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Rainwater Harvesting-an alternative water supply in the Future for Pakistan

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Abstract

Availability of potable water is the major issue in countries like Pakistan. The problem has aggravated due to more population density and least permeable surfaces. Thirty year rainfall data obtained from Meteorological Department of Islamabad for the study areas of Rawalpindi and Lahore has been used to validate the inbuilt rainfall data of SamSam Rainwater Harvesting Model. The model worked out storage reservoirs for flat roof sizes of 110 m^2, 220 m^2, 280 m^2 and 400 m^2 with dwellers of 2, 4 and 8 number. To meet 45% needs of non-potable water demands, in areas with appreciable rainfall, the minimum suggested roof size is 220 m^2 for single family (4 persons) and 400 m^2 for two family units (8 persons). On the other hand, for areas with lesser rainfall, the minimum suggested size is 280 m^2 for single family and 400 m^2 for two family units. Implementation of such measures will help saving of 45% (almost half) of potable water.

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Introduction

Water scarcity is the biggest challenge all over the world. The problem is more pronounced in developing countries like Pakistan. Availability of fresh water is reducing against the increasing demands of growing and concentrating population. Water demand roughly doubles after every 21 years (Zhe *et al.*, 2010) over the globe. Rainwater harvesting is a technique used to collect and store rainwater and reuse it for various uses later on e.g. flushing, gardening, floor & car washing etc. Rainwater has great value for its purity and softness because its pH value is nearly neutral soon after occurrence of rainfall (The Texas Manual for Rainwater Harvesting, 2005). The rainwater harvesting has various advantages such as: water is free; its direct collection & storage near the place of use eliminates need of distribution system & its maintenance cost; good quality for various applications; it helps to reduce run-offs which otherwise cause street-flooding; it reduces need of fresh potable water for uses other than drinking; it decreases the costs of utility bills and helps to recharge the ground water. Rainwater harvesting system has six main elements which include catchment area, gutter with rainwater spout, filtration arrangement, storage system, treatment and delivery system (Che-Ani *et al.*, 2009). These elements are economical to be built, easy to be maintained and more effective if adopted at the scale of an individual house.

Studies indicate that rainwater harvesting techniques are being developed and practiced all over the world to address issues related to water scarcity for human use and to sustain the ecosystem. These studies (Marcelo and Enedir, 2011) have been carried out in Australia (Fewkes, 1999; Marks *et al.*, 2006), Brazil (Ghisi *et al.*, 2009), China (Li & Gong, 2002; Yuan *et al.*, 2003), Greece (Sazakli *et al.*, 2007), India (Goel & Kumar, 2005; Pandey *et al.*, 2006), Indonesia (Song *et al.*, 2009), Iran (Fooladman & Sepaskhah, 2004), Ireland (Li *et al.*, 2010), Jordan (Abdulla & Al-Shareef, 2009), Namibia (Sturm *et al.*, 2009), Singapore (Appan, 1999), South Africa (Kahinda *et al.*, 2007), Spain (Domènech & Saurí, 2011), Sweden (Villareal & Dixon, 2005), UK (Fewkes, 1999), USA (Jones & Hunt, 2010), Taiwan (Chiu *et al.*, 2009) and Zambia (Handia *et al.*, 2003), to name a few.

This study aims to suggest effectiveness of rainwater harvesting in new developments of major cities of Pakistan. Availability of potable water is becoming serious issue in Pakistan due to no urban planning in old areas of cities like Rawalpindi and Lahore, there is seen high concentration of population within few kilometers of the center of each city. If we look at the google maps (figures 1 and 2) of these two (Rawalpindi and old Lahore) cities, it is clear that there is a cementitious layer of roofs with only a few open spaces that are likely to get covered after few years. On the other hand new developments away from centers of these cities (refer figures 3 and 4) are being properly planned with adequate green spaces. But there is still no mechanism defined to harvest the rainwater at house-scale level. This mechanism will help to resolve the issues of water scarcity.

So far here in Pakistan, no studies have been carried out to point out planning measures while preparing master plan of a residential colony. This study got motivation from the fact that that ground water table in the Potohar region (Rawalpindi district and its surroundings) has depleted by 116m (380 feet) in the last 30 years as reported by WASA (Water and Sanitation Agency) Rawalpindi, in its finding in 2012. The underground water table is depleting very fast as shown in figure 5 below. Per capita availability of water is running out on fast pace (as shown in table 1) as it dropped to 850 cubic meters in 2013 as compared to 5,300 cubic meters in 1951. Pakistan has been placed in red zone by the Asian Development Bank (ADB) declaring it as water-stressed country and is likely to face an acute shortage of water in the next five years. Pakistan is likely to suffer water-scarcity in terms of major uses like water availability for irrigation, industry and human consumption. This paper shall focus on the steps that could be taken at public level to bring themselves out of this critical situation. Government departments will be required to make legislation to help community to enforce the suggested measures at the community level. The success of the suggested steps can be checked by implementing these on fast track pilot projects.

Material and methods

Study area

Rawalpindi with an appreciable amount of rainfall and Lahore with very less rainfall are the study areas in this paper.

Fig. 1. A view of Rawalpindi focusing Lalazar.

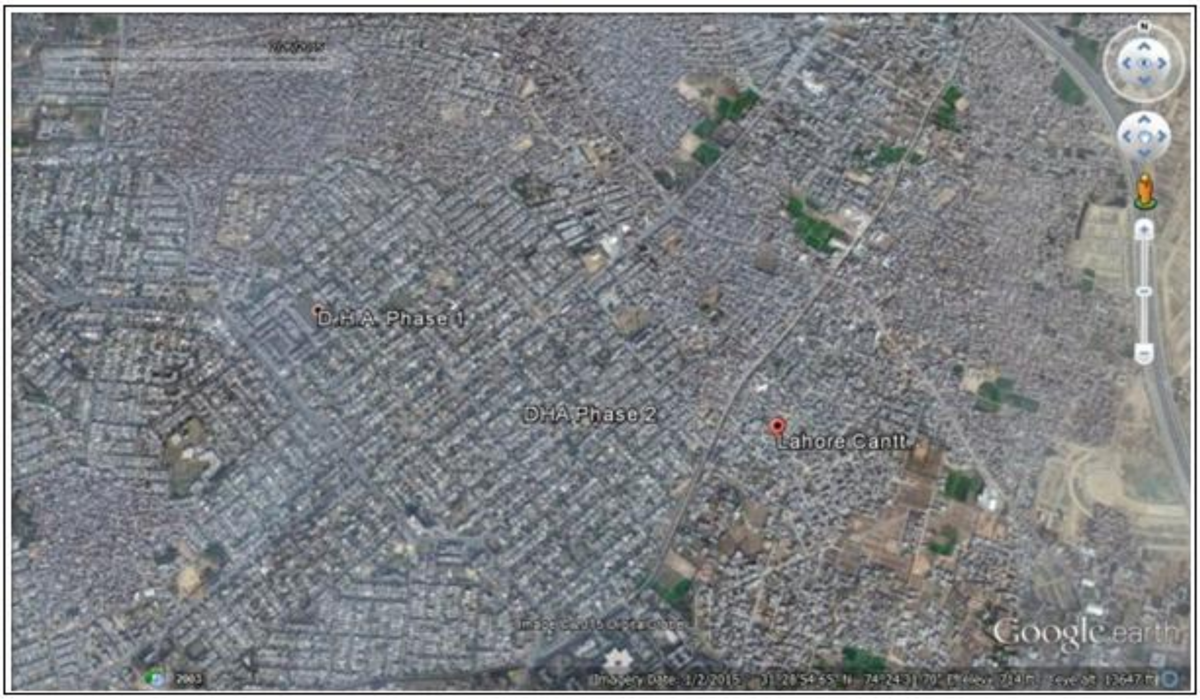


Fig. 2. A view of Lahore around Saddar.

Rawalpindi features a humid subtropical climate. In Rawalpindi and Islamabad most rainfall is accompanied by a thunderstorm with peak activity experienced in August. Record rainfall was experienced in the year 2013 at a massive 1,952 millimeters (76.9 in) mostly due to an unusual wet monsoon season.

Fig. 3. A view of planned Bahria Town Rawalpindi.

Lahore receives major rainfall during the monsoon season from June till September, and in winter season from December till February. The year 2011 with 1,576.8 millimeters (62.08 in) of rainfall recorded the highest-ever annual rainfall in Lahore. Lahore received below normal rains in 2009, and normal rains in 2007 and 2010.

Fig. 4. A view of Lahore extension areas.

Typical dwelling sizes of 25'x50' (roof area 110m^2), 35'x70' (roof area 220m^2), 40'x80' (roof area 280m^2) and 50'x90' (roof area 400m^2) located in Rawalpindi and Lahore have been studied.

Problem statement

The study is carried out to work out and suggest number and sizes of family in a particular size of dwelling keeping in view the climatology (rainfall) of the area, and water demands. The study shall also suggest ways and means to increase the ground water table.

Rainfall data and its analysis

The rainfall data for Lahore and that of Rawalpindi (Rawalpindi is almost similar to Islamabad) were collected from Meteorological Department Islamabad. SamSam Water Foundation has developed tools and methods which can support water and sanitation projects.

These tools are available for everyone; they have all type of relevant data available within a specified tool to work out the required output. The data is up-to-date and reliable. SamSam model is capable to determine the size of rainwater harvesting tank depending upon roof area, local rainfall pattern and size of household.

Rawalpindi receives rainfall slightly less than that occurs in Islamabad. Figure 6 (a) is based on rainfall data received for Islamabad from year 1981 to 2010 (30 years). Figure 6 (b) is the output of SamSam model for study area of Lalazar in Rawalpindi. The visual comparison of these two figures (a and b) indicates that the data is correct in SamSam for analysis on Lalazar in Rawalpindi.

Figure 6 (c) is based on rainfall data of Lahore received from year 1981 to 2010 (30 years). Figure 6 (d) is the output of SamSam model for Lahore focusing the study area of Saddar in Lahore. The visual comparison of these two figures (c and d) also indicates that data is correct in SamSam for analysis on Saddar in Lahore.

Methodology

The efficiency of rain water tanks provided for dwellings with roof areas of 110 m^2 (25'x50'), 220 m^2 (35'x70'), 280m^2 (40'x80') and 400m^2 (50'x90') with 2, 4 and 8 occupants have been analyzed. SamSam Rainwater Harvesting Tool (SRHT) has been used to check performance of rainwater tanks for each roof area mentioned above.

The tool consists of four steps i.e. location, roof size, water demand and results. It selects location based on google map. After marking location of study area on google map, click next to enter the data such as roof area, roof type (mostly flat concrete roofs exist in study areas), number of people using water (2, 4 and 8 for this study), and average water demand (227 liters per capita per day). In the last step, detailed results are displayed for further analysis and discussion.

Results and discussion

The summary of results obtained in SamSam Model for Lalazar in Rawalpindi and for Saddar in Lahore are given in Tables 2 and 3, respectively.

Table 1. Per Capita Water Availability.

Year	*Population (million)*	*Per Capita Availability (m^3)*
1951	34	5300
1961	46	3950
1971	65	2700
1981	84	2100
1991	115	1600
2000	148	1200
2013	207	850
2025	267	659

Source Draft State of Environment Report 2005.

Reducing use of fresh water at domestic level

It is dilemma of the day that fresh water that can be used for potable purposes is also being used bravely for the non-potable demands at household level. About 45% of the daily domestic needs are non-potable. These needs can be met best by using rain water stored during the times of rainfall. As the volume of monthly rain water varies from minimum (almost zero) during no-rain fall months to the maximum during heavy monsoon (figure 6), so we cannot construct very large storage tanks to store all annual rain fall volume, therefore, a SamSam model develops an average capacity of rain water storage reservoir for different categories of house dwelling sizes and occupancy which are presented in tables 2 and 3 of this study. These sizes may be constructed to fulfill non-potable water demands, thereby reducing the use of fresh water at domestic level.

Table 2. Summary of Input and Results for Rawalpindi.

							Summary of SamSam Model Results				*Domestic Use (%ages)*	
Study Area	*Plot size (ft x ft)*	*Roof Area (m^2)*	*Roof type*	*Number of residents*	*Water demand (lpcd)*	*(lpd)*	*Capacity of storage reservoir (liters)*	*(lit/day)*	*Percent*	*Remarks*	*(A) Toilet + Others* 45	*(B) Bathing+kitchen+laundary+Hot water* 55
LALAZAR RAWALPINDI	25 x 50	110	Flat	2	227	454	25900 (5700 gallons)	216	47.58	2 perons Ok	Rainwater Can meet (A)	Potable water source is required
				4	227	908	25900 (5700 gallons)	216	23.79	4 persons not ok.	Rainwater Can meet about half of (A)	Potable water source is required
	35 x 70	220	Flat	4	227	908	51900 (11400 gallons)	431	47.47	4 perons Ok	Rainwater Can meet (A)	Potable water source is required
				8	227	1816	51900 (11400 gallons)	431	23.73	8 persons not ok.	Rainwater Can meet about half of (A)	Potable water source is required
	40 x 80	280	Flat	4	227	908	66100 (14560 gallons)	549	60.46	4 perons Ok	Rainwater Can meet (A)	Potable water source is required
				8	227	1816	66100 (14560 gallons)	549	30.23	8 persons little ok.	Rainwater Can meet about half of (A)	Potable water source is required
	50 x 90	400	Flat	4	227	908	94400 (20800 gallons)	784	86.34	4 perons Ok	Rainwater Can meet (A) + part of (B)	Potable water source is required
				8	227	1816	94400 (20800 gallons)	784	43.17	8 persons ok.	Rainwater Can meet (A)	Potable water source is required

Table 3. Summary of Input and Results for Lahore.

							Summary of SamSam Model Results				*Domestic Use (%ages)*	
Study Area	*Plot size (ft x ft)*	*Roof Area (m^2)*	*Roof type*	*Number of residents*	*Water demand (lpcd)*	*(lpd)*	*Capacity of storage reservoir (liters)*	*(lit/day)*	*Percent*	*Remarks*	*(A) Toilet + Others* 45	*(B) Bathing+kitchen+laundary+Hot water* 55
SADDAR LAHORE	25 x 50	110	Flat	2	227	454	19800 (4361 gallons)	117	25.77	2 perons Ok	Rainwater Can meet about half of (A)	Potable water source is required
				4	227	908	19800 (4361 gallons)	117	12.89	4 persons not ok.	Rainwater harvesting not sufficient.	Potable water source is required
	35 x 70	220	Flat	4	227	908	39700 (8445 gallons)	235	25.88	4 perons Ok	Rainwater Can meet about half of (A)	Potable water source is required
				8	227	1816	39700 (8445 gallons)	235	12.94	8 persons not ok.	Rainwater harvesting not sufficient.	Potable water source is required
	40 x 80	280	Flat	4	227	908	66100 (14560 gallons)	549	60.46	4 perons Ok	Rainwater can meet (A)	Potable water source is required
				8	227	1816	66100 (14560 gallons)	549	30.23	8 persons little ok.	Rainwater Can meet about half of (A)	Potable water source is required
	50 x 90	400	Flat	4	227	908	94400 (20800 gallons)	784	86.34	4 perons Ok	Can meet (A) + part of (B)	Some Potable water req.
				8	227	1816	94400 (20800 gallons)	784	43.17	8 persons ok.	Rainwater can meet (A)	Potable water source is required

Sufficiency of Plot sizes in Master Planning

In Rawalpindi, where appreciable rain falls, all plot sizes for dwellings with roof areas of 110 m² (25'x50'), 220 m² (35'x70'), 280m² (40'x80') and 400m² (50'x90') may be planned but smallest shall be the least in %age of total land use for residential. In case of Lahore, where less rain falls, smallest plot size for dwellings with roof areas of 110 m² (25'x50') is not suggested to be included in planning as it increases the water demands, against more population concentration, not being met with rainwater harvesting.

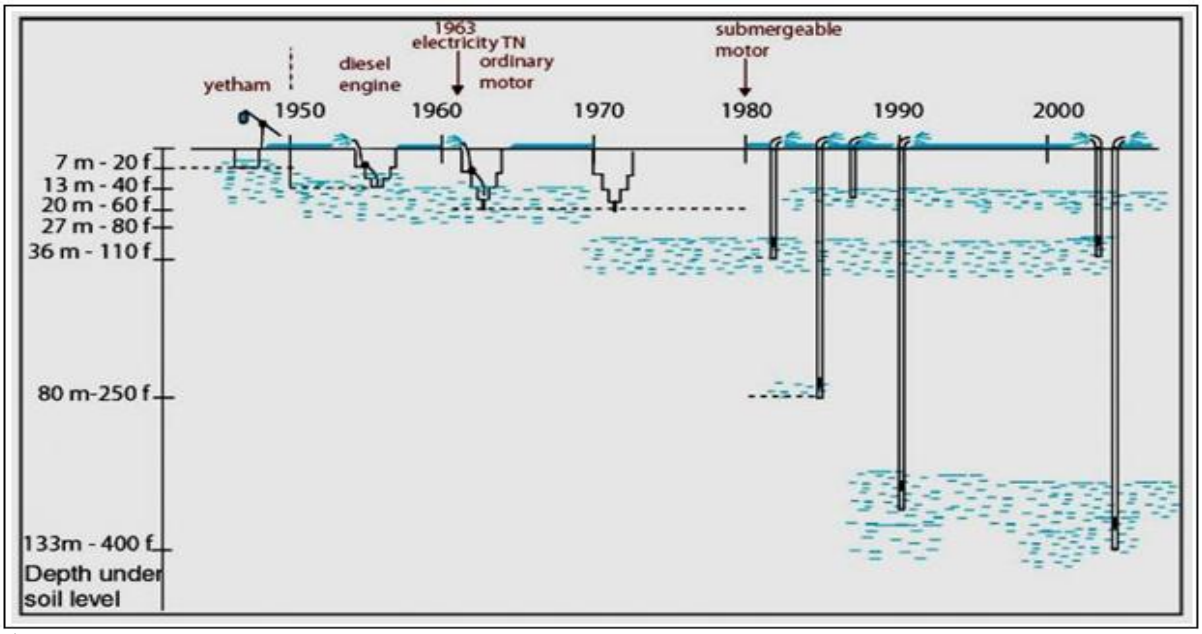


Fig. 5. Water Depletion - general trend (source: internet).

Check on family size in areas of appreciable rainfall:

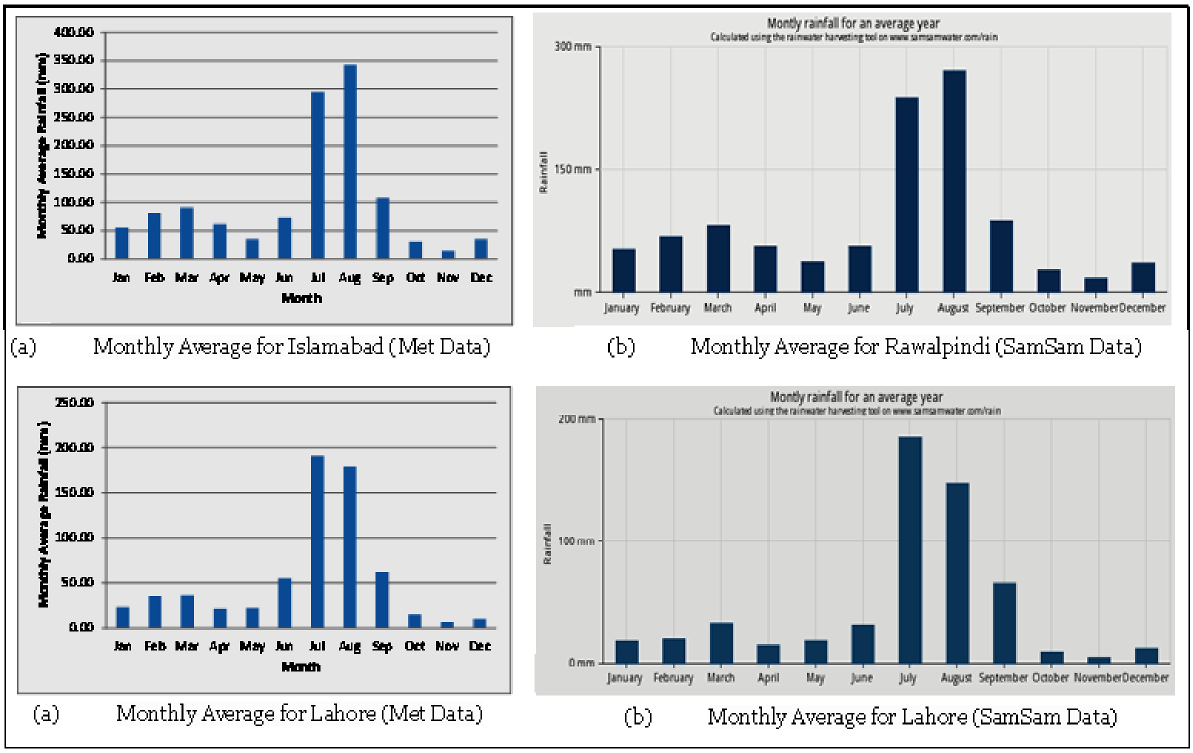
Table 2 shows that in Rawalpindi (with appreciable amount of rainfall): (a) 110 m² (25'x50') house with flat roof has sufficient size to accommodate 2 person and 4 persons at the most, (b) 220m² (35'x50') house with flat roof has sufficient size to accommodate 4 person and 8 persons at the most, (c) 280m² (40'x80') house with flat roof has more sufficient size to accommodate 4 person and 8 persons at the most and (d) 400m² (50'x90') house with flat roof has much sufficient size to accommodate 4 person and 8 persons. As the minimum expected size of family unit is expected to be 4, therefore, it is more desirable to have a minimum plot size of 35'x70' for a single family and 40'x80' (or 50'x90') for a two family unit, if rainwater harvesting is to be used to meet our daily domestic non-potable uses of 45%.

Check on family size in areas of less rainfall

The summary of results obtained in SamSam Model for Saddar in Lahore are shown in Table 3 below.

The table shows that in Lahore (with lesser amount of rainfall): (a) 110 m² (25'x50') house with flat roof has hardly sufficient size to accommodate even 2 persons, (b) 220m² (35'x50') house with flat roof has also hardly sufficient size to accommodate 4 persons, (c) 280m² (40'x80') house with flat roof has sufficient size to accommodate 4 person and 8 persons at the most and (d) 400m² (50'x90') house with flat roof has more sufficient size to accommodate 4 person and 8 persons.

As the minimum expected size of family unit is expected to be 4, therefore, it is more desirable to have a minimum plot size of 40'x80' for a single family and 50'x90' (or 50'x90') for a two family unit, if rainwater harvesting is to be used to meet our daily domestic non-potable uses of 45%.



(a) Monthly Average for Islamabad (Met Data) (b) Monthly Average for Rawalpindi (SamSam Data)

(a) Monthly Average for Lahore (Met Data) (b) Monthly Average for Lahore (SamSam Data)

Fig. 6. (a to d): Comparison of Met-data and SamSam Model data.

Conclusions

Appropriate sizes of rainwater harvesting tanks shall be constructed as modeled in SamSam rainwater harvesting model (tables 2 and 3). The minimum sizes of plot are required to be increased in new developments so that density of population can be reduced and more rainwater be captured for less use. For areas with appreciable rainfall (like Rawalpindi) the minimum suggested size is 35'x70' for single family (4 persons) and 50'x90' for two family units (8 persons). On the other hand, for areas with lesser rainfall (like Lahore) the minimum suggested size is 40'x80' for single family (4 persons) and 50'x90' for two family units (8 persons).

These sizes will support use of rainwater for flushing and other uses (except potable) which account 45% of daily usage. It means by adopting rainwater harvesting system with suggested sizes of storage reservoirs (mentioned in tables 1 and 2) and limiting the family units/sizes, there will be a saving of 45% of potable water. In other words, need of potable water will get reduced by 45% (almost equal to half) as compared to the needs of today.

Additionally, the construction of soakage wells/pits to receive excess rain water during the months of heavy rainfalls and directing this excess rainwater for groundwater recharge would swell the underground water aquifer volume.

Even if we do not reuse rain water, if we are able to construct wells of sizes equal to the suggested rainwater harvesting tank sizes having soaking mechanism, it will help to raise ground water level to fulfill our daily needs. Additionally, pouring of 85% daily water demand (15% toilet use cannot be used for recharging) in to the soakage pit(s) will help a lot in recharging the ground water reservoir and these steps will help us regain the water-tension free times of 30 years back.

Acknowledments

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work out rainwater harvesting for any specific site.

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