Effectiveness of Rain Water Harvesting (RWH) Systems as a Domestic Water Supply Option

Report Submitted to

Water Supply & Sanitation Collaborative Council (WSSCC)

Through

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by

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1. Introduction

1.1 Background

The present drinking water supply coverage in Sri Lanka is estimated to be 78%. Out of this 35% of the population enjoys piped borne water supply service. The balance 43% relies on sources such as dug wells, tube wells, spring and rain water harvesting. Due to lack of surface and ground water resources some locations, alternative drinking water supply facilities need to be promoted among people in Sri Lanka in order to achieve the MGDs. The Sri Lanka's target is to provide drinking water supply to all citizens by year 2025. It is estimated that approximately 31,000 domestic rain water harvesting units have been constructed under varies water supply development programs in all provinces of Sri Lanka during the last few decades. However, recent studies reveled that due to several reasons, substantial percentages of domestic rain water systems owners were reluctant to use rain water for drinking. This will undoubtedly make a huge impact on other rainwater users if these concerns are not properly understood and addressed. This proposal was formulated following a discussion held at the Water Supply & Sanitation Collaborative Council support meeting held in Sri Lanka.

Sri Lanka has a long history of rainwater harvesting, using both traditional (e.g. harvesting rainwater using broad leaves or from tree trunks) and modern structures. In rural villages, many people have informally collected rainwater from the roofs of their homes for storage in small-large containers for many years.

Large scale household Rural Rain Water Harvesting (RRWH) was introduced to the country under World Bank funded Community Water Supply and Sanitation Project I (CWSSP I) around 1995 in Badulla and Matara districts.

Since the completion of CWSSP number of other organizations and institutes have taken up to rainwater harvesting as a means of supplying water to water short households both in the wet and dry zones. Some of the noteworthy contributions in rainwater harvesting for domestic use are National Water Supply Drainage Board through ADB 3rd and 4th Water supply and Sanitation projects, Southern Development Authority, Lanka Rain Water Harvesting Forum (LRWHF) and Sarvodaya. It is estimated in August 2009 that at least 31,000 RRWH systems have been installed around Sri Lanka, covering most of the country (http://www.lankarainwater.org/rwhsl/systems.htm). Realizing the importance of rain water harvesting as a solution to overcome the water scarcity in the country the government of Sri Lanka passed a national policy on rain water harvesting in 2005 http://www.lankarainwater.org/rwhsl/policy.htm. The importance of promoting this concept was further emphasized when a declaration was signed by the relevant minister of 5 SAARC countries http://www.lankarainwater.org/rwhsl/joint_decalration_kandy_2006.pdf during an International workshop held in Kandy, Sri Lanka in 2006 and the mention of rain water harvesting in the SAARC Declaration made in Colombo 2008 (http://www.news.lk/index.php?option=com_content&task=view&id=6621&Itemid=44).

1.2. Literature Review

Even though both the government and other organization is actively promoting rain water harvesting, there hasn't been any empirical and coordinated studies or surveys conducted to evaluate the effectiveness of this technology as an alternative domestic drinking water source in rural Sri Lanka.

A study conducted by Ariyabandu, (1998) of rain water harvesting tanks in Matara and Badulla district which was constructed during the period 1995-1997 by CWSSP 1 reports that beneficiary households use rain water for 65% of their water demand and only 33% is fetched from other water sources. As a result there was a reduction in more than 50% water collected from dug wells. However, in Dematawelihinna in Dikkapitiya less than 10% of the Rain water users used it for drinking purposes. Most reason for not drinking rain water is the perception of water quality. Lacks first flush or filters in these system thought to be contributing to low confidence in water quality.

Study conducted few years later in Badulla district by A.J.M. Gunasekara and S Thiruchelvam (2002) indicates that rain water harvesting has increased the water consumption and water security in the household as much as 80% during the wet season. However, during the dry season the rain water usage is low as 40%. Similar to the earlier study, negative attitude on quality of the rainwater and poor management practice adopted by people were found to be the major constraint to the sustainability of the rain water harvesting system by this study.

Study conducted by 3rd ADB Water Supply and Sanitation project office in Hambantota district in of rain water harvesting units constructed in 4 Divisional Secretariat Divisions of Hambantota finds that rain water units constructed in high rainfall areas such as Katuwan the beneficiary use the units solely to collect rain water. Other divisions such as Hambantota, Ambanlantota and Tangalle, during period of drought the tanks are filled with water brought from bowsers and other water sources. However, 83%-90% of the households in all 4 areas use the water for drinking and cooking purposes.

A study conducted in 10 District Secretariat divisions in Anuradhapura district reports that more than 85% households use stored rainwater for drinking (M.A.C. S. Bandara, M.Sc Thesis 2010). For 71% of these households it is the most crucial water source during the dry season. Easy access of water, cleanliness and quality assurance by project partners were the main reasons given for drinking stored rain water.

Analysis of water quality of the rain water systems during this study has reveled that chemical and physical quality of the stored rainwater meet the Sri Lanka standard (SLS) of potable water quality. Most of the biological water quality parameters were also within the acceptable range with respect to potable water quality standard in Sri Lanka. However, number of sample has reported non acceptable level of Total Colioform. Similar results are reported by other authors on water quality studies. Ariyananda 2000 and 2003 reports no chemical contamination in stored rain water except high pH values in new tanks due to cement dissolving and low pH values in rain water collected in urban areas (Colombo) due to local pollutions of the atmosphere. Some studies show high turbidity levels in collected rain water and increased levels during rainy period (Padmasiri, 1998). High turbidity and colour was also recorded from rain water tanks in Dematawelihinn in Badulla district was thought to b due non application of first flush devises in these systems (Heijnen and Mansur, 1998).

In a study conducted in 4 countries including Sri Lanka in both rural and urban areas, more than 54% of the samples records less than 10 *E.coli* per 100 ml of water (test on fecal contamination), which is the low risk criteria according to WHO recommended value (Ariyananda 2003).

Similar finding were recorded in a study conducted Kurunegala and Puttlam district (Ariyananda 2005). During this study Ariyananda reports that well water in both districts does not comply with SL standard or WHO recommended value for potable water due to bacterial contamination and chemical contaminations.

A study conducted in 2005 in Inginimitiya in Kurunegala district where endemic dental fluorosis was highly prevalent shows a statistical and clinical plausible difference of Fluoride levels between common ground water sources and collected rainwater (Perera A.M. I.R etal, 2011). In this study it was recorded that majority (95%) of the households used water from the rain water tank for drinking, while 91% used it also for cooking. The study recommended drinking rain water to prevent dental fluorosis in individuals growing up in this area as well as other communities who are living in areas with high fluoride levels in their ground water.

Recent survey conducted by LRWHF in the Southern Province on tsunami resettlement areas shows that more than 80% of the households use the rain water for drinking purposes (LRWHF 2010). Similarly a study conducted by NWS&DB in Anuradhapura and Polonaruwa district in rain water tanks constructed under the 2nd urban and rural community water supply & sanitation project, reports that 75% of the households use the collected rain water for drinking purposes both during the dry and wet season. Of these beneficiaries 88% has stated that they like using rain water for domestic need. However, the reason given by those who does not like rain water is due mainly due to perception of water quality.

On the contrary, there have been reports that in some areas in Sri Lanka, that health and other authorities are discouraging people to opt for rain water harvesting as an alternative water source due to minor failures on operation and maintenance of RWH systems and subsequent issues.

Therefore, if rain water harvesting is to be promoted as a possible and feasible option for domestic rural water supply, it is important for sector stakeholders to understand its benefits, how effectively the rainwater meet the domestic level water requirement, where it can be introduced, its draw back (technological, social, economical), and areas of improvement in RWH systems etc.

1.3. Study Objectives

- To study the effectiveness of rain water harvesting as a domestic water supply option
- To identify the prevailing issues and constraints in promoting rain water as an alternative drinking water sources among rural communities
- Recommendation for future implementation of rain water harvesting projects
- Sharing information and experience within the sector

2. Study Methodology

2.1 Data Collection Tools

Data base maintained by Lanka Rainwater Harvesting Forum (LRWHF) on number of household rain water harvesting systems in Sri Lanka and their distribution was updated

through the partner network to prepare sample frame. Questionnaire survey and key informant discussions were conducted in the selected districts to collect necessary information for the study. Figure 1 below shows the distribution of household rainwater harvesting system in the island.

Figure 1: Distribution of Household RWH systems in Sri Lanka

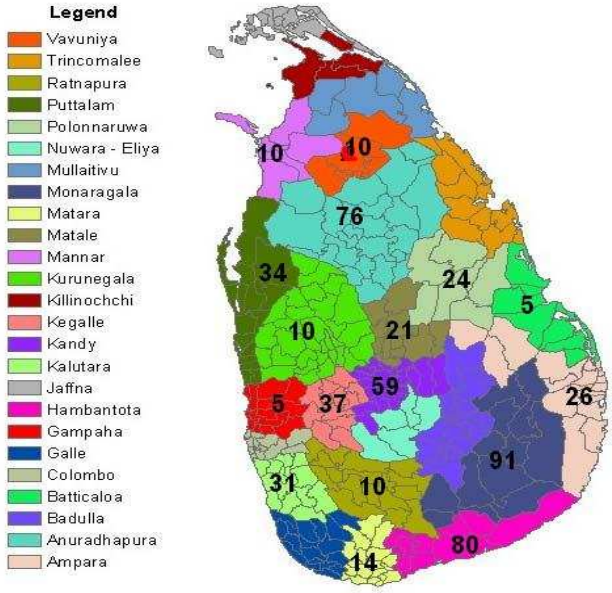
2.2 Sample Design

2.2.1 Selection of districts

From each of the 9 provinces in Sri Lanka, 2 districts where most number of rainwater harvesting system was reported were selected. There by the following district were selected for the detail survey (Figure 2).

Northern Province : Vavunia, Mannar
Eastern Province : Ampara, Batticaloe
North central Province : Anuradhapura, Polonnaruwa
North western province : Puttlam, Kurunegala
Central Province : Matale, Kandy
Western Province : Gampha, Kalutara
Southern Province : Matara, Hambantota
Subaragamuwa Province : Kegalle, Ratnapura
Uva Province : Moneragala, Badulla

Figure 2: Sample distribution by District



2.2.2 Selection of villages/Communities

Two villages from each district were selected where most rain water harvesting system were constructed. Out of theses only the systems constructed during the period 2000-2008 were selected since earlier system constructed has been evaluated and the reports are available and additionally the technology has been improved since 2000. The systems constructed after 2008 were also not selected since the community takes few years to adapt to the system and data collected from these households would not give a true picture of their usage.

The selection of sampling sites also was taken into account on rainwater harvesting systems constructed by many different implementing agencies as possible. Letters were sent to 25 different organization/institute informing them of the survey and requested them to send the beneficiary list of RWH projects implemented by the particular organization and contact details of the sites. Letters were also send to all local authorities (District Secretary and Divisional Secretaries) selected to inform them of the survey and to collect additional information.

2.2.3 Selection of Households

The number of household's rainwater harvesting systems to be surveyed was set at 500. Thereby, the number of households to be sampled from each village was calculated to reflect proportionate representation to make the data statistically valid. Where the number of households to be sampled was calculated below 5, a minimum number was set as 5 households (Table 1).

From each village surveyed 2 households who do not have a rainwater system were used as controls.

Table 1: Sample Distribution

District	Village	Implemented Organisation	No. of Tanks Constructed between 2000-2008	No. of RWH HH to be sampled
1. Vavunia	Cheddikulam	World Vision	25	5
	Kawanthisapura	BLT/LRWHF		5
2.Mannar	Nanaddan	IOM	91	10
3. Anuradhapura		Kala-oya River Basin Project	92	8
	Madawachchiya	ADB/Presidents fund (NWS&DB)	782	68
4. Polonnaruwa	Dibulagala	NWS&DB	288	9
	Medirigiriya	NWS&DB	491	15
5. Ampara	Alayadivermu (Kawedapitti)	Care International	31	5
	Kalmunai (Tamil)	LRWHF	141	22
6. Batticaloe	Monkerney	Asia Onlus	36	5
7. Puttlam	Puttlam (Sellakanda)	PRDA	248	13
	Maneveriya			06
	Nawagaththegama	NWS&DB	201	14
8. Kuruneegala	Polpitigama	Plan Sri Lanka	14	5
	Kotavehera	LRWHF	16	5
9.Matale	Namini Gama (Wilagamuva D.S.)	CWSSP	97	10
	Kirimatiya (Ukuwella)	CWSSP	140	12
10. Kandy	Galgedara	CWSSP	200	14
	Thirapane	CWSSP	307	44
11.Gampha	Divlapitiya	CWSSP	21	3
12. Kalutara	Panadura	Asia Onlus	37	5
	Weniwelketiya	NWS&DB	1395	13
	Palinda Nuwara			15
13. Kegalle	Galigamuwa	NWS&DB	384	20
	Aranayaka	NWS&DB	319	17
14. Ratnapura	Karathila (Eheliyagoda)	Min. of Urban Development and Water Supply (Wasaan Project)	22	5
	Nadrana	Min. of Urban Development and Water Supply (Wasaan Project)	74	5

15. Matara	Pelana North	LRWHF	80	7
16. Hambantota	Dampahala - west	LRWHF	72	7
	Koskoratuwa (Tangalle)	World Vision	32	11
	Weliwewa	NWS&DB/ADB	200	69
17. Moneragala	Badalkubura	NWS&DB	716	86
	Polwatta	Sarvodaya	10	5
Total			6562	**543**

2.3 Data Collection

2.3.1 Design of questionnaire

Questioner for the survey was developed consulting experts in the field (NWS&DB, HARTI). The questionnaire was pre-tested prior to full scale survey and improvement for the questionnaire was made using the results of pilot survey.

2.3.2 Selection and training of date collection team

Six qualified and experienced field enumerators were selected and provided one day training program by the Consultant on how to collect data and information from households. The field enumerators were stationed in different geographical regions to collect information and were regularly monitored by the research team.

The survey was conducted during February to April 2011 among 579 households (including the controls) throughout the districts selected.

Some picture from the Survey

			
Functioning tank at Madawachchiya	Household been questioned at Madawachchiya	Non functioning tank at Divulapitiya	Tank been used for storage at Dibulagala

2.4 Data Entry and Analysis

Data was entered in Excel sheets, and descriptive and tabular analysis was conducted

3. Socio Economic and Demographic Features of Sample Population

3.1 Age and Sex Distribution

About 11 percentages of the households are female headed. Masculinity ratio of the population is 1:1. Age distribution of the population is given in Table 2. The findings also shows that children below 15 years in the population is 22%.

Table 2: Age and Sex Distribution

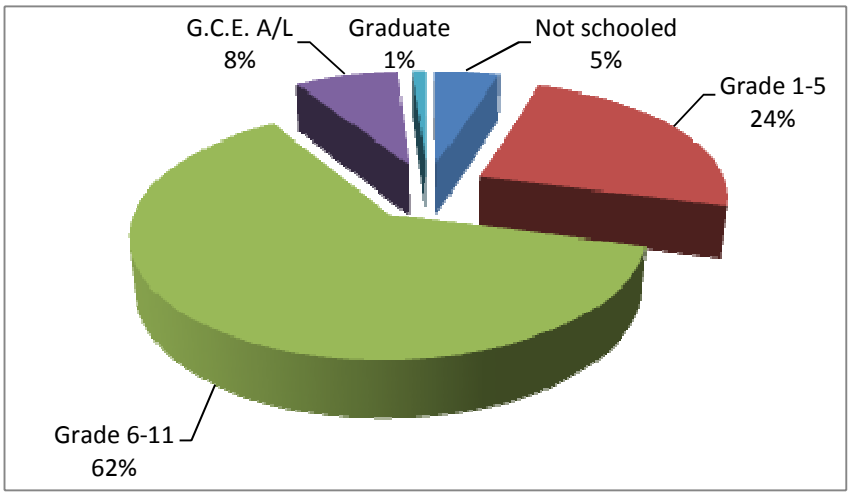
Age Group	Female %	Male %	Total %
>25 years	51	49	61
15-25 years	50	50	17
05-15 years	49	51	16
<5 years	42	58	6

Source: Survey Data, 2011

3.2 Education Level

Education levels of household heads are arrayed in Figure 3, indicating majority of them are educated upto grade 5-11 and about 5 percentages of the household heads are illiterate.

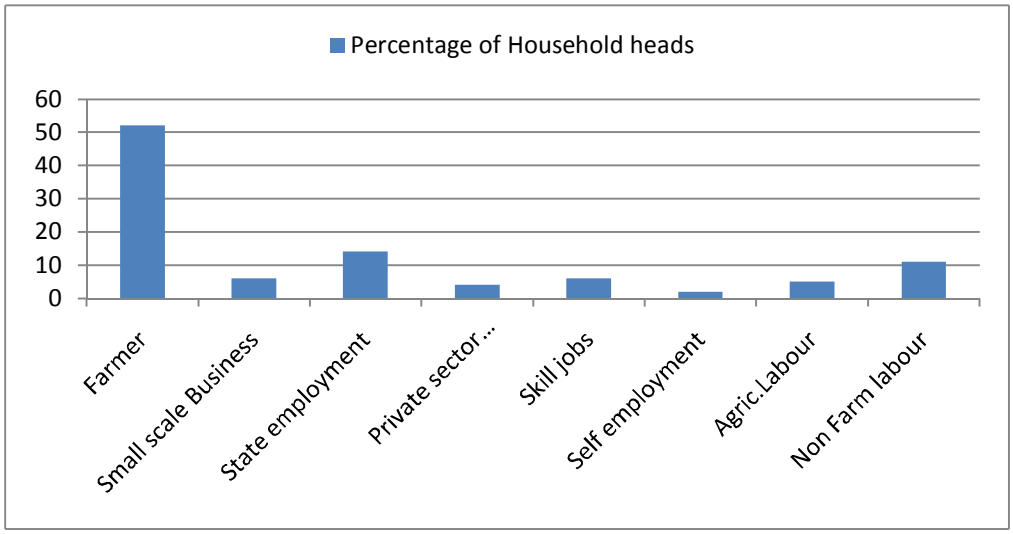
Figure 3: Education Levels of Household Heads



3.3 Employment of Household Heads

The findings show that majority of the household heads are involved in agricultural activities (52%) followed by state sector employment (14%). Figure 4 illustrates the employment pattern of the study area.

Figure 4: Type of Primary Employment of the Household Heads



About 45 and 42% of the households in the dry and wet zones respectively receive Samurdhi benefits. Highest numbers of Samurdhi beneficiaries are lived in Vavunia district followed by Batticoloa, Ampara and Matara districts. However the situation on number of Samurdhi beneficiaries would change if the government poverty safety net program is broadened in the conflict affected districts.

Table 3: Samurdhi Beneficiaries of the Sample

Zone	District	Samurdhi No.	% of total Beneficiary families
Dry Zone	Anuradhapura	26	22
	Ampara	21	64
	Batticoloa	05	71
	Hambantota	40	46
	Kurunegala	05	36
	Mannar	-	-
	Moneragala	53	55
	Polonnaruwa	10	36
	Puttalam	15	43
	Trincomalee	03	43
	Vavuniya	07	100
Wet Zone	Kalutara	14	40
	Kandy	14	22
	Kegalle	13	33
	Matale	09	37
	Matara	11	61
	Ratnapura	06	33
Total		252	742

3.4 Family Size

Average family size of the dry zone population is 4.39 while it is 4.20 in wet zone. Number of members in the sample families is given in Table 4.

Table 4: Family Size of the Sample Families

District	Family Size				Average Family Size
	<3	4 - 6	6 - 8	>8	
Dry Zone					
Anuradhapura	32	57	4	-	4.02
Ampara	33	55	6	6	4.09
Batticoloa	29	42	29	-	4.57
Hambantota	12	60	20	8	4.93
Kurunegala	36	50	14	-	3.79
Mannar	34	58	8	-	3.75
Moneragala	22	59	14	5	4.63
Polonnaruwa	32	57	7	4	4.18
Puttalam	43	49	8	-	3.66
Trincomalee	-	43	43	14	6.00
Vavuniya	14	29	43	14	4.39
Wet Zone					
Kalutara	23	63	14	-	4.37
Kandy	48	50	2	-	3.47
Kegalle	54	38	8	-	3.62
Matale	46	42	4	8	3.96
Matara	22	67	11	-	4.17
Ratnapura	33	67	-	-	3.81
Total	31	55	11	3	4.20

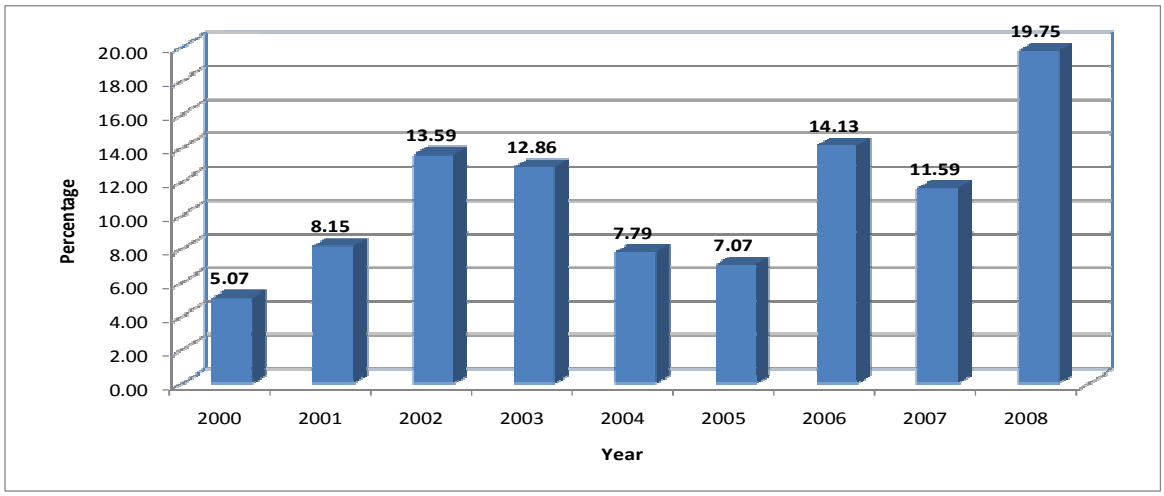
Source: Survey Data, 2011

4. Diffusion and Adoption of Rainwater Harvesting Systems

4.1 Construction of Rainwater Harvesting Systems

About 46% of the total rainwater harvesting system constructed during study period (2000-2008) is being constructed after 2006. The total number of rainwater systems constructed during 2000-2008 and distribution of rainwater systems based on wet and dry zone are illustrated in Figure 5 and 6. Number of rainwater harvesting system construction has shown marked increase after Tsunami disaster of 2005 especially in the coastal districts including North and East.

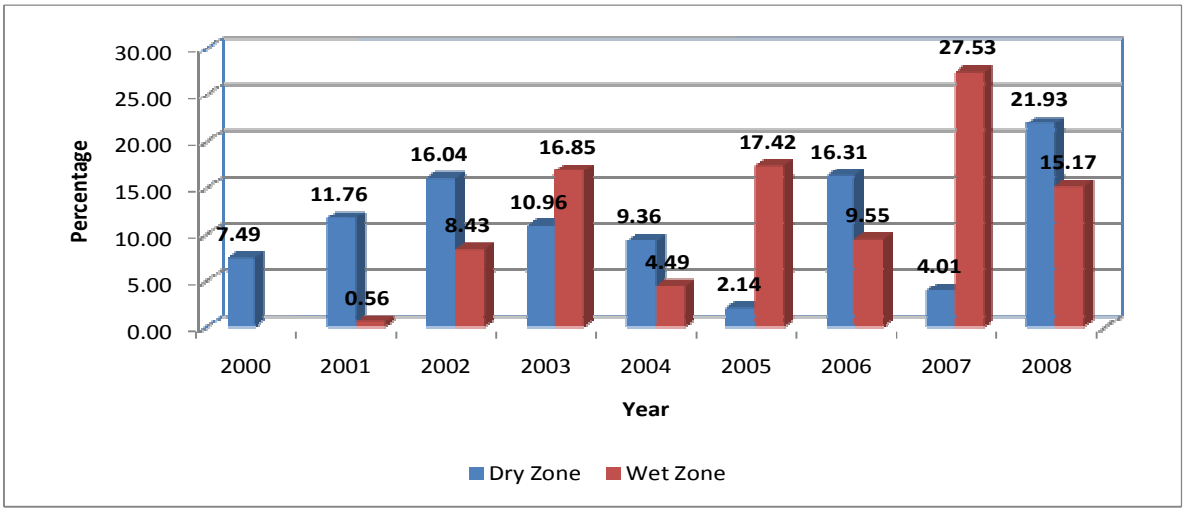
Figure 5: Construction Trend of Rainwater Systems over the Years



Source: Authors' Survey Data, 2011

Different organizations including government and Non government organizations have provided funding support to implement RWH projects. ADB is the largest contributor followed by CWSSP and NWSDB. The organizations made financial supports for the implementation of RWH projects are listed in table 5.

Figure 6: Construction of Rainwater Systems in Different Zones over the Years



Source: Authors' Survey Data, 2011

Table 5: Funding Organizations for the Construction of Rainwater Harvesting Systems

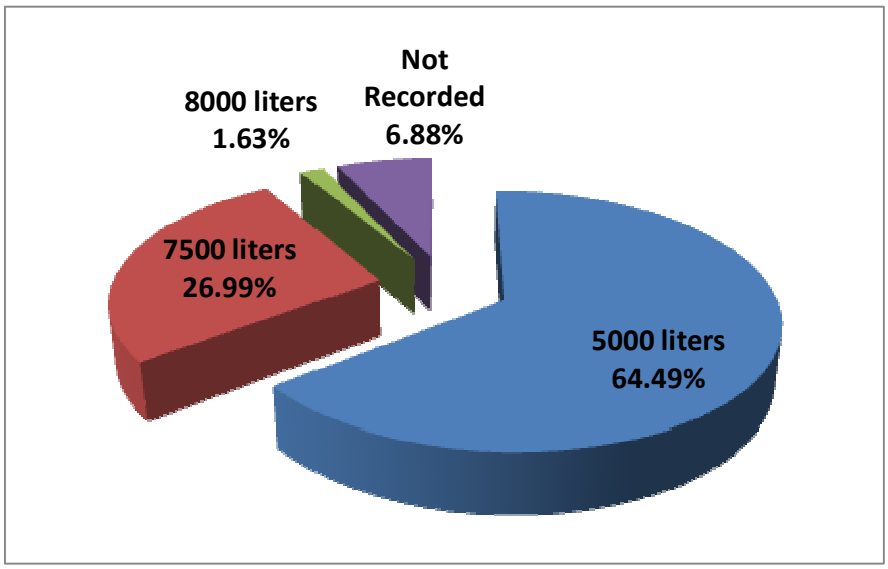
Organization	NO. of Systems	% of Total Systems
ADB	228	41.0
CWSSP	58	11.0
NWS&DB	56	10.0
ADB/SEL	23	4.0
World Vision	17	3.0
Community based projects	17	3.0
PRDA	17	3.0
CBOs	14	2.0
LRWHF	13	2.0
UD&M of WS-Wasana project	12	2.0
FAO	10	2.0
IOM	7	1.0
IUCN	7	1.0
BLIA	5	1.0
CARE International	5	1.0
Plan Sri Lanka	5	1.0
UCODEP Asia ONLUS	5	1.0
Sarvodaya	5	1.0
AF	2	0.3
Southern Development Authority	1	0.2
UNDP & AF	1	0.2
Not recorded	42	8.0
Total	551	100.0

Source: Authors' Survey Data, 2011

4.2 Capacity of Rainwater Tanks

There are three sizes of tanks in the sample population, namely 5000, 7500 and 8000 liters. About 60-65% of tanks are 5000 liter capacity both in wet and dry zones. Figure 7 illustrates size distribution of tanks in the study areas. There are no 5000 liters tank covered in Trincomalee and Vavuniya districts. Anuradhapura, Ampara, Polonnaruwa, Kalutara, Kegalle, Matara and Ratnapura districts were not included any 7500 liters tank in the sample population. 8000 liters capacity tanks were available only in the districts of Batticoloa, Trincomalee and Vavuniya.

Figure 7: Capacity of the Rainwater Tanks

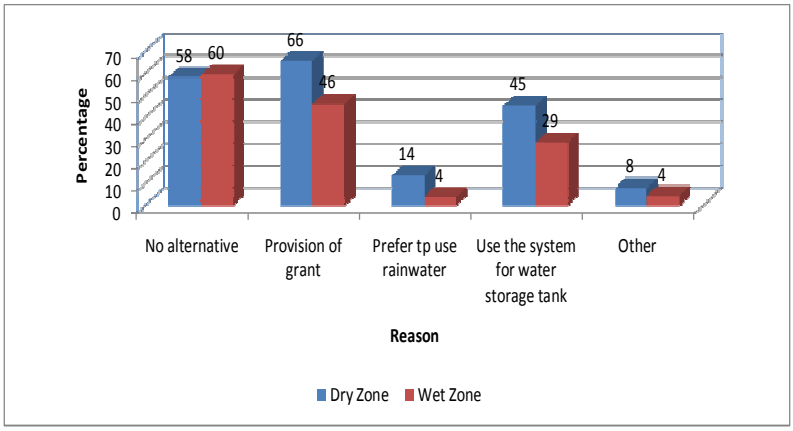


Source: Authors' Survey Data, 2011

4.3 Reasons for the Adoption of Rainwater Harvesting Systems

All the RWH programs implemented in the sample areas are linked with subsidy program with some elements of beneficiary contribution in most of the locations. Therefore, study attempt to find out the reasons for choosing RWH systems by the beneficiaries. The results are illustrated in Figure 8. The findings show that there are no differences in the reasons for selecting system between wet and dry zone. The major reason for the choice is provision of grant for the system construction. However the most negative aspect is that about 40% of the beneficiaries have decided at the inception to use the tank as a water storage facility rather than harvesting rainwater, indicating the drawback in beneficiary targeting and approach adopted in implementation.

Figure 8: Reasons for the Selection of Rainwater Harvesting System



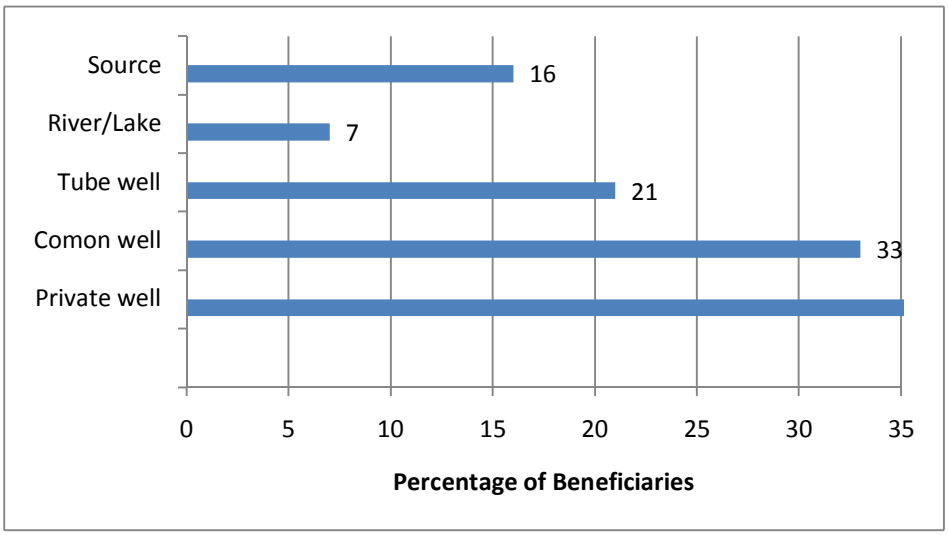
Source: Authors' Survey Data, 2011

5. Water Use at Household Level

5.1 Water Use Prior to the Rainwater Harvesting Project

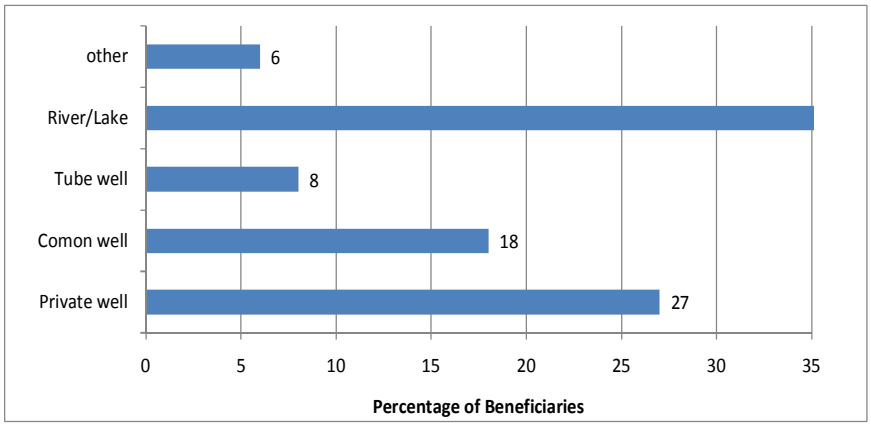
People in the water scarce areas generally dependent on multiple water sources to meet their daily water requirements such as private well, common well, tube well, river/lake and other sources. The survey findings shows that the most popular water source for drinking and cooking needs in both dry and wet zones before implementation of RWH project is common wells, followed by private well. However, in Moneragala district, first priority was tube wells, while in Anuradhapura, Polonnaruwa and Kurunegala districts the first choice for drinking and cooking needs was private wells. Water requirement for bathing was fulfilled from river/lakes in dry zone except in Ampara district. Common wells were mainly used to meet bathing requirements in Ampara district. In the wet zone, bathing water requirement was mostly met from private wells. River/lake was the main bating water source for about 56% of population in Rathnapura district while, 77% and 37% of Matara and Kalutara beneficiaries respectively were used common wells to meet bathing water requirements. Figure 9, 10 and 11 show the source of water for different water needs prior RWH project in both wet and dry zones.

Figure 9: Major Drinking Water Source before RWH Project (% of Beneficiaries)



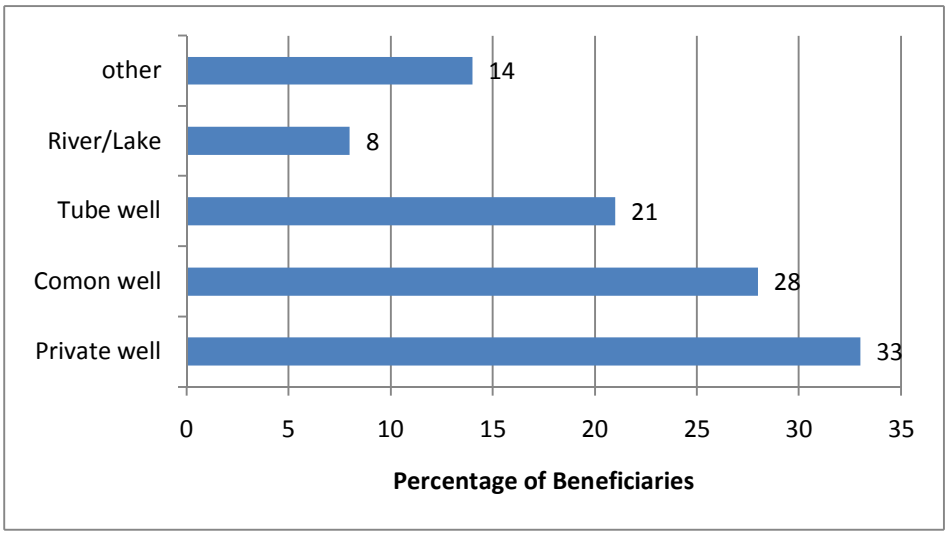
Source: Authors' Survey Data, 2011

Figure 10: Major Bathing Water Source before RWH Project (% of Beneficiaries)



Source: Authors' Survey Data, 2011

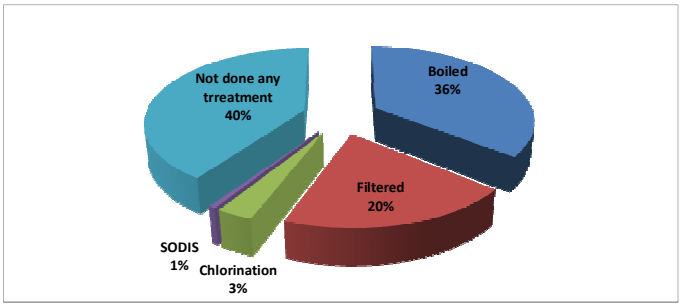
Figure 11: Major Water Source for Cooking before RWH Project (% of Beneficiaries)



Source: Authors' Survey Data, 2011

Almost 55% of the beneficiaries have used different types of treatment to clean the collected water from various sources before drinking, such as boiling, filtering, chlorination and SODIS method. However, about 40% of people have not adopted any specific treatment systems collected from traditional drinking sources (Figure 12). The findings show that, majority of the people in North and East districts and the beneficiaries of Matara are practicing both boiling and filtering.

Figure 12: Water Treatment Methods Adopted before the Project



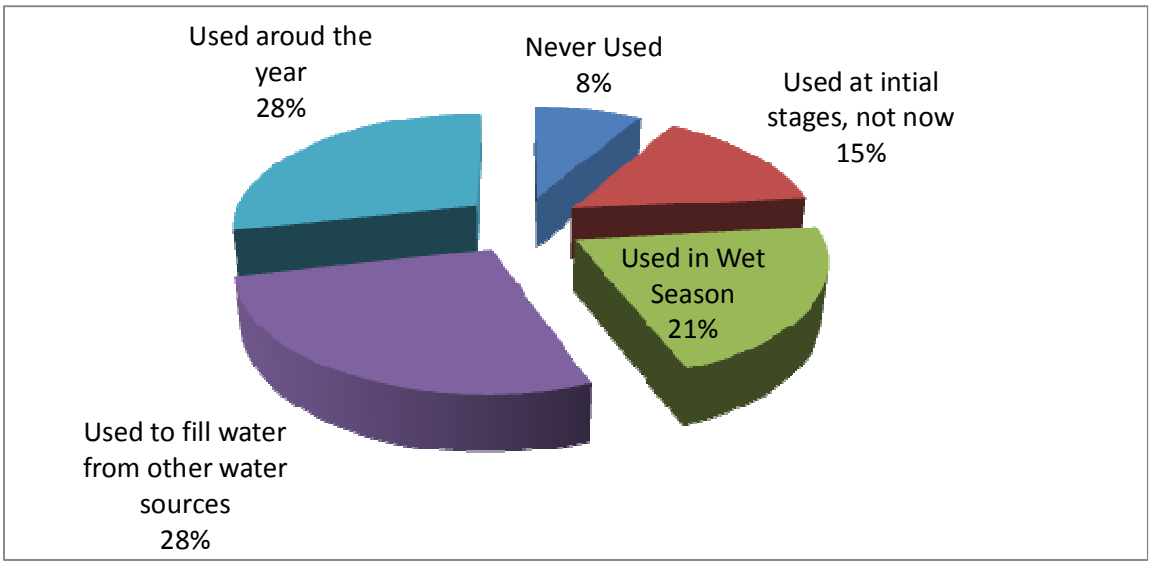
Source: Authors' Survey Data, 2011

6. Utilization of Rain Water Harvesting Systems

6.1 Functioning of RWH Systems

Rain water harvesting systems were constructed primarily to meet the water security at household level by providing clean water. It was expected to use the harvested rainwater for drinking needs with or without treatment. However, people use the RWH systems for various purposes including drinking and sanitation, cooking, washing cloths, bathing, gardening and other household needs. Figure No. 13 describes the level of usage of RWH systems for any purpose and rest are abandoned due to various reasons. The findings indicates that about 23% of the total sample are fully abandoned at the time of survey, while another 27% of the tanks are not used to harvest rainwater, rather used as storage tank for the collected from other sources.

Figure 13: Level of Utilization of RWH Systems

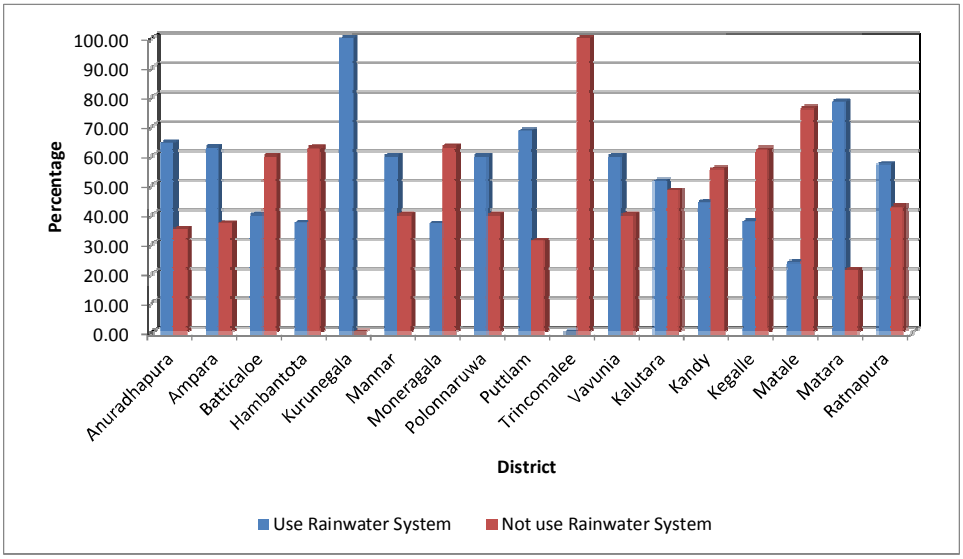


Source: Authors' Survey Data, 2011

Almost all the sample beneficiaries of *Kurunegala* District utilize the RWH systems. Over 60% of the beneficiaries in *Anuradhapura, Ampara, Matara* and *Puttalam* Districts utilize the provided rainwater harvesting systems. The lowest level of usage is recorded in *Trincomalee*. Wet zone districts of *Matale, Kegalle* and *Kandy* and dry zone districts of *Hambantotoa, Moneragala* and *Batticoloa* were recorded over 50% of non- users (Figure 14). Highest non users are in *Hambantota* and *Moneragala* (Table 6), despite the high level of water scarcity and water quality issues. This is by and large poor selection of target beneficiaries and approach adopted in delivering RWH systems.

There are several reasons indicated by the beneficiaries for the use of RWH systems (Figure No. 15). The choice of rainwater as one of their water sources is based on multiple reasons for a given beneficiary in majority of the cases.

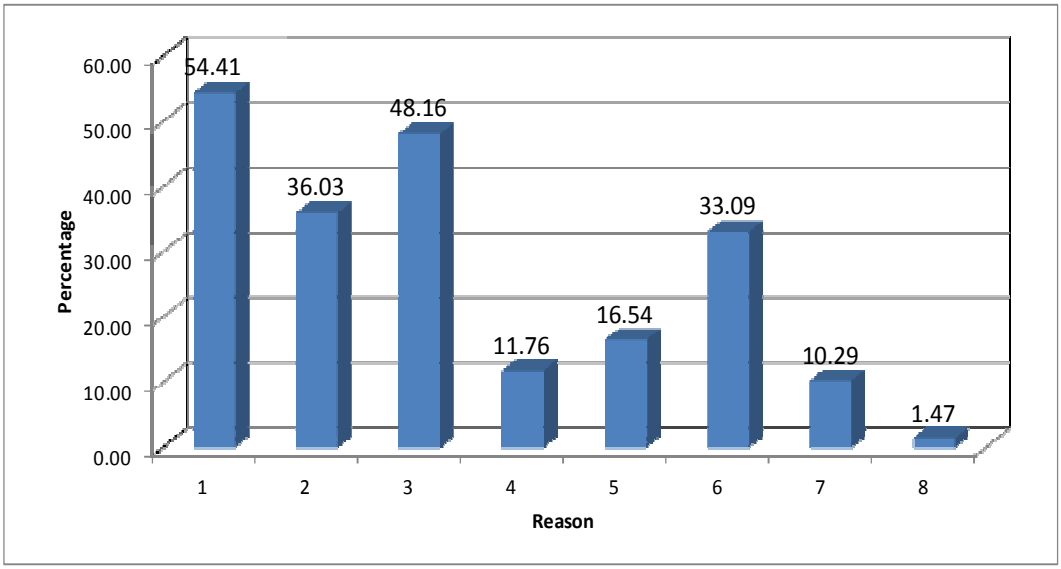
Figure 14: Level of Usage of Rainwater Harvesting Systems by District



Source: Authors' Survey Data, 2011

The major reason for over 50% of the users is lack of alternative water sources. Another 36% of the users expressed that they are using rainwater due to drying up of alternative water sources in dry seasons. It is interesting to note that only 10% of the total users have expressed their concern on the poor quality of available alternative water sources. However, in *Kurunegala* district, especially in *Polpithigama* area, one of the main reasons for use of rainwater for drinking purpose is high prevalence of chronic kidney failure believed to be caused by poor quality of groundwater and their acceptance of rainwater as best available quality water for drinking.

Figure 15: Reasons for the Use of Rainwater



Key:

1. No alternative water sources
2. Drying up of alternative water sources during dry periods
3. Convenient to use at homestead
4. Prefer to use rainwater
5. No one available in the household to carry water from outside
6. No cost involved
7. Low quality of water in the alternative water sources
8. Other reasons

Source: Authors' Survey Data, 2011

Table 6: Number of Systems not Utilized for Rainwater Harvesting

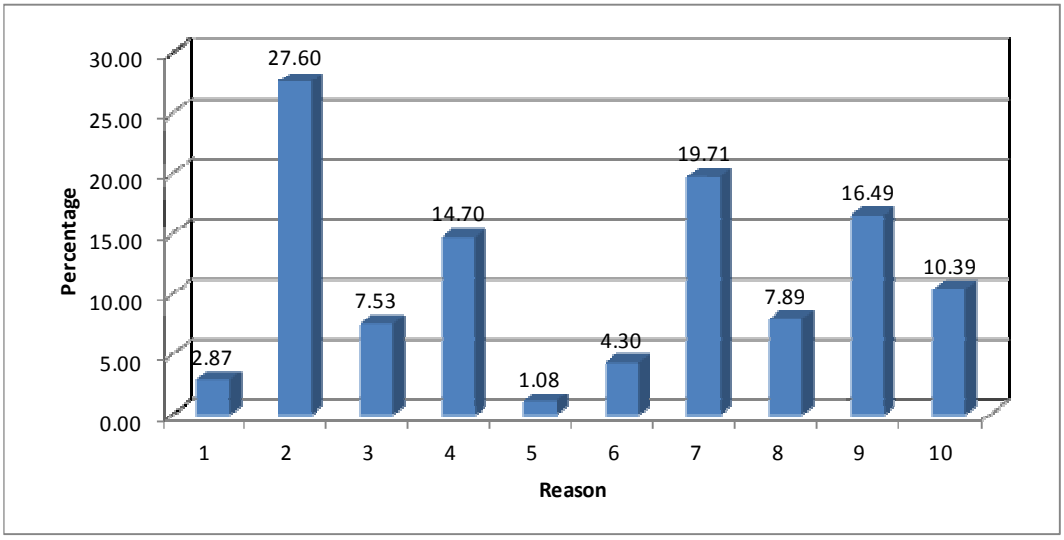
Zone	District	No.	% of Total Sample
Dry zone	Anuradhapura	28	34
	Ampara	10	30
	Batticoloa	03	43
	Hambantota	52	60
	Kurunegala	00	00
	Mannar	04	33
	Moneragala	58	60
	Polonnaruwa	10	36
	Putlam	10	29
	Trincomalee	05	71
	Vavuniya	02	29
Wet zone	Kalutara	15	43
	Kandy	34	53

	Kegalle	23	59
	Matale	16	67
	Matara	03	17
	Ratnapura	06	33

Source: Authors' Survey Data, 2011

The reasons for the non use are manifold (Figure 16). The main reason for the non use for over 28% of non users is non functional system at the time of survey due to various reasons such as non installment of supplementary components or broken supplementary components. Some of the other reasons given like unsuitable colour of harvested water and entry of fauna to the tank are also related to lack of supplementary components.

Figure 16: Reasons for not Using Rainwater Harvesting Systems



Key:

1. Incomplete construction
2. System is not functional
3. Harvested water is not sufficient
4. Not like to use rainwater
5. Un acceptable colour of water
6. Water leakage in the tank
7. Entry of other fauna into the tank
8. Have a tube well
9. Have pipe born water
10. No response

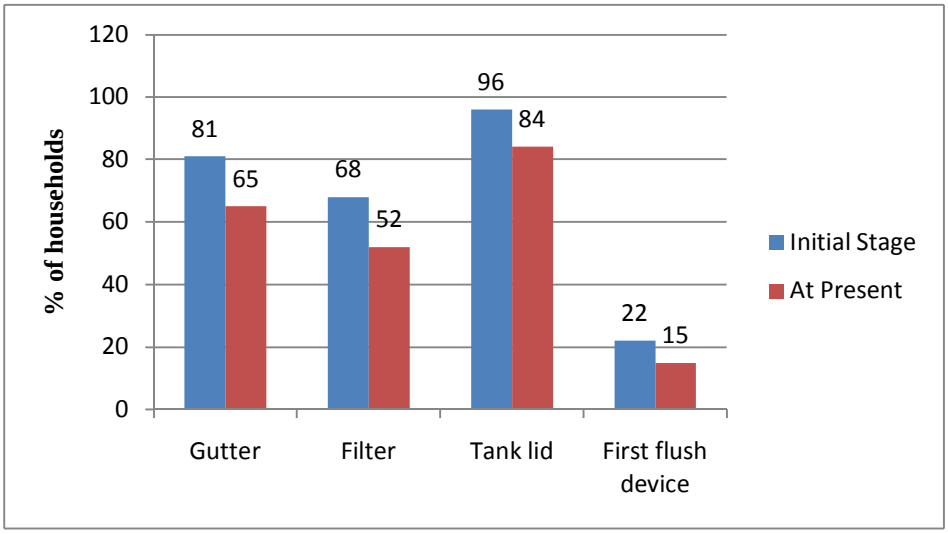
Source: Authors' Survey Data, 2011

6.2 Availability of Supplementary Components

This main investment requirement for RWH system is for the construction of stock tank. But, the availability of tank alone is not sufficient to function of RWH system properly. The complete system requires supplementary components namely roof gutters, sand filter, properly closing tank lid and first flush device to collect and store clean water. Figure No. 17 illustrates the availability of supplementary components at the time of construction and the time of survey. As most of the subsidized projects expect beneficiaries to contribute for the installments of supplementary components, it takes a time lag in installing such components depending on the economic situation of the beneficiary and his/her real need and willingness of collecting rainwater. Roof gutters installed at the initial stages are sometime not properly replaced by the beneficiaries when it is damaged mainly due to high cost involved as illustrated in Figure No.17. The findings show that number of beneficiaries replacing or repairing the supplementary component has reduced over the time.

Table No. 7 indicates the high correlation between lack of supplementary components of RWH system and non use of the system. All the non use system s are lacking one or more of supplementary component such as gutters, tank lid, filter and first flush device.

Figure 17: Availability of Supplementary Components at Initial Stage of Construction and at Present



Source: Authors' Survey Data, 2011

Table 7: Relationship between Non- availability of Supplementary Components and Non-use of RWH Systems

Supplementary Component	No. of RWH systems lack of a component	No. of non-used systems
Gutter	156	156
Filter	156	156

Lids	49	49
First flush device	231	231
Lack of one or more of above	279	279

Source: Authors' Survey Data, 2011

6.3 Maintenance of RWH systems

About 98% of rainwater users are cleaning the RWH tank, but frequency of cleaning differs. In the dry zone areas, frequency of cleaning is less than 5 occasions per year for 91% of beneficiaries, and rests of the beneficiaries clean the tank 5-12 times per year. The frequency of cleaning in wet zone is more than 5 times (5-12) per year for 19% of beneficiaries.

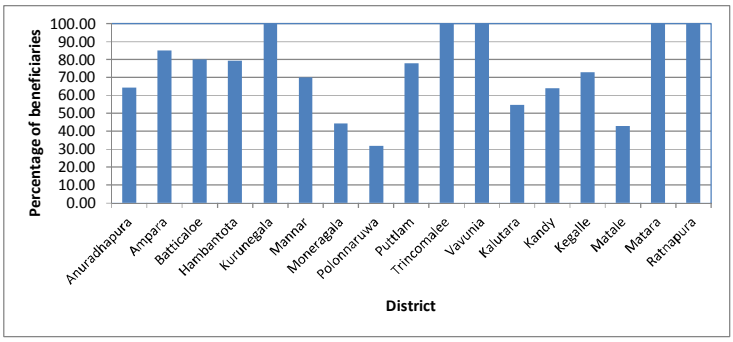
Cleaning of roof before on set of rainfall is important to collect litters free clean water. The findings show that about 98% of the rainwater users both in wet and dry zone clean the roof and gutters before rainfall. As expected, almost 100% beneficiaries who under take proper maintenance of RWH systems used the harvested rainwater for drinking (Table 8)

Table 8: Relationship between RWH System Maintenance and Use of Harvested Water for Drinking

District	No. of household used for drinking	% of households used for drinking		
		% of household clearing roof and Gutter system	% of households adopted first flush device	% of households regularly cleaning the tank
Dry zone				
Anuradhapura	32	97	97	97
Ampara	11	100	91	100
Batticoloa	2	100	100	100
Hambantota	15	87	93	100
Kurunegala	10	100	100	100
Moneragala	10	100	100	100
Polonnaruwa	7	100	100	100
Puttalam	19	100	95	95
Vavuniya	1	100	100	100
Wet zone				
Kandy	13	100	100	100
Kegalle	3	100	100	100
Matale	1	100	100	100
Matara	3	100	100	100
Grand Total	127	98	97	98

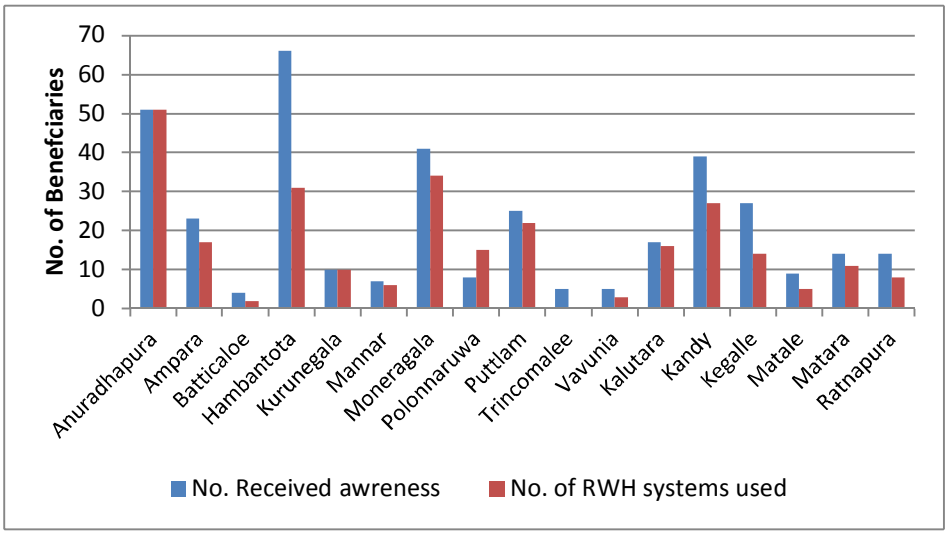
It is necessary to provide some awareness to beneficiaries on proper method of utilization of RWH system by the project implementers. However, only 66% of the total beneficiaries have received awareness on these aspects. Figure No. 18 illustrates the number of beneficiaries received awareness on use of rainwater harvesting systems and maintenance requirements during or after the project in different districts. According to the findings 100% of the beneficiaries of *Kurunegala*, *Vavuniya*, *Matara and Ratnapura* have received awareness of the maintenance of RWH systems. As the awareness has an impact on proper maintenance of the system and changing the attitude and behaviours of the beneficiaries, an attempt was made to find the relationship between awareness provided and the use of rainwater harvesting systems. The findings indicate the positive relationship between number of used systems and the awareness given in all districts except in *Hambantota*. (Figure 19).

Figure 18: Percentage of Beneficiaries Received Awareness on Utilization of Rainwater System



Source: Authors' Survey Data, 2011

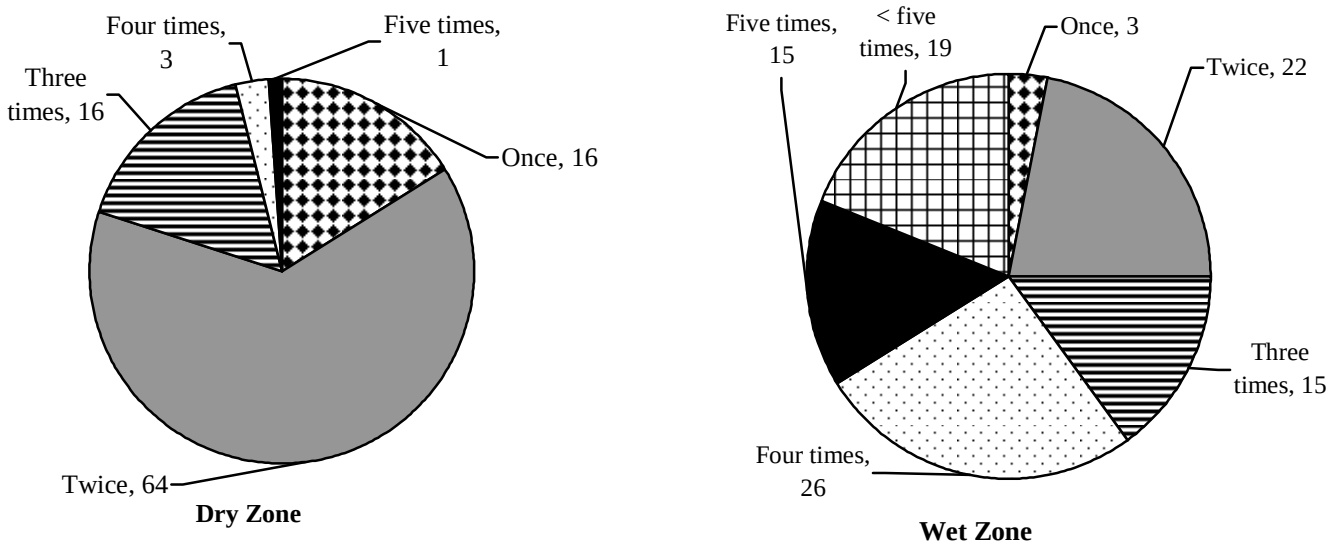
Figure 19: Awareness Provided and Use of RWH Systems



Source: Authors' Survey Data, 2011

Utilization of the RWH system depends on rainfall pattern and consequently how many times per year the storage tank is filled by rainwater. Therefore, the perception on how many time on average the tank is filled by rainwater per year was obtained among the users. In dry zone, the tanks were filled twice per year for 64% of beneficiaries, while in wet zone, over 75% of beneficiaries perceived the filling of tanks for more than three times per year. The results are illustrated in figure 20.

Figure 20: Frequency of Filling of Rainwater Tank per Year (%of beneficiaries)



Source: Authors' Survey Data, 2011

6.4 Maintenance Cost of RWH Systems

The maintenance cost RWH systems including cleaning of roof (labour cost), repairing of roof gutters, cleaning and repairing of filter, cleaning of tank (labour) and repairing of tank, if any (labour and materials). Repairing requirement of gutters indeed depend on the quality of gutters, otherwise it is not an annual maintenance requirement. Repairing of storage tanks becomes necessary when the tanks are ageing. Average annual estimated maintenance requirements in wet and dry zones are given in table No. 9. The main reason for the difference in maintenance cost is cost incurred for gutters repairs/replacement.

Table 9: Estimated Average Annual Maintenance Requirements (including imputed cost)

Requirement	Dry Zone (Rs.)	Wet Zone (Rs.)
Cleaning of roof	133	100
Repairing of gutters	280	-

Repairing of filters	149	125
Cleaning of tank	150	130
Repairing of tank	221	150
Total	933	505

Source: Authors' Survey Data, 2011

6.5 Use of Harvested Water for Different Purposes

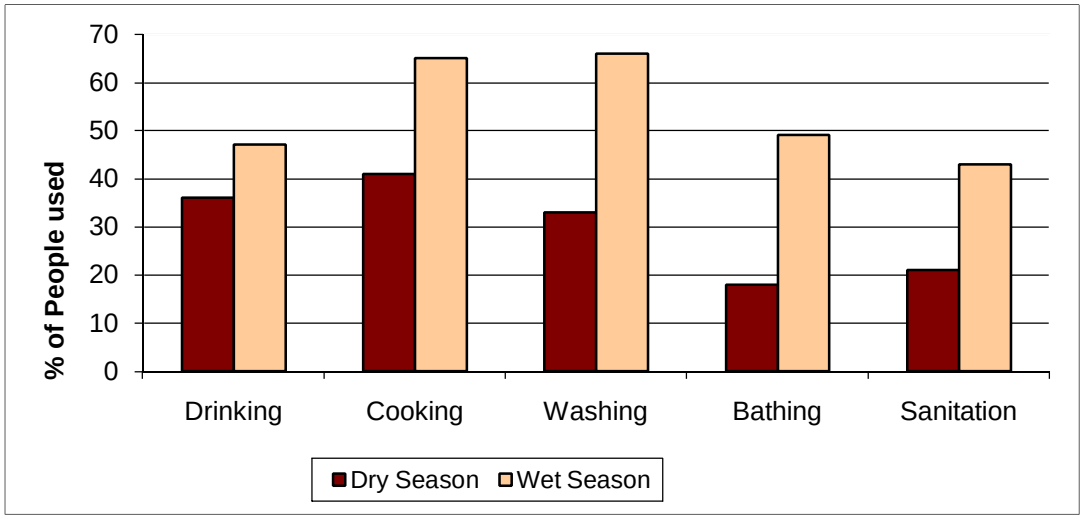
Table No. 10 describes the percentages of people using rainwater for different purposes. The key findings of the table is only 41% and 56% of RWH system users in the dry zone use the harvested rainwater for drinking purpose during dry and wet seasons respectively. This is around 25% in wet zone in both seasons. No beneficiaries in *Mannar*, *Kalutara*, and *Ratnapura* using the rainwater for drinking in any part of the year. The findings also highlights that, RWH systems implemented in *Mannar* are totally out of service during dry season for any purpose indicating scarcity of rain and need of larger volume of storage tanks. Figure 21 indicates that in dry seasons, drinking and cooking are the major activities accomplish by using rainwater, while washing cloths and bathing are the main water needs fulfilled using rainwater in wet seasons. The figure also highlights the high level of rainwater use for all the needs in wet seasons compared to dry seasons.

Table 10: Types of Different Usages of Rainwater (% of Beneficiaries)

Zone	District	Drinking		Cooking		Washing clothes		Bathing		Toilet use		Home gardening	
		Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
Dry zone	Anuradhapura	61	63	65	71	29	35	13	18	22	25	8	8
	Ampara	51	65	53	71	18	100	6	71	18	76	12	29
	Batticoloa	50	100	50	100	-	100	50	50	50	100	50	50
	Hambantota	10	48	16	97	10	93	6	87	13	100	6	93
	Kurunegala	100	100	50	60	-	-	-	-	-	-	-	-
	Mannar	0	0	-	33	-	67	-	50	-	67	-	33
	Moneragala	3	29	26	85	23	91	15	85	29	94	23	82
	Polonnaruwa	40	47	47	53	47	53	27	40	60	69	47	47
	Puttalam	77	86	86	95	18	14	4	-	18	9	18	9
	Vavuniya	0	33	-	33	-	67	-	66	-	67	-	33
	Sub total	41	56	46	77	21	60	11	47	22	57	15	41
Wet Zone	Kalutara	0	0	12	12	94	94	69	69	100	100	81	75
	Kandy	44	48	41	48	41	67	11	41	37	74	-	18
	Kegalle	21	21	36	36	64	64	50	50	64	71	29	21
	Matale	20	20	-	20	80	100	-	40	80	100	40	20
	Matara	27	27	55	55	45	100	-	64	54	100	36	82
	Ratnapura	0	0	12	25	75	87	75	75	87	100	75	87
	Sub total	23	25	31	36	62	80	33	54	64	80	36	46
	Total	36	47	41	65	33	60	18	49	35	66	21	43

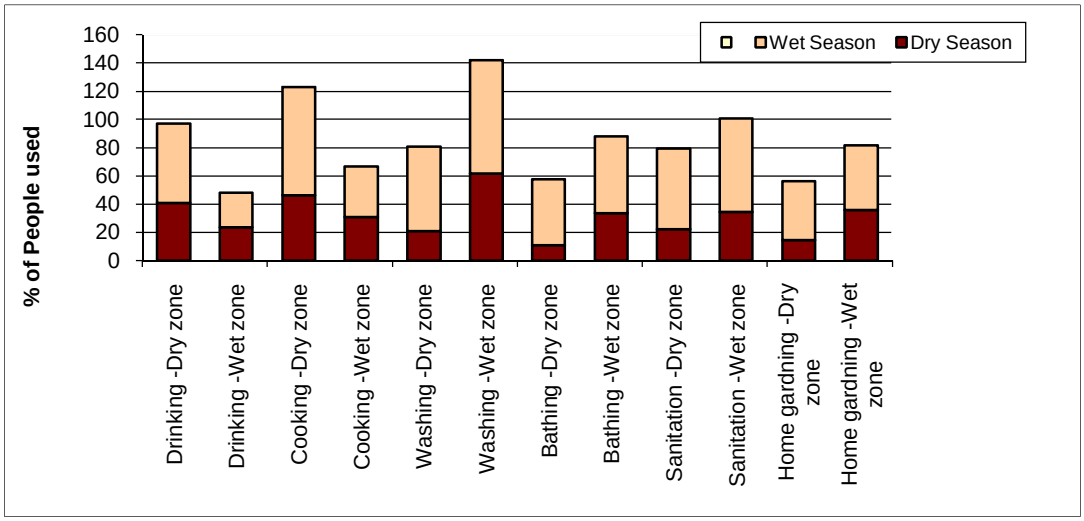
Source: Authors' Survey Data, 2011

Figure 21: Use of Rainwater for Different Needs by Season



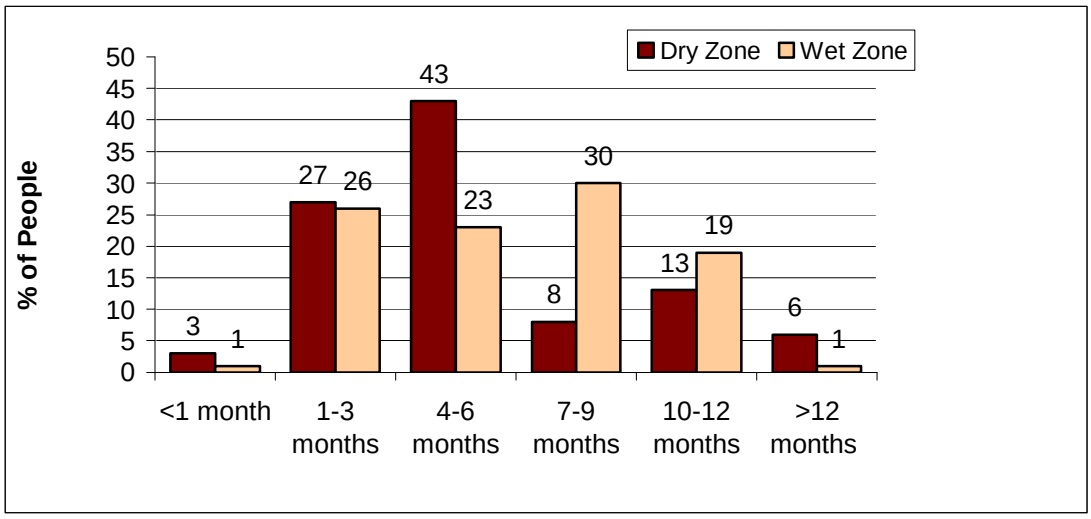
Use of rainwater for drinking and cooking needs which require potable quality of water is much higher in dry zone compared to wet zone in both wet and dry seasons (Figure 22). Rainwater utilization for washing clothes, sanitation and bathing is higher in wet zone districts is higher in both wet and dry seasons.

Figure 22: Use of Rainwater by Wet and Dry Zones



Over 70% of rainwater users are managing the harvested rainwater for more than 4-6 months in a year both in wet and dry zones (Figure 23). This is a good indicator to show the ability of RWH system to provide water security for the basic needs at least during dry seasons.

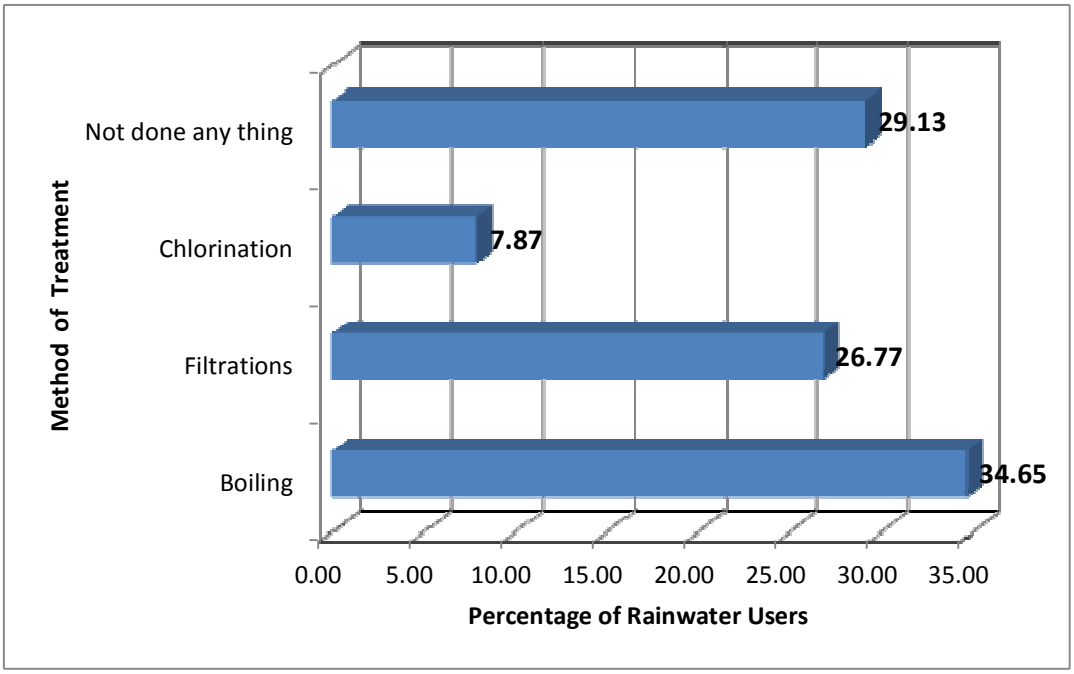
Figure 23: Average Duration of Rainwater Use (As Perceived by % of Beneficiaries)



About 70% of the beneficiaries who are using rainwater for drinking have adopted some water treatment method before drinking. Boiling and filtering are the major treatment methods adopted by the beneficiaries as illustrated in figure No. 24. Among the rainwater drinkers, about 30% are ready to accept the quality without any pre treatment.

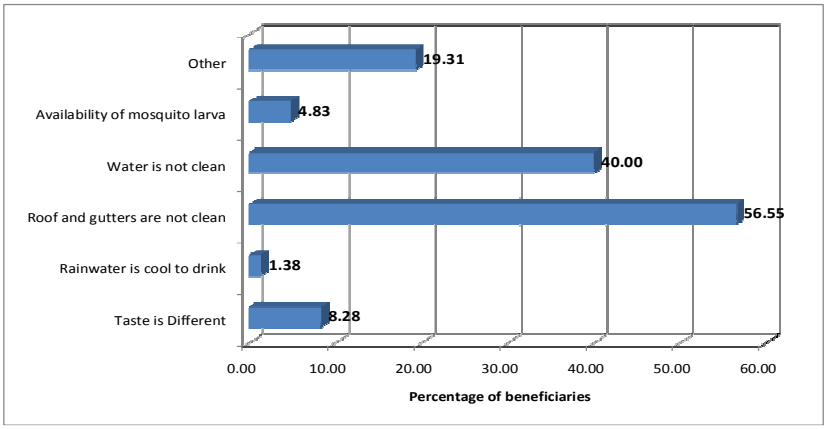
However, out of total rainwater users including non drinking water users, only 16.5% of them are accepting the rainwater quality to be usable without any pre treatment (Figure No.25).

Figure 24: Method of Treatment Adopted by Rainwater Users Prior to Drinking



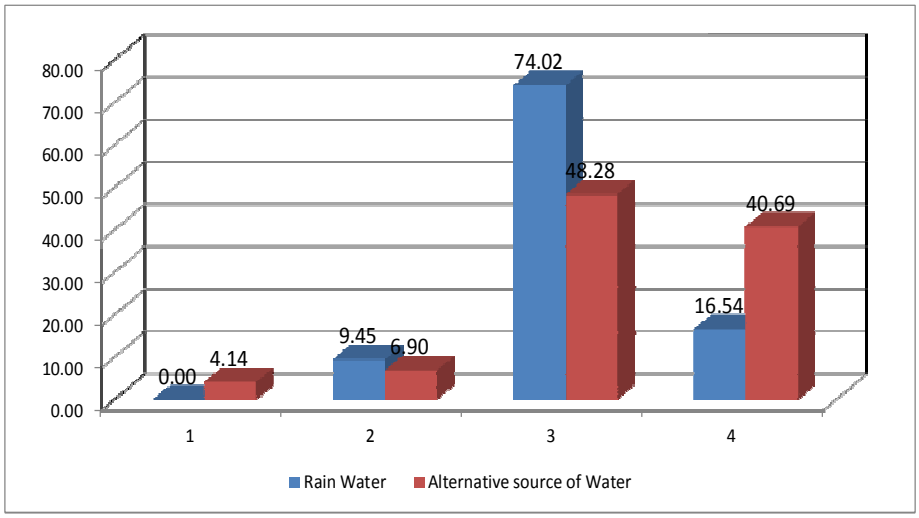
There are various reasons expressed by the rainwater users for non use of harvested water fro drinking (Figure 25). The main reasons are related to maintenance aspect of RWH system such as cleaning of roof and gutters, poor quality of water and availability of mosquito larva (due to lack of tank lid).

Figure 25: Reasons for the Non Use of Rainwater for Drinking



The figure 26 also indicates that although only 47 of rainwater users are utilizing harvested water for drinking purpose, 75% of the users accept that harvested water quality is good for drinking after some pre treatment.

Figure 26: Beneficiary Perception on the Quality of Water: Rainwater Vs Alternative Water Source



Key:

1. Not suitable for drinking, poor quality
2. Not suitable for drinking, but ability to drink after boiling or other treatment methods
3. Suitable to drink, yet, boiling or other treatment methods need to be applied before drinking
4. Suitable for drinking without any pre treatments

6.6 Acceptance of RWH Systems

There are different technologies available to fulfill the water needs of the given locality. Development of RWH system is one of such options. Beneficiaries were inquired about their opinion about sustainability of RWH technology chosen for the area to fulfill their water needs. The results are given in the table No. 11. Majority of the beneficiaries in all areas except Anuradhapura are not convinced that RWH system is the best option to solve their water problems. This may be due to lack of awareness or poor targeting of the beneficiaries. Rejection of RWH system as the best choice is very prominent in North-East districts.

Table 11: RWH System as the Best Method to Solve Water Problems (% of Beneficiaries)

District	Yes	No	No Answer
Dry zone			
Anuradhapura	51	33	16
Ampara	-	100	-
Batticoloa	-	100	-
Hambantota	3	96	1
Kurunegala	14	36	50
Mannar	-	100	-
Moneragala	4	96	-
Polonnaruwa	-	-	100
Puttalam	6	91	3
Trincomalee	-	100	-
Vavuniya	-	100	-
Wet zone			
Kalutara	-	9	91
Kandy	19	63	19
Kegalle	33	64	3
Matale	29	71	-
Matara	-	100	-
Ratnapura	-	100	-

Source: Survey data, 2011

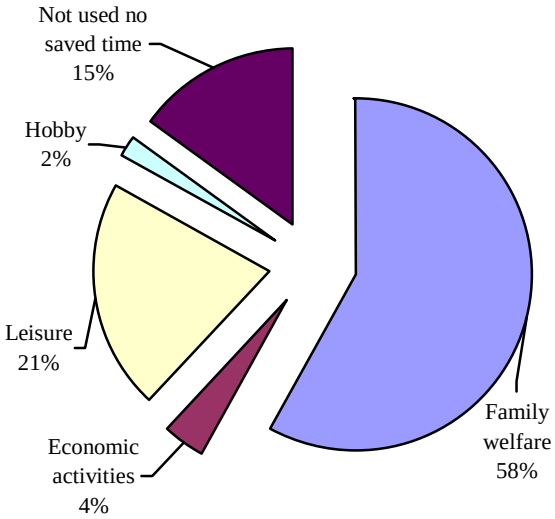
The majority of the beneficiaries (68%) prefer to have access to pipe borne water supply. This is largely because of having pipe borne water is considered as social status and availability of water at household all over the year conveniently. All the beneficiaries in the North-East districts, and *Matara* and *Ratnapura* prefer to access pipe borne water supply schemes. However, they do not have any idea about the technical and economic feasibility of pipe borne water scheme and the quality of water to be provided.

6.7 Impacts of RWH Systems

Availability of water at household level has an effect on saving the time spent for water fetching. The number of hours saved due to availability of RWH systems varies from 1 hrs to 6 hrs per day. The saved time was used for income earning economic activities, leisure and engaged in hobbies, child and family welfare and other various social service activities. Average time saved per day in the dry and wet zone is 4hrs and 3hrs respectively. Highest time saving of 6 hrs/day was recorded in *Anuradhapura, Moneragala, Hambantota* and *Kandy*.

The increased effect realized on various activities due to saved time is given in Figure No. 27. The figure describes that, increased effect on child and family welfare is most prominent in all districts compared to other effects.

Figure No. 27: Use of Saved time for Different Activities



Average economic return of saved time is described in Table No.12. The return of the saved time ranged from Rs.50/day to Rs.218/day. Highest economic return from the saved time was reported from *Hambantota* district followed by *Puttalam* and *Moneragala* district though failed cases of RWH

systems are higher in *Hambantota* and *Moneragala*. If we add the value for non-financial benefits such as increased leisure time, improvement in family welfare and health effects, the return to the saved time will be much higher.

Table 12: Estimated Economic Return of Saved Time

District	**Estimated Income**		
	Rs/day	**Rs/month**	**Rs/year**
Anuradhapura	195	5850	70,200
Ampara	100	3000	36,000
Hambantota	218	6562	78,750
Kurunegala	100	3000	36,000
Moneragala	188	5638	67,666
Polonnaruwa	50	1500	18,000
Puttalam	200	6000	72,000
Kalutara	105	3163	37,963
Kandy	150	4500	54,000
Kegalle	70	2100	25,200
Average	**129**	**3880**	**46570**

6.8 Beneficiary Contribution for RWH System Construction

Beneficiary contribution in the form of labour and kind has been mobilized for RWH system construction in all districts except *Trincomalee* and *Vavuniya* for 5000 liter capacity tanks. The amounts of beneficiary contribution in different districts are given in table No.13. The average beneficiary contribution for 5000 liter tanks is higher than 7500 liter tanks.

Table 13: Estimated Value of Beneficiary Contribution (Rs.)

District	5000 liter			7500 liter		
	Labour	material	Total	Labour	material	Total
Anuradhapura	2361	2293	4654	-	-	-
Ampara	-	500	500	-	475	475
Batticoloa	1500	667	2167	2000	2000	4000
Hambantota	1833	500	2333	1218	1804	3022
Kurunegala	2750	3000	5750	3167	-	3167
Mannar	-	500	500	-	500	500
Moneragala	1469	1666	3135	1173	1760	2933
Polonnaruwa	1580	1970	3550	-	-	-
Puttalam	2437	750	3187	3500	-	3500
Trincomalee	-	-	-	2000	1000	3000
Vavuniya	-	-	-	1500	500	2000
Kalutara	1454	-	1454	-	-	-
Kandy	2368	4729	7097	2660	3007	5667
Kegalle	2520	3416	5936	-	-	-
Matale	1600	2900	4500	1860	2000	3860
Matara	1750	350	2100	-	-	-
Ratnapura	2400	3000	5400	-	-	-
Average	2003	2098	4101	2170	1826	3996

7. Conclusions and Recommendations

7.1 Conclusions

The beneficiaries are mostly belongs to farming community with an average family size of 4.2. Almost 40-45% of beneficiary families are under the government poverty safety net- Samurdhi. About 95% of the beneficiaries are literate.

The construction of RWH systems has been considerably increased after 2006. ADB is the main funding organization followed by the World Bank funded CWSSP. About 65% of the delivered RWH systems have $5m^3$ capacity storage tank. The major reason for adoption of RWH systems in homestead of sample beneficiaries is due to provision of subsidy or grant followed by lack of alternative water source in the accessible distance. People have been depending on multiple water sources such as private well, common well, tube well and river/lake to fulfill their basic water needs, but 45% of them have not adopted any treatment prior to drinking.

About 50% of the provided RWH systems are currently used for rainwater harvesting. Rest is abandoned (23%) or used as stock to store water collected from other source (27%). The use of RWH systems for storage of water from other sources is prominent in *Hambantota* and *Moneragala* Districts. Abandonment of systems mainly takes place due to technical reasons such as provided system is incomplete or absence of supplementary components and faults in the storage system arisen from poor construction.

About 46% of the tanks at the time of survey are lacking one or more of the supplementary components such as roof gutters, filters, tank lid and first flush device. Almost 95-97% of rainwater users are undertaking proper maintenance of the RWH system including cleaning of tank, roof and gutter system. It was found high correlation between availability of supplementary components and proper maintenance of RWH system on the use of harvested water for drinking. The use of RWH system also has a positive linkage with awareness provided on maintaining RWH system, proper collection of quality water and utilization of harvested water before the project implementation.

The main reason for the use of rainwater for 75% of the users is drying up of alternative water sources in dry periods. About 41% and 56% of RWH system users in the dry zone use the harvested rainwater for drinking purpose during dry and wet seasons respectively. This is around 25% in wet zone in both seasons. Some water treatment method is applied before drinking by 70% of the beneficiaries who are using rainwater for drinking. No beneficiaries in *Mannar*, *Kalutara*, and *Ratnapura* using the rainwater for drinking in any part of the year. The main reasons for the non use of harvested water for drinking purpose are related to maintenance aspect of RWH system such as cleaning of roof and gutters, poor quality of water and availability of mosquito larva (due to lack of tank lid). Rainwater utilization for washing clothes, sanitation and bathing is higher in wet zone districts in both wet and dry seasons. Over 70% of rainwater users are managing the harvested rainwater for more than 4-6 months in a year both in wet and dry zones. This is a good indicator to show the ability of RWH system to provide water security for the basic needs at least during dry seasons.

Majority of the beneficiaries in all areas excluding *Anuradhapura* are not convinced that RWH system is the best option to solve their water problems. This may be due to lack of awareness or poor targeting of the beneficiaries. The first choice of over 65% of beneficiaries is pipe borne water supply. The access to pipe borne water supply is considered as most convenient and higher social status despite the high cost involved and unsuitable quality in some many locations.

Availability of water at household level has an effect on saving time spent for water fetching. The number of hours saved due to availability of RWH systems varies from 1 hrs to 6 hrs per day. The saved time was used for income earning economic activities, leisure and engaged in hobbies, child and family welfare and other various social service activities. Average economic return of saved time ranged from Rs.50/day to Rs.218/day without non-financial social benefits.

7.2 Recommendations

1. It is important to ensure the beneficiary contribution for the RWH project by proper awareness and mobilization of beneficiaries.
2. The installments of supplementary components such as gutters, filters, tank lid and first flush device should be assured before completion of the project. If beneficiaries failed to include these components, the project should accommodate the cost of these components to make it successful.
3. Installing good quality gutters is essential for the long use of the systems as most of the beneficiaries failed to replace the gutter system after damages occurred.
4. A standard training module for RWH system maintenance, collection good quality water, proper utilization ant rationing of rainwater and change of beneficiary attitudes and behaviour on myths of rainwater use should be developed and implemented before completion of RWH project
5. Most people think rainwater is a clean water source, but they are lacking confident on the system they used to collect and store good quality water. Therefore, the quality parameters and their short term and long term health impacts of rainwater and other alternative water sources should be educated to the beneficiaries.
6. Target beneficiaries must be carefully selected considering their real need, willingness to contribute for the project and other socio economic characteristics such as family size, roof area and quality and the surrounding environment.
7. Appropriate and easy to manipulate tank lids with proper sealing should be introduced, as to facilitate trouble-free cleaning of tanks and protect the rainwater tanks to become as mosquito breeding sites especially dengue mosquito. Entry of different fauna also develops negative perception on water quality.
8. Proper monitoring system by the authorities after project completion is needed.
9. A systemic water quality survey should be conducted taking into account different variability's to give recommendation for best operation and maintenance practices.

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