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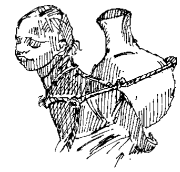
INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION



# Low-cost roofwater harvesting in the humid tropics

*Mr Dai Rees and Dr Terry Thomas, UK*

Domestic roofwater harvesting is a centuries-old technique. In the latter half of this century, domestic rain-water, or roof-water harvesting (DRWH) has been promoted mainly in arid areas, where the alternative water sources are scarce and/or prohibitively expensive. It is a technology that is now employed primarily when other conventional options have been discarded due to complexities or cost, or where subsidies are applied for specific promotion of DRWH.

In this paper we will consider the use of domestic roofwater harvesting in *humid* tropical areas of the world. It is demonstrated that the uptake of this technology in areas with favourable climatic conditions, and where users are willing to modify their behaviour, can bring sufficient quantities of clean water to large numbers of people for a large part of the year, without the usual prohibitive initial costs.

Firstly, we will consider the climatic implications on DRWH and see what effect preferential rainfall patterns can have on the cost of the DRWH system, especially the cost of water storage. Secondly, we will consider user patterns and show how suitable user behaviour (consumption pattern) can again improve the desirability of a DRWH system. Finally we will look at the work being done at Warwick University (and by other members of the Roofwater Harvesting Research Group) on reducing costs of roofwater collection systems and improving the quality of stored rainwater for use in high rainfall areas.

## Rainfall patterns and DRWH

Rainfall patterns vary dramatically throughout the world. Even within the tropics there is a strong variation in the quantity and the pattern of precipitation. For the purposes of this paper we will consider 4 distinct humid, tropical rainfall patterns:

- Single short rainy season with long dry season – Monsoon climate.
- Single long rainy season and short dry season.
- Bimodal rainfall pattern - two rainy seasons with short 'less rainy' seasons.
- Uniformly distributed rainfall pattern.

Figure 1 shows mean monthly rainfall distributions for locations representing each of these tropical climate types and calculates for each the fraction of annual consumption that would be needed to be stored to meet a particular performance criterion. We may call this the 'normalised storage requirement'. (The criterion used for Fig. 1 is that when annual demand exactly equals mean annual roof run-off, the storage tank would be just large enough to enable steady consumption to be maintained throughout an 'average' year). Note the big increase in normalised storage requirement - from 10 per cent to 61 per cent of annual consumption - as one moves from San Juan, an area of fairly even rainfall, to Mumbai, an area of very seasonal (Monsoon type) rainfall. Other criteria and techniques can be used for sizing tanks, but all give a similar relation between normalised storage requirement and rainfall pattern.

Figure 1 demonstrates that storage requirement decreases, and so DWRH becomes more economically attractive, when the rainfall pattern is preferential.

## Styles of RWH

Similarly, a favourable user regime can help to reduce the costs of DRWH. Below we consider a number of common user regimes that have been developed in response to the diverse range of socio-economic, climatic and technical contexts in which DRWH is practised. We also look at ways in which these patterns or behaviour can be modified to reduce storage requirement and hence cost.

We can classify most systems by the amount of 'water security' or 'reliability' afforded by the system. There are four types of user regimes outlined below:

- *Occasional (or opportunist)* - water is collected occasionally with a very small storage capacity, say a few small pots catching water from the eaves. During the wet season the user will benefit considerably and most, if not all, of the user needs can be met on rainy days.
- *Intermittent (or seasonal) RWH* – here, the full requirements of the user are met for a part of the year. A typical scenario is where there is a single long rainy season (or two shorter rainy seasons) and, during this time, most or all of the users needs are met. During the dry season an alternative water source has to be used or, as in Sri Lanka, water is carted/ bowsered in from a nearby river and stored in the RWH tank. A small or medium size storage vessel is required to bridge the days when there is no rain.
- *Partial RWH* – providing partial coverage of the water requirements of the user during the whole of the year. An example of this type of system would be where a family gather rainwater to meet only the high-quality needs, such as drinking or cooking, while other needs, such as bathing and clothes washing, are met by a water source with a lower quality. This could be achieved

**Table 1.**

| *Cost reduction for water storage* | *Health improvements through novel design* |
|---|---|
| • Below-ground plastic-lined tanks with soil stabilisation.<br>• Low-cost partially-below-ground tanks using plastic linings.<br>• Brick or block built tanks (possibly using Cement Stabilised Soil Blocks [CSSB]) with external reinforcing.<br>• Very-thin-walled ferrocement water tanks.<br>• Recycled plastics for tank linings.<br>• Low-cost tank cover design - thin ferro-cement and domed mortor covers that need no shutting. | • Selection of roof, gutter and tank materials to improve water quality.<br>• Low-cost water lifting from below-ground tanks.<br>• Guttering design improvements (e.g. self cleaning gutters).<br>• Pre and post-storage filtration systems.<br>• Maximising water quality improvement during storage (e.g. use of baffles, floating off-takes). |

either in an area with a uniform rainfall pattern and with a small to medium storage capacity or in an area with a single (or two short) wet season(s) and a larger storage capacity to cover the needs during the dry season.

- *Full (or modified full) RWH* – with this type of system the total water demand of the user is met for the whole of the year by rainwater only. Usually requires a large storage capacity and is therefore costly. Alternatively, if demand can be varied throughout the year, say reducing consumption during the dry season, the storage requirement can be dramatically reduced, while still providing a reduced but sufficient supply of water. Figure 3 demonstrates this point by considering the case for Kigoma. If demand is halved during the dry season, then the normalised storage requirement is reduced from 38 per cent to 20.7 per cent.

The level of water security or reliability becomes an issue here. There is a pronounced law of diminishing returns when considering storage capacity against reliability[4]. It can be argued that it is preferable to have a high level of water security for a large part of the year, with a period of lower water security, than to have a low water security year round. Providing 100 per cent reliability is far more costly (on a per unit basis) than providing 80 per cent reliability. If users are prepared to be flexible in their demand, and be prepared to actively monitor their water consumption, then storage costs can be reduced significantly. This is admittedly an area of controversy as few users are keen to have to monitor their water use. It has worked, however, in Sri Lanka for example, where careful control of consumption has generated high levels of water security despite small storage capacity.

## Low-cost DRWH

The main cost component of a DRWH system is, with few exceptions, the storage vessel. If storage requirement is reduced then system costs decrease and the technology becomes more attractive in low-income areas. Low-cost roofwater harvesting obviously requires adequate mean rainfall and sufficient roof area - less obviously it requires a favourable rainfall distribution. When users are prepared to modify their consumption patterns then this can also bring great savings in costs of DRWH storage.

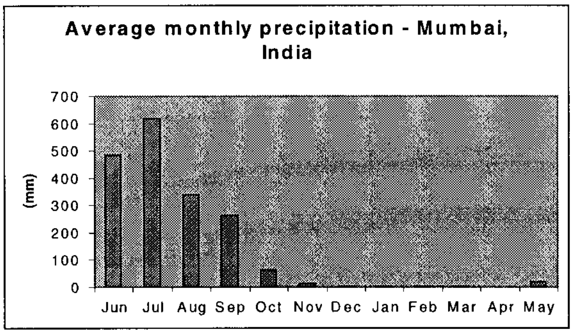
DRWH, when practised in this way, is a technology that can bring enormous benefits for relatively low initial cost. Where such DRWH has been promoted, by the World Bank sponsored Community Water Supply and Sanitation Programme in Sri Lanka for example, the results have been spectacular. Water can be provided for the majority of the year for a family of 4-6, using a storage vessel as small as 5000 litres. It is for this reason that the 4-partner Rainwater Harvesting Research Group is looking in more detail at the application of DRWH in the humid Tropics and in particular at reducing costs and improving health through good design practice.

## Reduction in cost of storage tanks – some initiatives being researched at Warwick

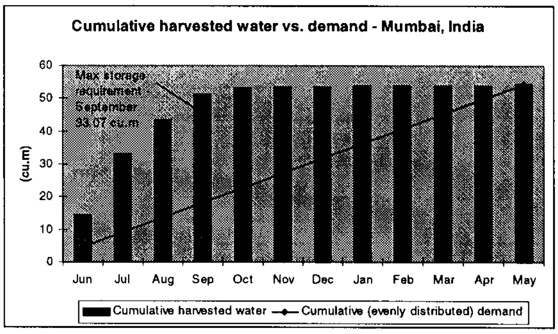
Warwick's task within the (European Commission financed) RHRG programme is to look at the technical issues related to cost reduction and health improvement for DRWH. We are still in the early stages of the programme (start date was August 1998), but some of the main aspects we are researching are outlined above.

## Conclusion

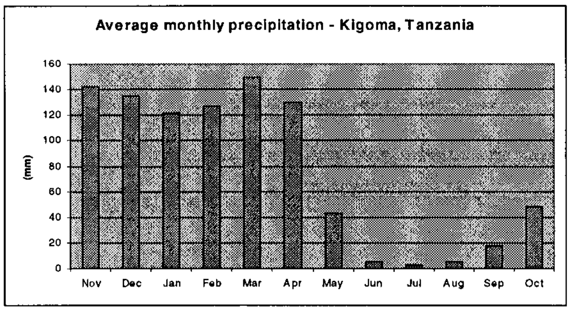
Although roofwater harvesting is a widely practised technology, its extension into new geographical areas, in particular into the humid tropics, requires lower costs and perhaps higher health performance, new institutional attitudes and better understanding of water security issues. These are being researched in a programme whose technological part is outlined above. Further information and results of this work can be found on the DTU Roofwater Harvesting Web Site at *Error! Bookmark not defined.* and the Rainwater Harvesting Research Group Web Site at Error! Bookmark not defined. Any comments and input are gratefully received and any group interested in collaboration can contact us at Error! Bookmark not defined.



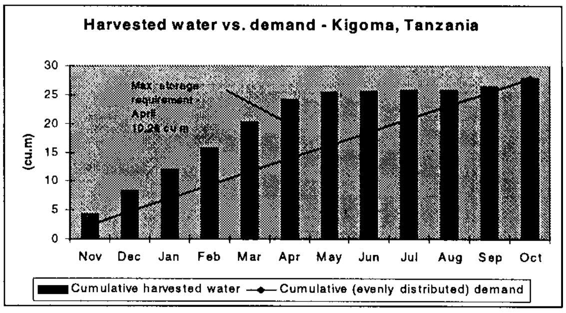

Graph 1a



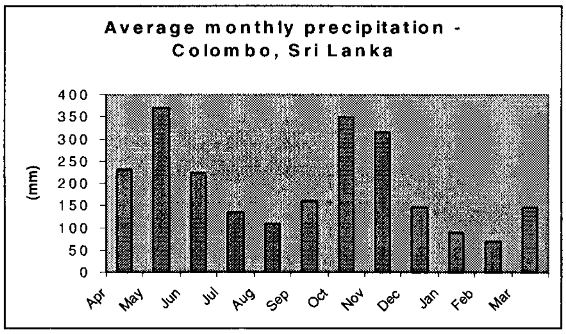

Graph 1b



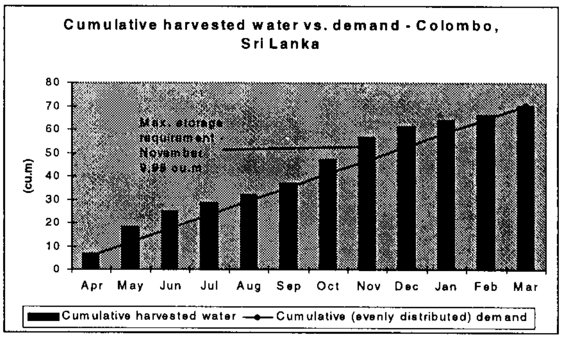

Graph 1c



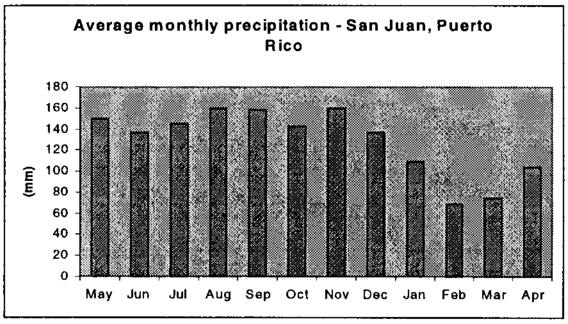

Graph 1d



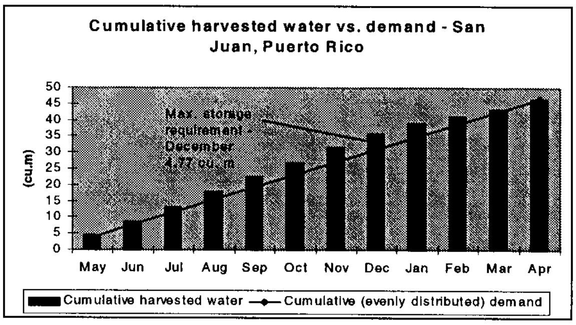

Graph 1e




Graph 1f




Graph 1g




Graph 1h

**Figure 1.**
Graph 1a shows the rainfall pattern for the single short wet season of Mumbai, India. Graph 1b shows the cumulative water harvested from a 30m$^2$ rooftop and the demand for this water distributed evenly throughout the year. The maximum storage, if all the possible harvested water is to be used, occurs in September (33.07 cu.m) and gives a normalised storage requirement of 60.9%. Graph 1c shows Kigoma's single long wet seasons. The maximum storage, if all the possible harvested water is to be used, occurs in April (10.26 cu.m) (Graph 1d) and the normalised storage requirement is now 38%. Graph 1e shows a bimodal rainfall pattern with two clear wet seasons. In this case the normalised storage requirement is 14%. Graph 1g shows an evenly distributed rainfall pattern. Graph 1h again shows the cumulative water harvested from a 30m$^2$ rooftop and the normalised storage requirement has now dropped to 10.3% with a maximum storage requirement of 4.77 cu.m.

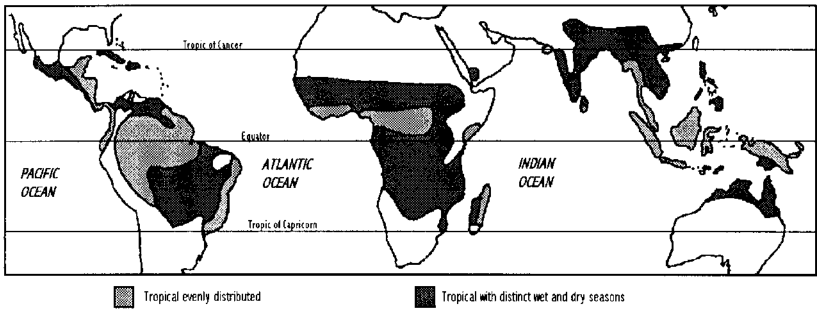
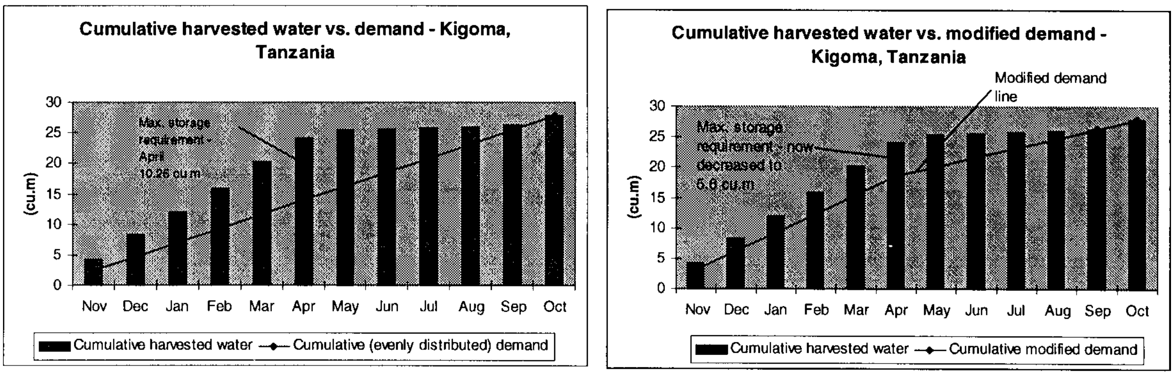



**Figure 2. Map showing areas of evenly distributed rainfall and areas with distinct wet land**




**Graph 3a** **Graph 3b**

**Figure 3.**

Graph 3a and 3b shows the cumulative harvestable rainwater from a 30m² roof the Kigoma town, Tanzania. Graph 3a shows the demand for this water evenly spread over the year. In this case the normalised storage requirement is 38%. When the demand is modified – consumption is halved during the dry season – the normalised storage requirement falls to 20.7% (Graph 3b)

## References


HAPUGODA, K.D., 1995, Action Research Study on Rain Water Harvesting. Project Report 2, Community Water Supply and Sanitation Project, Ministry of Housing, Construction and Public Utilities, Sri Lanka.

PACEY, A., and CULLIS, A., 1986, Rainwater Harvesting: the collection of rainfall and runoff in rural areas. Intermediate Technology Publications, UK.

PEARCE, E.A., and SMITH, C.G., 1998, The Hutchinson World Weather Guide. Helicon Publishing Ltd, Oxford, UK.

THOMAS, T., 1998, Domestic water supply using rainwater harvesting. Building Research and Information 26(2), 94 –101.



MR DAI REES, University of Warwick, UK.
DR TERRY THOMAS, University of Warwick, UK.