdiction of Aizawl Municipal Corporation (AMC). Aizawl city is categorized into 19 AMC wards and each ward consists of 3-7 localities. From all the 19 AMC wards, one locality each was selected for field survey which means that 19 localities were selected for field survey. Basically, there are 83 localities in the city out of which 19 localities i.e. 22.89% of the total localities were firstly selected for household level field survey. And the selection of locality from each ward was based on the number of households in the locality. It was selected in such a way that it covers the whole locality as well as the whole Aizawl city properly and impartially.

The total household from 19 selected AMC wards is 14,358 households or families. Firstly, 10% of the sample (1,435 families or samples) was selected for household level field survey. But, as per the census of India 2011, only the number of households is listed for each locality in Aizawl city instead of the number of houses or buildings. So, 10% of the sample is further divided by 2 because most of the buildings or houses in the city are occupied by 2 or 3 families or households. Subsequently, the final number of samples for household level field survey comes to 722 samples.

Similarly, from each locality, 10 % of the households are selected for the household level surveys. In certain cases, some houses are occupied by 5 or more households and some household are having separate water connection while in some cases there are no separate water connections for 3 or 4 families living in the same building. Thus, dividing 10% of the sample by 2 is justified as shown in the below table.

Method on selection of number of samples from selected localities				
Sl. No.	**Name of localities**	**Total HH**	**Sample size (10% from HH)**	**10% divided by 2. (Number of HH selected)**
1	Kanan	713	71	36
2	Tuikual North	983	98	49
3	Bawngkawn South	468	47	25
4	Chanmari	1262	126	63
5	Armed Veng	833	83	43
6	College	611	61	31
7	Durtlang	812	81	41
8	Hunthar	564	56	28
9	I.T.I	899	90	45
10	Khatla	1491	149	75
11	Ramhlun S.C	210	21	11
12	Ramthar north	375	38	19
13	Zemabawk	2022	202	101
14	Saron	675	68	34
15	Zonuam	556	56	28
16	Sakawrtuichhun	284	28	14
17	Maubawk	815	82	41
18	Upper republic	544	54	27
19	Melthum	241	24	12
Total	**19**	**14,358**	**1,435**	**722**

Collection of Data

Household questionnaire was prepared and survey was being conducted from 19 wards of Aizawl Municipal Council. At least one locality each was selected for conducting field survey so as to cover all the 19 wards of the city. This questionnaire mainly tried to assess rooftop water harvesting practice and potentials, opinions and observations of the people as well as problems relating to water. The main compositions of the questionnaire are size of households, types of roof, size of the buildings, quantity of household's daily water consumption, PHE water connection status, frequency of water supply from PHE, sources of water, capacity of water tank, families practicing or not practicing rooftop water harvesting, household buying or not buying water from commercial sources, etc. Using this questionnaire, household survey was conducted from 722 samples or households in Aizawl city.

Key Findings

1. The research observed that the Tlawng river, the main source of water supply for Aizawl city is becoming insufficient due to increasing demand of population as well as the declining efficiency of the water pump house as time passes by. It is revealed that as many as 91% of families have water connections provided by Public Health Engineering Department (PHED) while 74.65% of the families in Aizawl city is depending solely on the Water supply provided by (PHED). Regarding the frequency of water supply, it is noticed that as many as 574 (79.50%) household receives water supply once in a week while just 9 (1.2%) of them receives twice in a week and 56 (7.75%) household receives once in two weeks which could be the reasons for water deficiency for such households and 2.77% of the samples receive water thrice in a month. With regards to the quantity of water supply from PHE, it has to be kept in mind that the quantity or volume of water installed capacity seldom actually reached the main reservoir due to power supply, the inefficiency of the pumping machine, distribution loss due to leakages of water pipelines, etc. Thus, the calculation of the share of water per head per day from the total installed capacity is erroneous. Thus, a conclusion could be made from the quantity of daily average water supply during the lean season in January and February 2021 that the average share of water per head per day in Aizawl city ranges from 40 – 60 litres approximately, which seems to be very insufficient for the city.

2. It is also found from the study that the correlation between deforestation and quantity of rainfall is minimal or negative for the last 16 years (2005-2020) particularly in the state of Mizoram. There is a loss of whopping 678 square kilometres forest cover area in the state within a span of 15 years (2005-2019). On the other hand, even though the pattern of rainfall for the last 16 years (2005-2020) is irregular and sporadic, the quantity of rainfall is more or less the same except for the last three years (2018-2020). The quantity of rainfall in the state decreased or increased almost every alternate year. Thus, it could be inferred that the pattern of deforestation in the state of Mizoram still does not have large scale immediate impacts on the quantity of rainfall for the last 16 years (2005-2020). This might be attributed to the fact that the quantity of rainfall of a particular region does not increase or decrease due to deforestation of such region or state or country. Rather it seems to change noticeably due to deforestation of a much larger scale such as continental or global scale; or possibly, may be only 16 years of deforestation or rainfall is too short to notice the effects as well.

3. As a whole, G.I sheets account for 47% of the roofs; grass/thatch/bamboo/wood etc account for 21.42%; and concrete accounts for 8.21% of the roofs in Mizoram. Thus, most of the roof in the state is of G.I sheet (68.47%) which is considered to be very suitable for practicing rainwater harvesting. As a whole in Aizawl city, 9 localities (Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Armed Veng, College, Zonuam, I.T.I and Khatla) have a very high and ideal condition for practicing rainwater harvesting in the city while five localities such as Kanan, Zemabawk North, Hunthar, Upper Republic and Ramhlun Sport Complex localities possess medium potential to practice the same. Lastly, five localities such as Tuikual North, Bawngkawn South, Maubawk, Chanmari and Saron possess poor or low potential to practice rainwater harvesting in the city.

4. The localities with high number of families practicing rooftop water harvesting includes Kanan, Melthum, Durtlang, Sakawrtuichhun, Ramthar North, Zonuam and I.T.I localities as the percentage of practices rooftop water harvesting from these localities range from 60.71% to 85.71%. Moderate or medium potential localities to practice rainwater harvesting on the basis of households storing and not storing rooftop water includes Bawngkawn South, Maubawk, Chanmari, Zemabawk, Hunthar, Ramhlun S.C, Khatla and Saron localities. The common percentage of storing and not storing rooftop rainwater ranges from 41% to 59% in this group. The localities of low potentials on the basis of practice of rooftop water harvesting include Tuikual North, Armed, College and Upper Republic localities in which the percentage of practices range from 22-25%. Meanwhile, inferences could be drawn from the number of households practicing full-fledge RWH system in the city from the samples that rainwater harvesting is one of the best techniques to supplement the water scarcity in the Aizawl city as of now. Even though Durtlang locality has very irregular water supply frequency (once a week) which is only 14.63%, almost half of the samples are self-sufficient in water. Had the pattern of full-fledged rainwater harvesting practices in all the localities is as prevalent and efficient as it is in Durtlang locality, the present scenario of water scarcity in the city could have been avoided and the massive financial expenses of the government of Mizoram on water could have been lessened to a great extent. It is also found from the study that there is a positive correlation between frequency of water supply, practices of RWH and type of roof in the city. The frequency of water supply and type of roof impact the practices of RWH in Aizawl city. The area where the frequency of water supply is sporadic and irregular, and where G.I roof is prevalent, the number of households practicing RWH is generally high.

5. There are also many other attributes of rainwater harvesting. The average household size is 5.3 family members in the city. According to the 2011 census, there are 2,93,000 persons living in Aizawl city, which rose to about 3,78,000 persons in April, 2021. Inferences could be made in such a way that one of the main problems for insufficiency of water in the city is the storage facility for water as almost 65% of the sample's water tank capacity is limited to 5,000 litres only. The quantity of water is of no use when the facility for storing the same is inadequate. It is clearly revealed that when 86.01% of the samples can rely on their water tank just for a period of 1-3 weeks, it is obvious that the storage facility is not enough for most of the households in the city. And 45% of the samples possess insufficient water storage facility while about 52% do not even have a proper storage facility in the city from which conclusion could be made that storage facility is the main concern. Space and financial constraints are the main problems of the people from the samples to acquire sufficient water storage facilities. As many as 12.74% of the samples which account for 92 families from the samples still buy commercial water with costlier prices, which reveals the inadequacy of water from PHE department, for many families in the city.

There are as much as 82 unoccupied buildings in the study area, these buildings could have been very potential sites for rainwater harvesting; these 82 unoccupied buildings could have turned into the source of supplementing the shortage of water in the city if rational and systematic approaches were being implemented. Almost 99% of the citizens want the government to mandate implementation RWH for every upcoming building in the city. 86.8% of the citizens opined that RWH is practicable in the city as well. Presently, one or more water tanks of around 50,000 litres capacity is the ideal water tank capacity for a household in the city to suffice the minimum requirement of water during dry season of the year (months of January to March). This is also the ideal capacity to practice efficient and reliable rainwater harvesting in the city presently.

Keywords: - Water condition, scarcity, distribution, problems, lean season, rainwater harvesting, rooftop, rainfall, deforestation, water demand, share of water.