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Short Communication

The potential benefits of rainwater harvesting for households in the Jaffna Peninsula

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Abstract

Recent development activities in the Jaffna Peninsula are threatening the viability of the region's natural groundwater supply. Rainwater Harvesting (RWH) represents one important approach to remedying this situation. By accumulating freshwater during Jaffna's wet season, household RWH systems can supply drinking and cooking water for use during the water-limited dry season. Additionally, a RWH calculator created by the International Water Management Institute (IWMI) can be used to customize a RWH system for each family given particular household parameters such as rooftop size and daily extraction rate. When paired with cost estimates for tank construction, a RWH installation cost-benefit analysis can be determined for either a specific household or for a collection of households within the Jaffna region.

Keywords: rainwater harvesting calculator, Jaffna, groundwater

Introduction

The Jaffna Peninsula of Sri Lanka has experienced a welcome resurgence in economic investment following the end of the civil war. Development interests have brought significant, national and international attention to the Jaffna region for the first time in decades. Although subsequent expansion has been largely positive, the rapid growth in the region has not been an unqualified blessing. In many ways, the rate of infrastructure and population growth has outstripped environmental and human health considerations particularly in relation to Jaffna's water resources.

Unlike many other regions in Sri Lanka, the Jaffna Peninsula lacks any perennial rivers or substantial fresh water reservoirs. As such, Sri Lankans in this region rely primarily on naturally occurring aquifers for their water requirements. Although replenished by rainwater, these aquifers are restricted in size and thus represent a limited resource. Additionally, though they contain freshwater, the aquifers rest upon a layer of saltwater that can contaminate the overlying freshwater if over-extraction occurs (Mikunthan et al. 2011).

Unfortunately, these groundwater sources have been vulnerable to the negative side effects of human development. Excessive agro-chemical fertilizer application and intensive agricultural practices within the region have been apparent since the 1980s. These issues are liable to become even more prevalent due to the removal of fertilizer and fuel restrictions following the end of the civil war in 2009 (Mikunthan et al. 2011). Twelve out of 44 wells surveyed across the Jaffna Peninsula contained nitrate levels exceeding the Sri Lankan drinking water recommendation level of 10 mg L^{-1}; several wells had nitrate concentrations higher than 30 mg L^{-1} (Mikunthan et al. 2011). Water with such high concentrations of nitrate is unsuitable for human consumption. This is especially true for infants because they are more susceptible to methemoglobinemia which can result from over-consumption of nitrates in drinking water (Knobeloch et al. 2000).

Farming yields are also vulnerable to ill effects resulting from compromised groundwater sources. Due to high groundwater extraction rates in the Jaffna Peninsula, many wells are experiencing “saltwater intrusion” or “upconing.” This phenomenon occurs when excessive pumping of water from a freshwater aquifer pulls the underlying saltwater upward until it contaminates the freshwater. This can make well water unsuitable for drinking. Saltwater intrusion is particularly prevalent in the coastal regions of Jaffna Peninsula because the saltwater is comparatively close to the water table near the shoreline (Janen and Sivakumar 2014).

Other point source pollution issues also threaten Jaffna groundwater. Poor wastewater management and sewage disposal have led to alarming bacterial coliform contamination in wells near Jaffna municipality (Barthiban and Lloyd 2009). Chunnakam Power Plant has allegedly leaked 400,000 L of crude oil into the underlying aquifer within the last year seriously contaminating local drinking water supplies (Wijenayake 2015).

While the enumerated threats are certainly concerning, many strategies to mitigate Jaffna’s water crisis exist and are in various states of implementation. Yet, it may be years before any large-scale initiatives – including the River for Jaffna and Jaffna-Kilinochchi Water Supply and Sanitation Project – are completed. In the meantime, more immediate strategies to provide Jaffna residents with clean drinking water are urgently necessary. One such strategy is rain water harvesting (RWH). The Lanka Rain Water Harvesting Forum (LRWHF), established in 1997, has installed more than 15,000 RWH systems throughout Sri Lanka. These tanks have not only increased water security for numerous households, but they have also reduced water procurement time for many women who are typically charged with this household task (Ariyananda 2004).

Materials and Methods

Although RWH is not prevalently implemented in Jaffna peninsula, efforts have been made to determine the potential benefit that RWH could provide to the region. Gamage (2006) determined that tank size has a greater impact on potential water security than rooftop size using Jaffna rainfall data in equation 1, *A* represents the efficiency of collection and *B* is the absorption loss from the rooftop (Gamage 2006).

Runoff = A x (Rainfall – B) x Roof Area (1)

Using the following simple equation (eq. 2), the amount of household water consumption in a given month can be determined.

Water Consumption per month = Number of People x Daily Water Use per Person x Days in Month (2)

Once monthly rooftop runoff and household water consumption have been computed, they can be used to determine the cumulative tank water present at the end of a given month as depicted in equation 3.

Tank Water present at the end of a given month = Monthly Runoff + Tank Water from Previous Month – Monthly Water Consumption *(3)*

Using these three simple equations, IWMI produced a RWH calculator that determines RWH system capacity given the necessary specifications. Within Equation 1, *B* (the absorption loss from the rooftop) and rainfall are both typically expressed in mm/month. The calculator converts *B* to m/month in order to depict runoff in m^3 $month^{-1}$. Additionally, within Equation 2, daily water use per person is typically conveyed in L day^{-1}. This parameter is converted to m^3/day within the calculator in order to depict monthly household water consumption in m^3/month. For Equation 3, it is important to recognize that the cumulative tank water amount cannot exceed the predetermined rainwater harvesting tank capacity.

Within this calculator, parameters such as rooftop size, monthly rainfall, per capita daily water use, number of people per household, and tank capacity can be manipulated. As such, the calculator can be used to help individual households determine what size tank is necessary for annual water security given their own particular living situation.

Results and Discussion

Based on average Jaffna parameters – about four people per household (Vidyarathne 2011), rooftop size of around 75 m^2 (IWMI, unpublished), and 1,385 mm of annual rainfall (Mikunthan et al. 2011) – RWH can provide a household with its entire annual basic water requirements if each member consumes 20 L day^{-1}. This is enough water for necessities like drinking, cooking and basic hygiene practices such as hand washing and food cleaning (Howard and Bartram 2003). This conclusion assumes a collection efficiency of 0.7 and a rooftop absorption rate of 2 mm $month^{-1}$ (Gamage 2006). A tank capacity of 5 m^3 is also assumed.

In Table 1, the RWH calculator depicts the amount of rainwater that can be harvested by an average Jaffna household during a drought year (2012) with only 612 mm of rainfall. As can be seen, even during years of rainwater scarcity, a 5 m^3 RWH tank can supply a typical Jaffna household with its annual basic water requirements. Notably, this is only possible when rainwater collection efforts commence around the months of October/November. This period of the year marks the beginning of Jaffna's wet season during which enough rainfall typically descends to fill a 5 m^3 tank to capacity. Water obtained at this time can be used to supply household water during subsequent low-rainfall months. On the other hand, if rainwater collection begins in January, it is unlikely that enough water will be collected initially to supply basic water requirements for the household throughout the rest of the year.

Table 1. Rainwater Harvesting Calculator produced by IWMI. Monthly rainfall rate is reflective of a drought year m^3 (2012) and daily water use per person is set at 7.5 L day^{-1}

Variables	Units	
Collection Efficiency	N/A	0.7
Rooftop Absorption Rate	mm/month	2
Rooftop Area	m^2	75
Number of People	people	4
Daily Water Use per Person	L/day	7.5
Tank Capacity	m^3	5

		Oct	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
Monthly Rainfall	mm/month	395.3	23.6	6.4	0	8.3	65	7.2	0	2.6	8.6	13.4
Days in Month	days	31	31	31	28	31	30	31	30	31	31	30
Monthly Rooftop Runoff	m^3/month	20.6	1.1	0.2	-0.1	0.3	3.3	0.3	-0.1	0.0	0.3	0.6
Monthly Household Water Consumption	m^3/month	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Cumulative Tank Water	m^3/month	5.0	5.0	4.3	3.4	2.8	5.0	4.3	3.3	2.4	1.9	1.6

Also, worth noting is the low level of water extraction (i.e., 7.5 L $person^{-1}$ day^{-1}) required to allow such minimal rainwater to provide for a household's entire yearly requirements. This is the minimum level of daily water consumption required by most people in most circumstances for survival (Howard and Bartram 2003). This would only be enough water for basic necessities such as drinking and cooking.

Table 2 illustrates the reduced benefits of RWH during the same drought conditions when a higher per capita daily rate of extraction is employed. If each person in a typical Jaffna household consumes 20 L of water per day during a drought, the harvesting tank will be emptied after about four months. Sporadic days of rainfall will be able to provide some additional tank water in the remaining months, but such accumulation will be insubstantial during Jaffna's dry season. Increasing the harvesting tank capacity to 10 m^3 extends the period of tank water availability to eight months, but year-long water supply would still remain unattainable.

Nevertheless, as has been demonstrated, RWH can still provide a substantial and even year-long source of water for many families during times of water scarcity. This is only possible, however, when family members maintain near subsistence per capita water use in order to ensure adequate water supply. Also, proper RWH system management is of the utmost importance if such a water supply strategy is to be effective. In other words, appropriate maintenance of the RWH system and strict daily portion control are essential for assuring a year-round supply of water.

Table 2. Rainwater Harvesting Calculator produced by IWMI. Monthly rainfall rate is reflective of a drought year (2012) and daily water use per person is set at 20 L/day.

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
Monthly Rainfall	mm/month	395.3	80.6	23.6	6.4	0	8.3	65	7.2	0	2.6	8.6	13.4
Days in Month	days	31	30	31	31	28	31	30	31	30	31	31	30
Monthly Rooftop Runoff	m^3/month	20.6	4.1	1.1	0.2	-0.1	0.3	3.3	0.3	-0.1	0.0	0.3	0.6
Monthly Household Water Consumption	m^3/month	2.5	2.4	2.5	2.5	2.2	2.5	2.4	2.5	2.4	2.5	2.5	2.4
Cumulative Tank Water	m^3/month	5.0	5.0	3.7	1.4	-0.9	-3.1	-2.2	-4.4	-6.9	-9.3	-11.5	-13.3

Although, RWH is by no means a catch-all, silver bullet solution to Jaffna's water supply problem, it can provide a significant, quantifiable step toward the achievement of water resource sustainability in the region. While its benefits are limited by rainfall abundance, many Jaffna households can obtain significant water supplies from RWH even during years of drought through careful resource management. During years of average or heavy rainfall, RWH systems can be enormously beneficial in supplying enough water for basic survival requirements and beyond.

The RWH calculator introduced in this paper serves as a useful tool to customize a RWH system for each family based on their needs. In conjunction with the cost estimates depicted in Table 3, the RWH calculator can help determine the viability of installing a RWH system for a particular household in the Jaffna region. It can also be used to determine the optimal tank size for such a system given specific household parameters. This determination can be made not only for Jaffna households but also for any household for which the necessary parameters are known or can be approximated. Potential donors and development organizations can use this information in conjunction with the RWH calculator to procure an estimated cost-benefit comparison of monetary input to water collection.

Table 3. Approximate costs incurred when installing various rainwater harvesting systems. Table adapted from information provided by Dr. T Ariyananda (Pers. Comm.). Prices are based on LRWHF data and are subject to variation.

	Cost Estimates for Ferro Cement Tank Construction (Rs.)			
	5 m^3	8 m^3	*10 m^3	30 m^3
Materials	30,000	35,000	99,000	303,000
Gutters	3,000	3,000		7,500
**Valence Board	4,000	4,000		-
First Flush	1,500	1,500		2,000
Skilled Labour	7,500	8,000	6,000	120,000
**Unskilled Labour	12,000	12,000	12,000	60,000
***Reusable Frames	20,000	20,000	-	50,000
Total (excludes Reusable Frames)	58,000	63,500	117,000	492,500
Total sans Beneficiary Input (excludes Reusable Frames)	42,000	47,500	105,000	432,500

*Cost estimates for plastic tank rather than ferro cement

**Typically part of beneficiary contribution

***Fixed cost - can be reused for 50+ tank projects

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