Norwegian University
of Life Sciences

Master's Thesis 2016 30 ECTS
IMV – Institute for Environmental Sciences

Potential of Rainwater Harvesting in Nepal - A case Study

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Masters of Natural Resource Management

POTENTIAL OF RAINWATER HARVESTING IN NEPAL
A case study of Kathmandu

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Declaration & certification

I declare hereby that the research and work presented in this thesis is genuine work done originally by me and has not been submitted or published yet for the requirement needed of a master's degree program. The fieldwork, calculation and literature extracted from others are cited within this report.

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Abstract

This paper gives an overview of RWHS in urban Kathmandu valley (27°32'13"- 27°49'10" N 85°11'31" & 85°31'38" E). The rainwater collection is during monsoon season (June-August) and some amount of water can be collected by rainwater in dry period to minimize the daily water demand among different households. The main study of research is to analyze and interpret the collected rainwater and household catchment area together to know the capacity of individual household of different land sizes. The research ultimately gives the framework of design storage tank depending on amount of rainfall collected from different roof catchment areas.

*The annual rainfall data of Kathmandu valley (2003-2013) is collected from department of hydrology and meteorology. The roof catchment area and land size data of different households in ward-9 were collected from ward office of KMC. The household land sizes and roof catchment area of different land area (2-4,4-6,6-8,8-10,10-12) Anna gives different rainwater harvesting potentially that amount of rainwater can be harvested. This is basis for design of the harvesting system. The capacity of collecting rainwater depends on roof catchment area and there is more collection of rainwater as the catchment roof area increases accordingly with respect to land area. The monthly precipitation of Kathmandu valley is more in June – September with monthly precipitation of 215mm, 375 mm, 315 mm and 244 mm and average area roof surface of 2-4 Anna is 72.66*m^2 *and it increases to 167.38*m^2 *of 10-12 Anna.*

The collected data shows that there is high potential of water harvesting and collected water can be useful as a domestic resource. The household member gets benefitted with an additional water source by the use of simple and easily accessed technology. In the same way there is less water supply pressure to the government and authorized institutional bodies, and ultimately beneficial for environmental risk of flooding as well.

Acknowledgement

I am overwhelmed to acknowledge my gratitude to all who helped me to accomplish the thesis despite of different circumstances. Firstly, I would like to thank professors Petter D. Jenssen and Manoj Pandey for giving me opportunity to accomplish the project of my interest in rainwater harvesting system in a partial fulfillment for the Master's degree in Sustainable Water and Sanitation, Health & Development, IMV department. I have been able to accomplish my project with continuous guidance and valuable information given from both my supervisors.

I express my deep gratitude to the Hydrology and Meteorology department of Nepal for providing me the rainfall data from 2003-201, Kathmandu metropolitan city ward number 9 for providing data from different household land area as well as roof catchment areas. I would like to thank my brothers Prayash Pokhrel and Prajwol Pokhrel for being with me all the time during the data collection period. Thanks to Biswo Raj Adhikari, Neeraj katwal and Synnøve Elshaug who gave me proper information about the thesis writing.

Finally, thanks to my family and friends who gave me unconditional and moral support to accomplish the project successfully.

Abbreviations

Symbol	Description
RWHS	*Rainwater Harvesting System*
DRWHS	*Drinking Rainwater Harvesting System*
KUKL	*Kathmandu Upatyaka Khanepani Limited*
ADB	*Asian Development Bank*
JBIC	*Japan Bank for International Co-operation*
NORAD	*Norwegian Agency for Development Co-operation*
MWSP	*Melamchi Water Supply Project*
GON	*Government of Nepal*
MLD	*Millions of Liters per Day*
KMC	*Kathmandu Metropolitan City*
PPT	*Precipitation*
HH	*Household*
CV	*Coefficient of Variation*
PVC	*Polyvinyl Chloride*
ICIMOD	*International Center for Integrated Mountain Development*
AD	*Anno Domini*
BC	*Before Christ*
NW	*Northwest*
Rs	*Rupees*
Mm	*Millimeter*
M	*Meter*
m^2	*Square meter*
m^3	*Cubic meter*
Sq.km	*Square kilometer*
Cu.m	*Cubic meter*
L	*liters*
Sq. ft.	*Square feet*

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Introduction

1.1 Background of study

RWHS is extraction of rainwater from the roof catchment area. Water scarcity is one of the growing problems in urban cities. The main problem of water scarcity in Kathmandu valley is due to leakage of pipe. Due to lack of proper management of rainwater, less amount of water is stored. Water scarcity ultimately creates severe drought in arid areas, mostly in the African countries like Kenya, Rwanda, Burundi, and Malawi. In late 1987 there was severe drought in Ethiopia (Falkenmark 1989). Due to the lack of proper advanced technology and proper co-ordination among the government and the public, the problem of drinking facility is increasing more these days. Due to the climate change, there is scarcity of drinking water in urban places.

The rapid urbanization in Kathmandu Valley started from the early 1950s after the drastic change in the political situation. The valley also started developing as a center of the country since 1940s. The development of infrastructures and rapid development in institutional as well as trade relations among European countries started, and at the time of rapid development it lacked proper design in basic facilities like water supply and roads for the future. Due to lack of proper vision and structure design, the valley is facing severe problems regarding drinking water facility, and the water supply compared to the present water demand is very less. In recent years the winters are being drier even though there are huge amounts of precipitation in rainy periods. In 2009 the country experienced more winter drought, as there was less rainfall during the monsoon period. In a way the country is facing more water problems due to lack of proper storage facility.

Although there is a high amount of precipitation in Kathmandu Valley, rapid urbanization and lack of proper planning on water facilities creates two major changes in population increase and land use pattern. The government of Nepal was unable to manage the current situation that ultimately creates more and more problems to meet the demand of the increasing population. The rapid urbanization affects the rainwater recharge to the underground aquifer, as the result water table decreases, creating severe problem in supply of drinking water to meet the present demand. The major issues creating lack of proper drinking water supply in Kathmandu Valley are use of old damaged pipelines and irregular monitoring of the supply system and its components.

The GON together with ADB, JBIC (Japan) and NORAD (Norway) initiates MWSP project in 2003 that was approved in 2001. The project was designed to meet 170 MLD water to the valley, and its implementation is not proper yet.

The direct benefit of RWHS in urban area is to mitigate flood. The various types of recharge structures are designed in public places i.e. recharge pits that help to prevent the excessive flooding. In the same way, RWHS improves the quality & quantity of groundwater, which is indirectly benefitted. A survey conducted in Chennai, India by Rain center shows that the water table had risen by 6 meters when introducing RWHS after monsoon in 2006 (Gopalakrishan,2002).

1.2 Need of rainwater harvesting in cities

It is challenging to fulfill the water demand in the cities, as it is increasing with rapid growth in population. Rainwater harvesting is the best option in those areas where there is inadequate supply of ground water or surface water. It helps reducing overloads to the water treatment plants as well as it prevents runoff from going to the drainage system, thereby effectively utilizing the rainwater. Similarly, it helps in recharging water into aquifers and improves the quality of ground water through dilution. In different urban places rainwater is used for primarily drinking water as well as various secondary uses like irrigation, groundwater recharge and flushing toilets. Most of the arsenic affected places in Bangladesh; rainwater is a primary source of drinking water.

Changi Airport in Singapore that is considered as world best airport that uses 63,500 tons of rainwater for flushing toilets and more often for cooling the terminal buildings. Similarly, Gansu Province in china supplies supplementary irrigation for 236,400 hectares of land with 300mm of rainfall. Moreover in India, annual recharge of rainwater that goes directly into the ground (Shrestha 2009) resulted in increase in groundwater level up to 5-10 meters in a period of just two years.

1.3 Need of rainwater harvesting in Kathmandu

Water scarcity is a major problem in Kathmandu along with its rapid growing population. With the rate of increasing population, government and institutional bodies fail to fulfill the required water demand to Kathmandu Valley. In this scenario, rainwater-harvesting technology is a promising approach to satisfy water demand in some extent. The average rainfall pattern in Kathmandu is around 1900mm. In total 640 sq. km Kathmandu valley annual rainfall is 1.2 billion cu.m/year or 3353 MLD, that is 12 times the current water demand in Kathmandu Valley (Shrestha 2009).

1.4 Potential of rainwater harvesting in Kathmandu

When the annual rainfall is high, Kathmandu Valley can meet the demand of the public in some extent. The annual average rainfall in Kathmandu Valley is higher than the estimated total valley average i.e., 2500mm in the last four years. The current water demand of a family member with averagely 5 family members is about 170 cu.m per year. But a building of 100 sq.m can collect 200 cu.m per year if almost 80% of the total rainfall on a particular building is collected easily (Shrestha 2009).

Practically it is impossible to store the exact potential, so the rest of the rainwater can be artificially recharged to groundwater aquifer. Out of total 640 sq. km of Kathmandu Valley, if only 10% of total area can be used for rainwater harvesting, then 128-million cu.m rainwater per year could be recharged (Shrestha 2009). Practical action, suitable recharge techniques and proper location investigations are much required to implement plans in an efficient way.

1.5 Objective of study:

The overall objective of the study is to analyze the rainwater harvesting potential in urban Kathmandu to supplement the water supply. The specific objectives are:

To estimate the RW roof catchment area in different land sizes.

To estimate the volume and quantity of RWHS in different land sizes.

Chapter 2: Literatures

2.1 Rainwater harvesting system

2.1.1 Historical development

Romans used RWHS, and its historical remains are found on Capri and Malta islands as well as in historical places of Spain and turkey. The oldest rainwater harvesting technique system was constructed in Istanbul, Turkey by Caesar Justinian in 527-565 AD with capacity of 80,000 m^3 and measures 140m by 70 m. (Source: Rainwater reservoirs above ground structure). RWHS is considered to be one of the oldest technologies used to collect water for domestic purposes. During the third millennium BC, simple stone rubble structures were used to extract rainwater in India. Similarly, the same technique for collecting rainwater was used throughout the Middle East and Mediterranean.

In Western Europe, Australia and America, rainwater was the primary source of drinking water. The water used to be collected from roof surfaces and it was stored in underground reservoirs together with masonry domes. The practice of collecting and storing rainwater for agricultural practices mainly has been used widely throughout different continents for thousands of years. "Dying Wisdom: Rise, fall and potential of India's traditional harvesting systems" gives a good historical overview of such practices in India. (Agarwal and Narain 1997)

2.1.2 Rainwater harvesting type/technology

Ground water harvesting

GWHS is the natural harvesting system where rainwater falling on the surface area gets precipitated into aquifer region through the movement along with rocks, soil and finally accumulates at a point under the ground in aquifer. For ground water harvesting the particular area should be suitable enough to receive precipitation and percolates down to the soil. Following rock and aquifers get recharged. To sustain the ground water recharge for a long time, the harvesting area should be protected with forest fire, overgrazing and deforestation.

Rainwater harvesting

Rainwater harvesting technology refers to the collection of rainwater and its collection using DRWHS. It allows recharging, and then collected water overflows most of the time during the monsoon season. Rainwater is collected from roof area using gutters, pipes, and then it is collected in the storage tank. The harvested rainwater can be used for multi purposes like water supply for irrigation, domestic uses etc. It helps recharging excess rainwater to aquifer for more water recharge. A case study in Jordan shows that a maximum of 15.5 Mm3/y of rainwater can be collected from roofs of residential buildings provided that all surfaces are used and all rain falling on the surfaces is collected. This is equivalent to 5.6% of the total domestic water supply of the year 2005.(Abdulla and Al-Shareef 2009)

2.2 Water harvesting techniques from different sources

RWHS uses simple and easy technology and it is easy to understand. The domestic rainwater harvesting systems usually have three main components that are described as:

1.Catchment surface: It is the area that collects rainwater that falls on the roof surface or other surfaces. Depending on the type of catchment area there is variability in storing the amount of rainwater, as different catchment area (roof, tile and other surfaces) has different absorption and collection capacity depending on type of catchment area.

2. Delivery system: It is an intermediate component of DRWHS as it transports the available rainwater from the roof to the storage tank through gutter and drainpipe. Moreover, it is the basic component that needs to be designed in a proper way to access rainwater flow fluently coming from the catchment area to the delivery system or storage tank.

3.Reservoir tank: It is used to collect and store rainwater until the stored water is not used for domestic uses. Depending on the location of the tank and frequency of uses, the tank needs to have a water extraction device that might be tape or a bucket. Tape is more widely used and more effective as well.

(Kasula 2012)

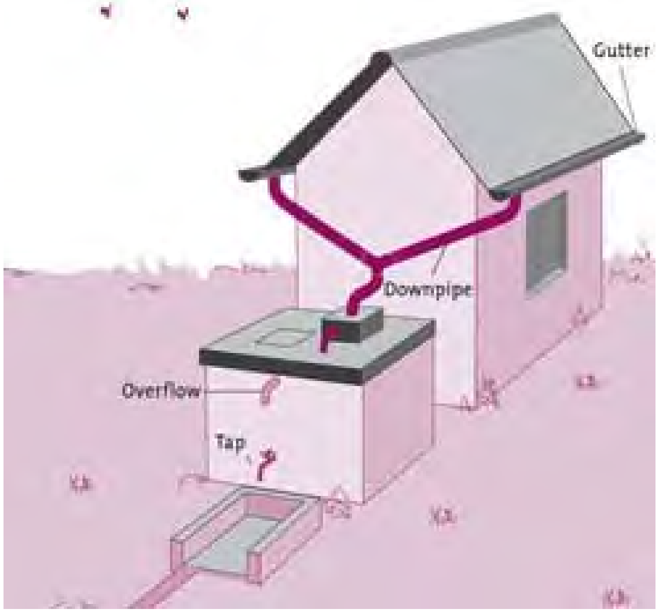


Fig. 1 Rooftop rainwater collection system (Smet 2003)

2.3 Storage tank capacity

In RWHS, collected water is stored in a storage tank. The storage tank is one of the most important components to be considered while installing rainwater-harvesting systems, as it needs almost 50-70% of the total initial cost (Li, Boyle et al. 2010). Generally, the storage tanks are separated in two different categories depending on the location. Either they are placed underground or above the ground. It is easy to detect leaks and cracks in the tanks above, and water can be extracted through gravity if the tanks are raised up above the ground. The initial cost is less compared to the underground tanks as well and they are very easy and feasible for regular maintenance and cleaning. Similarly, the underground tanks are effective and good in the way that it maintains the quality of the harvested water as well as it prevents light penetration. It is also challenging to extract stored water from the tanks underground, as they need an additional pump to extract water. Also there is a chance of contamination from floodwater and ground water. The size of the storage tank depends on the number of people consuming water on a daily basis, and the amount of average rainfall in that particular area. The volume of the storage tank depends on various factors while it is being designed, which are:

Total number of people in each household: How many people are living in the household determine the storage tank capacity, if there is a higher number of people, then it requires a bigger storage tank to obtain the same efficiency under the same roof area.

Per capita water requirement: It depends on the water consumption rate of the particular households and differs among households. How long the water can last also depends on the design of the storage system

2.4 Average annual rainfall

Periods of water scarcity: The pattern of annual rainfall determines the storage tank capacity. If more rain falls than the storage tank has capacity to hold, then the tank is considered to be small.

Type and size of the catchment: The type of roof material differs in runoff coefficient during the designing process. Also, by measuring the length and width of the roof catchment area, the size of the tank can be determined and with increasing catchment area, the size of the tank should increase as well.

2.5 Catchment required to satisfy demand

RWHS is an additional source to fulfill required water demand. Research conducted in Millennium Dome in London is an example of a large-scale rainwater scheme. The roof of the dome has a surface area of approximately 100,000 m^2 from where rainwater is collected using large hoppers (Villarreal and Dixon 2005). The RWHS has been significantly improved in saving water of residential areas in urban areas of different countries. A study conducted in Germany shows that water saving efficiency varies on the catchment roof area, and potential water demand from 30% to 60%. Also the study conducted in Australia concluded that potable water saving efficiency is about 60% by the analysis of 27 different HH_s. In a similar study conducted in different cities (62) of Brazil, it is shown that the range of potable water saving varies from 34% - 92% that accounts an average 69% of total water saving. (Abdulla, 2009). The harvested rainwater is important for supplying potable water for domestic uses. A study conducted in U.K. shows that about 30% of the total supply in the domestic sector are normally used for flushing toilets as well transportation of foul waste. This implication of using rainwater has subsequently made a reliable and practical way of reducing the water demand on waste treatment facilities and water supplying systems (Fewkes, 1999).

Around 10% of the total water demand can be obtained from the RWHSs even though the rate of collection was limited due to storage factors on-site. Maximum 100m^3 can be collected in one day. Also in London, rainwater is collected from a 2200 m^2 roof to a 14.56m^3 tank and used for flushing in the building; an overall annual efficiency of the system was estimated on 51%.

At Daimler Chrysler in the Potzdamer Platz at Berlin, roof runoff from 19 buildings (total area 32,000 m^2) is collected and stored in a 3500m^3 rainwater basement tank. (Villarreal and Dixon 2005) The collected water is used for watering gardens, flushing toilets, and for the replenishment of a vegetated pond. About 58% of the rainwater is retained locally by using this system. (Villarreal and Dixon 2005)

The RWHS usually consists of gutters or pipes that are the mediators of transforming collected rainwater towards the tanks by the use of gutters and pipes. The size of the gutters depends on the amount of rainfall. Roof catchment area and gutter size usually ranges between 20–50 cm diameters. Concrete tanks are the most commonly used, and as per requirement of people it can be built on different ground levels. They are usually made on-site and are durable and long lasting. Mainly there are three different types of tank for storage that can be constructed. The storage tank can be placed into different locations i.e., sub-surface, to the ground level, and underground level. The collection drums can simply be used as storage tanks. The average annual rainfall in Kathmandu valley is 1900 mm, that is more than world average (Upadhya 2009). The amount of rainfall varies from 600mm NW to less than 200mm in southern deserts and eastern part that posed 91% of total surface area. The total annual rainfall in Jordan varies from 6000×106 m3/y and 11,500×106 m3/y and in average is 6000×106 m3/y and 11,500×106 m3/y. Approximately 85% of the rainfall evaporates back to the atmosphere; the rest flows into rivers, and groundwater recharges occurs. The groundwater recharge is approximately 4% of the total annual volume of rainfall, and out of total rainfall volume, surface water is 11%. (Abdulla and Al-Shareef 2009)

Since the annual rainfall in Kathmandu is much higher than in Jordan, there is high potential of rainwater harvesting technique in Kathmandu valley. Harvested rainwater is a renewable source of clean water that is ideal for domestic and landscape uses. The collected rainwater can be used for drinking, cleaning as well as for irrigation. Due to shortage of available water for domestic uses, people collect additional water from external sources even though they are already getting from a water distribution system. Rainfall intensity and the number of dry days before a rainfall event affects the harvested rainfall quality. The quality of collected rainwater depends on the first collection of rainwater on roof catchment area and methods used for storing rainwater. Rainwater is usually free from physical and chemical contaminants such as pesticides, lead, and arsenic, color and suspended materials and it is low in concentration of salt and hardness. Regular maintenance assists in getting good quality water from rainwater tanks.

The storage tank should be maintained periodically from inner walls and the floor should be scrubbed. Cleaning is done using chlorine and then rinsed.

2.6 Roof catchment area

The roof catchment area is an important part in RWHS. It is an initial part of rainwater collection system. The majority of RWHS uses roof catchment area for collecting rainwater and storage tanks is used for rainwater storage. While designing the RWHS, some important factors need to be considered:

Roof Material: The type and quality of roof material are considered to be important while selecting roof material. The roof materials that contain asphalt shingle and metal are usually preferred, as they avoid the contaminations on collection surface. Similarly, the use of lead and woody material are not preferred, as they affect the quality of rainwater.

Slope: It is also an important factor to be considered, as the slope of catchment area (roof) affects the rate of drawdown of rainwater during rainfall period. In steep roof rainwater will percolate fast and it cleans the roof contamination easily and in same way if slope is less than it takes long time to pass through and there is high chance of mixing of contamination.

Sizing a Catchment Area: The amount of rainfall and total catchment area are important factor that gives proper basis for sizing of a catchment area. The calculations of total catchment surfaces and total amount of rainfall on same surface are determining factors determining for sizing roof a catchment area. The amount of rainwater to be harvested gives a framework for proper sizing.

2.7 First flush system

First flush system; it flushes off the first water that falls on the roof catchment area before it runs to the storage tank. Normally, first bird droppings, particulate and materials on the roof catchment area, and that are contaminating the rainwater. It is first of all essential to remove those types of contaminations before the water enters the storage tank. This system helps in maintaining the water quality.

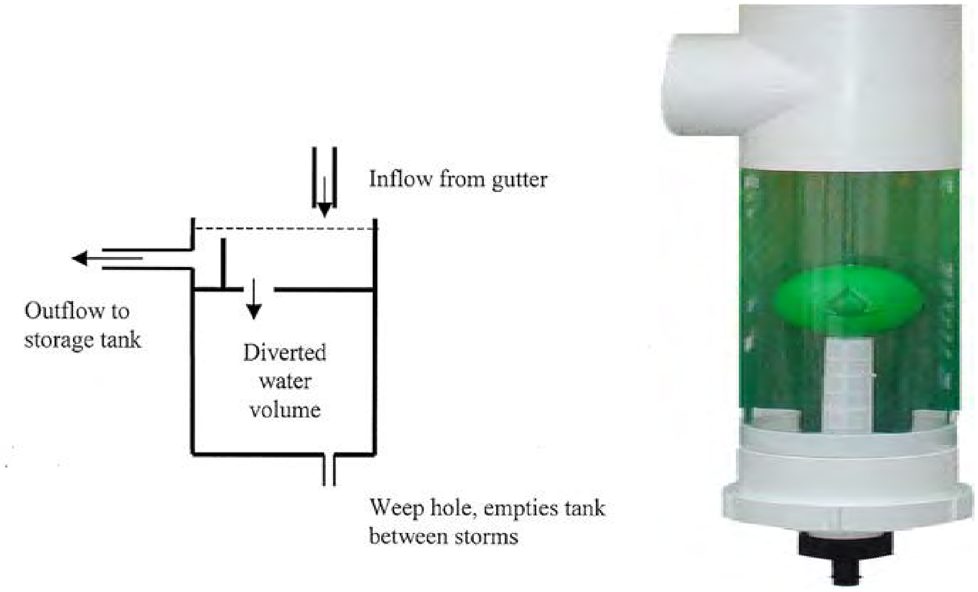


Fig 2: First flush diverter system

(Source: Rain harvesting PTY downspout first flush diverter)

In order to protect the water from contaminations, the first rainfall on the catchment area is diverted to the chamber of water diversion. The water diverter consists of a dependable ball and seat system (automatic system that is independent of mechanical and manual disturbances). The working mechanism of the diverter initiates with the increasing level of water in the diverter. As the diverter rises with the water flow, the ball floats on the surface. Once the chamber is full, the ball rests at a point inside the diverter and thereby preventing further entry of water, and finally the flow of water is directed towards the storage tank.

2.8 Rainwater harvesting in Nepal

Rainwater harvesting is the deposition of rainwater for reuse on-site, rather than runoff. RWHS was introduced in Nepal in 1988 as a pilot project in the middle school of Daungha village. Rainwater harvesting is a traditional technique that can be used efficiently to minimize the water demand. The rainy season, (June-August) is the main time with as much as 85% of the total annual rainfall. Kathmandu valley has a rainfall pattern of 160mm per year, which means 160,000l per hectare of land. The method of collection of rainwater differs in scale of the system (Kasula 2012). Normally domestic rainwater harvesting system is used. It is easy to collect rainfall from roofs and then store in rain barrel tanks. That is the most common and efficient collection techniques of rainwater in small scale. The system should be installed in such a way that the barrel downspout can be placed on the ground to allow water to flow down in the rain barrel collection.

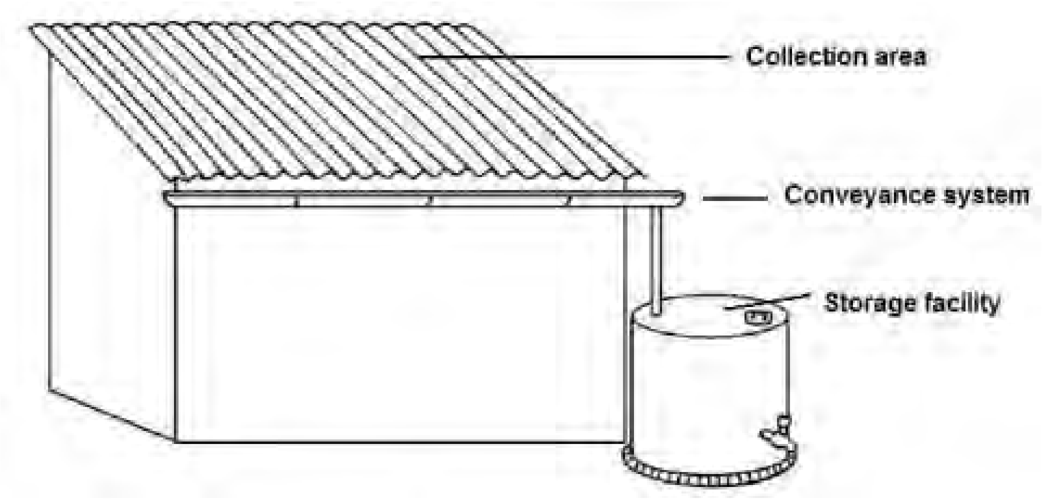


Fig 3: Simple model of rainwater harvesting technique

Kathmandu valley is facing a problem with shortage of water since the 1980s. The population of Kathmandu Valley has a water supply of 90 MLD in the dry season against a requirement of 320 MLD among 4 million people (Kasula 2012). The water supply in Kathmandu valley is almost 60% from tube wells and the rest 40% is from surface water sources (Kasula 2012). There is a shortage of drinking water nowadays more due to a rapid increase in population and also due to climate change problems. The increasing water demand in urban areas is putting stress on existing water resources.

Due to inadequate recharge areas in Kathmandu Valley, the rainwater is not being able to percolate in subsurface, and instead it is flowing through the rivers without being used properly. In the Northern part of the valley there is plenty of forest and a conservation area which allow sufficient recharge of rainwater, but in the main valley due to lack of proper management, rainwater is flowing along with the rivers without proper utilization.

2.9 Application of rainwater harvesting system

RWHS is both easy and affordable, and it overcomes the water demand. That makes it good for supplying in critical conditions and helps to minimize the drought conditions. DRWHS helps to mitigate the urban flooding and helps to recharge groundwater. That also reduces the demand of wells. Since the collected rainwater is free from chemicals and salts, it needs simple technology to be accessed for domestic use. It stabilizes the water supply and wastewater systems, therefore decreasing more pressure on supply and management systems and companies.

2.10 Benefits of rainwater harvesting system

RWHSs are simple to install, operate, and maintain. The main benefit is that they are cost effective during the installation. They are convenient to provide water in homes and are easily accessed. The collected water from DRWHSs can be used for multiple purposes such as irrigation, toilet flushing, washing, bathing, and laundries. The system is durable and lasts for a long time, and it has very low environmental impacts.

2.11 Use of Filters and chlorine for water purification

The rainwater quality is an important factor to be considered before domestic uses, mainly for drinking. The use of candle filters and chlorination purifies the water. The candle filters are easy in removing turbidity; pathogens and suspended solids from stored the water. It helps to improve the smell and taste by removing the iron particles and viruses (Sources: Ceramic candle filter). The use of candle filters improves the quality of water. The organic matter in water is settled down by the use of chlorine. Chlorination helps to deactivate microorganisms from water. It is better to use the candle filter because of its accessibility, price and durability.

CHAPTER 3: Research methodology

3.1 Study area

Fig 4: Map of Nepal showing the geographical location of the study area.

The study area is KMC, with totally 35 different wards. Kathmandu Valley has historical importance with its four different heritage sites Pashupatinath temple, Kathmandu Durbar Square, Boudhanath Stupa and Swoyambhu Nath Stupa. In metropolitan office, advisory support is given by the metropolitan city planning commission that provides guidance in designing, formulation and implementation of the project. It provides the urban facilities and services in the 35 different wards. (Source: Kathmandu Metropolitan Office). The main study area is in Kathmandu municipality ward-9. The total number of houses with different roof areas is taken from the municipality to calculate the roof area.

The study area is surrounded by the airport in the East, Dhobi khola in the West, Gaushala where is Pashupatinath, world heritage site in the North and different wards (10, 34 and 35) in the Southern part. The total area of ward 9 is 301.9 hectares, which contains 6,708 numbers of HH. The population was 29,263 people in 2001 with 15675 males and 13588 females. The basic facilities like drinking water, electricity and telephones are available in this ward with/where approximately 85% of the total population is provided with proper water facility. The most important heritage site in study is Ram Mandir at Battisputali. In the Chait Dashain a large numbers of devotees gather to worship once in a year. Dwarika hotel, which is considered to be a fine showpiece with indigenous architecture and building structures, is in the same ward. (Source: Kathmandu Metropolitan Office)

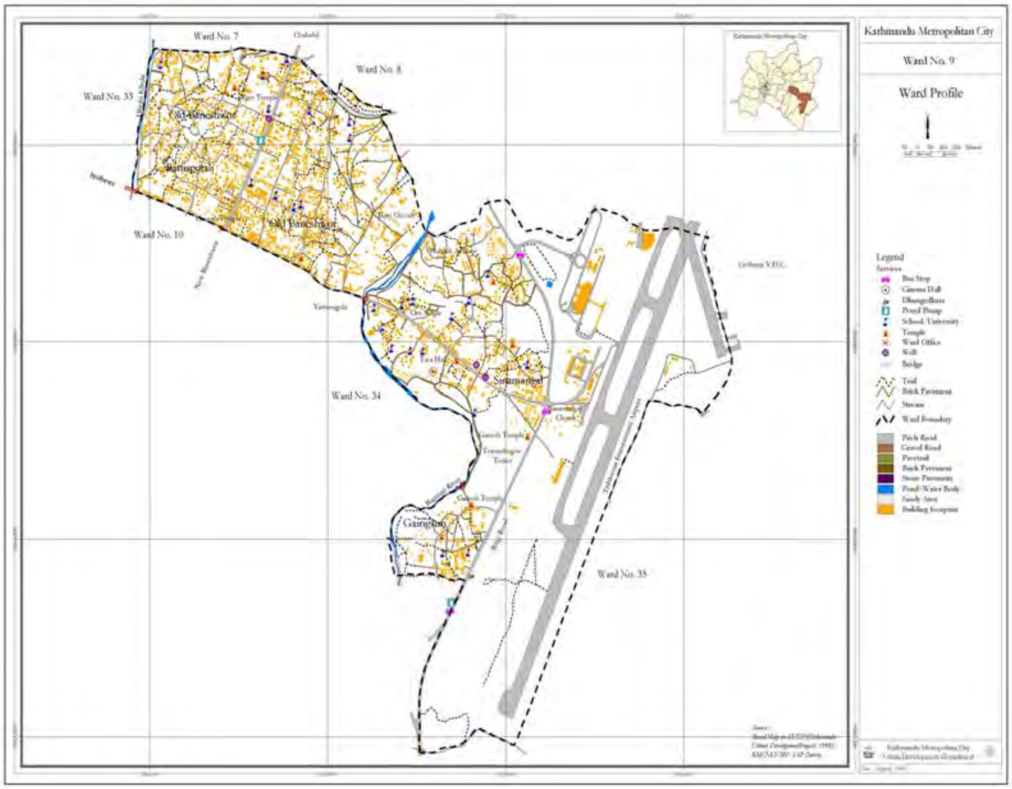


Fig 5: Map of ward-6 area of Kathmandu showing the locations and direction.
(Source: Kathmandu metropolitan office)

3.2 Data collection

The study of research is based on the statistical analysis of secondary data and interpretation of results, so as to analyze the potential of rainwater on different roof catchment surfaces in different household areas. The individual households that are made in different sizes of land are 2,4,6,8,10 Anna and these data are taken from the municipality office of ward number 9. The annual rainfall data is important to calculate to know the intra annual variability in rainfall pattern, and is taken from department of weather and metrology. Obtained data is used to calculate the coefficient of variations of different months. Inter annual variability of annual cumulative rainfall can be determined by finding the coefficient of variation of annual cumulative rainfall.

$VR = (R*H_{RA} *R_{C})/ 1000$
VR=Monthly rainwater volume (m^3)

R= Monthly rainfall depth (m)
H_{RA} = Roof area of household (m^2)
R_C = Runoff coefficient
The available rainwater can be estimated by the equation:

Q = C I A … Where Q is available rainwater quantity in m^3/ year, C is the coefficient of the available runoff, I is the intensity of the rainfall in m/year and A is the catchment area in m^2. Thus, the annual rainfall data is statistically determined.

Chapter 4: Result and analysis

4.1 Water supply demand

To ascertain the water demand per person per day, HH survey was carried out and the result of the demand survey is presented in the figure below:

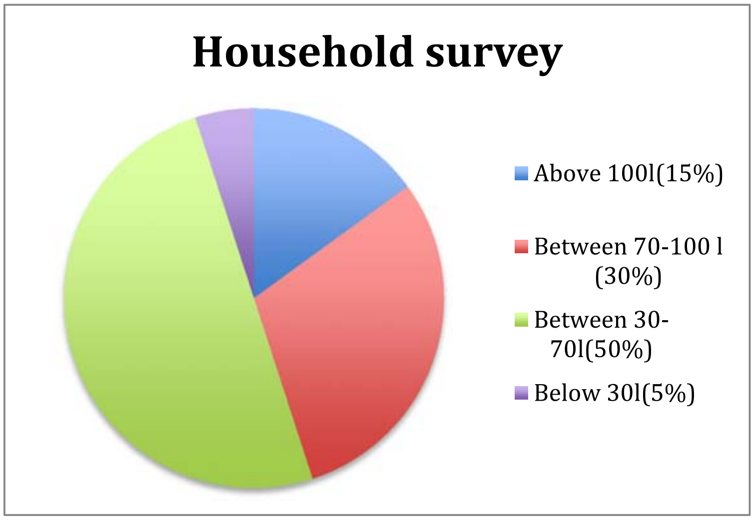


Fig 6: HH survey on water supply demand ratio.

The HH survey revealed at the present condition of water supply and expected demand per person is so far lower than what normally is adapted for urban water supply. The average water demand per individual is 50l L per capita per day and includes drinking, washing, and flushing. The demand is low because of the miserable water supply situation in Kathmandu, where the low value of 50l L per day is the main concern to get water. But all in all since they are all habituated to the condition, they are happy to get the low amount of water ensured.

4.2 Water supply sources

The questionnaire survey is carried out in order to determine the type of water resources that is being used or if it is able to meet the water demand. Several water supply sources were put in the questionnaire survey namely water from private tankers, shallow wells, deep wells, municipal water supply as well as RWHS. Based on the survey results presented in the figure below:

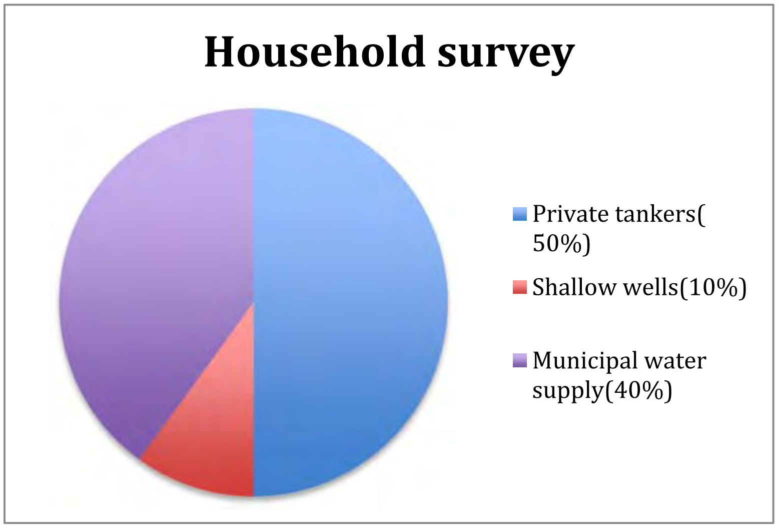


Fig 7: HH survey on different water supply sources

The results show that the main sources of water supply are partly from municipal and partly from the private water tanks. Only 10% of HH have shallow tube wells and no one of them has deep tube wells. Similarly, no one has proper RWHSs, but occasionally water is collected using only buckets and large containers as informal or unsystematic RWHSs. The result of the survey also revealed that dependency of municipal water supply system was low and other type of sources met the demand.

4.3 Rainwater harvesting system & practices to households

One of the questions that were posed during the questionnaire survey was the knowledge and awareness of RWHS. The result of HH survey on people awareness is presented in figure below:

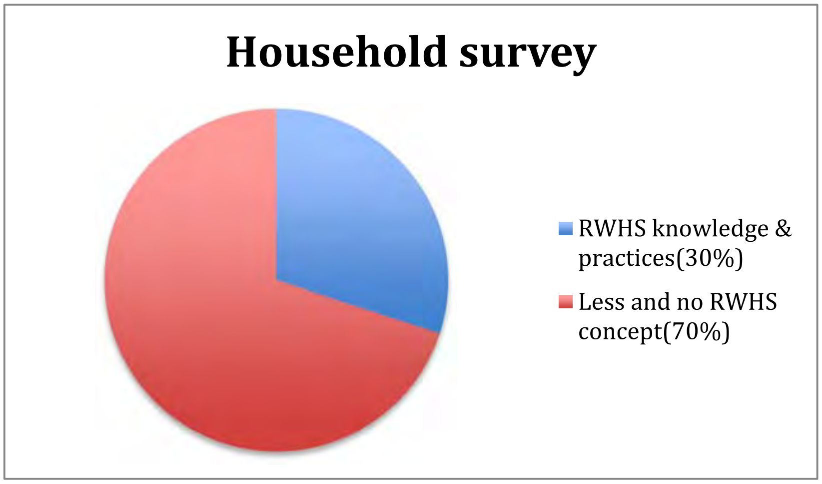


Fig 8: HH survey on RWHS practices.

It was found that only 30% of HH knew about RWHS and its benefit, and 70% of people were unaware of the potential of RWHS as a source of water supply. This result shows that there is a need of an awareness raising program to educate people on potential benefit of RWHS. Organizing the demonstration of how RWHS can be built and can be done by local wards or municipality. They could carry out such awareness-raising programs.

4.4 Sanitation practices and water uses

Around 20% of the total water supply to an urban HH is used for flushing toilets. The use of different type of sanitation system has a significant impact on the water demand. A questionnaire survey revealed that 60% of HH had toilet system with proper flushing facilities and 40% of HH had improper flushing toilets. Moreover, some amount of water is also used for anal cleansing because of the traditional societal system and culture. The result is shown in the graph below:

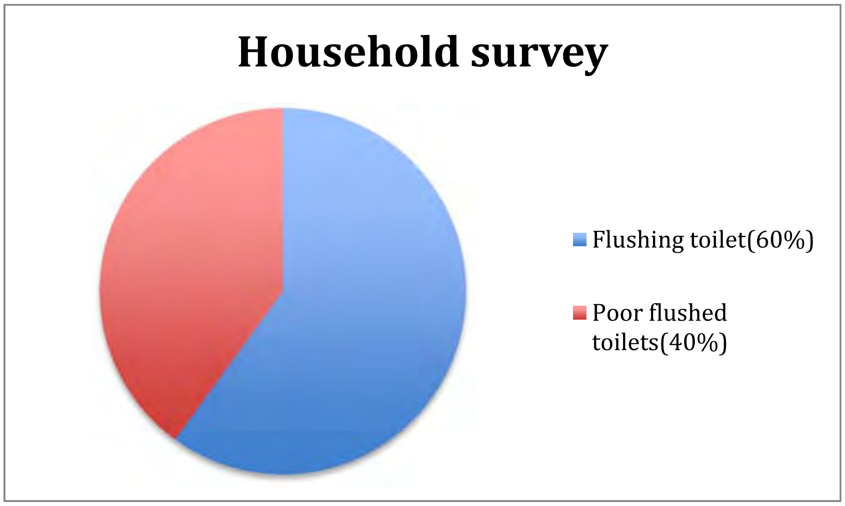


Fig 9: HH survey on sanitation practices and water use

4.5 Land holding size

In order to determine the sizes of roof catchment areas, the HH building maps were obtained from each HH during the survey, and the sizes of land and roof area were noted down. The minimum land area required to construct a building is 2 Anna. This survey of HH revealed that the size of land holding range from minimum 2 Anna to maximum 12 Anna (1 *Anna*= 342.25 sq. ft.). In order to simplify the land holding size data, the land size was divided into 2-4, 4-6, 6-8, 8-10, 10-12 Anna's. The survey revealed that the highest percentage of HHs were 2-4 (*Anna)*. Similarly, the size of roof area for each of HH survey was calculated and the size are presented in the table with standard deviation

Mean and standard deviation of different roof area size.

Anna	Mean (m^2)	Standard deviation
2-4	73	24
4-6	112	26
6-8	139	61
8-10	140	51
10-12	167	108

4.6 Water treatment practices

The most common water treatment used by HHs was boiling. 5% of HHs have water treatment facility with aeration sand filter, used by the HHs with shallow tube wells as a source of water supply. During survey it was found that the iron content in the groundwater was very high. About 20% HH has commercial water treatment filter, uses before drinking and cooking and considered to be more expensive. The water sources mostly did not have proper water treatment facilities. The result is shown in the graph below:

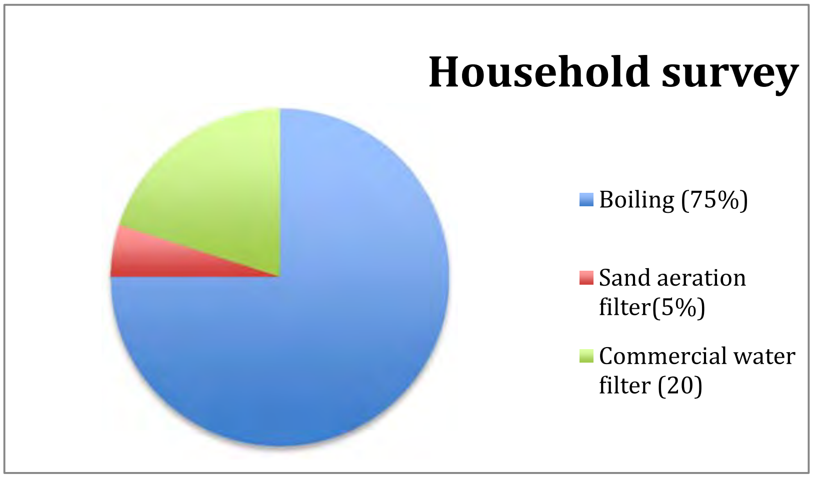


Fig 10: HH survey on water treatment practices

4.7 Frequency of water supply system

The municipal water supply system is not sufficient enough to fulfill the water demand in different individual HHs. Therefore, water supply is from different sources to fulfill water demand in some extent. Those who obtain the water from tankers roughly buy 2 tankers per month (12,000L). This investigation revealed municipal water supply is intermittent and in many cases water was supplied in the interval of 2 weeks and most HH said that they had to use pump to extract water from the municipal pipelines.

4.8 Roof catchment design

The amount of rainwater collected from the catchment depends on the type and quality of the roof catchment. The roof catchment with cemented roof catchment area has 0.85 coefficient of runoff and tile roof has 0.75 coefficient of runoff. The material with highest amount of rainfall can collect more because of high coefficient of runoff. The survey of 52 HH reveals that 85% of HH has concrete roof, 12% has roof with tiles and 3% has corrugated sheets. Similarly, 85% of HH had one type of roof and 15% has mixed roof type. The result is shown in the graph below:

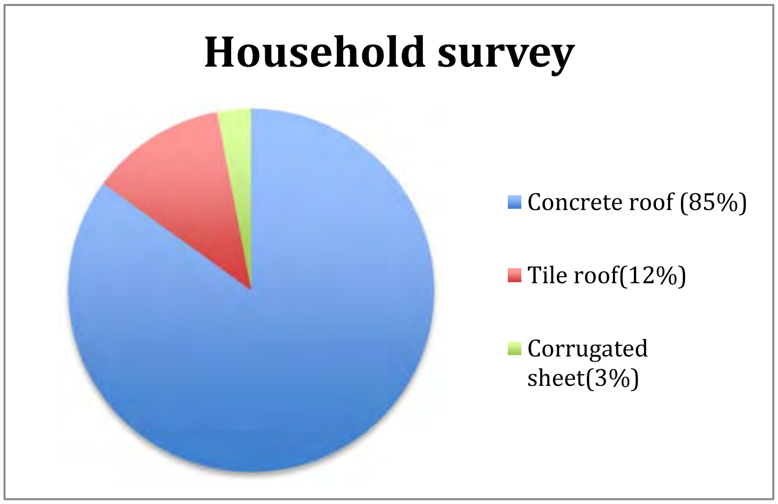


Fig 11: HH survey on Roof catchment design.

4.9 Willingness to invest for rainwater harvesting system

During the questionnaire survey, a question was posed to different HHs about whether they were interested in installing RWHS and what amount of money they were willing to pay. The survey revealed that if a RWHS can meet their demand of 50 L per person per day, they are willing to invest. Only 10% of the HHs were not capable to invest in RWHS despite knowing its benefits. This was mainly because they could not afford it. None of the HHs denied for unwillingness to invest in installation of RWHS. The range of the amount that they are willing to invest is presented in the figure below:

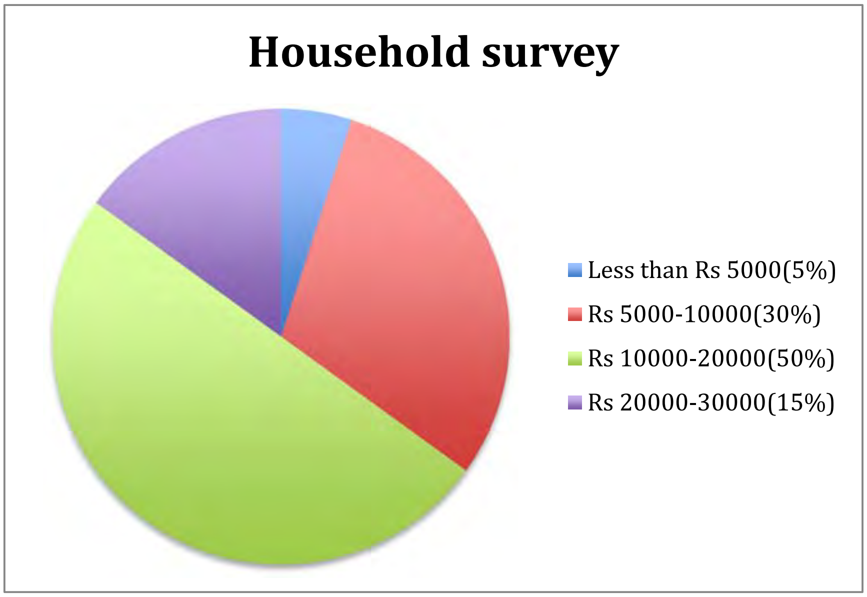


Fig 12: HH survey on willingness to invest on RWHS

4.10 Annual rainfall pattern analysis

The annual rainfall data is collected from the department of hydrology and meteorological. The calculation of monthly rainfall data from 2003 to 2013 together with its interpretation, analyzes rainwater harvesting system efficiency and potential that gives the model of design calculation of important components in the system. There are no significant changes in rainfall pattern the last 10 years. To calculate the coefficient of variations of different months and monthly rainwater volume, monthly rainfall data is analyzed to know the best time for rainwater harvesting so as to extract more water in the peak harvesting time to store for the dry period. Standard deviation and total mean of monthly rainfall are calculated to determine the coefficient of variation. Mostly in the monsoon season June-August, the average precipitation is more. As much as 374,91 mm in July, and December is the month with less precipitation with 3,61 mm. The difference in average monthly rainfall pattern gives information about the wet and dry periods that can be used during model design of RWHS. Similarly, data of HH roof areas together with monthly rainfall data gives the total volume of monthly rainwater. In a same way to calculate available rainwater in a year, the rainfall data is calculated annually. Year 2013 and 2009 are with the highest and lowest amount of precipitation. The annual average rainfall together with roof catchment area gives total rainwater available in a year. The average monthly precipitation from 2003-2013 is presented in the figure below:

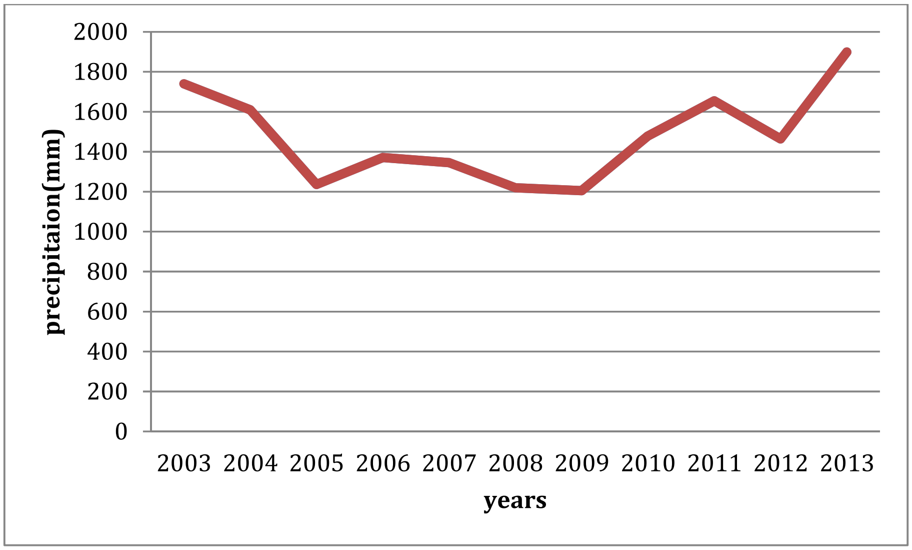


Fig 13: Average annual precipitation of 2003-2013.

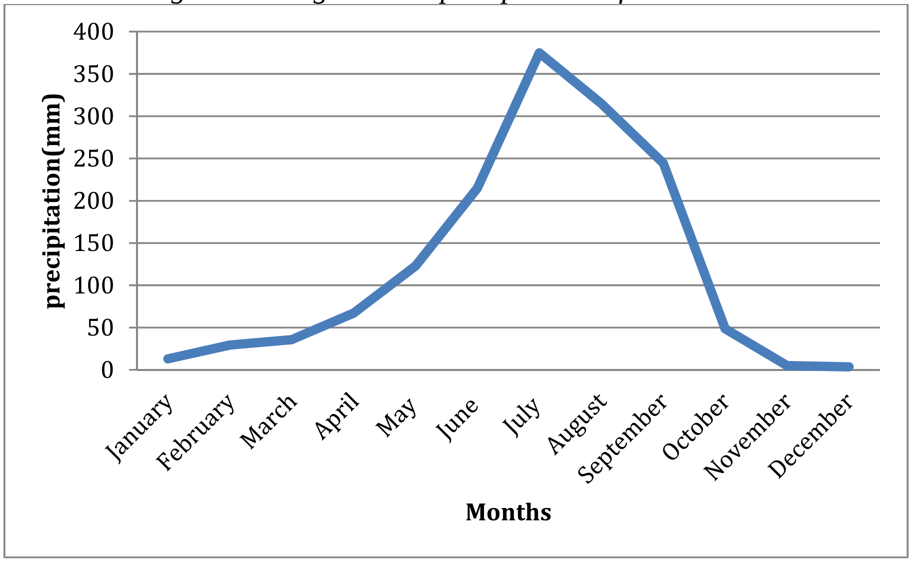


Fig 14: Average monthly precipitation of 2003-2013.

The total rainwater available in different sizes of roof catchment area gives the information regarding designing of the storage tank. The different roof areas 2-4 Anna, 4-6 Anna, 6-8 Anna, 8-10 Anna and 10-12 Anna depending on their water collection capacity with variation in sizes, gives the data of optimum limit that the particular type of catchment area can store. It is obvious that a roof catchment area with 8-10 Anna requires a larger storage tank compared to a 2-4 Anna roof catchment area due to their difference in roof size. The mean roof area of 10-12 Anna is 167 m^2 due to large catchment area and the mean roof area of 2-4 Anna is 72,66 m^2 due to small catchment area. The data of mean roof area size of different land size gives the basis of calculating annual rainfall available in different years.

The amount of rainfall available on roof catchment areas of different land sizes depends on the intensity of available rainfall as well as the size of roof catchment area. The calculation of available runoff gives a proper framework in designing the storage tank capacity and amount of rainwater that can be harvested depending on the family size, roof area and available rainfall. The total rainfall available in different years shows the amount of rainwater that can be harvested during monsoon season and also involves in designing suitable storage tank concerning the family size of different HH. The analysis of rainfall data and roof catchment area shows the amount of water that can be stored during the monsoon season and can be utilize during dry season so as to fulfill household water demand in some extent.

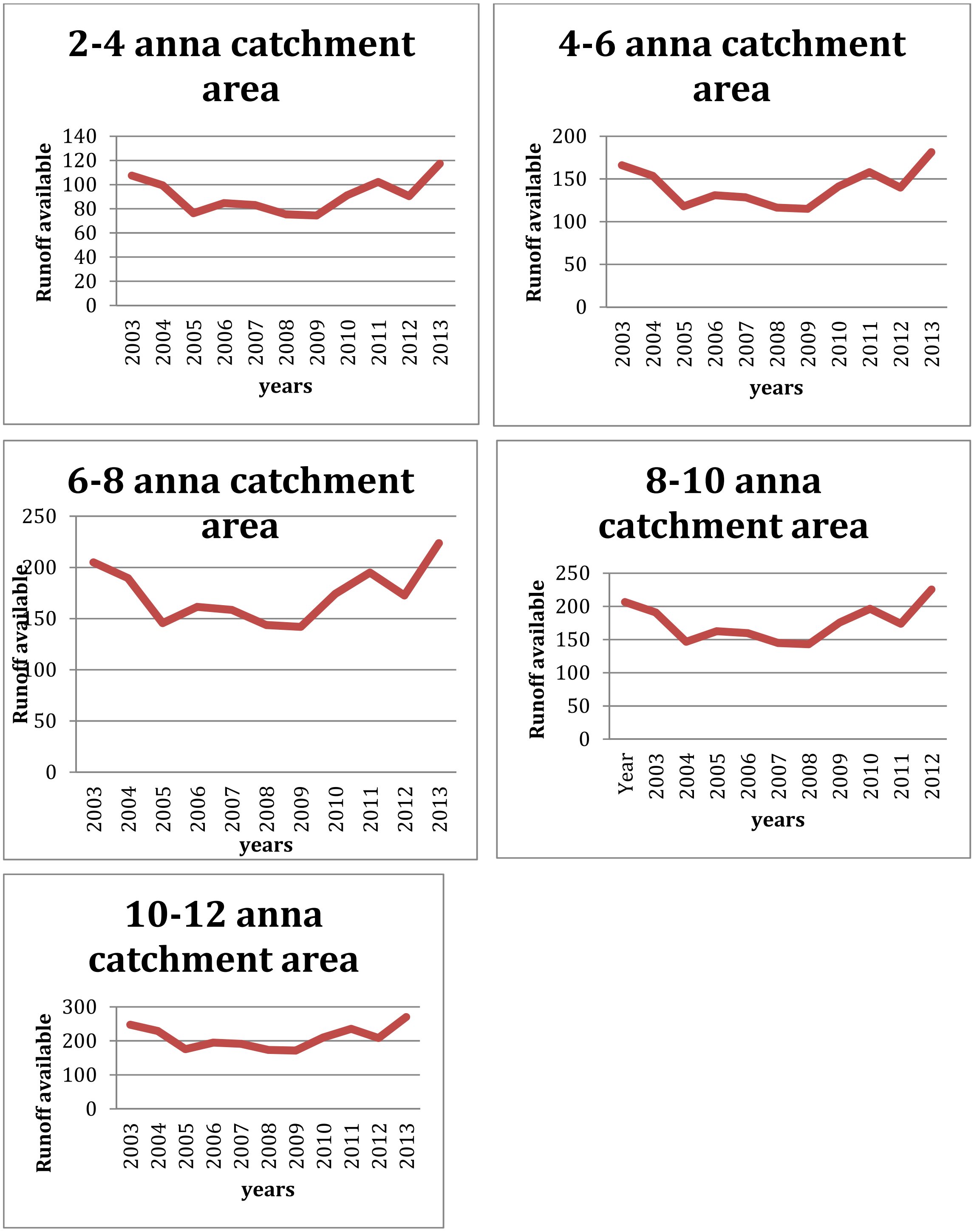
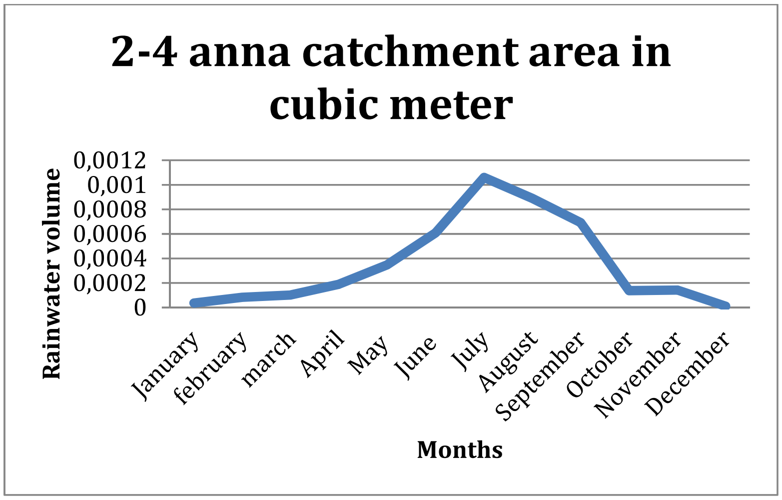
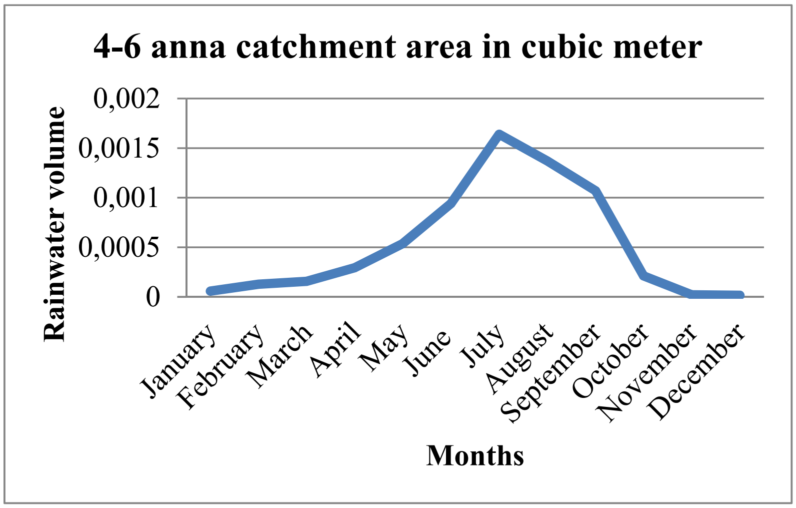
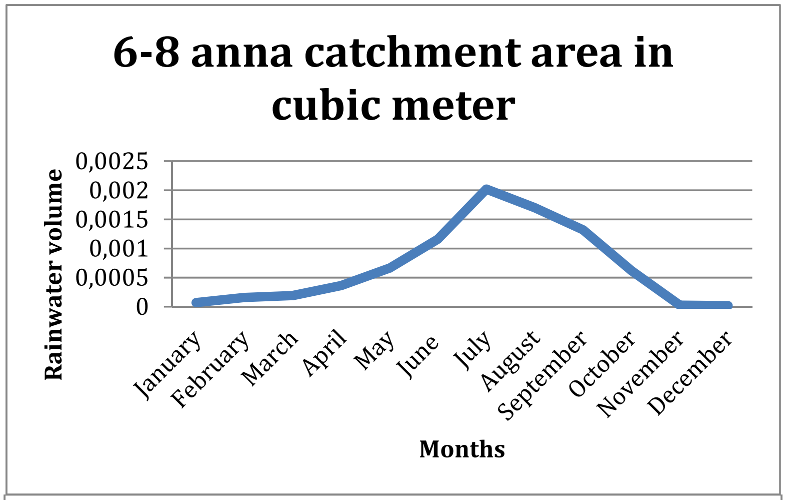


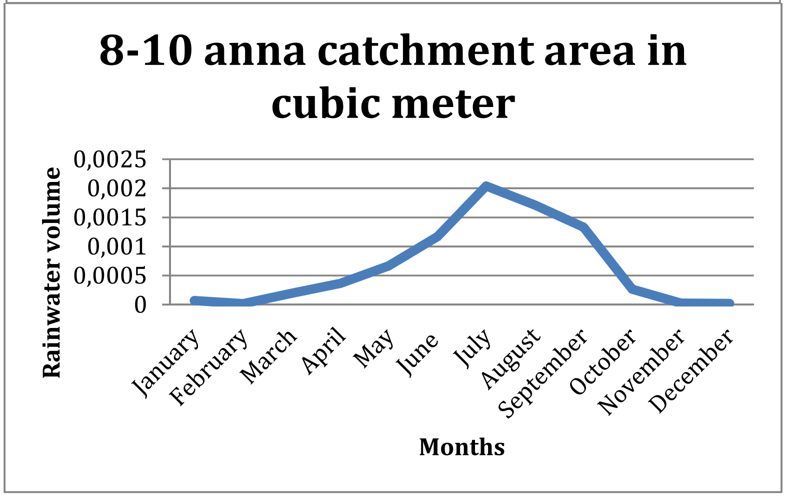
Fig 15: Rainfall available for 2-4 to 10-12 Anna catchment areas from year 2003-2013.

The total amount of available monthly rainwater is calculated in different roof catchment sizes of different households. The calculation of monthly volume of rainwater shows the available rainwater period and it gives the major framework in designing the DRWHS. In a same way it shows how much rainwater can be extracted mainly in the month of June, July and August. It shows the total volume of rainwater that fall on the different catchment areas and shows the potential of rainwater harvesting in rainy season and utilization of stored water in dry season so as to meet the water demand depending on amount of water needed in different households.









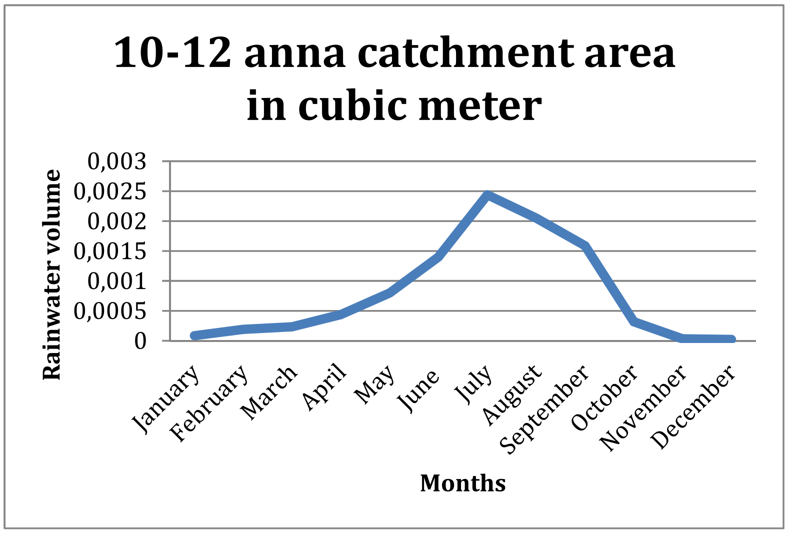


Fig 16: Available monthly volume of rainwater for roof catchment area 2-4 Anna

4.11 Rainfall data

The average annual precipitation data from the year 2003-2013 gives the annual rainfall pattern of the Urban Kathmandu. The calculation of precipitation data gives information about yearly average as well as monthly precipitation. This calculated data gives information gives about the peak rainfall period (wet period) as well as dry period. The calculation of average monthly precipitation gives the range of precipitation of different months. Also, the standard deviation and coefficient of variation are also calculated using the average monthly precipitation data.

Year	**Average annual precipitation (mm)**
2003	1740
2004	1610
2005	1236
2006	1371
2007	1346
2008	1220
2009	1205
2010	1479
2011	1655
2012	1465
2013	1899

Month	**PPT (mm)**	**Standard deviation**	**CV**
January	13	17	1,27
February	29	28	0,96
March	36	19	0,53
April	67	44	0,65
May	123	71	0,58
June	215	61	0,28

July	375	110	0,29
August	315	92	0,29
September	244	81	0,33
October	49	46	0,94
November	5	11	2,17
December	4	7	2

4.12 Calculation of storage tank capacity of different household roof areas

The size of the storage tank required for each land holding size is presented table below. The storage tank capacity of average household size 5 is calculated using mathematical calculation for suitable tank size for storing rainwater. For a daily demand of 50 l per capita per day, which was, obtain in HH survey in for domestic water demand but 20 Lpcd is used as rainwater can fulfill demand in some extent only. The study in Nepal by NEWAH has revealed that maximum storage and size demand for cooking and drinking depends on the water supply capacity. Therefore, increasing storage capacity beyond this size didn't result in any change in demand satisfaction. So, minimum storage capacity appropriate for Kathmandu urban area to satisfy the demand is calculated presented in table below:

Type of catchment area (*Anna)*	Storage tank capacity (L)
2-4	9700
4-6	7096
6-8	6600
8-10	6582
10-12	6078

Fig 17: Storage tank capacity of different types of roof catchment area (Anna)

The graph shows that the larger roof catchment area can supply less amount of water as larger roof area signifies the HH built on large area and total number of people living on large HH is more compare to the lesser ones. Similarly, water consumption is also more in the HH with large number of people.

The total number of HH in different types of land sizes varies in the study area as it depends on the on land availability and land area. So, the HH varies from 2 Anna- 12 Anna depending on size of land where houses are built. The total numbers of HH chosen were 52 and those 52 HH falls on the different category of land size.

Land Size Catchment area (Anna)	Number of HH
2-4	29
4-6	8
6-8	5
8-10	6
10-12	3

Fig 18: Total number of HH in different land size catchment areas

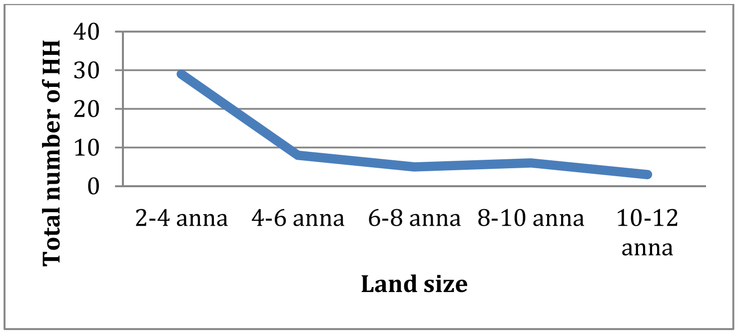


Fig 19: Total number of HH on different land sizes ranging from 2-4 to 10-12 Anna.

The graph signifies the population density related to the land size on which the houses are built. The total number of HH with 2-4 Anna is more and it decreases as the land size increases from 2-4 Anna to 10-12 Anna. That signifies that the population density is higher in small land size area, and the water consumption is higher.

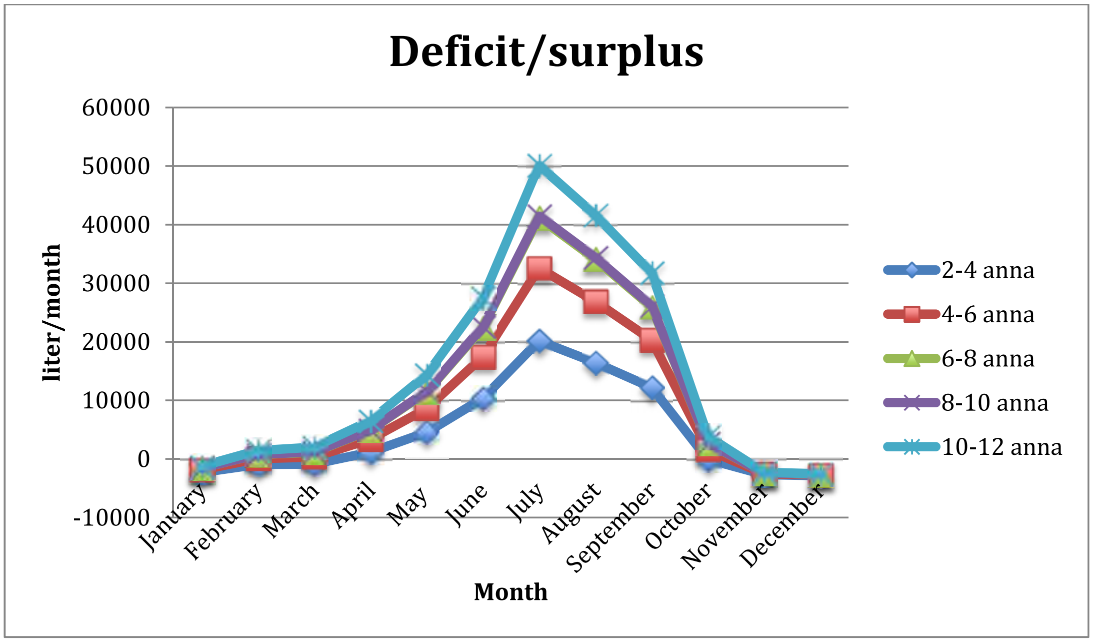


Fig 20: Total deficit/ surplus of water in liters of different months.

This graph shows the deficit/surplus of liter per month of different HHs in different months from January to December in different land sizes from 2-4 Anna to 10-12 Anna. It shows the water needed for HHs of different land size to compensate the deficit and required sizes of storage tanks for different land size catchment areas.

4.13 Cost benefit analysis

The cost benefit analysis approach determines the reliability of projects in terms of investment cost and its benefits. The calculation of cost benefit analysis shows whether the project is reliable enough to invest in or not. The cost benefit analysis gives the proper framework for feasibility of study by determining the amount of investment cost that will be able to surplus the investment cost in terms of benefits and saving without any type of external investment into the project. The cost benefit analysis also helps in understanding the negative and positive aspects of the project. To calculate the cost benefit analysis, the total investment cost used for different material before installing RWHS should be known.

4.14 Payback periods

The payback period is defined as the ratio of total amount to be invested in the total annual saving. In order to find out payback period it can be assumed a PVC pipe of 110mm diameter for conveying water, a 1000l tank and first flush diverter system is used to flush water and a cylindrical filter is used for water treatment. The costs of the items are presented in annexes. The total investment cost is Rs 23563,35. The operational cost is assumed to be 10% of investment cost that is Rs 2356,335. The payback period calculation gives an idea regarding the worthiness of the investment. Usually payback period of less than 5 years is regarded as safe and appropriate to make an investment. The estimated annual saving is calculated based on average expenditure in a HH of Rs 12, 000 per L of water bought from a private water supply company. In other words, the installation of RWHS will save the monthly amount of Rs 12, 000 which otherwise would have been expended in buying water from private water suppliers. Payback period is the duration at which invested amount is achieved in certain interval of time. It can be calculated as:

Payback period = Amount to be Invested/Estimated Annual Savings = 3.92 years.

Then, Payback period with 3 % annual increase is calculated as 3.42 years.

Similarly, payback period with an annual increase of 7% is 2.84 years and 10% is 2.46

Years	Constant rate (Rs)	3% increase (Rs)	7% increase (Rs)	10% increase (Rs)
1	12000	12000	12000	12000
2	12000	12360	12840	13200
3	12000	12730.8	13738.8	14520
4	12000	13112.7	14700.5	15972
5	12000	13506.1	15729.5	17569.2
6	12000	13911.3	16830.6	19326.1
7	12000	14328.6	18008.7	21258.7
8	12000	14758.4	19269,3	23384.6
9	12000	15201.1	20618,2	25723,1
10	12000	15657.1	22061.5	28296
	Rs 120000	Rs 137566	Rs 165797	Rs 191250

Chapter 5: Limitation of study

Subsequently the rainwater harvesting potential in different households of different sizes will be calculated. The water demand varies among the area of roof and it is used secondary data since 10 years, so annual variability of rainfall pattern differs in comparison to the present situation. In the same way it is difficult to predict in project sizing and design part because of changing annual rainfall variability.

Chapter 6: Conclusions and recommendations

6.1 Conclusions

The water supply in urban Kathmandu, ward-6 is less compared to the demand. To mitigate the problem, external sources like tube wells and water tanks are used to fulfill the water demand in some extent. The RWHS can meet 50% of the water demand in HH during monsoon season, thereby reducing extra cost of investment to buy water. Also, RWHS helps to mitigate urban flooding by holding the water. The reliability and efficiency system is considered to be feasible enough if the payback period is less than 5 years. The uses of annual rainfall data and roof catchment area of different land sizes (2-4,4-6,6-8,8-10,10-12 Anna) are used to calculate the annual rainfall available and monthly volume of rainwater. This calculation and statistical analysis shows how much annually and monthly rainwater can be extracted from the roof catchment area. June-August is supposed to have more precipitation and there is a high potential to extract rainwater in those three months that can be used in the dry period to fulfill water demand to some extent in the individual household.

The potential of rainfall available is analyzed. Depending on the different types of roof catchment area, 10-12 Anna roof areas is supposed to have 167,38m^2 and 2-4 Anna roof area is supposed to have 72.66 m^2 that means the potential of collection increases as surface roof area increases. The monthly precipitation of Kathmandu valley is more in June – September with monthly precipitation of 215.10mm, 374.909mm, 314.927mm and 244.390mm. Similarly, the calculated monthly rainfall data shows that the peak amount of rainfall can be collected during monsoon season so as to fulfill current household water demand to some extent. With the design calculation, concerning rainfall data and roof catchment area, the storage tanks of different roof areas are designed to meet the storage capacity of harvested rainwater for future use.

The rainwater harvesting system in urban Kathmandu is a much needed basic facility that can minimize the cost and effort in government level concerning drinking water supply to individual households. The implementation of this project in Kathmandu Valley where a population of almost 5 million people will be a step towards the new technology, as initial cost is estimated to be Rs 23563.35 and payback period is estimated to be 3.92 year.

6.2 Recommendations

- The field investigation measurement of runoff in HH gives more quantitative results.
- The field experiment is more appropriate.
- The concentration of small particulate level is more in atmosphere and thus the rainwater quality is supposed to be affected. So, to mitigate this problem quality of RWHS monitoring is required.

Chapter 7: Annexes

7.1 Calculations

7.1.1 Storage tank capacity:

Roof area = 73 m2 and Runoff coefficient = 0.85 of 2-4 Anna roof catchment area with standard deviation 24.							
Months	Days	Average rainfall (mm)	Demand for drinking and cooking	Cumulative demand	RWH	Cumulative RWH	Deficit surplus of each month(L)
January	31	13	3100	3100	807	807	-2293
February	28	30	2800	5900	1862	2669	-938
March	31	36	3100	9000	2234	4903	-866
April	30	67	3000	12000	4157	9060	1157
May	31	123	3100	15100	7632	16692	4532
June	30	215	3000	18100	13341	30033	10341
July	31	375	3100	21200	23269	53302	20169
August	31	315	3100	24300	19546	72848	16446
September	30	245	3000	27300	15202	88050	12202
October	31	49	3100	30400	3040	91090	-60
November	30	5	3000	33400	310	91400	-2690
December	31	4	3100	36500	248	91645	-2852
							Total 9700

Roof area = 112 m2 and Runoff coefficient = 0.85 of 4-6 Anna roof catchment area with standard deviation 26.

Months	Days	Average rainfall (mm)	Demand for drinking and cooking	Cumulative demand	RWH	Cumulative RWH	Deficit surplus of each month(L)
January	31	13	3100	3100	1238	1238	-1862
February	28	30	2800	5900	2856	4094	56
March	31	36	3100	9000	3427	7521	327
April	30	67	3000	12000	6378	13899	3378
May	31	123	3100	15100	11710	25609	8610
June	30	215	3000	18100	20468	46077	17468
July	31	375	3100	21200	35700	81777	32600
August	31	315	3100	24300	29988	111765	26888
September	30	245	3000	27300	23324	135089	20324
October	31	49	3100	30400	4665	139754	1565
November	30	5	3000	33400	476	140230	-2524
December	31	4	3100	36500	381	140611	-2710
							Total 7096

Roof area = 139 m2 and Runoff coefficient = 0.85 of 6-8 Anna roof catchment area with standard deviation 61.

Months	Days	Average rainfall (mm)	Demand for drinking and cooking	Cumulative demand	RWH	Cumulative RWH	Deficit surplus of each month(L)
January	31	13	3100	3100	1536	1536	-1564
February	28	30	2800	5900	3545	5081	745
March	31	36	3100	9000	4253	9334	1153
April	30	67	3000	12000	7916	17250	4916
May	31	123	3100	15100	14532	31782	11432
June	30	215	3000	18100	25402	57184	22402
July	31	375	3100	21200	44306	101490	41206
August	31	315	3100	24300	37217	138707	34117
September	30	245	3000	27300	28946	167653	25946
October	31	49	3100	30400	5789	173442	2689
November	30	5	3000	33400	591	174033	-2409
December	31	4	3100	36500	473	174506	-2627
							Total 6600

Roof area = 140 m2 and Runoff coefficient = 0.85 of 8-10 Anna roof catchment area with standard deviation 51.

Months	Days	Average rainfall (mm)	Demand for drinking and cooking	Cumulative demand	RWH	Cumulative RWH	Deficit surplus of each month(L)
January	31	13	3100	3100	1547	1547	-1553
February	28	30	2800	5900	3570	5117	770
March	31	36	3100	9000	4284	9401	1184
April	30	67	3000	12000	7973	17374	4973
May	31	123	3100	15100	14637	32011	11537
June	30	215	3000	18100	25585	57596	22585
July	31	375	3100	21200	44625	102221	41525
August	31	315	3100	24300	37485	139706	34385
September	30	245	3000	27300	29155	168861	26155
October	31	49	3100	30400	5832	174692	2731
November	30	5	3000	33400	595	175287	-2405
December	31	4	3100	36500	476	175763	-2624
							Total 6582

Roof area = 167 m2 and Runoff coefficient = 0.85 of 10-12 Anna roof catchment area with standard deviation 108.

Months	Days	Average rainfall (mm)	Demand for drinking and cooking	Cumulative demand	RWH	Cumulative RWH	Deficit surplus of each month(L)
January	31	13	3100	3100	1845	1845	-1255
February	28	30	2800	5900	4259	6104	1459
March	31	36	3100	9000	5110	11214	2010
April	30	67	3000	12000	9511	20725	6511
May	31	123	3100	15100	17460	38185	14360
June	30	215	3000	18100	30519	68704	27519
July	31	375	3100	21200	53231	121935	50131
August	31	315	3100	24300	44714	166649	41614
September	30	245	3000	27300	34778	201427	31778
October	31	49	3100	30400	6956	208383	3856
November	30	5	3000	33400	710	209093	-2290
December	31	4	3100	36500	567	209660	-2533
							Total 6078

7.1.2 Cost benefit analysis

To calculate the cost benefit analysis, the total investment cost used for different materials before installing rainwater harvesting should be known:

Cost of PVC pipe of 110 mm diameter for 10 meter = Rs 1650
Cost of 2 different 1000 L tanks = 2*5799= Rs 11598
Cost of gutter for collection rainwater = Rs 600
Cost of Tap for extracting water from storage = Rs 500
Cylinder filter = Rs 1050 Apollo water filter
First flush diverter = Rs 3165,35
Contract to authorized people on a daily basis (2 days) = Rs 5000
Total investment cost = Rs 23563,35

7.1.3 Payback period

Payback period is the duration at which the invested amount is achieved in a certain interval of time. It can be calculated as:

Payback period = Amount to be Invested/Estimated Annual Savings
= 23563,35/6000
= 3.92 years

A 1000 L Reno tuff water tank costs Rs 5799. Assume that a household of 5 members in a family has a water bill of Rs 1000 a month, that means a family member pays Rs 12000 in a year, and in 10 years Rs 120000. Assuming that increase in water rates at 3%, 7% and 10%, then the total utility water cost will be Rs 137566, Rs 165797 and Rs 191250 respectively.

Assuming that the household uses 50% of total water from the rainwater, then 1000 L 2 different storage tank will compensate today's prices in 3,92 years.

Similarly, if there is an increase in annual price at 3%, then the payback period is shorter and calculated as:

50% of 137566.1 /10 = 6878.30
Then, Payback period with 3 % annual increase is calculated as:
=23563.35/6878.30
= 3.42 years

Similarly, payback period with annual increase of 7% is 2.84 years and 10% is 2.46

7.2 Questionnaires

- What type of Water sources used to fulfill the water demand?
- What is the frequency of available water?
- Concept about RWHS or not?
- What type of sanitation practices has been implemented?
- Willingness to pay to install RWHS.
- Concept of roof catchment design.

7.3 Tables and Figures

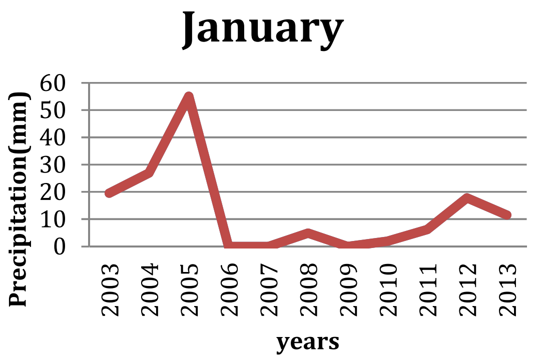
Monthly average precipitation of different months from 2003-2013

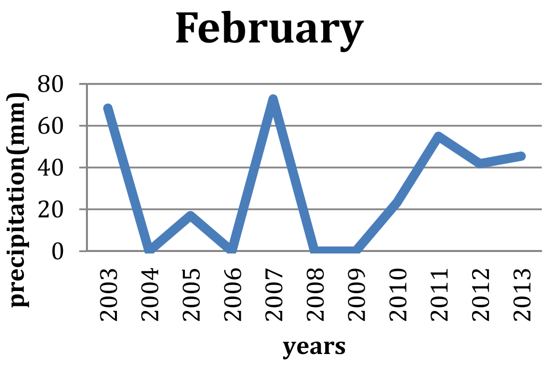
January	February	March	April	May	June	July	August	September	October	Nov	December
19,5	68,4	85,9	38	37,7	222,3	591,5	347	293,4	17,7	0	18.6
26,9	0	32,3	164,1	168,8	183	459,5	219,4	199,1	120,5	36	0
55,1	17	50,1	34,8	40,6	222,9	253,5	309,3	126,5	126,1	0	0
0	0	30,9	132,8	145,5	216,2	337	248,4	217,5	23,9	1,5	17.5
0	72,8	36,3	77,9	90,7	263	227,3	223,7	332,5	18,5	3,2	0
4,9	0	35,9	43,7	99,9	237,7	255,4	240,8	291,3	10,3	0	0
0	0	28,4	21,3	132	125	326,3	382,9	113,4	71,4	1	3.6
1,9	23,3	35,7	45,3	148	141,7	354,9	486,3	217,1	24,5	0	0
6,2	54,9	16,4	56,8	167,4	306	437,8	265,4	318	13	12,9	0
17,8	41,8	15,6	80,1	42,2	149,2	452,3	289,6	362,2	3,2	0,7	0
11,5	45,4	27,3	44,5	278,6	299,1	428,5	451,4	217,3	95,7	0	0

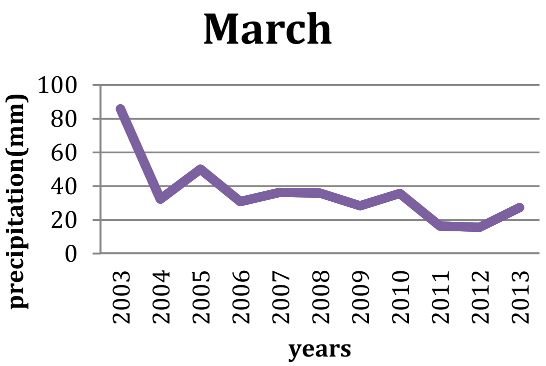
Household roof area and land area of different HH

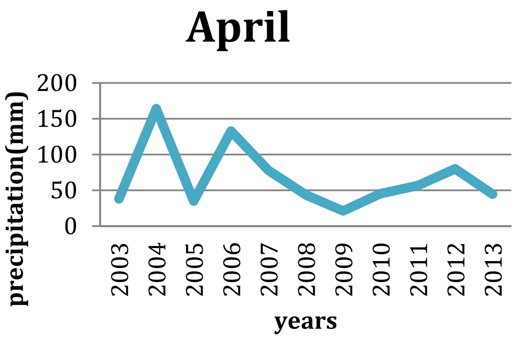
Household Roof area (sq. ft.)	Household Roof area (m2)	Land area	Land area (sq. ft.)	Land area (m2)
1198.47	111.34	0-8-1-3	2887.76	268.28
698.94	64.93	0-3-0	1026.75	95.38
880.1	81.76	0-4-0	1369.00	127.18
882.0	81.94	0-4-0	1369.00	127.18
422.0	39.20	0-1-2-2	556.17	51.66
1093.0	101.54	0-6-3-2	2352.98	218.59
547.50	50.82	0-2-0-0	684.5	63.59
1211.75	112.57	0-7-0	2395.75	222.57
553.5	51.42	0-2-1-0	770.06	71.54
1668.85	155.04	0-6-2-0	2224.62	206.67
2288.95	212.65	0-10-2-3	3657.82	339.82
1582.00	146.97	0-5-2-0	1882.37	174.87
666.63	61.93	0-3-2-0	1197.87	111.28
898.83	83.50	0-4-0-3	1433.20	133.14
728.52	67.68	0-3-0-0	1026.75	95.38
2130.36	197.92	0-10-0-0	3422.5	317.96
572.97	53.23	0-2-0-0	684.5	63.59
748.6	69.55	0-4-2-0	1540.12	143.08
2634.31	244.74	0-8-1-0	2823.56	262.31
3110.65	288.99	0-11-0-3	3828.95	355.72
938.25	87.17	0-4-0-0	1369.00	127.18
612.23	56.88	0-2-2-2	898.42	83.46
749.8	69.66	0-4-0-0	1369.00	127.18
1328.18	123.39	0-4-2-2	1582.92	147.05
653.67	60.73	0-2-2-1	877.02	81.47
912.00	84.73	0-11-2-0	3935.87	365.65
1051.79	97.71	0-6-0-0	2053.5	190.77
1482.49	137.73	0-4-3-1	1647.08	153.01
754.92	70.14	0-4-0-2	1411.8	131.16
517.54	48.08	0-2-1-0	770.06	71.54

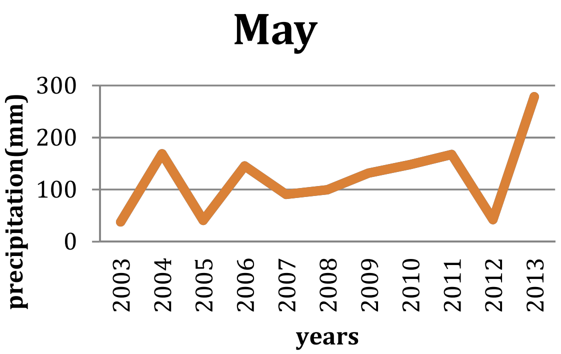
1412.07	131.19	0-7-0-0	2395.75	222.57
372.96	34.65	0-4-2-1	1561.52	145.07
990.6	92.03	0-4-2-2	1582.92	147.05
976.32	90.70	0-4-2-0	1540.12	143.08
640.8	59.53	0-2-0-2	727.3	67.56
902.94	83.89	0-6-02.5	2107.00	195.74
1024.75	95.20	0-10-0-0	3422.5	317.96
915.01	85.00	0-4-1-0	1454.56	135.13
968.44	89.97	0-5-1-0	1796.81	166.92
1001.88	93.08	0-8-3-2	3037.48	282.19
402.5	37.39	0-1-3-2	641.73	59.61
926.1	86.03	0-4-2-0	1540.12	143.08
1107.2	102.86	0-5-3-1	1989.33	184.81
981.76	91.20	0-3-2-1	1219.27	113.27
1382.29	128.42	0-11-0-2	3807.55	353.73
1173.2	108.99	0-9-0-0	3080.25	286.16
1041.35	96.74	0-4-2-0	1540.12	143.08
798.00	74.14	0-4-0-0	1369.00	127.18
1200.00	111.48	0-9-0-0	3080.25	286.16
1200.00	111.48	0-9-0-9	3272.85	304.05
1297.5	120.54	0-5-0-1	1732.65	160.96

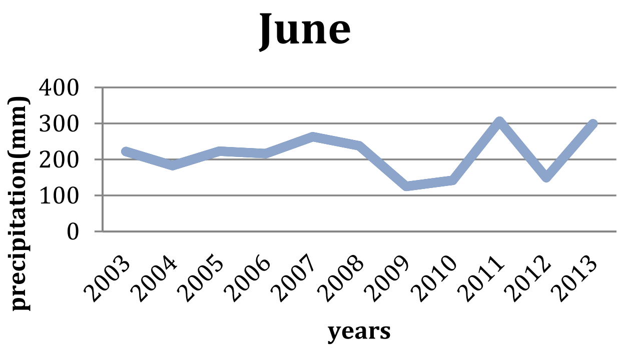

January
Precipitation(mm)
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years

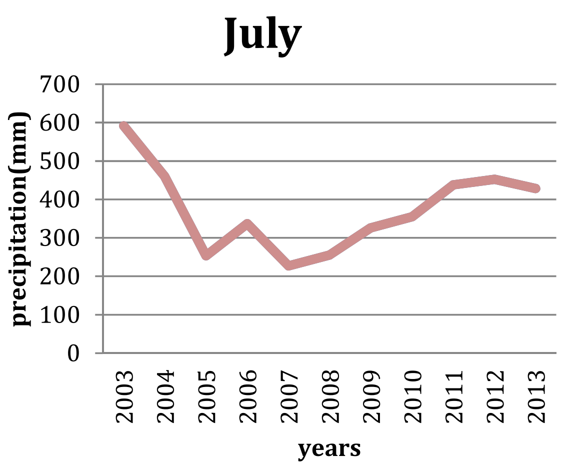

February
precipitation(mm)
80
60
40
20
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years

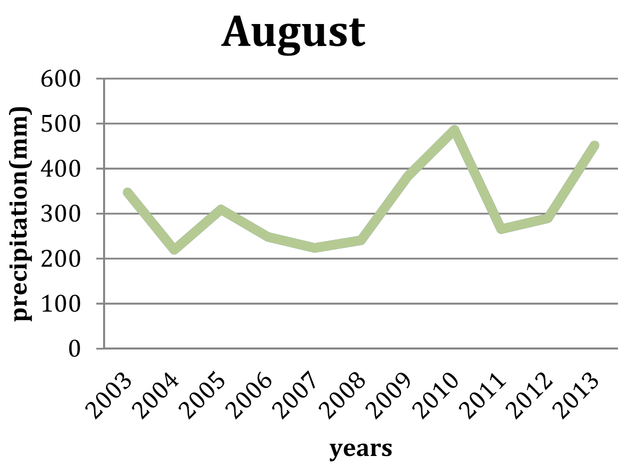

March
precipitation(mm)
100
80
60
40
20
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years

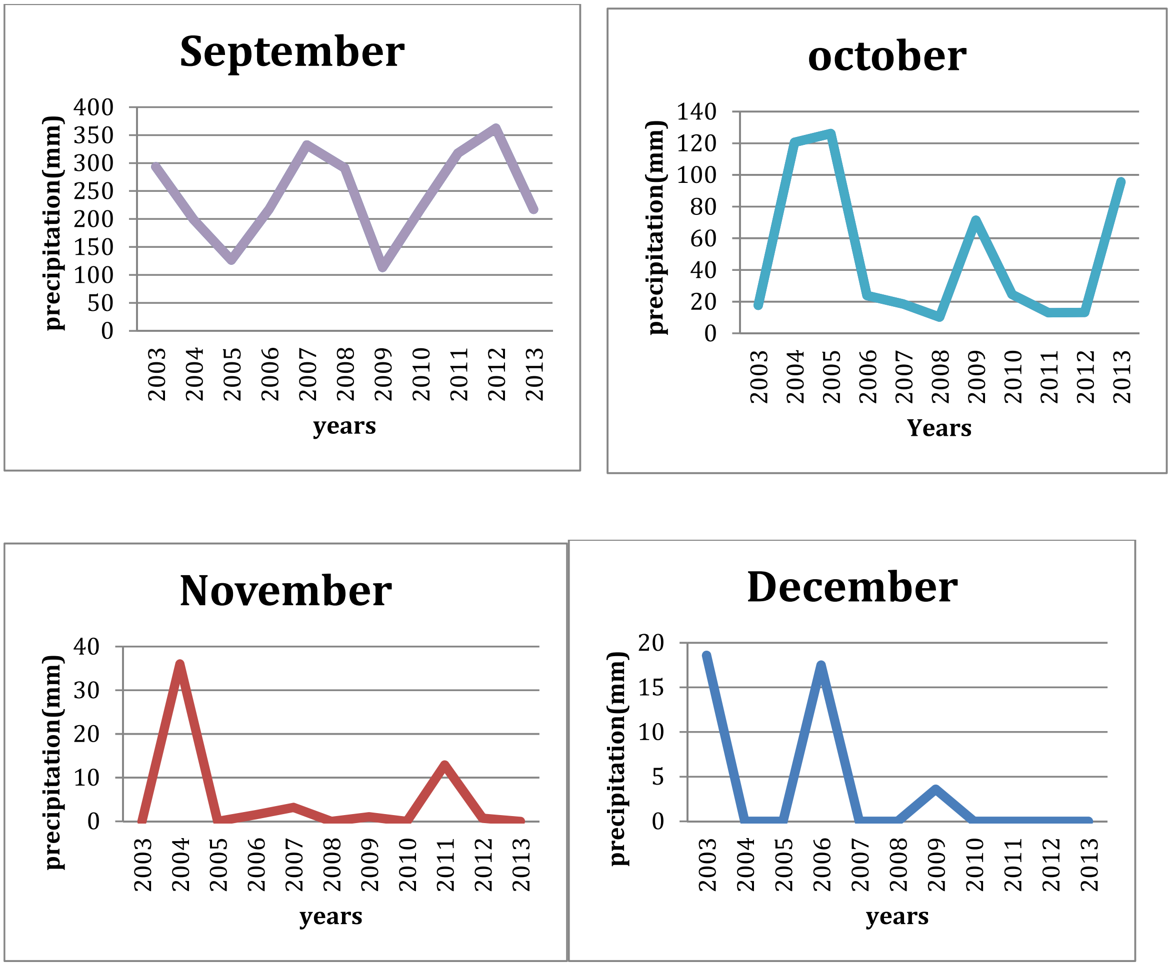

April
precipitation(mm)
200
150
100
50
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years


May
precipitation(mm)
300
200
100
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years


June
precipitation(mm)
400
300
200
100
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years


July
precipitation(mm)
700
600
500
400
300
200
100
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years


August
precipitation(mm)
600
500
400
300
200
100
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
years



Annual rainfall precipitation of different years from 2003-2013

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