Rainwater harvesting in challenging environments: Towards institutional frameworks for sustainable domestic water supply

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Rainwater harvesting (RWH) has proved to be a viable alternative water source in challenging environments where other means of water supply have no or very little potential. In the last two decades, interest in RWH has grown. Several governments of Southern countries have taken the initiative to scale up community-based RWH approaches and networks have been established between Southern and Northern civil society organizations, governments, private sector and research institutes to support and promote upscaling of RWH. This paper describes the approach taken by one of these network organizations in water-scarce, remote and marginalized areas, and discusses lessons learned, challenges and the way forward. The main challenges are: 1) the multi-layer institutional model requires substantial initial investment and effective communication between organizations, water users and governments; 2) women's involvement in community management of RWH systems is still weak; and 3) initial investment costs for rainwater harvesting tanks are relatively high, limiting replication by communities in challenging environments.

Keywords: Rainwater harvesting, water scarcity, right to water, institutional development, capacity centres.

People living in remote and water-scarce areas are mostly the poorest people within a country. Their natural resources are very limited and living conditions are harsh. Governmental involvement in solving water scarcity and other issues involving the livelihood of these people is often lacking, for economic, political, logistical or technical reasons. Although a regular supply of safe water is a basic human right according to the United Nations Committee on Economic, Social and Cultural Rights (2002), many governments fail to guarantee water supply in remote areas, and private companies have no interest in providing water services there, since profits are difficult to obtain.

Many governments and private companies fail to guarantee water supply in remote areas

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Rainfall events are more erratic and extreme, leading to longer dry periods

Climate change is aggravating this situation. Rainfall events are more erratic and extreme, leading to longer dry periods sometimes and high water availability at other times. Owing to the longer dry periods, available water sources are no longer sufficient, and groundwater levels drop even further, resulting in longer distances to fetch water. This confirms the importance of efficient and effective storage of as much water as possible during the rainy seasons.

RWH has been used for millennia and examples can be found in all the great civilizations throughout history (Worm and van Hattum, 2006). With the increasing availability of hard roofs in many developing countries, roofwater harvesting is becoming a viable option for the collection of rainwater. One 20-litre container of clean water captured from a roof can save a walk of many kilometres to the nearest clean water source. Women and girls in particular benefit from RWH since they are usually the ones responsible for water collection. Moreover, RWH can replenish groundwater resources, thereby reviving nearby shallow wells. As a decentralized and low-cost technology, RWH enables people at household and community level to manage their own water without the need to walk long distances. An average rainfall of 200 mm a year can be sufficient for RWH to provide a reliable source of clean drinking water for vulnerable communities to bridge the dry periods of the year.

Efficient and effective storage of as much water as possible during the rainy season is important

Storage in above-ground ferro-cement tanks is a viable option, usually cheaper than (imported) polyethylene tanks. In general, ferrocement tanks have a lifespan of an estimated 15 to 20 years, provided the systems are well-maintained. Besides above-ground tanks, several other options exist for water storage, such as (partially) below-ground tanks, plastic ponds and sand dams.

The quality of rainwater for drinking purposes depends mainly on the surface of the catchments and the maintenance of storage facilities. Guidelines have been developed for the maintenance and improvement of the quality of collected rainwater (RAIN Foundation, 2008). These should form part of RWH trainings for technicians, masons, households and water committees.

In sub-Saharan Africa the potential of rainwater havesting is yet to be fully recognized

In sub-Saharan Africa the potential of RWH is yet to be fully recognized as there is insufficient awareness and support of RWH as a water supply solution and a lack of local capacity for implementation. More policy advocacy is needed to convince authorities and to scale-up RWH initiatives, first in challenging environments where there is no other alternative to safe water supply and where climate change will have the worst impact. An institutional framework would help to address and overcome this gap.

Growing interest in rainwater harvesting

In the last two decades, interest in RWH has grown. Several global and regional declarations have pronounced RWH to provide a solution to the current water needs in many African countries and security against future droughts (e.g. the 2007 Brazzaville Declaration by the African Ministerial Council on Water, the 2006 Climate Change Convention in Nairobi and the UNEP General Assembly of 2005 to the Commission on Sustainable Development). Meanwhile, several Asian governments have taken the initiative to scale up community-based RWH approaches, notably China, India, Thailand, Sri Lanka and Nepal. Rainwater harvesting is used extensively in Latin America and the Caribbean, mainly for domestic water supply (UNEP, 1997). In Africa, Kenya is actively promoting RWH, and governments endorsing RWH include Benin, Egypt, Ghana, Guinea, Kenya, Mauritania, Rwanda, South Africa, Swaziland and Zimbabwe (Partners for Sustainable Development, 2005).

Networks have been established to support and promote upscaling of RWH

Networks have been established between Southern and Northern civil society organizations, governments, private sector and research institutes to support and promote upscaling of RWH. Smet (2003) and Ariyabandu (2003) list a number of external factors that facilitated increased interest in RWH, including:

- the shift towards more community-based approaches and technologies which emphasize participation, ownership and sustainability;
- the increased use of small-scale water supply for productive and economic purposes (livelihoods approach);
- the decrease in the quality and quantity of ground- and surface water;
- the failure of many piped water supply systems due to poor operation and maintenance (O&M);
- the flexibility and adaptability of RWH technology;
- the replacement of traditional roofing (thatch) with impervious materials (e.g. tiles and corrugated iron);
- the increased availability of low-cost tanks (e.g. made of ferrocement or plastics).

Looking across past examples of RWH programmes in various countries, certain success factors are repeatedly seen

Looking across past examples of RWH programmes in various countries, certain success factors are repeatedly seen. The first success factor is a needs- and demand-based approach, combined with community capacity creation, with women involved and leading in management. Collaboration with other development actors is essential, not only for drinking water supply but also for other uses of water (for a discussion on multiple use water services, see *Waterlines Vol. 29 No. 1*). Access to micro-credit and saving schemes is important for replication combined with the user's own investment. This is particularly

Sustainability is only created if programmes receive effective support from governments or investment by the private sector

interesting when RWH enables income generation activities. Micro-credit schemes offer an appealing alternative to subsidy-dependent initiatives (although as yet there are few documented successful experiences in payment for household water supply; e.g. Davis et al., 2008). Sustainability is only created if programmes receive effective support from governments or investment by the private sector.

In line with the growing interest in RWH, RAIN (Rainwater Harvesting Implementation Network) Foundation was established in the Netherlands in 2004, motivated to address appeals for action to achieve effective water supply solutions as raised during the World Summit on Sustainable Development in South Africa in September 2002. RAIN implements rainwater harvesting projects in close partnership with other non-governmental organizations (NGOs). Priority intervention regions are remote, semi-arid and marginalized areas without access to other sources such as piped water or water from wells, boreholes or springs, because of groundwater contamination (with arsenic, fluoride, salts, etc.) or inaccessibility (very deep or with overlying impermeable geological layers). This article describes RAIN's institutional approach and lessons learned in Ethiopia, West Africa and Nepal. An overview of achievements to date is given in Table 1.

Rainwater Harvesting Capacity Centres

RAIN encourages governments to establish and support an institutional framework for RWH

RAIN encourages governments to establish and support an institutional framework for RWH. In order to increase the awareness and adoption of RWH by public as well as private actors, RAIN and its partners establish Rainwater Harvesting Capacity Centres (RHCCs) in each country under the RAIN programme, overseeing project implementation, but also coordinating promotion and lobby activities at a national level. One of the aims is the inclusion and recognition of RWH in national water policies. The centres involve and bring together key players within the sector through workshops and more

Table 1. RAIN's activities per country 2004–2010

	Rooftop		*Sand dam*		*Surface runoff*			
	Roofwater harvesting (m^3)	*Beneficiaries*	*Sand dams (m^3)*	*Beneficiaries*	*Surface runoff (m^3)*	*Beneficiaries*	*Total (m^3)*	*Beneficiaries*
Burkina Faso	8,604	18,079					8,604	18,079
Ethiopia	735	844	21,000	8,400	1,110	388	22,845	9,632
Mali	6,836	11,195					6,836	11,195
Nepal	8,673	9,292					8,673	9,292
Senegal	9,246	14,924					9,246	14,924
Total	34,094	54,334	21,000	8,400	1,110	388	56,204	63,122

day-to-day consultations about RWH policies, water source mapping, water quality testing and the like.

For programme implementation, RAIN and the RHCCs identify priority intervention areas at a national level and contract NGOs already working within these regions (see Figure 1). The RHCCs and RAIN train these partnering NGOs in RWH and monitor and evaluate project implementation. The centres also play a central role in learning and knowledge exchange, systematizing best practices and experiences. User manuals have been developed in English and French, as well as rainwater quality guidelines. Most NGOs have been able to achieve ambitious construction targets despite the remoteness of most of the sites. In-country capacity development has increased the number of trained and experienced NGOs, technicians, masons and trainers in the RWH technology, as well as community-based water committees and households in management of the RWH systems. Extension workers support households and water committees to manage water distribution and payment schemes, and to maintain water quality and hygiene.

NGOs have achieved ambitious construction targets despite the remoteness of most of the sites

Cross-regional connections are facilitated by means of exchange visits, regional workshops and annual learning events between all implementing partners. Exchanges also take place with networks such as SEARNET (Southern and Eastern Africa Rainwater Network), IRHA (International Rainwater Harvesting Alliance), GHARP (Greater Horn of Africa Rainwater Partnership), the MUS Group (Multiple Use Water

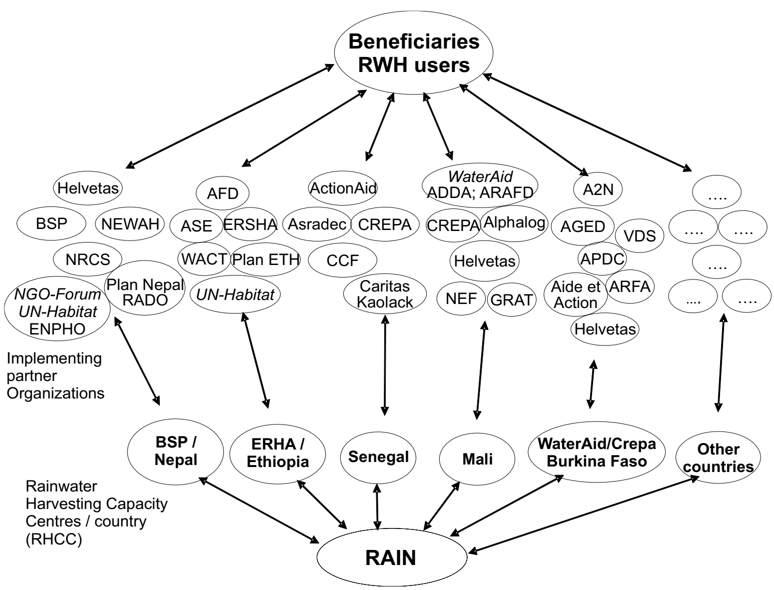

Figure 1. RAIN's institutional framework

Services) and CGIAR (Consultative Group on International Agricultural Research), and during annual events such as the Stockholm Water Week and the SEARNET International Conference.

Lessons learned in Ethiopia

Only 31 per cent of rural Ethiopians had sustainable access to an improved drinking water source

According to the WHO's Statistical Information System (WHO, 2010), only 31 per cent of the Ethiopians living in rural areas had sustainable access to an improved drinking water source in 2006. The situation is becoming more alarming as a result of a growing population, dropping groundwater levels as a result of over-exploitation, and the negative impacts of climate change. In 2005, RAIN established an RHCC in Ethiopia within an existing organization called ERHA (Ethiopian Rainwater Harvesting Association) and started implementation with four partner organizations, which constructed 11 tanks with a total storage capacity of 445,000 litres to supply water to more than 3,000 people. The collected rainwater is currently used at schools and health centres, mainly for drinking and hygiene purposes.

People depend largely on open water sources such as rivers and ponds, which tend to dry up quickly

Borana, one of RAIN's working areas, is a semi-arid region in southern Ethiopia with two annual dry seasons. During these periods, most people walk between 6 and 8 hours to fetch water. People depend largely on open water sources such as rivers and ponds, which tend to dry up quickly after the rainy season, providing unreliable water quality and quantity. In large areas, groundwater is not accessible or contains arsenic or high salt levels making it unsuitable for drinking. RAIN's work in Borana began in 2007 with the key aim to improve access to safe drinking water for remote communities, a programme funded by the Dutch Government.

A combination of water harvesting techniques provides a reliable solution to the availability of drinking water

A combination of water harvesting techniques (surface water runoff with below-ground tanks and sand dams) provided a reliable solution to the availability of drinking water. Subsequently 15 local implementing organizations were trained in sand dam technology and are constructing sand dams within their interventions areas. The sand dams are designed so that runoff water is infiltrated in the sand behind a small dam traversing the riverbed, serving as an artificial aquifer. In this way, evaporation losses are limited, the quality of water remains high and water can be extracted from the sand in the dry season using shallow wells. The dams contribute to groundwater recharge and reduce the risk of erosion and flooding (for more information on water recharge, retention and reuse, see van Steenbergen and Tuinhof, 2009). If a sand dam is properly constructed, it requires little or no major maintenance.

In time, the dams should protect the livelihoods of the people of Borana from the foreseeable effects of climate change. Their design was taken from interventions by SASOL (Sahelian Solutions) and Acacia Water in the Kitui region in Kenya (see http://www.sanddam.org). RAIN, Acacia Water, ERHA, AFD and SASOL won the Swiss Re International ReSource Award 2007 for this project. The pilot project served to ensure further upscaling in Ethiopia in 2008–2010.

Lessons learned in West Africa

In West African countries such as Burkina Faso, Mali and Senegal, the majority of people are dependent on water sources of unreliable quality. In some areas this is due to contamination from human or animal excrement, agricultural residues or industrial pollutants, in others because of high concentrations of naturally occurring minerals, such as arsenic and fluoride, which negatively affect the quality of groundwater. Adequate purifying mechanisms are usually absent or too costly to purchase. In addition, as in Ethiopia, in many areas groundwater levels are dropping, making groundwater extraction too expensive or unfeasible. Drinking water problems differ for urban and rural areas. In urban areas many schools, public facilities and even households are connected to piped systems. However, cuts in supply are becoming more and more frequent and prolonged. Also the increasing prices of water force users to look at RWH as an alternative to piped water supply. In rural areas the mere access to sufficient water of an acceptable quality is a problem, in particular during the dry period. In 2006, the population with sustainable access to improved drinking water resources in rural areas was 48 per cent in Mali, 65 per cent in Senegal and 66 per cent in Burkina Faso (WHO, 2010).

In many areas groundwater levels are dropping, making extraction too expensive or unfeasible

In 2006, RAIN obtained funding from the Dutch Ministry of Foreign Affairs (with co-funding from Fondation Ensemble) to extend its activities into West Africa. Subsequently RAIN started working in Burkina Faso in 2006 and focused on capacity building among four implementing organizations. A RHCC was also established in 2007 through a joint venture between WaterAid Burkina Faso and CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût). CREPA BF is responsible for the technical aspects and WaterAid for the organizational, managerial and financial aspects. Partnerships with three additional organizations were established at the end of 2007. Together they create a solid base for large-scale implementation of rainwater harvesting in Burkina Faso, and for lobby and advocacy at the level of the national government.

Use is made of roofwater harvesting with above-ground ferrocement tanks for storage at household level (80 per cent of the tanks) and school level (20 per cent of the tanks). This approach has advantages and disadvantages. Maintenance of the tanks is anticipated to

Maintenance of the tanks is anticipated to be higher with individuals and families

be higher with individuals and families than with groups of people. The availability of adequate rainwater capture area (i.e. roofing of corrugated iron), however, is a limiting factor for RWH at household level. At schools and community buildings, an adequate capture area (corrugated iron roofs) is often easily available. Water committees are formed by beneficiaries in order to ensure maintenance of the RWH systems. CREPA provides the training for roofwater harvesting systems with above-ground storage in ferro-cement tanks.

Soon after starting in Burkina Faso, RAIN started implementation in Senegal and Mali with, respectively, four and six implementing partner organizations. It was decided to focus on rural communities with no alternative options for access to water. In 2009 an RHCC was established in Senegal within CREPA Senegal. Thus far, the Burkina Faso RHCC has fulfilled the role of strengthening the organizational and technical skills of the Malian implementing organizations, by giving technical training and organizing national and international knowledge exchange events. RAIN is currently organizing the establishment of a RHCC within Helvetas (a Swiss NGO) Mali.

There is a debate on whether rainwater quality and quantity is acceptable according to national norms

The impact of RAIN's interventions on policy in these countries is currently at the level of a debate on whether rainwater quality and quantity is acceptable according to national norms. RWH is not yet included in the water sector policies and legal framework of these countries; however interest is high at all levels. Programme evaluations confirm that the RWH systems in Senegal, Mali and Burkina Faso are of good quality and that beneficiaries have been well trained in system management, operation, maintenance and repair. All implementing organizations will continue to construct rainwater harvesting systems on a larger scale.

Lessons learned in Nepal

Monsoon rain causes catastrophic soil erosion whereas water scarcity is faced in the dry periods

About 60 per cent of Nepal's terrain can be graded as steep to very steep (i.e. mountainous). The problem in the hills and mountains is that excessive rain in the monsoon causes catastrophic soil erosion whereas water scarcity is faced in the non-monsoon periods. A substantial part of monsoon rainfall is wasted as surface runoff. Most people in these areas rely on natural springs and gravity-flow water supply systems (Merz et al., 2003). Women and children in particular experience the dangers of carrying water on hills and slippery footpaths. Water source depletion is an increasing problem. Farmers have traditionally managed ponds along ridges and on slopes for watering animals. These ponds improved recharge and also helped to increase spring yields. Over time, however, many ponds disappeared because farmers did not maintain them and they silted up. Next to this, climate change seems to have an impact on water availability as well, shortening the rainy season (winter rains have been almost absent in recent years) and springs and streams are receding more and more.

Harvesting excess rainwater is a viable solution to reduce surface erosion and downstream sedimentation

Effective harvesting of excess rainwater can be a viable solution to reduce water shortage on one hand and reduce surface erosion and downstream sedimentation on the other hand (Shrestha, 2001). However, until some years ago, the use of rainwater and its storage for drinking purpose was hardly practised in Nepal, probably because stored water was regarded as impure and flowing water as pure (Campbell, 1973 cited in Shrestha, 2001). Local systems called *punyalo*, made of bamboo mats and pieces of cloth laid horizontally on four bamboo supports to harvest rainwater were used for livestock only (Dixit, 1991 cited in Shrestha, 2001). Considering the water scarcity in the dry season in combination with the steepness of the hills, roofwater harvesting would help to increase water supply. In the last couple of years, the collection of rainwater for domestic use has been promoted by the Government of Nepal, mainly through a large-scale programme supported by the Finnish Embassy (formerly FINNIDA). Technical guidelines have been produced for the application and construction of rainwater systems in rural areas and urban areas.

In order to address the problems of water shortage and land degradation, RAIN and its RHCC at Biogas Sector Partnership Nepal (BSPN) are providing water through rainwater harvesting, mainly rooftop harvesting, to remote hilltop households. Through its implementing partners, the RHCC and RAIN are not only reaching out to the rural unserved in Nepal, but have also been able to support the establishment of a national policy on rainwater harvesting in which the Nepalese government recognizes rainwater as a source of drinking water. Currently, the RHCC is co-developing a national programme on rainwater harvesting with the Ministry of Local Development. At the moment, the RHCC is investigating options for alternative financial models, such as microfinance, and low-cost technologies, enhancing upscaling and replication of the technique within the country. The programme in Nepal is looking at rainwater not only as a source of drinking water, but also for other uses and livelihoods, such as the production of biogas.

The Nepal programme collects rainwater as a source of drinking water, but also for livelihood uses

Challenges and the way forward

The multi-layer institutional model requires substantial initial investment and effective communication between organizations, water users and governments. In choosing a multi-layer institutional model RAIN has had to develop approaches to set up an RHCC that is well respected and capable of carrying out this integral role at a national level. For other NGOs to wish to cooperate fully with the RHCC, they must experience its 'added value' as a source of technical and management expertise and more importantly, a mobilizer or 'broker' of information and implementation funds. Developing this capacity and working arrangements takes time, a well-considered strategy, multi-stakeholder platforms for collective planning, ongoing communication and awareness raising. It is RAIN's intention that the RHCCs and the national RWH programmes become autonomous. Ideally there can be a shift away from donor-driven intervention to implementation that is community-driven and accessible to the poorest and most vulnerable persons. In order for this to happen, the necessary institutional capacity needs to be developed and the viability of RWH as a relevant water supply option needs to be demonstrated to gain the support of government and alternative financing institutions. This will take time as well as a substantial initial investment.

The viability of RWH as a water supply option needs to be demonstrated to gain support

Women's involvement in community management of RWH systems is still weak. Women are the traditional water managers, responsible for household water provision, and yet it is not easy to genuinely involve them since decisions are often taken by men. Informing women about the different possibilities of RWH systems and involving women in decision making, design, operation and maintenance will lead to appropriate and more sustainable RWH systems. Although RAIN emphasizes the importance of the participation of women in water committees, more efforts are needed in terms of lobbying, support and encouragement to make women's involvement in community management of RWH systems effective.

More efforts are needed to make women's involvement in community management of RWH systems effective

Initial investment costs for RWH technology are relatively high, limiting replication driven by communities in challenging environments. RAIN's experience is that community willingness to replicate RWH measures is high; however, costs to replicate RWH systems by poor communities, as in other safe water supply systems, are still high: €40–100/m^3 of storage capacity using ferro-cement RWH technology in RAIN's remote target areas. RAIN's innovation places emphasis on accelerating a further reduction of the construction costs per cubic metre. Therefore a research and development programme has been set up in Burkina Faso, Ethiopia and Nepal to look into cost-efficiency of the tanks. According to the World Water Development Report 2009, the main obstacle to the expansion of small-scale water providers is lack of financing. A sustainable way of financing seed capital for RWH could be the provision of micro-credit. Experiments with micro-credit for RWH are few to date on a global level. RAIN is currently developing pilots with RWH and micro-credit schemes, starting soon in Nepal and Senegal.

The main obstacle to the expansion of small-scale water providers is lack of finance

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