STUDY OF WATER MANAGEMENT AND DEVELOPING STRATEGIES ESPECIALLY FOR HILLY TERRAIN IN INDIA

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Abstract - Rain carries a large amount of water most of which usually drain out & causes soil erosion, especially in hilly regions. There are many ways to conserve water. Conventionally, rainwater harvesting is practised across the country. Apart from that, the atmosphere has a significant amount of water in the form of fog & mist, which can be utilized. The methodology includes the study of research papers & best practices, that could be incorporated, & with the help of which some suitable models for hilly terrain are proposed. Here we have taken the case of Dehradun. We can see that by resolving one issue we can also resolve other issues, like employment & air-pollution. This could be incorporated into the Smart City mission.

Keywords - Air-pollution, conserve water, Dehradun city, employment, fog & mist, hilly terrain, rainwater harvesting, Smart city mission & soil erosion.

I. INTRODUCTION

India has the second-largest population in the world, whereas land is limited. The use of natural resources is more. So, here challenges are more as compared to the rest of the world. Water is a natural resource. The main source of it is the monsoon, which usually occurs from June to September. But because of global warming, its uses may start early or late also. India is privileged with sufficient rainfall as a whole & the average annual precipitation is about 1170 mm. This is much higher than the global average of 700 mm. However, the rainfall distribution in the time domain is skewed with 75% of it taking place only in the monsoon season. There is also a very large spatial variation (Athavale, 2003). Water scarcity is a serious problem throughout the world both for rural and urban communities due to increasing population urbanization, industrialization, and the use of chemicals in agriculture (Sharma, 2017). In the last few decades, we have seen that floods, as well as draughts, are happening very frequently. Water harvesting & wastewater management is practised around all over India. According to a blog the water harvesting is started in India, in the ancient period, 2000 BC along with Mesopotamia, China & modern-day Israel (perfectwater.com, 2020). Hilly regions face more problem than plain areas, as the transportation problem is very prominent there along with snowfall in winters, water scarcity etc. The livelihood in a hilly city is majorly dependent upon, Agriculture & Tourism.

II. METHODOLOGY

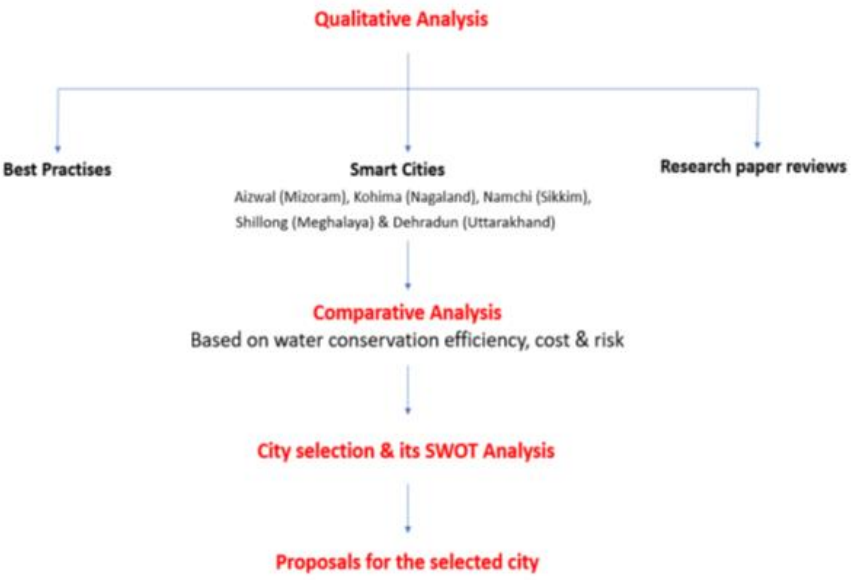


Fig.1. Flow chart of Methodology.

III. LITERATURE REVIEW

(Baby, Arrowsmith, & Ansari, 2019) conducted a study on GIS. This was a study conducted in Eucalypt Estate Wollert, Victoria, Melbourne Australia, the objectives of this study were to calculate the total potential of rainwater to cater for the daily needs of residents by using the Geographical Information systems (GIS) systems. Applications of GIS are, first, demand analysis for that demographical data is secured, and the no. of people lives there. Then historical data on water consumption, litres per person per day. Then, how many houses are there and what type of roofs? Roof area & finally Road catchment areas. After the analysis, it was found that the region has the potential to generate approximately 180 litres of water for each person per day per year, and if we count only dry days, I.e., 245 lit., then around 270 litres of water generation is possible. This study can help us in the calculation of knowing the demand and potential of a region.

(Shaheed, Judeh, & Riksen, 2020) conducted a study which was conducted in Palestine, Europe. The objectives of this study were to use rainwater harvesting as a tool to enhance agriculture productivity especially in agriculturally water-poor areas of Palestine. To achieve the objective, they integrated agriculture water-poor (AWP) and agriculture rainwater harvesting suitability (ARWHS) maps for the identification of suitable areas using a Geographical Information system (GIS). Two methods are used which are, The weighted overlay summation process (WOSP) & Analytical hierarchy process (AHP). This study can help us in identifying the appropriate area of the selected region where rainwater harvesting can be used for agriculture.

(Tucunan, Ariastita, Setiawan, Navastara, & Medha, 2018) conducted a study, which was conducted in Indonesia. This study had targeted low-middle income groups. The objective of this study was to determine the appropriate implications of rainwater harvesting techniques based on area type, i.e., Urban, and suburban areas. For an urban area, they have proposed a “recharge pit” and “recharge trench” for houses, based on the roof area, which is for a Recharge pit around 100 sq. m. (1076 sq. ft.) & for the Recharge trench, it is around 200 to 300 sq. m. (2153 to 3230 sq. ft.). For the sub-urban area, they have proposed, “gully plug” & “contour bund”.

(Ngachan, 2012) conducted a study in the North-eastern region of India. Here the focus is to mitigate drought, groundwater preservation, preventing soil erosion and saline prevention, by using, locally available low cost and innovative techniques (low-cost ferrocement storage tanks) for rainwater harvesting, the objective is to store the water when it is in abundance, and using the same for lean days. For the household purpose and agriculture. This study helps draft strategies as the north-eastern regions are also hilly.

(Zheng, Gao, Jin, & Zhang, 2018) conducted a study in Chifeng, China. The focus of the problem was to find a suitable area for rainwater harvesting, the procedure for that includes using “Soil Conservation Service curve number" and potential risks of water & soil loss based on the "universal soil loss equation". The accuracy of the model was found to be 87.5 per cent. Here the climate is Temperate which is similar to India.

(Tashi, Norphel, & Padma, 2015) conducted a study of the Ladakh city in India. Which has high aridity and low temperature, because of that the water availability has significantly downing over the last four decades. Water harvesting techniques which they use are diversion canal, water reservoir, gravity canal, lift irrigation scheme & snow harvesting. Artificial glacier technique is practised from 1987 till today. In this study, the major focused was on the familiar conditions, risks, and challenges of an artificial glacier. This study can help us understand a city in hilly terrain, that has the same climatic attributes.

(Tractors, 2017) featured, Dr Ajit Gokhale who is a founder and leader of Natural Solution has over two decades of experience in Natural Resource Conservation, Water Resource Development, Water and Wastewater Treatment & Solid Waste Management. said that water conservation can be done in hilly areas by using Flanged vented dam, Spring cordoning, making a dam in a river, Not using synthetic chemicals for agriculture. This study can help us understand the context of Indian practices.

(TERI, 2018-20) conducted a study in Supi village in Uttarakhand. The method used was a collection of rainwater in tanks, then the circulation of water-based on need, in quarries inside “polyhouse”, according to use. Mostly medicinal plants are used. The revival of traditional crops like millets and rajma. Why Polyhouse? – It saves from harsh weather as well as protects from animal attacks Drip irrigation method – is used to minimize wastage of water. This study canhelp us understand the context of Indian practices.

(Vinoj & Gavaskar, 2018) conducted a study in India. They have used the Internet of things (IoT) as a tool to reduce the water problem by 39 per cent by more saving. Here the water losses are minimized by using different sensors, which are connected via the internet. Automatic metering of collected water is done. Here the name of the model proposed is called “Arduino sensor device”. List of technical devices incorporated are LED Display, Rainwater sensor processing, Stepper motor function, Internet of things (IoT), The global system of mobile communication (GSM) & Water level sensor. The mechanism is simple, the door opens & closes, according to the need. This study can help us in increasing the efficiency of proposals. Also, it meets with the smart city’s smart interventions.

(Qadir & Jimenez, 2018) conducted this study for various cities in the world. the study focuses on fog harvesting and reinforcing the fact that it is a green

technology. It had also suggested that it can be used to decrease smog pollution. Here the challenges are also discussed, which are biophysical, socio-economical as it is not suitable for dry climatic areas and only applicable for specific topographical and geographic conditions. This study can be used for proposing fog harvesting techniques.

(Tu & Hwang, 2020) conducted a study in China. Various innovative water harvesting techniques are reviewed and research gaps are found which are evaluated and proposals are given for humid and dry climatic regions. (Tiedemann, Lummerich, & J., 2010) conducted a study in Australia. The focus was to make a financial model of fog harvesting to showcase its economic potential and attract financially strong investors and poor communities. Here the authors have showcased "Astropod" and "Effiel" models as a solution of screener and fog collector. See figure 2. (Jarimi, Powell, & Riffat, 2020) conducted this study in Malaysia. This study aims to review fog water harvesting and dew water also harvesting its efficiency and feasibility. See figure 3.

According to (Issuu, 2017), "Warka Water" can provide 100-liter potable water every day. See figure 4. The structure is 9.5 m (31 feet) tall. Weighing 80 kgs. Material is made up of bamboo structure, plastic mesh & ropes. It is portable as well as easily foldable. Having 8 fixation points can be placed radially around the tower base. It is well stable also because a network of ropes is attached & fastened to create more stability & make it withstand the winds. It catches water from rain & dew. Ground coverage area is 19m. (Mishra, 2019) had done extensive research on "Warka Water" & performed a cost analysis for the Indian context. According to which, the cost was found to be 250 dollars & for the Indian context, the cost was found to be 33000 Rupees.



Fig.2. Types of fog harvesters. The above image shows Eiffel, Harp and Diagonal Harp collector, from left to right. The below image shows an Astropod screener.
Source: (Tiedemann, Lummerich, & J., 2010).

The fog collector	Size/design	Type of application	Advantage	Maximum water collection (litres/day)	Country
Eiffel collector	4×8×0.3 m metal frame, two separated layers of Raschel 50% net with 10 additional stripes in between	Large scale experiment	A 3D collector that is advantageous for places with no unique wind direction associated with the occurrence of fog.	2650 l per day during the peak fog season.	Peru
Harp collector	2×4×0.3 m metal frame, 2256 m of 1.5 mm rubber string vertically installed	Large scale experiment		200 l/day during peak season	Peru
Diagonal Harp collector	2×4×0.3 m metal frame, 1520 m of 1.5 mm rubber string diagonally installed	Large scale experiment		94.2 l/day during peak season	Peru

Fig.3. Details of fog harvesters. Source: (Jarimi, Powell, & Riffat, 2020).



Fig.4. Front view and sectional elevation, explaining dimensions and working procedure of the "Warka water".
Source: (Issuu, 2017)

IV. DATA ANALYSIS

Based on the literature review It was found that three methods would be useful for our context. Here the costing of each type of fog water collector types is given below. There are three types for fog harvesting i.e. Eiffel, harp collector & Diagonal Harp collector, followed by IoT based rainwater harvesting model.
Here from Table I to Table IV, items & their quantities are referred from the literature review. Rates are referred from various online sources, mostly from "Indiamart.com". So, the idea of providing costing here is just to give a basic idea regarding the affordability of the model for the Indian context. These models are not physically performed & the total costs of models are tentative & not actual.
Quantities are given in Table I to Table III are referred from figure 3. Table IV is referred from research by (Vinoj & Gavaskar, 2018). The cost of "Warka Water" is directly referred from the research by (Mishra, 2019).

Eiffel (Size: 4x8x.3m)				
Item	**Rate**	**Cost (In Rs.)**	**Maximum water collection capacity in the peak season (litre per day)**	**Source**
Raschel net (2 units)	28 Rs. per sq. meter	1792	2650	Adobe Acrobat PDFXML Document (Garware Technical Fibres Limited, 2021)
Outdoor hoarding (steel)	450 Rs. per sq. ft.	154998		Rectangular Flex Hoarding Sign Board, For Promotional, Thickness: 10 Mm (IndiaMART InterMESH Ltd., 2021)
Total		**1,56,790 (Tentative)**		

Table I

Diagonal Harp Collector (Size: 2x4x0.3m)				
Item	**Rate**	**Cost (In Rs.)**	**Maximum water collection capacity in the peak season (litre per day)**	**Source**
Rubber cord 1.5mm (1520m) *Note: instead of rubber string, I assumed a rubber chord.*	16 Rs. per meter	24320	94.2	R. C. S. Enterprises Goregaon East, Mumbai, Maharashtra. (R.C.S. Enterprises, 2021)
Outdoor hoarding (steel)	450 Rs. per sq. ft.	38749.50		Rectangular Flex Hoarding Sign Board, For Promotional, Thickness: 10 Mm (IndiaMART InterMESH Ltd., 2021)
Total		**Rs. 63,069.50 (Tentative)**		

Table II

Harp Collector (Size: 2x4x0.3m)				
Item	**Rate**	**Cost (In Rs.)**	**Maximum water collection capacity in the peak season (litre per day)**	**Sources**
Rubber cord 1.5mm (2256m) *Note: instead of rubber string, I assumed a rubber chord.*	16 Rs. per meter	36096	200	R. C. S. Enterprises Goregaon East, Mumbai, Maharashtra. (R.C.S. Enterprises, 2021)
Outdoor hoarding (steel)	450 Rs. per sq. ft.	38749.50		Rectangular Flex Hoarding Sign Board, For Promotional, Thickness: 10 Mm (IndiaMART InterMESH Ltd., 2021)
Total		**Rs. 74,845.50 (Tentative)**		

Table III

IoT based model for Rainwater harvesting				
Item	**Rate**	**Cost (In Rs.)**	**Increase inefficiency**	**Source**
Arduino	330 Rs. per piece	335	39%	(ElectronicsComp.com, 2021)
LED display	204 Rs. per piece	204		(Amazon.com, Inc. or its affiliates, 2021)
Stepper motor	1200 Rs. per piece	1200		(IndiaMART InterMESH Ltd., 2021)
GSM - GPS module	Rs. 825	825		(ElectronicsComp.com, 2021)
IoT service	12000 Rs. per unit per year (100 devices)	120		(IndiaMART InterMESH Ltd., 2021)
Water level sensor for Arduino	Rs. 799 per piece	799		(Amazon.com, Inc. or its affiliates, 2021)
Rainwater sensor	80 Rs. per piece	80		(Amazon.com, Inc. or its affiliates, 2021)
Ultrasonic sensor	999 Rs. per piece	999		(Robomart.com, 2021)
Total		**Rs. 4,562 (Tentative)**		

Table IV

Comparative Analysis							
Item	**Type**	**Features**	**Cost of one unit**	**Risk & Challenges**	**Capacity (per day)**	**Best suited for**	**Source**
Eiffel Collector	Fog	1. Sustainable 2. Passive 3. Low maintenance 4. Air purification through smog reduction. (Eiffel Collector)	Rs. 1,56,790 (tentative)	1. Only applicable in specific topographical & geographical dry climatic zones. 2. Unaffordable for lower-income segments. 3. Initial investment is too high.	2650 lit. in peak season	High-traffic zones	Table I, Table II, Table III, (Tiedemann, Lummerich, & J., 2010), (Jarimi, Powell, & Riffat, 2020) & (Qadir & Jimenez, 2018)
Harp Collector	Fog		Rs. 74,845.50 (tentative)		200 lit. in peak season		
Diagonal Harp collector	Fog		Rs. 63,069.50 (tentative)		94.2 lit. in peak season		
IoT model for RWH	Rainwater	1. Increases productivity of aquifer. 2. Flood hazard reduction. 3. Drought mitigation.	Rs. 4562 (tentative)	1. Electronic devices need maintenance. 2. Electricity dependent.	39% increase in water-retaining capacity	The existing household has an RWH system or willing to adopt it.	Table – IV & (Vinoj & Gavaskar, 2018)
Warka Water	Fog, Rainwater & mist.	1. Sustainable 2. Passive 3. Most economical 4. Low maintenance	Rs. 33000 / 250 USD	Demand a significant amount of land cover. Collector size - 87 sq ft (8.1 sq m), Canopy size - 32 ft (10 m)	3000 litres (Avg. 100 litres)	Agriculture purposes	(Mishra, 2019) & (Issuu, 2017)

Table V

V. SWOT ANALYSIS: DEHRADUN UTTARAKHAND

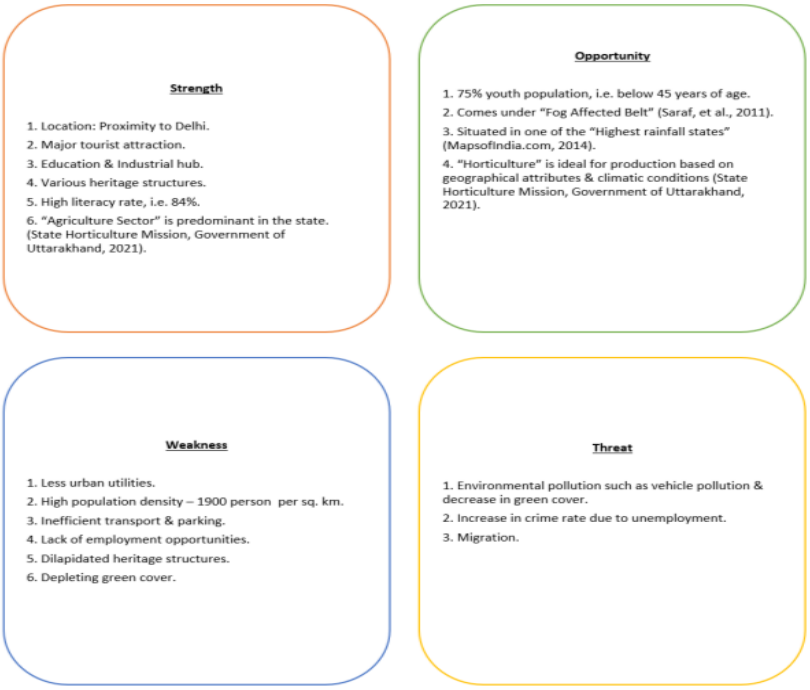


Fig.5. SWOT analysis of Dehradun city, Source: (Ministry of Housing & Urban Affairs, Government of India, 2016)

VI. CONCLUSION & RECOMMENDATIONS

Based on the data analysis, it was found that all three models can be useful in different places in Dehradun city. For example, we can use the "Eiffel" type collector out of all three types of fog harvesting model, because it has more water collection capacity. This model can be placed in areas which are having a significant amount of smog.

"IoT based RWH model" can be installed anywhere where there is a pre-installed rainwater harvesting system or where people are willing to install sone.

"Warka Water" can be used specifically for agricultural purposes. As the implementation of it can boost the agriculture sector & can call the migrating young generation back to the city. As we know that 75% of the population is young.

As we all know that monsoon season starts in June & ends in September. Also, the fog falls from December to February. So, a total of 7-months of water problem can be mitigated.

In the last, I will conclude that these proposals would be helpful & can be incorporated in Smart City interventions, in mitigating many issues of the city like employment, pollution control.

CONFLICTS OF INTEREST: The authorsdeclare no conflict of interest.

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