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An Investigation on Potential of Decentralized Rainwater Harvesting for Improving Sustainability of an Urban Residential Area - A case of Samakhusi, Kathmandu

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Abstract

This study aims to identify the potential of rainwater harvesting on a neighborhood scale by doing qualitative and quantitative analysis. Small neighborhood of Samakhusi, Kathmandu was selected as a good representative of compact urban residential area. Samakhusi lies in northern belt of Kathmandu valley where there is high infiltration rate for ground water recharging but also has water logged streets during rainy days and water scarcity during dry seasons. Based on a statistical analysis of the rainfall, the amount of rainwater that might be captured from roofs and ground surfaces was calculated. Potable water consumption of households of urban residential was determined based on the standard data from literature. In this study, potential of rainwater in compact urban area for regenerating water sensitive urban development was evaluated. In addition, a possibility of minimizing wastewater from rainwater harvesting was evaluated. The study also examined case studies with success stories, which reflects improved urban scenario through rainwater harvesting. Moreover, social perspective from community, government institutions and technology providers on rainwater harvesting was also analyzed. Based on the qualitative and quantitative data, direct and indirect benefits were explored that helps to improve water sustainability and water sensitive planning of an urban residential area.

Keywords

Urban Residential Area, Rainwater Harvesting, Groundwater Recharge, Water Sustainability, Water Sensitive Urban Development.

1. Introduction

The sustainability of water resources and energy is one of the two major factors that challenge the world in the 21st century.The only piped water supplier in Kathmandu, Uptyaka Khanepaani Limited (KUKL) mentioned that the daily demand for water is 360 millions of liter per day (MLD), while the supply is only 150 MLD in the season of rains, and it is reduced to 60 MLD per day in the dry season. Therefore, households are only expected to supply tap water once every five days.

Beside, government piped network, the water supply system in Kathmandu consists of three different parts: a traditional water system consisting of stone spouts, dug wells, tanks and ponds; household and industrial private water extraction; and different types and sizes water vendors. It is said that the most traditional supplies, such as public water tanks, have stopped working. With this in mind, households and businesses have responded to the shortage by investing in local personal water supplies and internal storage, installing private wells to self-extract groundwater, and relying on water from vendors for their water supply [1].

According to the Kathmandu Valley Water Supply Management Board, approximately 35-50 % of the population in the valley depends on underground water. There is no longer water supply from the bore wells, hand pumps and ancient stone taps as before which is the direct consequence of depleting shallow groundwater aquifers. Moreover, groundwater quality is also an issue: Chemical contaminants such as arsenic, ammonia, and nitrate have been found in deep aquifers in many areas of the valley [2]. According to an investigation by the Groundwater Resources Development Committee, the groundwater level in the valley has been gradually decreasing. In the past, there was water 8 to 10 meters underground in the valley, but now it is difficult to find water when digging 40 to 50 meters.Experts say that almost 83% of the land in Kathmandu is sealed by cement and concrete to prevent water from entering the surface which has directly affected the ground water level in the valley. According to a study conducted by Japan International Cooperation Agency (JICA) in 1990, if almost 150 million liters of are extracted from the valley, this will cause the water level to drop and cause a greater natural imbalance [2].

Although these cities have a lot of rain, urban center faces an ironic situation nowadays. On the one hand, there is a serious water shortage and on the other hand, the streets are often water logged during the rainy season.Along with the excess groundwater extraction, haphazard building constructions, roads and paved surfaces and the subsequent sealing of the natural recharge areas have led to the depletion of the groundwater table, thus creating acute water shortage during dry periods. Groundwater recharge is done mainly to store surface runoff during the monsoon. This water is then extracted through community wells, dug wells, boring and through stone sprouts and spring outlets. Thus groundwater recharge helps in maintaining groundwater table and revives community wells, stone sprouts and spring source.

Whereas, rainwater is a relatively clean and free source of water. Harvesting rainwater can save high-quality drinking water sources by reducing flooding, soil erosion and replenishing groundwater levels, and reducing pressure on sewers and the environment [3].

2. Methodology

In this research, the potential of decentralized ground water recharge through rain water harvesting of the urban residential buildings was reviewed using research paradigm like post positivism and constructivism which focuses both on objective and subjective reality. The research strategy used was correlation and phenomenology. And the research approach was inductive research approach as it starts with the observations and theories that are proposed towards the end of the research process as a result of observations and analysis.

To achieve the main objectives of the research, both qualitative and quantitative methods and a combination of primary and secondary sources have been used in this research. The qualitative data supports the quantitative data analysis and results. The study includes a site survey of residential buildings of small neighborhood of Samakhusi, Kathmandu which lies on ward number 26 of Kathmandu Metropolitan City. The study also measures the public perception from individual and organizational level on the concept of rainwater harvesting. The survey was based on direct observations and using questionnaires/ in-depth interviews. The result obtained was triangulated since the qualitative and quantitative data types are used in the data analysis.

3. Literature Review

3.1 Relation between Population and Water Problem of Kathmandu

It is said that the Kathmandu valley has suffered from drinking water shortages since the 1980s and the situation is getting worse.

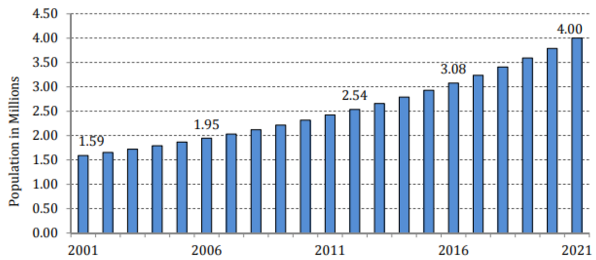

Figure 1: Annual population growths in Kathmandu Valley - Source:[4]

Figure 1 shows the annual population growth in Kathmandu valley which is gradually increasing. And Figure 2 graphically shows the water supply capacity of KUKL, estimated demand, estimated deficit without MWSP and estimated deficit if MWSP first phase could be completed. This clearly depicts the gap in water demand and supply in Kathmandu.

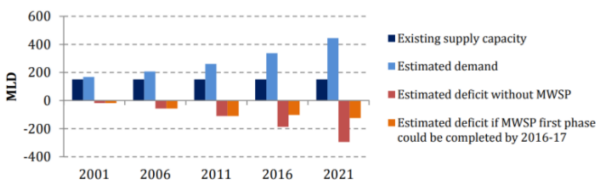

Figure 2: Water Supply, Demand and Deficit of KUKL Service Area - Source:[4]

3.2 Weather Patterns and Local Rainfall Data of Kathmandu

Due to geographical and topographical characteristics, Nepal's weather can be divided into four seasons: spring from March to May, summer from June to August, autumn from September to November, and winter from December to February. Summer is the monsoon season from June to September, and almost all-annual rainfall falls during this period. Whereas, the remaining October to June of the year is often referred to as the dry season [5]. Annual rainfall in Kathmandu is approximately 1600 mm (equivalent to 160,000 liters per hectare of land) [6]. Many people are not aware, of which the Kathmandu valley receives an average of 1600 mm rain every year. This is within the distance of what should bring the Melamchi water supply project (170 MLD a day).

3.3 Soil Condition of Kathmandu Valley

The groundwater system of the valley, it is supposed to have closed and isolated groundwater basin having irregular and discontinuous aquifers. Where the north and northeastern parts of Kathmandu valley have great potential for deep aquifers [2].

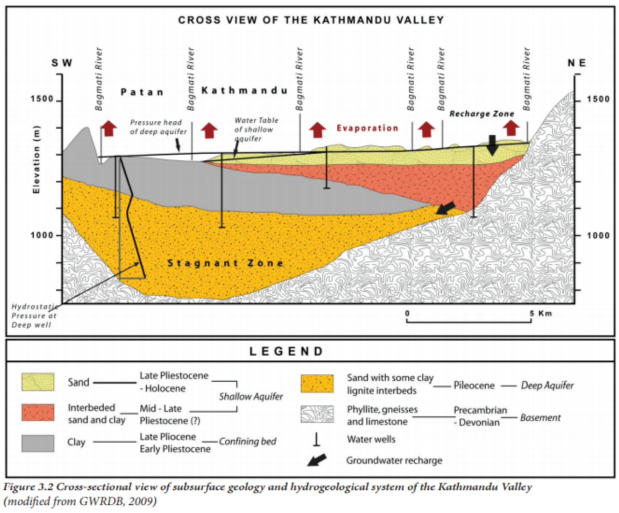

Figure 3: Cross sectional view of Kathmandu Valley

3.4 Water and Sustainable Development

Water is at the core of sustainable development and is very essential to social and economic development and healthy ecosystems. Water is also a finite and irreplaceable resource that is essential to human well being. Only when properly managed can it regenerate. It is essential to reduce the global burden of disease and improve the health, well-being and productivity of the population. Water is also at the heart of adaptation to climate change and an important link between the climate system, human society and the environment. Today, more than 1.7 billion people live in river basins that have been depleted through use and exceed natural reconstruction. By 2025, two thirds of the world's population will live in countries with water scarcity. This trend is becoming a serious challenge for sustainable development. But it can be managed effectively. To be fair, in the face of rapid and unpredictable changes, water can play a vital role in strengthening the resilience of social, economic and ecological systems.

3.5 Water Sustainability

Water sustainability simply means managing of water resources in effective and holistic way. Today's demand for water resources is diverse and requires sustainable, integrated and comprehensive water resources management.

Figure 4: Three elements of a sustainable water future

3.6 Hydrological Cycle

As shown by the water cycle, all water will eventually be recycled in the ecosystem. The water cycle refers to the continuous transportation of water in the environment, evaporating from the surface of biota, land and water bodies connected to clouds, moving through the climate system, and then precipitation in the form of rain or snow. Humans have learned to intervene in this cycle by developing water storage tanks and network systems to promote water use, subsequent treatment for reuse and/or return to the environment. The hydrological cycle's components are illustrated in Figure 5.

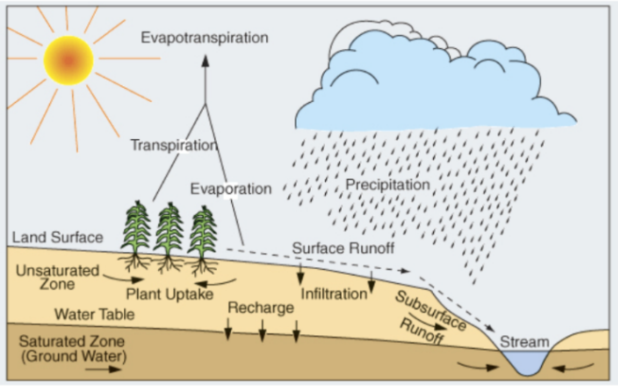

Figure 5: Hydrological cycle

In natural environments, rainwater generally evaporates, is absorbed by plants, or seeps into the ground. Urban development is changing these processes drastically by clearing the land of vegetation and covering it with impermeable surfaces that do not allow the passage of water which leads to ecological imbalance [7].

3.7 Rainwater Harvesting (RWH)

Rain is the first known form of water in the water cycle and is therefore our main source of water i.e. primary source. There are two main methods can be defined for RWH. It either collects onshore runoff in any type of storage tanks or reservoirs or directly penetrates into the ground to supplement the groundwater level, or it collects rainwater directly from the roof.

3.7.1 Rainwater Harvesting for Immediate/ Household Use

During a rainy period, rainwater falls either on the ground surface or on rooftops surface and it is directed to storage tanks to irrigate fields, bath or wash clothes. And, for even drinking if various precautions are taken [5].

3.7.2 Rainwater Harvesting for Groundwater Recharging

Simply, groundwater recharging is the diversion of the surface rainwater runoff into underground soil surface after the filtration. The groundwater can be recharged artificially when surface runoff is allowed to move into the ground through the simple techniques like construction of recharge wells with filter chambers. This may need some improvements in the surface drainage system including surface levelling. There are currently several methods available for assisting groundwater recharge. These measures include recharge structures and permeable walkways that allow rainwater to penetrate deeper into the soil [2]. Different recharge structures are like recharge pits, recharge wells, boring recharge, etc.

3.8 Water Sensitive Urban Design (WUSD)

Water sensitive urban design (WSUD) is an important component of water cycle management which is an integrated approach for urban planning and design. Water-sensitive urban design is an integral part of nature-based solutions that use the natural environment to respond to various ecological, economic, social and climatic challenges.

WSUD can be implemented on any scale, from unique projects in individual lots to interconnected projects at regional level.

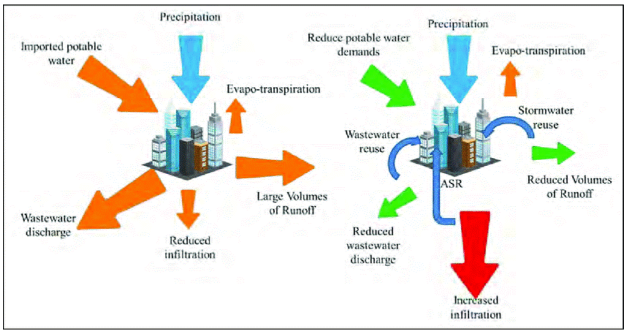

Figure 6: Before and after water sensitive urban design

In Figure 6, urban water balance is shown in left side and water sensitive water balance is shown in right side. Comparing the both figures water sensitive urban design has benefits of reduction in potable water demands, reduction in wastewater discharge and reduction in volumes of runoff along with increased infiltration.

Figure 7 shows the decrease in infiltration with the increase in impervious surface. Here, more are the hard surfaces, less is the infiltration of water into the ground which is also the major issue of the urban developments. For e.g. Urban area having 70 to 100% impervious surfaces has only total infiltration of around 15%.

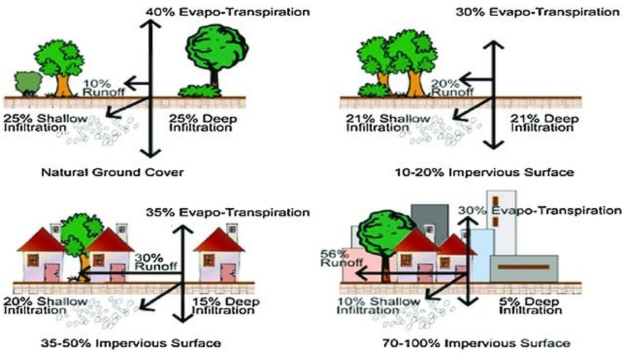

Figure 7: Evapo-transpiration, runoff and infiltration of different surfaces in percentage - Source:[8]

3.9 Benefits of Rainwater Harvesting in an Urban Context

• Reducing in the water consumption rate and as a result reducing the water bill.

• Protecting the soil from the accumulation of salts if the collected water is used for irrigation purposes.

• Rainwater harvesting reduces flood and surface runoff especially in urban areas and reduces soil erosion and water contamination.

• Reducing the over-pumping from groundwater aquifers and the preserving natural resources

• Decreasing the amount of water flowing into the sewer network and thus prolonging the lifespan of networks and avoiding possible flooding.

3.10 Case Studies

3.10.1 Panchsheel Park Colony, Delhi, India

The project was implemented in June 2002 where the cost of the entire rainwater harvesting system was Rs 8 lakh. Here, average annual rainfall in Delhi was taken as 611 millimetres (mm). It has total rooftop and surface area: 3,57,150 sq.m. where total volume of rainwater harvested is 1,74,575 cubic metre (m3), or 174,575,000 litres (2002). This represents 80 percent of the total potential of the water harvest. For the rainwater collection, a storm water drainage network is used throughout the residential area for the rainwater collection and the outflow of the surface. About 36 recharge wells of 1m x 1m x 2 m are built in the drainage of the storm water to facilitate the top-up of groundwater. The quality of the runoff passing through 15 m borehole is passed through the filter bed of pebbles. Before implementing rainwater harvesting, the water level was around 28.6 m below ground level. The water level in July 2003 after the monsoon was 27.3 m, representing a total rise of 0.7 m, or 2.29 feet. According to the source, the area depends largely on tube wells.

3.10.2 Eco-home, Dallu, Kathmandu

Dr Roshan Raj Shrestha has eco-friendly features in his new home of area 135 sq. m. (1453.127 sq. ft. or 0R-4A-0P-3.93D) that was built in November 2002. The three-year average rainfall (2005-2007) was 2576 mm where almost 90% of the rainfall fell in just 6 months (April-September) [9].Having 90.4 m2 of roof area, it has more than 180 m3/year of rainwater harvesting potential.

The house depends on rain for nearly nine to ten months for which rainwater is stored in an 8,000 litres underground storage tank, and excess water is replenished in wells dug of capacity nearly 10,000 litres to provide water for the remaining months. The water of dug well also promotes groundwater recharging.

It is said that recharging the groundwater has also improved water quality in the dug well especially in the reduction of nitrate level [9].

4. Analysis and Findings

4.1 Existing Scenario

4.1.1 Case Area

The case area selected for the thesis is small neighborhood of Samakhusi which lies in Ward number 26 of Kathmandu Metropolitan City. Samakhushi is one of the urban cities of Nepal. Samakhushi is one of the cities within Kathmandu which looks like a quiet area. Samahkusi borders Ranibari to the east, Gangabu to the north, Balaju to the west, and Golkopakha to the south. It is good representative of compact urban area. It lies in highest belt -northern belt of Kathmandu Valley and has sandy soil, which is best portion for the ground water recharge.

There are 27 plots in the selected neighbourhood area where 2 plots are vacant with the total number of 25 households. Total area of the case area is 3772.63sq.m. The chart shown in Figure 8 also clearly depicts the land distribution of the case area.

This shows that the sample urban neighborhood has almost 76% of the hard surface and 24% soft surface.

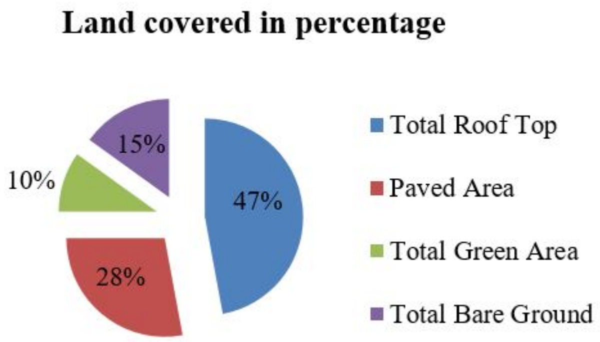

Figure 8: Land Coverage of the case area (in percentage)

From the site study, it was known that almost 1/4th houses do not have municipal pipeline. To fulfil the water demand, people rely on many water sources like tankers, jars and deep well as per the site study. However, according to the observation, people are more dependent on deep wells as 96% of the residences have installed bore wells for their water security. Even in past 5 to 8 years, people have increased the bore well depth to 75' to 100' from around 35'. This clearly shows that ground water level is in decreasing state of the case area.

4.1.2 Rainfall Pattern

Rainfall data was taken from Department of Hydrology and Meteorology (DHM) of last 10 year frequency. As Panipokhari station is closer to the case area, the rainfall data was used of the Panipokhari Station of Kathmandu Valley, which is calculated as 1558mm per year in average based on data given by DHM. As per the calculation, the average rainfall with peak intensity fall on the month of June, July, August and September which is also illustrated in Figure 9.

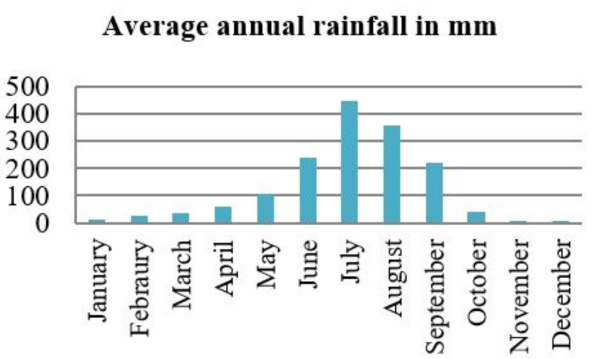

Figure 9: Average monthly rainfall of last 10 year frequency

4.2 Water Demand met by RWH

The total volume of rainwater collection when only rainwater from the roof top considered deducting first flush of 5%, is 107710.149 litres per year. There is no excess rainwater remaining to ground recharge. It is because the rainwater from the rooftop hardly fulfils the water demand of the residents for whole year.

If rainwater is used for household purpose assuming 150 litre per capita per day (lpcd), then in average, water demand met by RWH would be only from one to six months depending upon the household size and the catchment area.

Or if rainwater is used for household purpose assuming 150 lpcd, then in average, water demand met by RWH would be only from 7 % to 51% depending upon the household size and the catchment area.

4.3 Potential Groundwater Recharging

Total volume of rainwater is calculated by multiplying the total catchment area, runoff coefficient and the average rainfall data, which is 3347.20 cubic meter per year.

4.3.1 Mapping Feasible Locations for Recharge pits

The recharge pits were designed as per the technical details given by the source – Center for Integrated Urban Development (CIUD). According to the source recharge pit comes with the filter chamber. The diameter of recharge pits are from 42" to 48" and about 20' deep. Whereas, filter chamber is around 42" diameter and 5'deep. So, as per the total catchment area and space availability, 31 number of recharge pits were estimated.

If only rainwater from roof top is considered for groundwater recharging then the total volume of rainwater collection from the rooftop is 2146.224 cubic meter per year, which is 64 % of the total potential rainwater collection.

If only rainwater from ground surface is considered for groundwater recharging then the total volume of rainwater collection from the ground surface is 1200.975 cubic meter per year, which is 36% of the total potential rainwater collection.

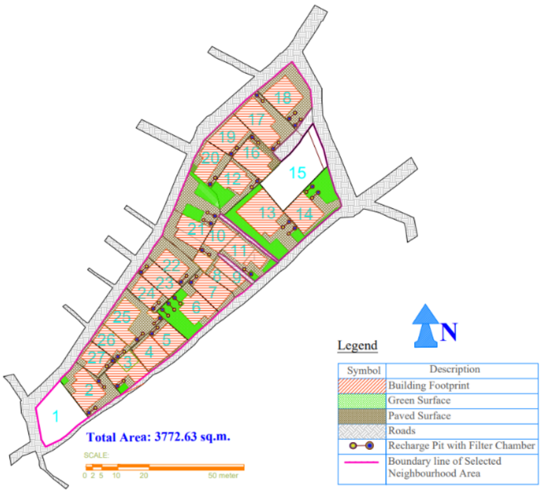

Figure 10: Selected neighborhood with recharge pits in existing scenario

4.3.2 Change in Infiltration if Rainwater is Ground Recharged

If all rainwater from roof top and ground surface is ground recharged, then the increase in infiltration in such urban neighborhood would be around 42% and so on as shown in Table 1.

Table 1: Increase in infiltration (in percentage) for different cases by groundwater recharging.

Infiltration in 70 to 100 % of impervious surface (from literature)	Increase in infiltration if all rainwater is recharged i.e. from Roof Top & Ground Surface (calculated)	Increase in infiltration if only Ground Surface rainwater is recharged (calculated)	Increase in infiltration if only Roof Top rainwater is recharged (calculated)
15 %	41.942 %	4.881 %	18.923 %

4.4 Potential Wastewater Reduction

From the data given by DIP (Project Implementation Directorate) as mentioned in Appendix of Sewer Network Master Plan Report 2017, annual amount of domestic sewage in drain per square meter is calculated as 802.656 litres and annual amount of peak Dry Weather Flow (DWF) of wastewater in drain per square meter is calculated as 2167.263 litres. Where, annual amount of rainwater in case area is 3368552litres. So, there is huge percentage of rainwater comparing to waste water generation that is 13.26% rainwater is more than domestic sewage and about 42.70% of peak DWF is equal to potential rainwater in drain. If the rainwater harvesting is done in such urban areas then this would eventually reduce the sewer and wastewater treatment plant overloads and help in urban sustainability. This will also directly help in solving water-clogged streets in rainy days as well.

4.5 Social Perspective towards Rainwater Harvesting

80% of the total population responded as they have the idea of rainwater harvesting and 20% responded as they do not have idea of rainwater harvesting.

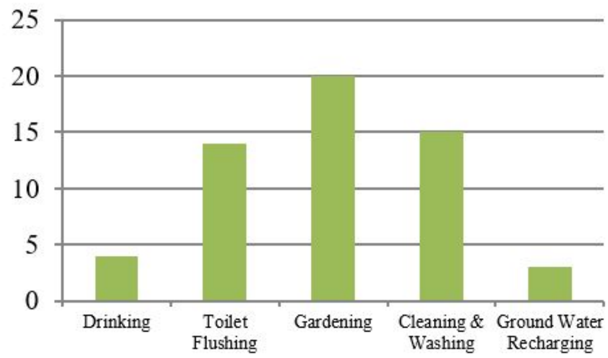

Figure 11: Answer to the question: For what purposes do you prefer to use rainwater?

This shows that the residents prefer less to use rainwater for groundwater recharging in comparison to other domestic uses as shown in chart above.

The government and non-government organizations that are working for decentralized rainwater harvesting projects that are mainly focused for immediate use. However, there are some rainwater harvesting projects focused for ground water recharging are only implemented on community level.

Studying the people's perception on the cause of drying water wells, people are not much aware about sending all rainwater to drain or there is decrease in ground water recharging rather they blame in increase in population or increase in number of drain/ bore wells. Where almost one third of the population i.e. 32% responded as they have no idea about the cause of drying water sprouts.

Studying the people's perception on the water logged streets during rainy days, people are not much aware about the increase in impervious pavement or decrease in ground water recharging rather they blame on poor design and management of sewer system. Where almost 20% responded as they have no idea on water logged streets during rainy days.

5. Conclusion/ Recommendations

There is water shortage in urban areas where people are approaching the alternative sources, rainwater harvesting could be helpful in reducing potable water consumption to some extent and contribute to water sustainability. But being more focused on ground water recharging, an urban area could contribute much as water sensitive urban development which is also in reverse to groundwater depletion.

There are no policies for ground water recharging to implement in individual level. It is said that the individual project of Rainwater Harvesting System (RWHS) is only circulating among the people who could easily afford according to source- Smartpaani.

People in the urban areas have the idea of rainwater harvesting but have very less positive responses towards rainwater for drinking and ground water recharging. People from community are willing to use rainwater mainly for the purposes like toilet flushing, gardening, washing and cleaning.

The condition of water level in the urban areas is in decreasing state. People are not much aware about the cause of the issues like dry wells and urban flooding. Although residences have separate pipe system to drain rainwater from roof top, it directly enters to sewerage, if it is ground recharged it will increase infiltration by around 19%. If all rainwater from urban residential is sent to ground water recharging, the volume of infiltration will be as much as of natural catchment, which also help to minimize urban flooding and wastewater treatment overloading improving urban sustainability.

So, rainwater harvesting should be the part of policy and could be practiced in individual scale as like in different parts of India. For e.g. in the case of new buildings with an area of 1000sq m/1500sq m or with a roof area of more than 100 square meters, the use of rainwater could be authorized. Likewise, a rebate of around 6 percent on property tax could be offered as an incentive for implementing rainwater harvesting systems. All new water and sewer connections could only be provided after the rainwater harvesting system had been installed. Where various offices related to Urban Development authority, ground water authority, Municipal Council, Ward office can be participated in implementing new law. Either rainwater harvesting is used for immediate use or for ground water recharging, it directly helps in minimizing sewer and treatment plants overload. There should be awareness program to make people realize about the benefits or potentials of rainwater harvesting systems. The long term benefits to individual and society should be informed. So, every individual should be made aware along with the current water related issues and their causes.

Rainwater harvesting systems should be incorporated into property development at the design stage. So, not only locals but also the experts like architects and environmental engineers should be involved in the planning process regarding water sustainability.

If there is increase in joint effort from individual, businesses and individual level to popularize the rainwater harvesting technology along with its favorable impacts, it eventually promotes sustainability of an urban environment in one or other ways.

References

[1] A Raina. Inequities in household water consumption in kathmandu, nepal. global water forum, 2017.

[2] Roshan Raj Shrestha et al. Rainwater harvesting and groundwater recharge for water storage in the kathmandu valley. *ICIMOD Newsletter*, 56:27–30, 2009.

[3] Norma Khoury-Nolde. Rainwater harvesting. *Zero-M organization, Germany*, 2010.

[4] Parmeshwar Udmale, Hiroshi Ishidaira, Bhesh Raj Thapa, and Narendra Man Shakya. The status of domestic water demand: supply deficit in the kathmandu valley, nepal. *Water*, 8(5):196, 2016.

[5] Solveig Höfer. Evaluation on the feasibility to implement rainwater harvesting systems.

[6] Jeewan P Thanju and Basanta D Shrestha. Rain water harvesting in kathmandu. *Hydro Nepal: Journal of Water, Energy and Environment*, 7:24–25, 2010.

[7] G Markovi, M Zele, Daniela Káposztásová, Gabriela Hudáková, et al. Rainwater infiltration in the urban areas. *WIT Transactions on Ecology and the Environment*, 181:313–320, 2014.

[8] Chitresh Saraswat, Pankaj Kumar, and Binaya Kumar Mishra. Assessment of stormwater runoff management practices and governance under climate change and urbanization: An analysis of bangkok, hanoi and tokyo. *Environmental Science & Policy*, 64:101–117, 2016.

[9] Roshan Raj Shrestha. Eco home for sustainable water management: A case study in kathmandu, nepal. In *International Conference on Sustainable Sanitation:"Food and Water Security for Latin America". Fortaleza, Brazil*, 2007.