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Impact of Roof Rain Water Harvesting on Domestic Water Consumption and Rural Livelihood: A Case Study in the Badulla District

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ABSTRACT. *Roof Rain Water Harvesting (RRWH) has received considerable attention since 1995 in the water short districts of Sri Lanka. In the past few years, many studies were conducted to evolve technical alternatives for RRWH, but less emphasis was given to the impact of RRWH on consumption and rural livelihood. The present study was conducted to assess the impact of RRWH on domestic water consumption and rural livelihood in the Badulla district. Data were collected by an interview survey of 60 randomly selected households from two villages in the Badulla district. Domestic Water Scarcity Index (DWSI) was computed. Descriptive statistics and non-parametric statistical tools were used as analytical tools. The results clearly indicate that RRWH has increased water consumption and water security by as much as 50% during the wet season. The improved water security has given the users time for leisure and productive use, which have added quality to their life. Negative attitudes on the quality of the rainwater and poor management practices adopted by people are found to be the major constraints to the sustainability of the RRWH technology. It is recommended that awareness generating programmes be initiated about both quality and quantity of rainwater and RRWH systems.*

INTRODUCTION

The present policy of Sri Lanka on water supply is "some water for all, rather than more water for some" as endorsed at the New Delhi global consideration in 1990. The present level of water supply coverage in Sri Lanka stands at 89% in urban and 60% in rural areas. Sri Lanka needs an investment of Rs. 8000 million annually to supply safe drinking water to all by 2010 (Abeyaratne, 1998). Achieving this level appears to be difficult due to technical, financial and institutional reasons. Further, there is growing conflict among water users, drying up of water resources and growth of demand for water due to population pressure. It is estimated that Sri Lanka will face a water deficit of 1400 million m^3. The estimates also indicate that 33000 m^3 or 65% of the runoff to the sea, which is a vast potential, can be trapped to meet the ever increasing demand for water in Sri Lanka. The total annual run off in Sri Lanka is approximately estimated at 50000 million m^3 of water (approximately 20% of the mean annual rainfall), of which a substantial proportion is now utilized for irrigation and hydropower. Surface water and groundwater is under pressure due to urbanization, deforestation and pollution. Therefore, to meet the growing demand on water supplies, new types of water sources needs to be developed. Given this situation, roof rainwater harvesting (RRWH) to meet the water supply needs of the rural and urban

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population has a tremendous potential. While rainwater harvesting has a broad generic description in the rural context as water collected mainly for agriculture purpose, RRWH has a clear definition as water collected from rooftops chiefly for domestic consumption. In view of the existing constraints faced by the authorities in meeting the increasing demand for water, it is vital that RRWH be used as a new source of water in the areas that cannot be serviced by the existing schemes.

Rainfall in all zones of Sri Lanka is adequate to initiate rainwater harvesting (Chandrapala, 1996; Rajkuma, 1998). A feasibility study of rain water harvesting for domestic purpose revealed that RRWH can be successfully practised in Sri Lanka (Hapugoda, 1995). In 1995, the World Bank sponsored the Community Water Supply and Sanitation Project (CWSSP), which introduced RRWH through roof surface for domestic use, in three wet zone districts: Badulla, Matara and Ratnapura. Under this project, two types of $5m^3$ storage tanks were introduced to each household. Both collect roof runoff through a system of gutter and down pipes. They also introduced sand filter and hand pumps to draw water from under ground tanks and that facilitated improvements to the quality of water (Lanka Rainwater Harvesting Forum 2000). Though the initial reaction to RWH technology was negative, it was later accepted by many people who have started to adopt RWH as a source of domestic water (Ariyabandu, 1998). The Lanka Rain Water Harvesting Forum, formed in 1996, aims to foster, disseminate and research into the potential of utilising rain water as an option for domestic water supply in Sri Lanka.

In the past few years, many studies were conducted to evolve technical alternatives for RRWH, but less emphasis was given to the impact of RRWH on consumption and rural livelihood. Heijnen and Mansur (1998) and Ariyananda (1999) investigated the improvement in water security of the RWH beneficiary community and showed that RRWH remains neglected due to lack of awareness and recognition by the policy makers on the technology, Visvanath (2001) reported similar issues in RRHW in India and stressed the necessity to monitor and learn more from implemented projects.

Thus, this study attempts to assess the impact of roof rainwater harvesting on the contribution to domestic water needs and the changes on rural livelihoods as an optional water source in the Badulla District. This study also aims to investigate the constraints in RRWH and suggest policy recommendations for improving the RRWH system.

METHODOLOGY

The study area

The study was conducted in Badulla, where of the 10,000 RWH units in Sri Lanka over 5000 applications are found. Two villages Ehala Kotawara and Pahala Kotawara were purposely selected for the field investigation. The area receives more than 1200 mm of annual rainfall and the duration of rainfall is limited to a few months (October to January). The rest of the months receive very little rainfall. Villagers who live in this area do not have their own water sources and water is fetched from long distances. Organized rainwater harvesting systems were introduced by CWSSP in 1997 as an optional domestic water source. Using the stratified random sampling method, 30

each from RRWH households and non-RRWH households were selected from the two villages, which made a total of 60 respondents for the study.

Data collection and empirical procedure

The researcher personally interviewed each of the selected respondents with a structured schedule. The schedule consisted of open-ended questions, to assess the level of awareness of households about RRWH benefits and limitations. The data collected were supplemented by information collected by observations. Data were collected during April to May in 2002. Descriptive statistics and non-parametric statistics were used as analytical tools.

Domestic Water Scarcity Index (DWSI)

To measure contribution of rainwater harvesting to water availability, the domestic water scarcity index (DWSI) was developed. The DWSI developed by Weligamage (1998) was used as a base for this. Weights were assigned to water sources to depict increasing water scarcity as using a greater number of sources. DWSI was calculated for each water use identified in the households. Weights were assigned according to volume of water used by an individual for different uses as follows:

i) Drinking and cooking = 0.20
ii) Washing of utensils = 0.25
iii) Sanitation = 0.25
iv) Laundry = 0.30

Final cumulative DWSI (CDWSI) was calculated as a weighted DWSI. Two components, (a) IMS (Indicator of multiple sources) and (b) IDS (Indicator of distance to source) were used in calculating DWSI for each water use.

$$DWSI = \{(IMS + 2IDS)/3\}100$$

Non-parametric statistical tool (Wilcox on Matched pairs signed ranks test) was used to measure the impact of rainwater harvesting. The impact of rainwater harvesting was evaluated through responses of the people. Each response was categorized into five variable groups and scores also assigned.

RESULTS AND DISCUSSION

Contribution of roof rainwater harvesting for domestic water scarcity in wet and dry seasons.

The distribution of rainwater harvesters and non-rainwater harvesters and the related domestic water scarcity index (DWSI) in wet and dry seasons is presented in Table 1. The results show that DWSI of rainwater harvesters is low compared to non-rain water harvesters. This is due to water being fetched from long distance for all domestic purposes by non-rainwater harvesters. DWSI is low being for three non-rainwater harvesters, the main reason they have their own dug wells as a main water source.

Table 1. Households domestic water scarcity index in wet and dry seasons.

Households	Domestic Water Scarcity Index (DWSI)		
	Wet Season		
	Low (<3)	Medium (3 – 6)	High (>6)
Roof Rain Water Harvesters	22	5	3
Non Rain Water Harvesters	2	12	16
		Dry Season	
	Low (<7)	Medium (7-10)	High (>10)
Rain Water Harvesters	10	12	8
Non Rain Water Harvesters	3	19	8

Wet season X^2 calculated = 30.557 χ^2 table – 13.815 Significant level - * 0.001
Dry season χ^2 calculated = - 6.621 χ^2 table – 5.991 Insignificant level - 0.050

In the wet season, DWSI ranged between 1.20 and 14.37 among rainwater harvesters and for non-rainwater harvesters it ranged between 2.52 and 17.58. In the dry season, DWSI ranged between 2.37 and 17.81among the rainwater harvesters and for non-rainwater harvesters it ranged between 2.82 and 19.63. According to chi-square test, there is a significant difference in DWSI between rainwater harvesters and non-water harvesters in the wet season, but not in the dry season. It may be inferred from these findings that RRWH benefits can be expected manly in the wet season and its usefulness is limited in the dry season.

Contribution of rainwater for domestic consumption

The contribution of stored rainwater for domestic water requirement is more than 80% in the wet season. Since rainwater tanks provide water as a home based source, it is directly used for domestic purposes easily. The households used stored rainwater mainly for sanitation, washing utensils, and washing clothes. Water is fetched from other sources for drinking and cooking only. About 13% of the households used rainwater for drinking purposes. These householders fetch one or two pots of water from other sources after the introduction of rainwater harvesting tanks. About 10% of households used other sources as the main water source. Rainwater tanks of these households have not been properly managed. Water leaks in other tanks due to fracture in the tanks.

Rainwater usage in the dry season is very low; it is less than 40% of the total domestic water requirements of all the households. Stored rainwater is mainly used for sanitation and washing utensils in the dry season. Rainwater could not be used for drinking and cooking during the dry season due to low quality of rainwater and low amount of water in tank. When the rainwater is stored in tanks for many days, the quality is reduced. Therefore, water in the tank has been used for domestic water needs as early as possible. Three or four months can be considered as the dry season and during this time other water sources have been used for domestic water needs. Contribution of stored rainwater for domestic water needs is low in the dry season. None of the rainwater-harvesters have used rainwater tanks as a main source.

Further, the investigation revealed that before the adoption of RRWH the average water consumption of rainwater harvesters was 21 liters per capita per day (lpcd). After the adoption of RRWH, the average water consumption has increased to

39 lpcd. Accordingly, the water consumption of rainwater harvesters has increased by as much as 50%. However, compared to the estimation (28 lpcd and 43 lpcd) in 1998 by Ariyabandu in Badulla district, these figures are low. This indicates the growing scarcity of water and the importance of RRWH to meet the growing domestic water demand.

Time spent on fetching water

Table 2 presents the difference between the water collecting time between the wet and the dry seasons. Time taken to collect water depends on the distance from house to the water source. Time taken varies between 1 and 3 h in the wet season and 3 and 5 h in the dry season. Less than one hour has been spent for fetching water by more than 50% of rainwater harvesters in the wet season. This situation completely changes in the dry season due to low amount of rainwater in the tanks and low quality of rainwater. More than three hours have been spent for fetching water by 31% of rainwater harvesters in the dry season.

Table 2. Time spent to fetch water for domestic requirement during wet and dry seasons.

Time spent / Water fetching / Day	% of Households	
	Rainwater Harvesters	Non Rainwater Harvesters
	Wet Season	
< 1 hr.	53 (16)	07 (02)
1< - < 2 hrs.	37 (11)	43 (13)
2< - < 3 hrs.	10 (03)	50 (15)
	Dry Season	
< 2 hrs.	37 (11)	10 (03)
2 < - >3 hrs.	32 (10)	22 (07)
3 < - < 5 hrs.	31 (09)	68 (20)

* Figures in parenthesizes indicate the number of households.

Rainwater harvesting tanks have not been properly managed due to time constraints. Due to this reason water is fetched from other sources. Non-rainwater harvesters spent more time for collecting water from long distances.

There is a significant difference in time spent on fetching water before and after rainwater tank establishment (Table 3). Prior to the introduction of roof rainwater harvesting tanks, rainwater harvesters had to walk in steep terrain 3 - 5 times a day to fetch water. On average they spent 2 – 6 h per day to collect water for domestic water needs. Time spent on collecting water before and after establishing roof rain water-harvesting tank shows a significant saving of time (about 30%) in the dry season. Table 3 indicates that 21 households spent more than 3 h per day for fetching water prior to the introduction. However with the introduction of rainwater tanks this was reduced to 12. These households have properly managed rain water-harvesting tanks and also adequate measures were taken by them to cope with water shortages.

Table 3. Time spent by households per day for fetching water before and after establishment of rain water harvesting tank.

Rainwater Harvesting Tank Establishment	Number of Household			
	Wet Season		**Dry Season**	
	Time spent per day		Time spent per day	
	< 1 hour	> 1 hour	< 3 hour	> 3 hour
Before	4	26	9	21
After	22	8	18	12

Wet Season X^2_{cal} – 25.338 χ^2_{table} – 10.827 Significant level - 0.001
Dry Season X^2_{cal} – 5.454 χ^2_{table} – 3.841 significant level - 0.050

Impact on water security and water consumption

Result of the Wilcoxon signed rank test on the peoples' perception of the consumption of water evidenced a significant increase in water consumption after the introduction of RRWH (Table 4).

Table 4. Peoples perspective on water security and water consumption. (Result of the Wilcoxon singed rank test)

Criteria	No. positive	No. Negative	Mean	Z value	Probability
After rainwater harvest tank establishment Household water consumption and water security	5	12	0.941	29.0	0.020**

According to the household perspective, after the introduction of rain water harvesting tanks, water consumption level and water security have increased significantly. The most significant impact of the roof rain water harvesting is the assured supply of domestic water needs. Water security has increased due to the use of rain water. This has obviously led to increased use of water for consumption.

Conflicts related to water use

Peoples' perspective on conflict among people relating to water use after establishment of rain water harvesting tank was tested and results are presented in Table 5.

The wilcoxon-signed test evidenced that the conflict between people related to water use has significantly reduced after the establishment of rain water tanks. Less amount of water fetched from other sources and reduction in the use of common water.

source by rain water collectors have contributed to reduce conflict for water among people.

Table 5. Peoples' perspective on conflict among people related to water use.

Criteria	No. Positive	No. Negative	Mean	Z value	Probability
Conflict among people related to water	39	5	1.667	942.6	0.000**

Impact on social life

Prior to the adoption of RRWH, social life of rain water harvesters was restricted due to lack of adequate water. This specially affected the women, who were responsible for carrying water. People in the two villages indicated that due to time spent on fetching daily water they had to restrict their social visits, personal development, entertaining friends and relations. When young girls had to attend festivals and social functions outside the village, they had to fetch more water per day to compensate for their absence. After the introduction of roof rain water harvesting tanks most of these problems have been reduced. The presence of assured water has changed their life style significantly. With availability of a roof rain water-harvesting tank, the users could entertain friends and relations, indulge in social visits and attend to career development programs.

Quality of roof rainwater

More than 90% of the household perception regarding quality of rain water was that it is not fit for drinking, and also 24% of the households think that rain water is good for cooking purposes. The main reasons for this situation are roof litter and bird droppings flowing with water into the tank and mosquito and other insects breeding in the tank. Another important factor is the taste of the rain water, which is mainly due to low amount of minerals in rain water. People's perception regarding quality of rain water is one factor that threatens the sustainability of rain water harvesting systems.

Technology adaptability

Table 6 shows the technology adopted by households to harvest clean rain water. Only 3% of the households have adapted more than four management practices together. Down pipe was disconnected for a few minutes during rain as a first flush system. However, it was not properly carried out. About 3% of the households used separate down pipe with flush system but pipe height is not enough. Water extraction device was used by 27% of the households, and tap was used as a water extraction device. No households used hand pumps. Bucket was used to take water from tank. Due to this practice the tank lid was opened several times per day which leads to contamination and mosquito breeding in tank. Roof litter and other particles were stored in tank with water since filters were not used. Poor level of adoption of appropriate techniques is the main constraint for expanding the use of rain water harvesting technology.

Table 6. Technology adopted for rain water harvesting.

Adopted technology	% of household
Use of filter	13 (04)
First flush system	23 (07)
Water extraction devices	27 (08)
Tank covered by lid	76 (23)
Filter and first flush system	10 (03)
Filter, lid, water extraction device	8 (02)
Filter lid, water extraction device, first flush system	3 (01)

* Figures in parentheses indicate the number of households.

About 53% of the households have cleaned the tank once per year. About 40% of the households have cleaned the tank 2 or 3 times per year. Other rainwater tanks were not cleaned even once a year. Due to this reason roof litters and other organisms were stored in the rainwater harvest tank and reduced the quality of rainwater. Among 60% of the households, roofs were not cleaned even once a year. Cleaning the gutters was not properly done. Due to these poor management practices, quality of the rainwater is poor. Low adoptability of management practices is the main constraints for the efficiency and sustainability of rainwater harvesting system.

CONCLUSIONS AND RECOMMENDATIONS

The result of the study clearly reveals that roof rain water harvesting has significantly reduced water scarcity and doubled the water consumption among rain water harvesters compared with non-rain water harvesters in the wet season. More than 80% of rainwater is used for domestic water requirement in the wet season. Rain water is used mainly for sanitation, washing utensils and washing clothes. About 13% of the households used rain water for drinking purposes. Rain water usage in the dry season is very low (40%). The use of RRWH option has significantly reduced the time in fetching water from other sources and conflicts among the people with regard to water usage. The saved time in fetching water has been used for household activities, productive activities and has a significant impact on the social life, especially of women. Findings of this study demonstrate that people's perception of the quality of rain water is not favourable. It is a major constraint for sustainability of roof rain water harvesting technology. Poor management practices and low technology adopted by roof rain water harvesters are the limitations to RRWH technology.

The following recommendations could be made on the basis of the study findings:

Roof rain water harvesting could be recommended, as an optional water source for domestic water needs for wet season although its usefulness is limited in the dry season.

Through awareness programmes, people should be educated on maintenance and operation of the RRWH system to ensure collection of good quality water.

Also research should be carried out in this sector to improve RRWH technology and investigate impact on the quality of life.

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