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Feasibility of roof top rainwater harvesting potential - A case study of South Indian University

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A R T I C L E I N F O

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A B S T R A C T

Shortage of water source has been a major problem for rapidly growing cities in country like India due to increase in consumption of water. Besides this the coastal cities like Mangaluru are currently challenged by temporary floods due to increased precipitation. Hence it demands a flawless planning for managing the water resource. Rooftop Rainwater Harvesting (RTRWH) has proven to be the most economical and environmental friendly method. The principal objective of this study is to design the RWH system for a South Indian University (SIU), to transform the present campus with green initiative by effective utilization of water resource. An integrated study on rooftop storm water runoff for quantitative and qualitative analysis was conducted. The SIU can resolve the water scarcity issue by accumulating about 1,13,678.9 m^3 of stormwater from rooftop in a year, and use it during the non-monsoon season. These findings can significantly influence the similar RTRWH initiatives in various government and private establishments for sustainable water management.

1. Introduction

For the survival of any living beings on earth, water is one of the most important resources as much as food and air. It plays a major role is development of communities, economical and social activities. Unfortunately not much attention is given for the conservation of this precious resource. India is a land of versatile weather where inconsistency in rain is quite frequently experienced. Due to rapid urbanization, industrialization and infrastructure development the demand of water scarcity arises in ecosystem (Carmon et al., 1997). Ecosystem is adversely affected due to exploitation of the water resource especially by rapid growth of population (Sukerema et al., 2013). The investigation conducted by Schewe et al., (2014), described the unfavorable impact of climate change over water scarcity (Schewe et al., 2014). So in order to have a backup plan for water requirements, a system has to be developed to conserve storm water that could be help in solving most of the water scarcity issues. Owing to the excess use of ground water through over pumping, the level of ground water at various locations has been drastically decreasing. In case if this issue is not addressed then the future generations may have to face a challenge of water scarcity.

The major source of potable water is rainfall. Hence, if rainwater is harvested then the water scarcity issues can be altogether decreased and even eliminated. It is well known fact that the collection and storage of rain water is being practiced since many centuries (Khaleq and Ahmed, 2007). Rain water harvesting is a technique through which the rain water is captured, stored and reused for various purposes (Stec and Kordana, 2015). Various studies has suggested to use harvested storm water for domestic and land-scape purpose (Abdulla and Al-Shareef, 2009). The investigation conducted by Sturm et al., (2009), presented the economical and technical feasibility of rain water harvesting system (Sturm et al., 2009). Marlow et al., (2013), reviewed a critical reassessment of sustainable urban water resource management by considering its advantages and limitations (Marlow et al., 2013). An advanced modified technique of decentralized water management that combines grey water recycling and rainwater management for densely populated city is examined by Zhang et al., (2009) (Zhang et al., 2009). This study reports a satisfactory outcome with better water resource management. Similarly several other studies have suggested the importance of adopting rainwater harvesting technique either in small scale (individual dwelling) or for large scale (city/town) levels.

A rooftop rainwater harvesting system that consists of various elements for conveying storm water through pipes or drains after collecting from catchment area into storage tanks is presented in Fig. 1. During the course of first rain event the storm water will be flushed out of the system to stop contaminants entering the storage tank. Based on the

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Nomenclature

ADM	Administrative Block
AFPRO	Action For Food Production
ATM	Automated Teller Machine
Ca	Calcium
Cl	Chlorine
EC	Electrical Conductivity
GH	Guest House
HP	Horse Power
INR	Indian Rupees
MBA	Master of Business Administration
Mg	Magnesium
RCC	Reinforced Cement Concrete
RWH	Rain Water Harvesting
RWHS	Rain Water Harvesting System
RTRWH	Roof Top Rain Water Harvesting System
SA	Slab Area
SIU	South Indian University
SV	Single Volume
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TV	Total Volume
UNICEF	United Nations Children's Fund
UNICEF	University Science Instrumentation Centre
WA	Wall Area

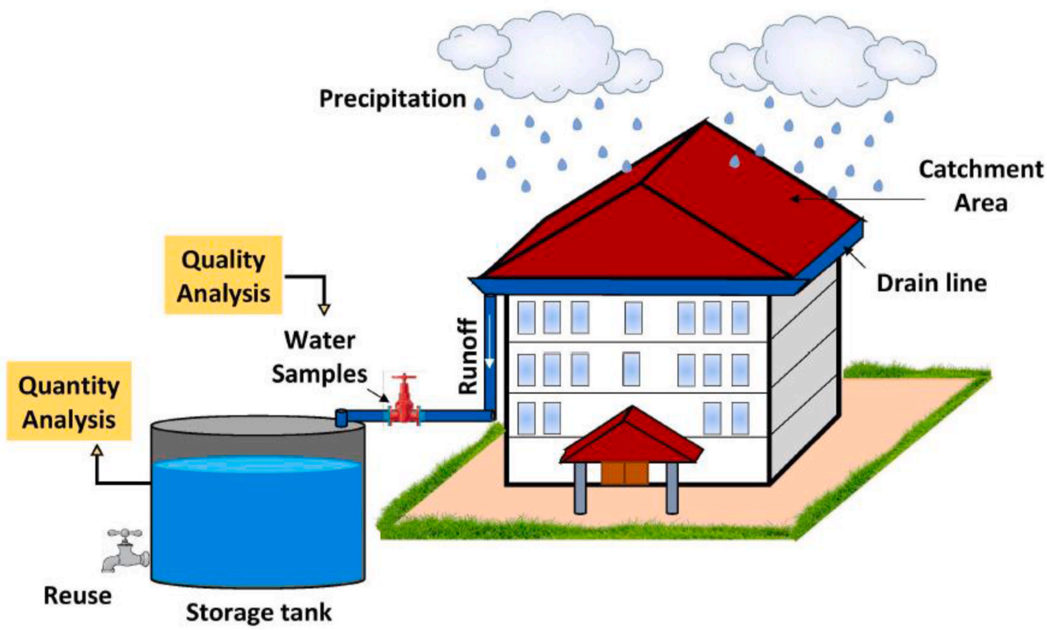

Fig. 1. Schematic representation of RTRWH along with analysis criteria.

water reuse application some RWH systems also incorporate filters (especially sand, gravel and charcoal filters) to ensure effective pre-treatment technique. Eventhough the RWH technique has gained rapid popularity, estimating/designing the storage tank volume for collecting the rooftop stormwater has always been a challenging task.

Hence the rooftop rainwater harvesting technique will be more effective in heavy rain intensity regions with well distributed rainfall over the years (Kumar, 2004). Because of vast rooftop area the public institutions will be a focal point to have effective RTRWH system (Adugna et al., 2018). Generally they have a significant rooftop area with single managing system with sufficient financial assistance that will favour towards easy implementation of RWH system. Additionally being the larger administration, it also establishes the trust over rainwater harvesting technique to locals and other organizations. However a very little initiative and research is reported over the government building on rooftop rainwater harvesting potential especially at University/Institution level (Saeedi and Goodarzi, 2020).

The practices followed within any University campus plays a prominent role in quality of living in society covering a large percentage of populations like students, staffs and faculties. Landscaping with campus green spaces develop a unique sense of community that forms a main structural characteristics within the campus (Speake et al., 2013). It is one of the factors that a student observes during their admission survey among the universities. A substantial proportion of green space across the campus was suggested by most of the students to reduce the stress of college life during a survey conducted by Seitz et al., 2013) (Seitz et al., 2013). The study on undergraduate students by McFarland et al., (2008), also suggested the influence of green space within the campus for overall academic accomplishment (McFarland et al., 2008). In the present study an attempt has been made to examine the current status of the water requirement, the rooftop RWH potential in a South Indian University Campus. This study integrated quantitative and qualitative analysis of rooftop rain water and its potential for harvesting. The objectives of this study are (1) To examine the present status of water requirements for major academic and residential units at South Indian University, (2) Evaluate the potential of storing roof top rainwater in major units of university campus, (3) Propose measures to improve the quality and quantity of rainwater collection. The principal purpose of this research is to maximize the use of rain water and transform a South Indian University to self-sustainable through green campus initiatives.

This article is divided into five sections. Following the introduction in first section, Section 2 describes the study area. Section 3 will provide an overview of step by step methodology followed for the study. Further in Section 4, the findings of the study are presented. Section 5, presents

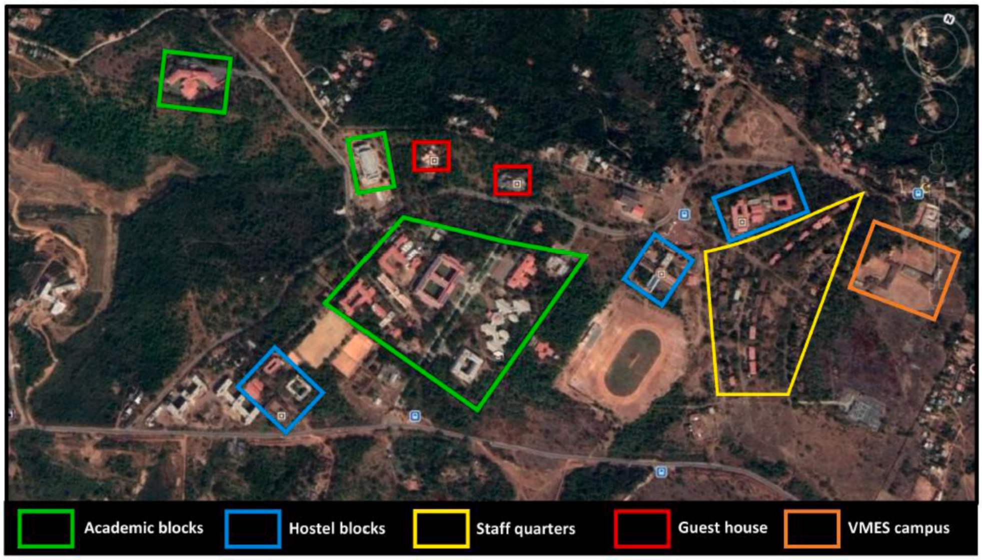

Fig. 2. South Indian University campus map with zones (Source: Google earth).

Table 1
Meteorological and topographical data of the study area.

Parameter	Average value	Remarks
Average rainfall	3800 mm	May to October period
Humidity	75.3%	62% in January 89% in July
Temperature	27 C - 34 C	Tropical climate
Wind	-	Moderate to gusty during day Gentle during night time
Topography	-	Highly undulating terrain
Geology	-	Hard laterite on Hilly terrain
Earthquake zone	-	Seismic zone III

the conclusion section.

2. Study area

The South Indian University is situated at Mangalagangothri campus around 20 km from Mangaluru city towards southeast (12.9141 N, 74.8560 E). The campus is spread across 353 acres of land located overlooking Netravathi River towards its west and western ghat ranges on east. Since the year it became independent university (1980), it has grown to greater level with self-sustained facility to excel in higher education. The University campus consists of various edifice like Administrative block, Science block, Central library, Student hostel

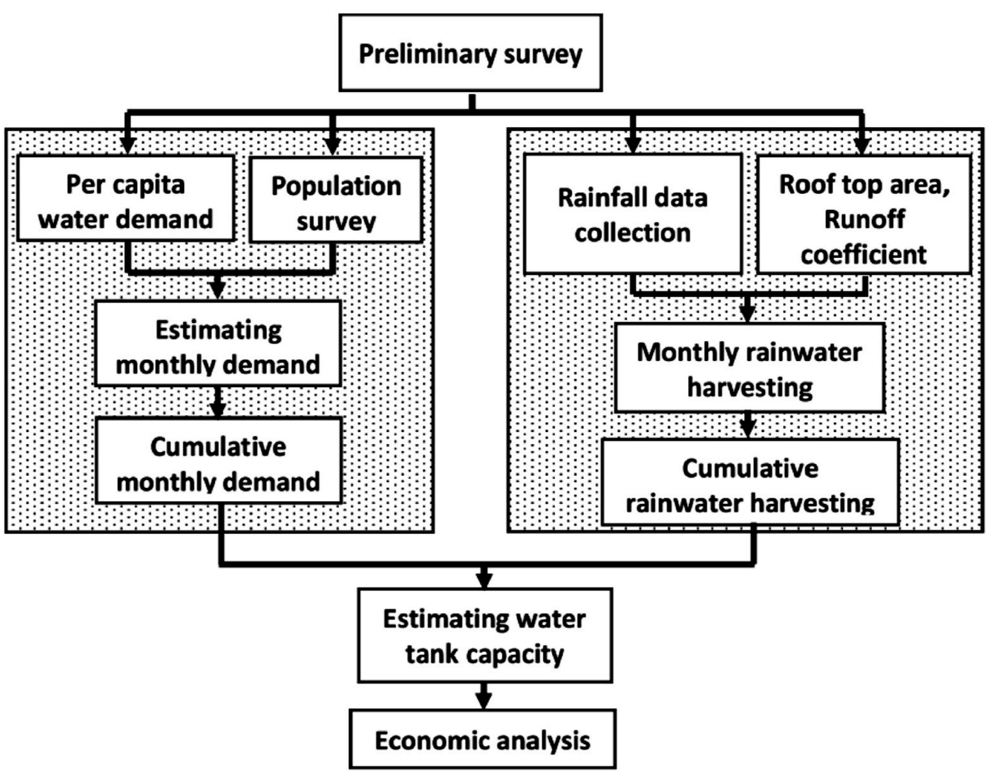

Fig. 3. Study methodology flowchart.

Table 2
Runoff coefficient values for various roof types.

Sl. No.	Type of roof	Runoff coefficient
1.	Galvanized iron sheet	0.90
2.	Asbestos sheet	0.80
3.	Tiled roof	0.75
4.	Concrete roof	0.70

Source: Water harvesting. A manual for design & construction of water harvesting schemes for plant production (1991)

Table 3
Standard run-off coefficient value (Garg et al., 1976).

Sl. No.	Types of Area	Flat Land (0–5%)	Rolling Land (5–10%)	Hilly Land (10–30%)
1.	Urban Area	0.55	0.65	–
2.	Single Family Residence	0.3	0.3	0.3
3.	Cultivated Area	0.5	0.6	0.72
4.	Pastures	0.3	0.36	0.42
5.	Wooden Land or Forest	0.3	0.35	0.50

Table 4
Rooftop runoff quality results.

Sl No.	Parameter	Unit	Range
1.	pH	–	5.5–7.1
2.	Electrical conductivity	mS/sec	45–158
3.	Total Dissolved Solids (TDS)	mg/L	30–83
4.	Total Suspended Solids (TSS)	mg/L	00–28
5.	Calcium (Ca)	mg/L	11–42.5
6.	Magnesium (Mg)	mg/L	0.2–0.44
7.	Chlorine (Cl)	mg/L	16–53

blocks (Girls & Boys), Staff quarters and other units like Microtone centre, Humanities block, Cooperative society, Instrumentation centre and Sports complexes. A google map representing various zones of establishments within the campus is shown in Fig. 2. The soil sprawl across the campus is laterite in nature with highly undulated ground surfaces. The highest altitude of 119.24 m and lowest of 56.78 m was recorded across the campus.

The main source of water is withdrawn from Netravathi River about 15 km from the campus. Specifically the water transfer system includes two stages of pumping and a gravity flow line of about 10 km stretch. Once the water is received at SIU campus, it is then treated by aeration, seven stage sand filter and clarifier before disseminating. About 1.4 million liters of water is received and treated every day in the treatment unit. Ground water is extracted from two tube wells for specific campus activities like vicinity cleaning, gradening etc. Since University campus is spread across wide area cover, even having the catchment type rain water harvesting system may improve the ground water table. The meteorological data of study area is presented in Table 1. Normally in this region the rainy season start from May month and conclude during September and October month. The area receives mean annual rainfall of about 3800 mm (data obtained from Meteorological Department, Mangaluru).

3. Methodology

The descriptive step-wise procedure undertaken during the course of the study is presented in Fig. 3. A preliminary survey is carried to examine the nature of the land and to verify the rooftop area. In due course the rooftop area is calculated using remote sensing and GIS approach and substantiated with data provided by SIU, Engineering department and also authenticated during field visits. This was followed by representative storm water sample collection from each rooftops and analyzing it for various water characteristics in Environmental Engineering Laboratory, Department of Civil Engineering at Manipal Institute of Technology, Manipal (MIT). The population and water consumption within the SIU campus is recorded by a detailed inquiry. The data collected from SIU water supply unit is utilized to determine individual building unit water demand. Meanwhile the meteorological data are collected from Meteorological department, Mangaluru. For the present study the rainfall data was collected for a period of 2000–2014 from two nearest rain gauging stations. Statistical analysis was conducted over the various set of data using IBM SPSS software to understand the nature of collected data.

The potential of RTRWH is calculated using Equation (1) for selected establishments. Further the mass curve technique is adopted to estimate the volume of the tank and a detailed design plan is discussed in this study (Alrayess et al., 2017). Finally an explicit study upon economical aspects and rebate period of RWH system is undertaken to acknowledge the efficiency of the RTRWH system (Ndeketeya and Dundu, 2019).

3.1. Collection calculation

Based on local precipitation the rooftop RWH potential could be calculated using the equation given below

$$Q = CIA \tag{1}$$

here, Q represents total discharge from roof ($m^3 s$), C indicates coefficient of runoff, intensity of rainfall (mm) is denoted by I, and A represents total rooftop catchment area.

Generally the value of runoff coefficient is selected based on roofing material properties like imperviousness and infiltration capacity that is used to collect and drain-off the storm water to storage unit (Mao et al., 2021). Table 2 presents the runoff coefficient values for four common roofing materials used for construction. For the current study the building rooftops were covered by galvanized iron sheet and concrete roof. These various varieties, periodic cleaning of rooftop and environmental conditions may impact the rooftop rainwater quality (Appan et al., 2000). Skarzynska et al., 2007 reviewed the techniques and equipment's to capture the storm water by considering the composition of run-off waters (Skarzynska et al., 2007). If a large area/locality/region is considered for RWH to recharge the ground water table, then the type and gradient of ground surface decides the runoff coefficient value (Mishra et al., 2020). In such cases, the RWH potential could be estimated using following runoff coefficient values Table 3.

4. Results and discussion

The preliminary survey executed across the campus provided an insight of existing situation and cross examined the data collected from genuine sources. The rainwater harvesting potential of each establishment was estimated for average 15 years precipitation statistics. Subsequently supreme site location for constructing storage tanks are also suggested with elementary design specification.

4.1. Storm water quality analysis

The location specific environmental conditions, roof cover material and periodic cleaning/maintenance may impact the rooftop rainwater quality (Chiang et al., 2013). About 15 number of rainwater samples were collected from the roof top of selected buildings and analyzed for various water characteristics. Descriptive results of characteristics analysis on rooftop storm water is shown in Table 4. Characteristically the minimum and maximum range of values for pH, electrical conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Calcium (Ca), Magnesium (Mg), Chlorine (Cl) are provided in Table 4. The quality analysis was either performed immediately or within 24hrs of collecting sample. The samples were collected in sterilized glass bottles and then transported, stored in cold storage. The investigation suggested

Table 5
Residing population survey data.

Sl. No.	SIU Campus zone	Population
1.	Staff quarters	690
2.	Boys hostel blocks	350
3.	Ladies hostel blocks	460
4.	Working women hostel	320
5.	Guest house & International hostel	65

lower concentration of chlorine anion and prominent cations like magnesium and calcium in the water samples. Likewise pH and electrical conductivity values recorded are also well within the drinking water standards in India (IS 10500:2012). Hence the analysis outcome recommends providing a fundamental filtering unit to trap the roof sediments before entering the storage tank.

4.2. Population statistics

A campus poll is documented by the population count of SIU. The recorded population who resides within the SIU campus is mentioned in Table 5.

About 1000 staffs and students are externs who visit SIU campus during institute working days. These statistics represents average public movement/residents during institution working period.

4.3. Rainfall statistics

The rainfall data were collected from Meteorological Department, Mangaluru for 15 years span (Jan 2000 to Dec 2014) have been considered for RWH study.

Fig. 4 represents 15 years rain statistics with an average rainfall of 3800 mm in the study area. The data indicates less recorded rainfall event during 2000–2005 wherein it increased for 4000 mm during the year 2006–2013. Through the statistical analysis it could be concluded that estimated mean value (3779.26 mm) was much higher when compared with Karnataka state yearly mean data (1248 mm). While variance of 111777.97 and standard deviation of 334.33 also suggested substantial fluctuations in yearly rainfall events.

Further the monthly average rainfall data was also determined to understand the monthly potential of RTRWH. It clearly indicates that June and July month recorded (around1000 mm) highest precipitation events when compared with rest of the months. Every year the rainy season commenced from April month and generally prevailed till December. Usually during the rainy season (June–December) there won't be any shortage of water resource. During the peak summer season the campus faces shortage issues to meet the regular water demand. The SPSS statistical analysis on average monthly precipitation data indicates the mean value of 414.4 mm that was majorly because of three months during peak rainy season. While the analysis also provided the standard deviation value of 405.73 and variance value as 164642.50 suggested gradual variation of monthly rainfall events. Fig. 5 presents

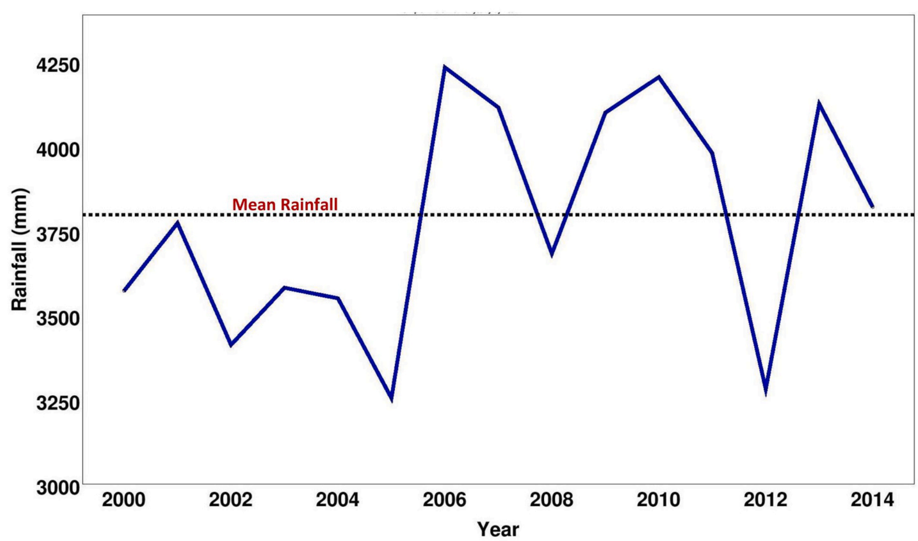

Fig. 4. Yearly total rainfall recorded for the year 2000–2014.

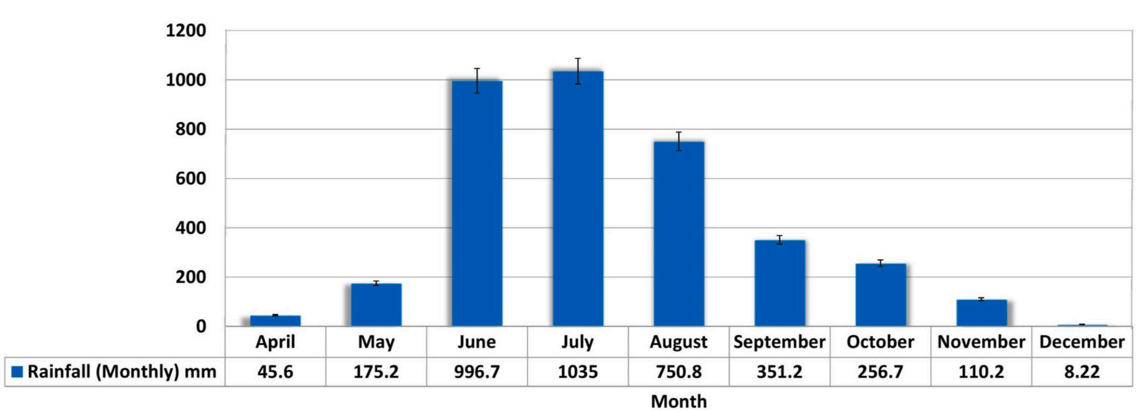

Fig. 5. Monthly average rainfall data for the year 2000–2014.

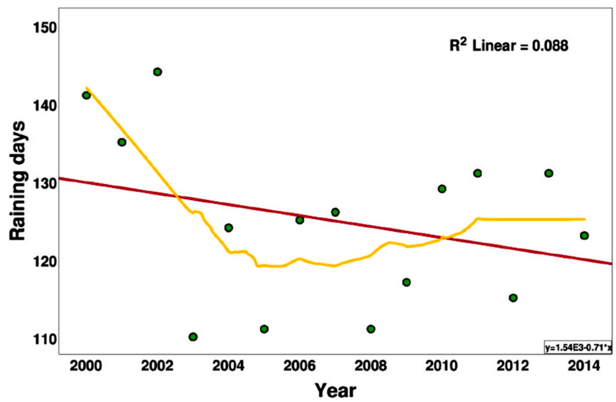

Fig. 6. Rainfall occurring days recorded for the year 2000–2014.

the monthly average rainfall chart for the period of 15 years.

The yearly rainfall days recorded for 15 years (2000–2014) is presented in Fig. 6. The pattern expresses gradual reduction of precipitation days as the year progresses. The regression analyses were performed by considering other two rain gauge stations in the nearby locality. This analysis on data of rainfall days suggested excessive variation in rainfall events as the year progresses ($R^2 = 0.088$). While the other two nearby rain gauge stations recorded gradual decrease in rain fall events when compared with considered rain gauge stations.

4.4. Effective rooftop area

Following preliminary field survey, 19 building units with effective roof cover was chosen for RWH study. The rooftop areas of each establishment are shown in Fig. 8. Further the percentage of each building roof area adopted for RWH study is estimated and plotted in Fig. 7. The larger roof area is covered by three boys hostel blocks (9.6%) and combined roof area of individual staff quarters (11.1%). Followed by science block and central library with 8.5% each and then bio-science and auditorium building by 6.6% and 6.3% respectively. The remaining roof areas of other each establishment were below 6% of total RWH study.

4.5. Water demand

The major influential factors for water demand is population residing in the building, and purpose of water usage (Wung et al., 2006). It is a challenging task to estimate the water demand in universities since people involve in vastly diverse activities. The water demand data for each month is documented from water supply and maintenance office within the SIU campus (Fig. 9). Correspondingly the staff quarters water demand was recorded highest of 7500 m^3 followed by Science block (3000 m^3), Ladies (2520 m^3) and Boys hostel (1920 m^3) units. Other major establishments with significant water demand were Administrative blocks (1500 m^3), Working Women's hostel (1170 m^3) and Central Library (750 m^3). Below 300 m^3 of RWH potential was estimated for remaining establishments. To determine the yearly rainwater harvesting potential of each units an assumption of same water demand for all the months were considered.

4.6. Rainwater harvesting potential

As discussed in the methodology section, the rainwater harvesting potential from selected building units are estimated and presented in Table 9. Similarly the average monthly rainfall data of 15 years were considered for estimating the monthly RTRWH potential. Fig. 10 illustrate the total monthly RTRWH potential of all the chosen establishments. It is evident from meteorological data that June, July and August month will have more precipitation hence increased potential of RWH about 26.72%, 27.75% and 20.13% respectively of total capacity. Whereas April, May, September, October, November and December contributed remaining 25% of total RTRWH potential.

Similarly individual building RTRWH potential was estimated and presented in Fig. 11. It clearly indicates that the staff quarters consisting highest roof area has greater potential of 12,671.80 m^3 for yearly storm water capture. Likewise Boys hostel units, Central library and Science block may harvest 10,863.20 m^3, 9708.70 m^3 and 9612.40 m^3 respectively. And other units like Bio-science block, Auditorium building, Working women hostel, MBA-Commerce block, Old ladies hostel, Indoor stadium, Shopping complex, Kannada commerce block, Yakshagana kala Kendra, Administrative block, Kaveri guest house, Yogic science block, Nethravathi guest house and Electronic building could harvest 7476.20 m^3, 7216.80 m^3, 6713.30 m^3, 6305.00 m^3, 6042.00 m^3, 5544.20 m^3, 4994.70 m^3, 4960.80 m^3, 4463.60 m^3, 4340.30 m^3,

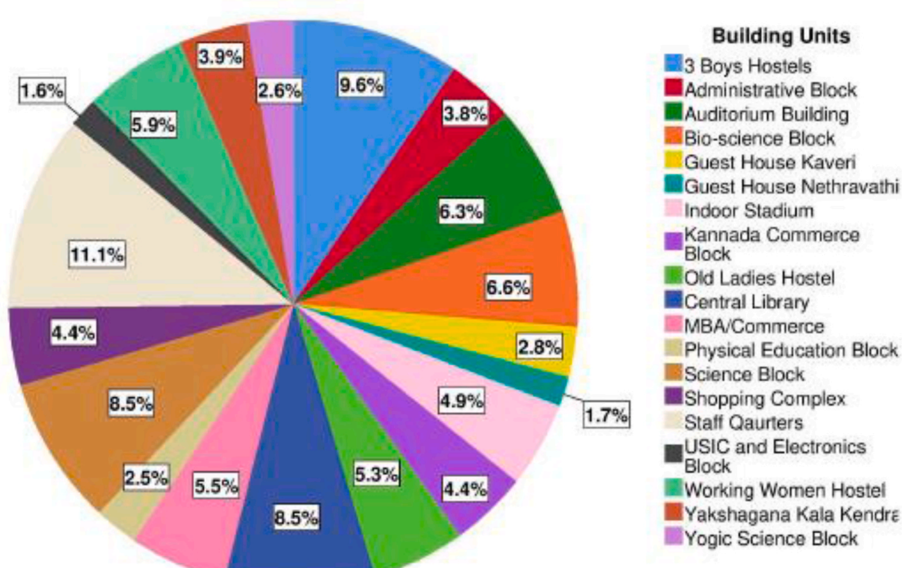

Fig. 7. Rooftop area percentage of selected building units in SIU campus.

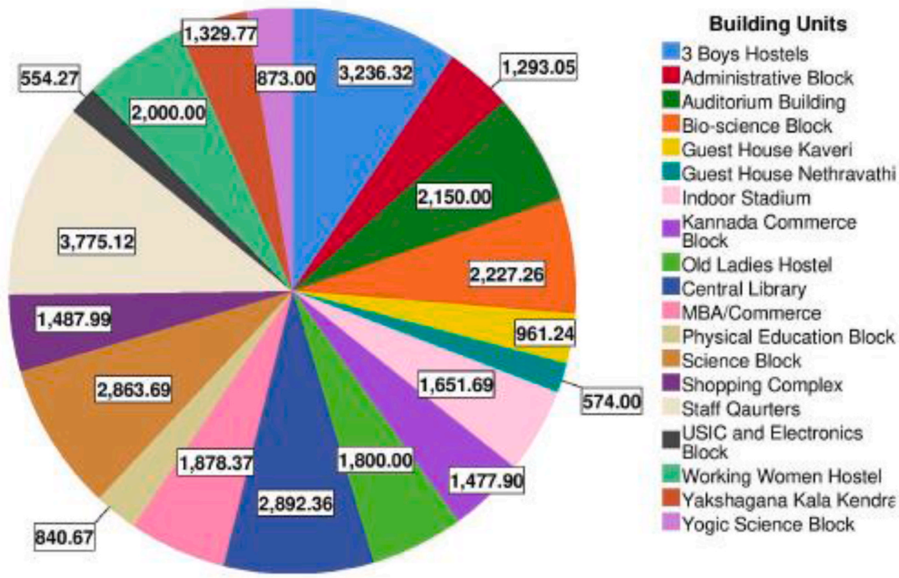

Fig. 8. Rooftop area for respective building units in SIU campus.

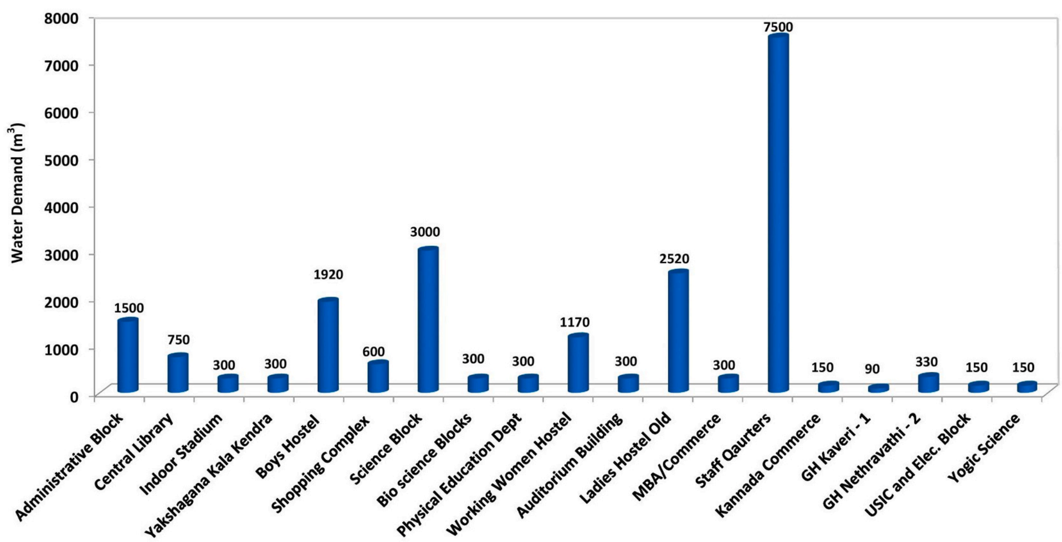

Fig. 9. Monthly water demand for respective building units.

Table 6
Designed storage tank dimensions.

Tank	TV (m^3)	SV (m^3)	Dimensions (m)	WA (m^2)	SA (m^2)
1.	2100	1050	15 x 14 x 5	290	210
2.	3200	1600	20 x 16 x 5	360	320
3.	2100	1050	15 x 14 x 5	290	210
4.	1800	900	15 x 12 x 5	270	180
5.	1600	800	14 x 12 x 5	260	168
6.	1600	800	14 x 12 x 5	260	168
7.	5100	1275	16 x 16 x 5	320	256

TV: Total Volume, SV: Single Volume, WA: Wall Area, SA: Slab Area.

3226.60 m^3, 2930.40 m^3, 1926.70 m^3 and 1860.50 m^3 respectively.

4.7. Positioning of storage tank

For the present study, seven main tank locations with eight sub-storage tank locations are selected and are recommended in the figure shown below (Fig. 12). This process could be effectively executed using Remote Sensing and GIS tools when compared with conventional field survey (Adham et al., 2018).

Table 7
Cost estimation of storage tanks.

Tank	Wall Cost	Top Slab Cost	Bottom Slab Cost	Water Proofing Cost	Total Cost
1.944820		319284	592956	100780.8	19,57,841
2.1172880		486528	903552	125107.2	26,88,067
3.944820		319284	592956	100780.8	19,57,841
4.879660		273672	508248	93830.4	17,55,410
5.847080		255427.2	474364.8	90355.2	16,67,227
6.847080		255427.2	474364.8	90355.2	16,67,227
7.1042560		389222.4	722841.6	111206.4	22,65,830
Units in INR					

Table 8
Details of garden area cover in campus (Anchan and Shiva Prasad, 2020).

Sl No.	Types of Area	Area (Sq. mtrs)
1.	Near Science Block	1537.80
2.	Library Front	1133.12
3.	Double Road	2913.73
4.	Around SBI ATM	849.83
5.	Beside Main Bus Stop	4330.13
6.	Inside Science Block	1294.99
7.	ADM Front	1456.86
Total		13516.5

To meet the growing water demand & the identified RWH potential as discussed in previous section, seven potential storage tanks with their capacity to hold the rainwater were chosen after understanding the ground surface gradient. The proposed tank positioning was determined based on gravity flow of harvested water that turns out be effective when compared with other water supply system. Minimizing the project cost by reducing pumping head and pumping distance are the two prominent factors that determined the tank locations. The main storage tank is the final destination of harvested storm water, whereas sub-storage tanks are utilized to make use of storm water in intermediate locations. Since staff quarters is spread across large area two sub-storage tanks are provided to utilize the harvested water. This enables to reduce the pumping cost of water from main storage tank.

4.8. Storm water harvesting potential from seven storage tank

After locating the storage tanks across the campus at functional locations, the storage potential of each tank was estimated.

The quantity of rain water harvested from each of the seven tanks is shown in Fig. 13. Highest estimated yearly storm water inflow will be for tank seven with 29,662.1 m^3, followed by tank three and tank two with 17,750.00 m^3 and 16,013.7 m^3 respectively. About 12,671.8 m^3 and 10,863.2 m^3 water harvesting potential is estimated as inflow for tank four & tank six and least of 11,557.1 m^3 and 10,697.4 m^3 for tank one and tank five respectively are recorded. This inflow volume is directly depended on the water demand fulfillment using sub-storage tanks.

A detailed estimation of yearly and monthly storm water harvesting potential from selected seven tanks is displayed in Table 10. As discussed previously June, July, August and September months contribute significantly for storm water harvesting potential. Hence the harvested

Table 9
Rooftop rainwater harvesting potential (m^3) for selected building units.

	Roof Area	WD	April	May	June	July	August	September	October	November	December
Administrative Block	1293.05	1500	53.1	203.9	1159.9	1204.5	873.7	408.7	298.7	128.2	9.6
Central Library	2892.36	750	118.7	456.1	2594.5	2694.2	1954.4	914.2	668.2	286.9	21.4
Indoor Stadium	1651.69	300	67.8	260.4	1481.6	1538.5	1116.1	522.1	381.6	163.8	12.2
Yakshagana Kala Kendra	1329.77	300	54.6	209.7	1192.8	1238.7	898.6	420.3	307.2	131.9	9.8
3 Boys Hostel	3236.32	1920	132.8	510.3	2903.1	3014.6	2186.8	1022.9	747.7	321.0	23.9
Shopping Complex	1487.99	600	61.1	234.6	1334.8	1386.1	1005.5	470.3	343.8	147.6	11.0
Science Block	2863.69	3000	117.5	451.5	2568.8	2667.5	1935.1	905.2	661.6	284.0	21.2
Bio science all Blocks	2227.26	300	91.4	351.2	1997.9	2074.7	1505.0	704.0	514.6	220.9	16.5
Physical Education Dept	840.67	300	34.5	132.6	754.1	783.1	568.1	265.7	194.2	83.4	6.2
Working Women Hostel	2000	1170	82.1	315.4	1794.1	1863.0	1351.4	632.2	462.1	198.4	14.8
Auditorium Building	2150	300	88.2	339.0	1928.6	2002.7	1452.8	679.6	496.7	213.2	15.9
Ladies Hostel Old	1800	2520	73.9	283.8	1614.7	1676.7	1216.3	568.9	415.9	178.5	13.3
MBA/Commerce	1878.37	300	77.1	296.2	1685.0	1749.7	1269.3	593.7	434.0	186.3	13.9
Staff Qaurters	3775.12	7500	154.9	595.3	3386.4	3516.5	2550.9	1193.2	872.2	374.4	27.9
Kannada Commerce	1477.9	150	60.7	233.0	1325.7	1376.7	998.6	467.1	341.4	146.6	10.9
GH Kaveri	961.24	90	39.4	151.6	862.3	895.4	649.5	303.8	222.1	95.3	7.1
GH Nethravathi	574	330	23.6	90.5	514.9	534.7	387.9	181.4	132.6	56.9	4.2
USIC and Elec. Block	554.27	150	22.7	87.4	497.2	516.3	374.5	175.2	128.1	55.0	4.1
Yogic Science	873	150	35.8	137.7	783.1	813.2	589.9	275.9	201.7	86.6	6.5

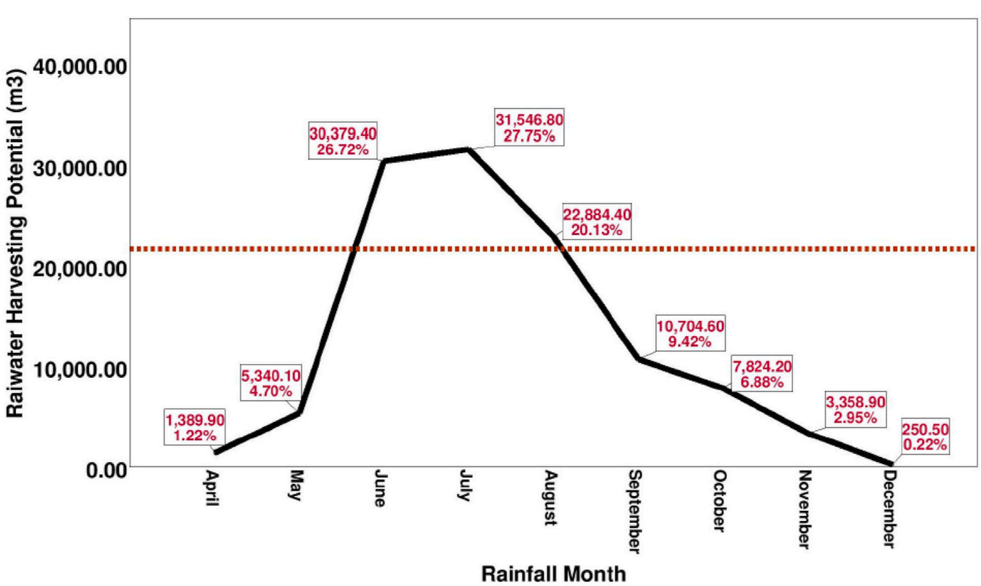

Fig. 10. Monthly rainwater harvesting potential.

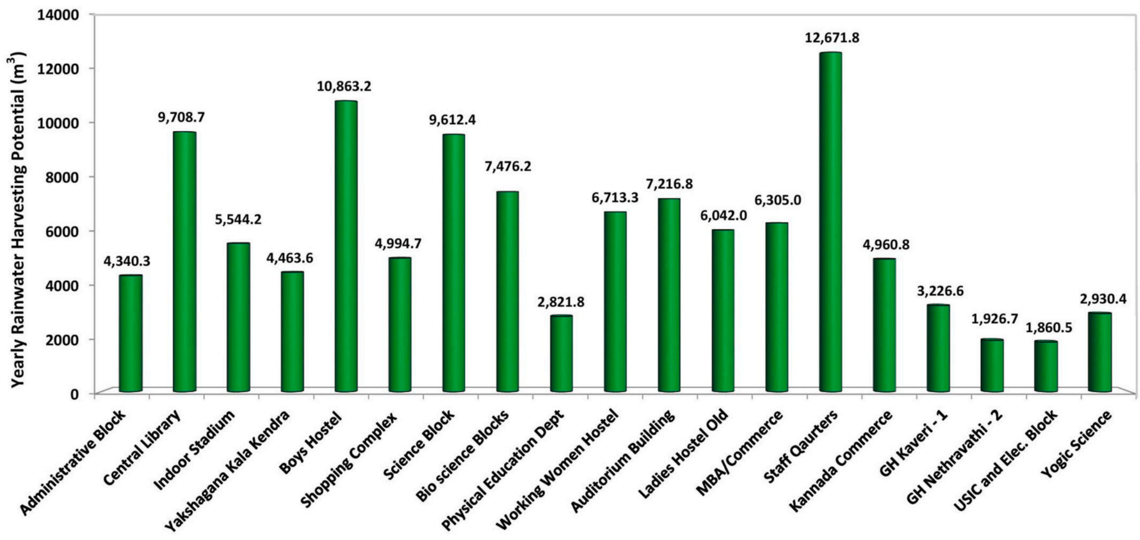

Fig. 11. Yearly rainwater harvesting potential for each building units.

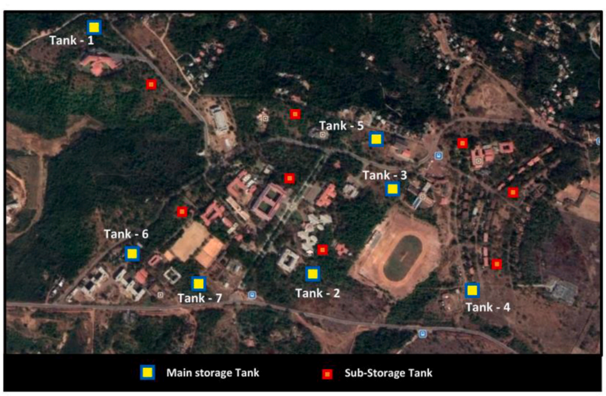

Fig. 12. Tank location map of SIU campus.

water during rainy season could be stored and re-used during summer period. Based on storage tank positioning and respective water demand of convenient establishments few conclusions can be drawn. With the contribution of harvested water from tank one, tank two, tank three, tank five, tank six and tank seven during June, July and August, the neighboring establishments like Administration block, Central library and MBA block, Ladies hostel, Guest house and Indoor stadium, Boys hostel block and Science block could easily sustain with its two months of water demand without external supply of water. Wherein the harvested storm water from tank four may be utilized to meet few of the staff quarters water demand.

To interpret the potential of RWH system a cumulative monthly storm water harvesting potential versus cumulative monthly water demand is plotted for seven storage tank (Fig. 14). It is evident that tank two & tank five has excess harvested water when compared to its monthly water demand. Wherein tank one, tank six and tank seven could marginally full-fill its water demand. Further tank three and tank four received very minimal quantity of storm water that is deficit when compared with high water demand in nearby establishments. April, May, August, September, October, November and December months of rainwater harvesting is represented using numerical series 1–9. This curve represents simultaneous usage of harvested water for fulfilling monthly water demand of respective building units. To resolve water scarcity problem the harvested water from rainy reason could be stored

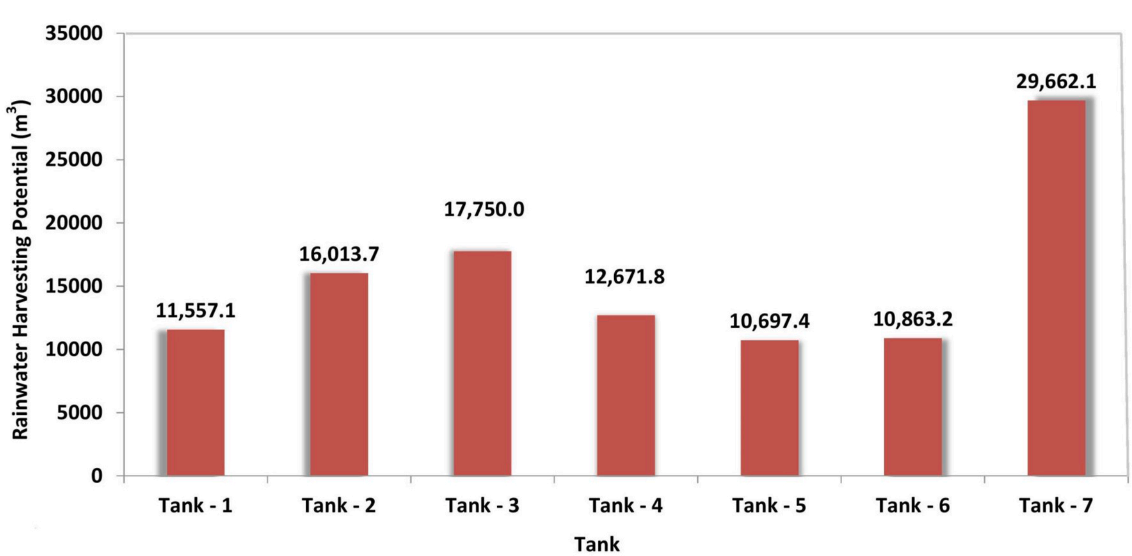

Fig. 13. Rainwater harvesting potential for selected storage tank.

Table 10
Yearly and monthly storm water inflow volume (m^3) for seven tanks.

	April	May	June	July	August	September	October	November	December	Yearly total
Tank - 1	141.3	542.9	3088.5	3207.2	2326.5	1088.3	795.4	341.5	25.5	11557.1
Tank - 2	195.8	752.2	4279.5	4443.9	3223.7	1507.9	1102.2	473.2	35.3	16013.7
Tank - 3	217.0	833.8	4743.5	4925.8	3573.2	1671.4	1221.7	524.5	39.1	17750.0
Tank - 4	154.9	595.3	3386.4	3516.5	2550.9	1193.2	872.2	374.4	27.9	12671.8
Tank - 5	130.8	502.5	2858.8	2968.6	2153.5	1007.3	736.3	316.1	23.6	10697.4
Tank - 6	132.8	510.3	2903.1	3014.6	2186.8	1022.9	747.7	321.0	23.9	10863.2
Tank - 7	362.7	1393.4	7926.9	8231.5	5971.2	2793.1	2041.6	876.4	65.4	29662.1
Total	1335.3	5130.4	29186.6	30308.2	21985.9	10284.3	7517.0	3227.0	240.7	

and utilized in summer season for required purpose.

4.9. Design of storage tank

An optimized storage tank volume is designed by having storm water inflow and water demand as a deciding criterion. Table 6 provides a detailed design specification with total volume and dimensions of the storage tanks positioned at seven locations within the SIU campus. The popular mass curve method is adopted to estimate the storage tank volume. To overcome the complication of maintenance the total volume is sub divided into smaller units. Except tank seven that has four individual units, all the remaining storage tanks have two units constructed side by side for optimal operation.

The two major factors deciding the optimized tank volume is intensity of precipitation (tank inflow) and required operation water demand (Rahman et al., 2012). The schematic diagram of proposed storage tank design for tank one is presented in Fig. 15. Based on the results from storm water quality analysis an uncomplicated gravel layered filter is adopted for the design. The coarse aggregates, pebbles and fine aggregates separated with thin layered mesh is recommended for a vertical filter composition. A periodic backwash or cleaning of filter material is advisable for effective filtering system. The walls of storage tank are built by laterite stone with cement plastering. Top and bottom slab are manufactured by Reinforced Cement Concrete (RCC). Based on the proportion of storage tank, the number of branched inlets could be designed for effective filtering system.

4.10. Cost estimation

Generally 95% of the total rainwater harvesting project cost is solely due to tank construction and increases largely through increase in size (Abdulla and Al-Shareef, 2009). The tank size mainly depends on rainfall, inflow water and water demand. A detailed estimation of construction cost considering local rate is illustrated in Table 7. The calculated total construction cost includes material rate, labour charges and land preparation cost excluding pipeline cost. To eliminate the loss due to leakage even water proofing cost has been added to the total construction cost. Increase in the capacity of water storage directly impacts the construction cost. Based upon the tank size, tank two and tank seven will involve higher construction cost when compared with tank one, tank four, tank five and tank six.

Two pumps of 50HP and 100HP are operated daily to transfer the water from Nethravathi River to SIU campus. Wherein 50 HP pump is operated for 18hrs and 100 HP pump for 12 h a day. The water is then treated with seven stage sand filter and disinfected at water treatment unit. Accordingly the unit cost of electricity comes out to be Rs. 3,59,160.00 (INR) per month. Hence by considering barely three months of water demand met through rain water harvesting the payback period for the total RWH system will be 13 years. This calculation does not include the maintenance cost of water supply equipment's and line. However because of rapid increase in water demand the prices on water are expected to increase thereby reducing the payback period (Santos and Taveira-Pinto, 2013).

4.11. Re-use of harvested storm water

When compared with conventional water supply system the harvested storm water does not need large treatment units since it is already free from various contaminants (Sturm et al., 2009). The harvested storm water could be directly reused for inferior activities like gardening, washing and cleaning. No ancillary treatment is required for such activities making the system more feasible. The water quality analysis has to be conducted to ensure the use of collected water for non-portable purpose. The conventional water supply may be adopted to fulfill the water demand on drinking, cooking and laboratory purpose. Provided adequate treatment to stored storm water it may be also utilized for bathing and dish washing purposes.

This SIU campus has many established garden area. The location and size of each garden area calculated using remote sensing tool is shown in Table 8. As recorded the total water consumed for garden maintenance is around 50,000 L per day. Hence the harvested water can be effectively used for maintaining all the garden area without major pre-treatment to it. The tank locations have been appropriately selected to ensure the gravity flow in most of the occasions.

The excess overflow from storage tank may be directed towards ground water recharge system wherein it contributes to increase in ground water table of the locality. This is one such initiative that should be taken up by the institutions to transform towards greener campus.

5. Conclusion

If hydrological opportunities are concerned then the RTRWH system is one of the supplementary systems for conventional water supply method. The success rate of RTRWH in Mangaluru may be high since rainfall is not extremely vulnerable in the region. Therefore, precipitation plays a vital role is deciding the efficiency of the RWHS. The present study illustrates the potential of implementing RTRWH system in SIU campus with Ecogeospatial RWHS for the community living. Approximately 1,13,678.9 m^3 of storm water may be captured with selected 19 rooftops of building units. A comprehensive quantitative and qualitative analysis on storm water and its rooftop harvesting potential is presented in this work. Additionally the article also provides an insight on economical aspects of rebate concept.

The cost of implementation is incomparable with rainwater harvesting methodology for providing sufficient good quality water is a social responsibility and public institution is a better place to start off with. It is underlying fact that the RWHS has its merits and demerits as other technological alternatives. This method is well suited for SIU campus since the water is conveyed from a long distance pipeline from Nethravathi River in order to fulfill the water demand of the campus. It is also evident that Mangaluru is being one of the fasted growing city in the state with the need for water is increasing every minute while ground water level is decreasing at faster rate. City being the education hub itself and chosen for Smart City Program, institutes like SIU should be a role model to get CII award for Excellence in Rainwater Harvesting. Hence this initiative could help SIU to be self-sustainable for water resources. Rather than completely replacing the conventional water supply system to RWH system it is advisable to have both systems

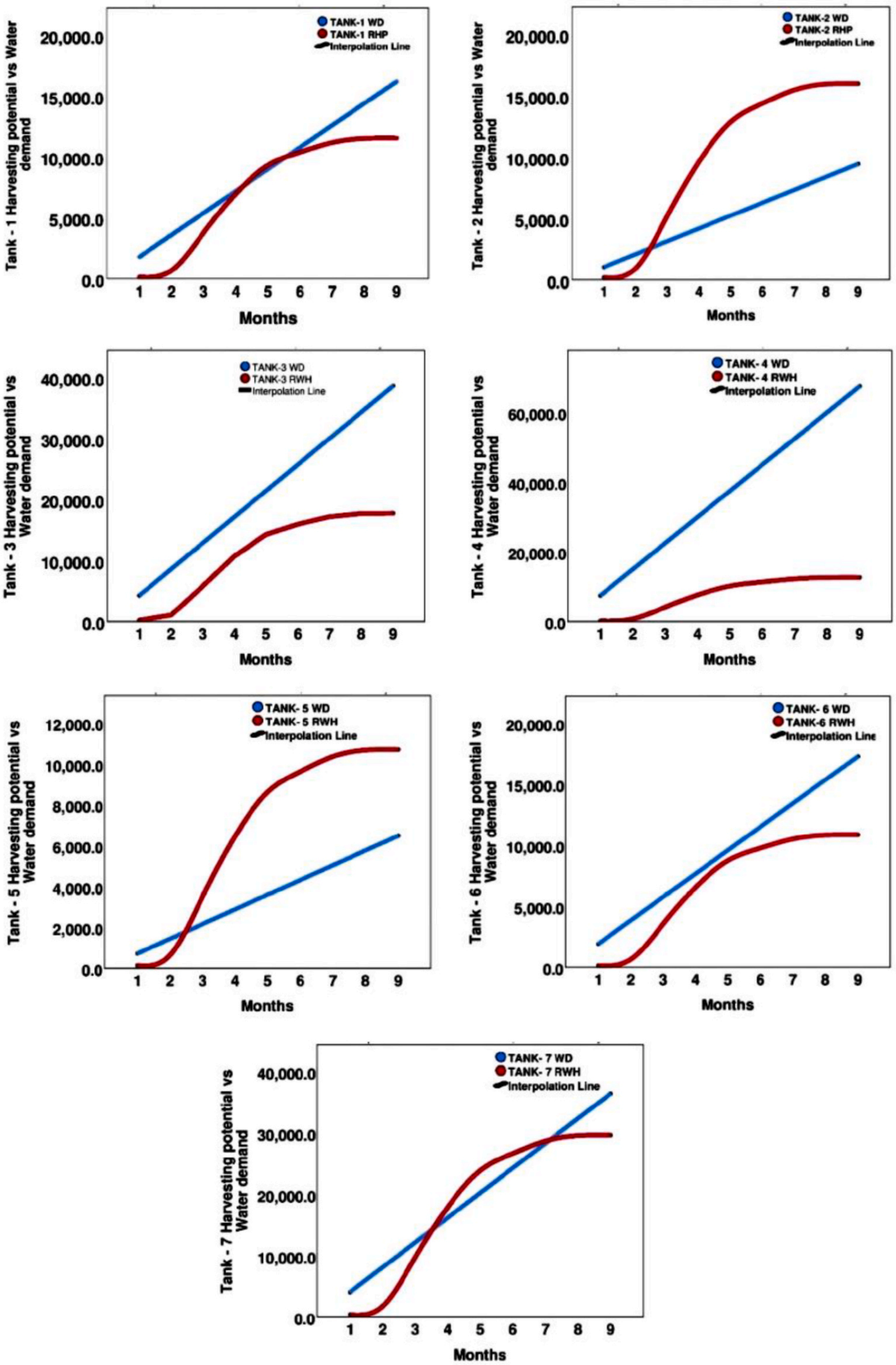

Fig. 14. Rooftop rainwater harvesting potential vs Water demand curve for seven storage tank.

simultaneously supporting each other. The conventional centralized water supply should be synchronized with and new decentralized RWHS. The captured storm water could be directly utilized for inferior operations like gardening, cleaning, flushing and washing purposes. The necessary quality analysis has to be conducted to make sure that the collected water could be used for non-portable purpose.

From the cost estimation of implementing RWHS it is clear that the payback period is about 13 years. Eventually the cost of the RWHS is directly depended on storage capacity hence a structured approach is essential before implementation. The majority of designed storage tanks may effectively fulfill the water demand for two to three months. Under such scenarios, RWHS could be justified with incurring construction cost when compared with existing system. In case of low rainfall the RWHS cannot pass through scrutiny of economic benefit for the present study area. Meanwhile the University can also plan to capture the ground water runoff and store it in open lake/pond. The present ground terrain and existing pond within the campus will be beneficial for this approach.

Further such RWH initiative should be supported by incentive from

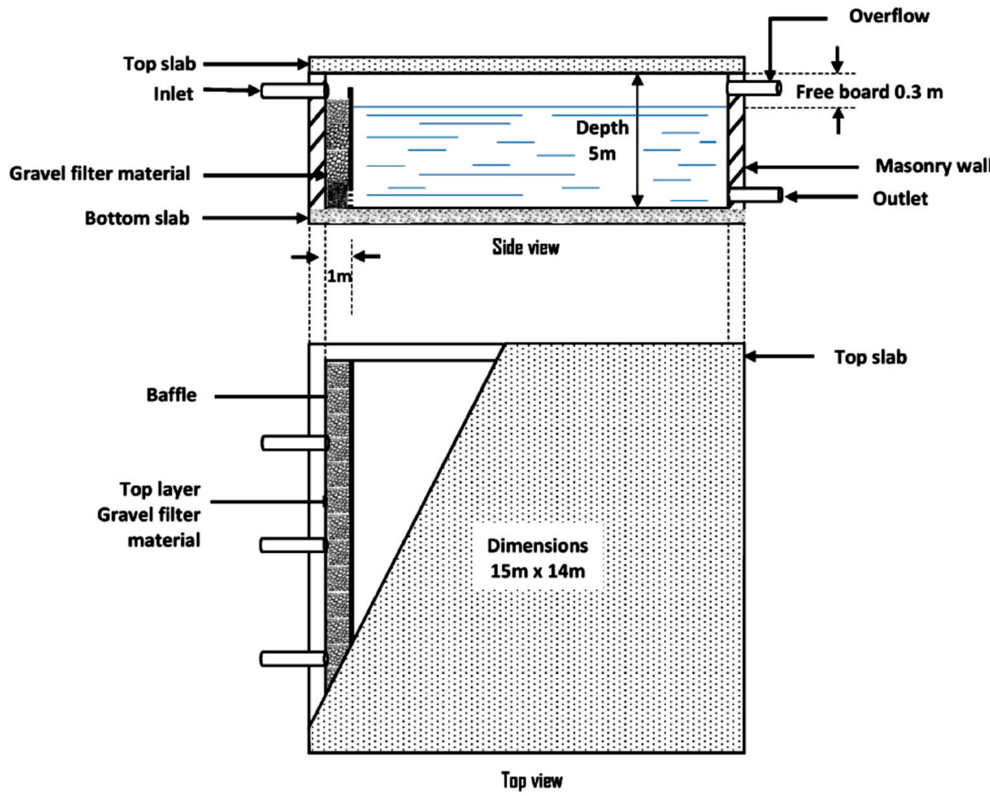

Fig. 15. Schematic diagram of designed storage tank (Tank - 1).

the government to encourage various sectors to take it further. Policies, water pricing and promotional activities should be practically and effectively designed before implementation. The future work includes a detailed survey of water demand based on particular activities, since it will guide to increase the efficiency of the system and complete cost estimation. Hence RTRWH is a simple, economical technique that is socially accepted and environmentally sustainable.

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