Working Paper:
Rainwater Harvesting Methods

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'Rainwater harvesting system has been regarded as a sound strategy of alternative water sources for increasing water supply capacities.'
(Su et al. 2009, p. 393)

Abstract

Only around one percent of water is currently easily accessible for human needs. This has encouraged a search for solutions to fight local scarcity. One proposed answer is the collection of rainfall through Rain Water Harvesting (RWH) methods. The process consists of collection, storage, and local use of rainwater. RWH systems can be sub-categorised based on the catchment size, runoff transfer distance, source of water, mode of storage, mode of usage, and other details. As an integral part of human settlements and farming for thousands of years, RWH methods present a number of benefits if suitably applied, namely, diversification with better yields that can increase income, create a number of jobs, reduce poverty level, promote sustainable forms of agriculture, mitigate climate change and spread year-round vegetation cover. However, the benefits of these systems come with certain challenges: most notably the provision of a high quality and sufficient quantity of water with feasible measures. In this paper, challenges have been divided into technical and quality issues, legislative, economical aspects and lack of awareness. In order to help tackle the above mentioned challenges, as well as to promote and scale-up the usage of RWH systems, the Gansu Province case in China and the North-eastern region of Brazil are presented in an exemplary way as best practices.

Keywords: Agriculture, Catchment, Rainfall, Rain Water Harvesting, Runoff, Water Scarcity

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Introduction

Water may seem abundant, but less than one percent of the world's water is readily accessible for human needs. The 2011 FAO study *The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk* raises questions on water availability, as it claims that water demand has been increasing worldwide at a rapid pace, resulting in a gap between support and fulfilment of human needs, and actual supply and access to high quality water, especially in low to medium-income countries. This increase in demand has been caused by demographic changes, socioeconomic factors, and changes in agricultural practices, in addition to climatic variation (Fewkes 2012; Lee et al. 2016). Thus, improvements in water use efficiency are required to address water scarcity, and therefore water stress, as well as the avoidance of possible conflicts that may arise from the given stress. Currently, water stress is defined only numerically, that is, when renewable water supplies drop below 1,700 m^3 per capita per year, and it does not take into account local factors affecting access to water (WWAP 2016). To fight this water scarcity and stress, and include local factors into the equation, one proposed solution are water harvesting practices, and more specifically Rain Water Harvesting (RWH).

RWH methods represent access to water often through decentralised systems, which translates into users having direct management of them. That is, it empowers households and communities in the decision-making processes and systems' usage (König 2009). Furthermore, the benefits RWH systems provide are not limited to the provision of drinking water, but their positive effects have direct and indirect repercussions into the social, economic, and environmental spheres of the users' livelihood, communities, and ecosystems. These effects are a result of synergies between human well-being, development and improvement, and ecosystems' regeneration and maintenance (Barron 2009; Dile et al. 2013; Falkenmark et al. 2001; Sanches Fernandes, Terêncio & Pacheco 2015; Su et al. 2008; Vohland & Barry 2009).

This inclusive positive response of RWH methods has made them an integral part of human settlements and farming, going from small dams to runoff systems for agricultural processes, to having water reserves for drinking purposes (Mbilinyi et al. 2005). The literature presents examples of RWH techniques that date back as far as over 5000 BC in Iraq (Falkenmark et al. 2001), 3000 BC in the Middle East (Barron 2009), and 2000 BC in the Negev desert in Israel, Africa, and India (Fewkes 2012). In spite of their long history, RWH have been displaced in the last century by other technologies that have taken the lead in water management systems. However, some of them excluded indigenous knowledge, while others did not consider social, geological, and economic background of the sites, making them unsuccessful or possible only with a high environmental and/or economic cost. Thus, in the last couple of decades, RWH has regained importance as a holistic approach for sustainable growth (Barron 2009; Lee et al. 2016; WWAP, 2016; Zhu 2008). Current best practices can be found world-wide in Japan, Germany, and Australia as leading exponents for urban rainwater harvesting systems, and China, India, and Botswana for rural systems. Nonetheless, there are still challenges that RWH systems need to face to be able to scale-up and be widely used, namely, water quality control, government and public authorities' direct involvement in form of legislations, financial support, and spreading of knowledge and final-users' commitment. Since the 1970s, the literature on RWH has grown in depth and understanding of the importance of specialising the systems for each given economic, social, geological, and environmental context. This specialisation has also created specific categories and sub-categories of RWH Systems according to the study approach taken by the researcher. This literature review tries to provide a general overview of the benefits and challenges from implementing RWH systems, while illustrating two best practices, the Province of Gansu in China and the north-eastern semi-arid region of Brazil, to create a better understanding of RWH methods, while highlighting the importance of water for a sustainable development.

Categorisation of RWH Systems

Rain Water Harvesting is composed of a wide array of technologies, ranging from high-tech to traditional ones and from high to low cost; depending on the area of application and space that they cover (Barron 2009). RWH usually consists of three main components: a catchment area, where the rainfall is collected, a storage facility, where the water is stored to be used immediately or later, when water is scarce, and a target system, that is, what usage it will be given, what target it will serve. Generally, the main aim of their usage is for human consumption and supplementary water-related activities, as well as the lag of runoff during rain periods (Fewkes 2012).

Plant production

This richness of RWH technologies and components makes its classification vary in the literature, depending on the focus given by the researchers. For instance, for agricultural purposes, the 1991 FAO study *A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production* divides RWH into 3 major categories, classifying them according to the catchment area size and the runoff transfer distance into: Internal or Micro-catchment rainwater harvesting, External or Macro-catchment rainwater harvesting, and Flood water harvesting. Other authors include an initial division to these three categories, called: in-situ rainwater harvesting, or soil and water conservation, as its function is to capture and store rainfall directly in the soil, helping to increase soil infiltration and regeneration (Hatibu & Mahoo 1999; Ibraimo & Munguambe 2007; Mbilinyi et al. 2005; Mzirai & Tumbo 2010). Furthermore, other authors, as Prinz and Malik (2002) exclude the third category of floodwater harvesting in their categorisation of RWH.

Internal or Micro-catchment rainwater harvesting, are also called Within-field catchment systems and refer to systems where rainfall is collected in small catchment areas ranging between 1 to 30 meters according to FAO (1991). Oweis, Prinz and Hachum (2001) increased the threshold to up to 1000 square meters. The runoff of these systems is stored directly in the soil, and there is usually no provision for overflow. They cater directly to trees, bushes, or annual crops. Examples of these systems are contour bunds, contour ridges, and semi-circular bunds, among others (Critchley & Siegert 1991; Dile et al. 2013; Falkenmark et al. 2001; Ibraimo & Munguambe 2007).

External or Macro-catchment rainwater harvesting are correspondingly known as Long slope catchment technique. Different to micro-catchment systems, they involve large areas to collect runoff from 30 to 200 metres, and are able to overflow excess water. Moreover, the distance to the target systems is much larger (Critchley & Siegert 1991; Falkenmark et al. 2001), and as Ibraimo and Munguambe (2007) argued makes this approach much more labour intense. Another major difference is that the runoff capture is lower compared to what is collected in micro-catchment systems (Oweis, Prinz & Hachum 2001). Examples of this system are: trapezoidal bunds and contour stone bunds.

Floodwater harvesting is also known as Water spreading and sometimes Spate irrigation. Oweis, Prinz & Hachum (2001) categorise it together with external or macro-catchments systems as they share similar characteristics, such as the provision of overflow and the presence of turbulent runoff; however, their catchment area is far larger, covering several kilometres of distance (Critchley & Siegert 1991). Examples of this system are: permeable rock dams, and water spreading bunds.

Oweis, Prinz & Hachum (2001) further divide their target system to include a domestic category. To do this, they present a further subcategorisation of the micro-catchment systems, which includes land catchment surfaces mentioned by the 1991 FAO study and add a non-land catchment surface, including rooftop systems, courtyards, and other impermeable structures. They further explain that this type of collection is mainly used for domestic purposes, although if the quality of the water is low, it could be also used in agriculture practices or to support home gardens.

Source of water

The UNEP and Stockholm Environment Institute (2009) study *Rainwater harvesting: a lifeline for human well-being,* classified RWH based on the source of water (catchment area) into: in-situ and ex-situ technologies, and manmade/impermeable surfaces. This division is founded on a proposal made by the Stockholm International Water Institute (SIWI). Other authors follow this division, but use only the first two categories, in-situ and ex-situ for their analysis (Cortesi, Prasad & Abhiyan 2009; Falkenmark et al. 2001). In both cases, the main objective of in-situ systems is to reduce runoff water by enhancing soil infiltration (Barron 2009; Helmreich & Horn 2009; Mbilinyi et al. 2005). In this scenario, water is collected directly where it falls and is stored in the soil (Cortesi, Prasad & Abhiyan 2009), terracing and living barriers are examples of this collection method. The ex-situ technologies, differently to in-situ systems, store runoff water externally to where it got captured (Barron 2009; Helmreich & Horn 2009). Examples of these systems are pavement collection, ponds, and/or swales.

Once the rainfall is collected, it requires a storage system, thus the UNEP study also provides a subcategory to divide RWH in terms of the mode of storage. These systems can be located externally or underground. Some of the main forms used are: micro-dams, earth dams, farm ponds, sub-surfaces, sand dams or check dams, and tanks (Falkenmark et al. 2001). Fewkes (2012) mentions, that the storage capacity has a relevant economical and operational connotation for the system. And when referring specifically to tanks the material of construction – plastic, concrete, or steel- helps to determine its durability and cost. Falkenmark et al. (2001) also discussed a further subdivision in terms of the time the water remains stored in either of the previous systems. Figure 1 provides a complete schematic of the division and subdivision of RWH in terms of source of water, mode of storage, and principal water use.

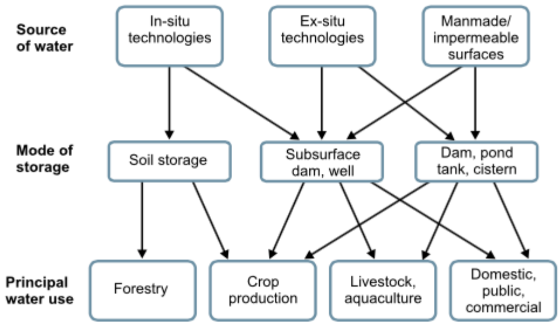

Figure 1 - Schematic of rainwater harvesting technologies based on source of water, storage mode, and principal use (Barron 2009).

Finally, the term Domestic Rain-Water Harvesting (DRWH) systems has been used by authors such as Helmreich & Horn (2009), as a category of RWH that collects water for domestic purposes. It is mainly found in studies that analyse the spur of urbanisation and how to cope with the rise in water demand in this area (Mwenge Kahinda, Taigbenu & Boroto 2007). The collection in DRWH can be carried out by different methods: roofs, streets, and ponds, among others.

To summarise, RWH systems can be categorised in different manners. This diversity of categories helps to portray the richness of RWH systems to adapt to different needs, budgets, and spaces to be covered, in addition to providing researchers with a more exact terminology for their analysis. The categories can be determined by catchment size, runoff transfer distance, source of water, systems of storage, and usage, among others.

RWH Design Techniques

As described previously, there is a variety of usages and forms of RWH systems, which help to reflect its dynamic and flexibility (Barron 2009). This section of the paper will help to illustrate two design techniques of RWH systems: keyline systems, which are used for agricultural purposes, and rooftop catchments, as an example for domestic water provision.

Keylines Rainwater Harvesting Systems

Keylines are a holistic approach of rainwater harvesting systems used in agriculture. Their main goal is to increase soil fertility by increasing the total organic matter content within soil. The system was developed in Australia in the 1950s by P.A. Yeomans, and is based on the natural topography, contours, and slopes of the land.

One of the most powerful tools it offers is the construction of swales or ditches with a small gradient away from gullies, thus bringing overflow runoff in the erosion gullies into the shoulders. Yeomans (1954; 1958; 1971) gives full guidance to where and how swales and small dams should be implemented with the given features of topography. Although the system has received little scientific support (Ferguson 2015; Toensmeier 2016), it is popular with farmers, who regard it for its soil organic matter improvement properties (Toensmeier 2016).

The main exponents of this implementation are David Holmgren and Bill Mollison, who developed the framework for a new agricultural ecosystem called permaculture, based on the adoption of many concepts of the keyline plan (Ferguson 2015). The reason behind this adoption are the several benefits keyline systems offer, some of which can be seen immediately, while others have a long-term result. These can be enumerated as: reduction of soil erosion, restoration of subsurface hydrological flows and aquifers, abatement of floods and droughts and reduction of sediments carried by rivers, among others (Feineigle 2013).

Rooftops: Domestic Rain Water Harvesting design technique

Rooftops are excellent collectors of rainfall for domestic usage. Fewkes (2012) states that out of the different methods currently used, the most common technology for collection are rooftops. To have a full advantage of rooftop systems, it is important to pay attention to the selection of construction material, sloping of roofs, maintenance, pollution, and extra water usage. For instance, a study by Helmreich & Horn (2009) says that roofs tied with bamboo gutters are not suitable, due to health problems that derive from it. Their study further expressed that although zinc and copper helped to channel water easier than other systems, it is necessary to pay attention to possible pollution of those with metallic paint or other coatings, due to the heavy metal concentration. Moreover, in the last couple of years there has been an increased usage of green roofs, as they provide an extensive range of benefits widely known in the literature, namely, sound insulation, urban heat effect reduction, CO_2 emissions reduction, as well as diversification, and maintenance of biodiversity, among others (König 2009). Nonetheless, when it comes to their analysis as RWH systems, it is relevant to count water use for their irrigation, which, as An et al. (2015) pointed out, is a factor that is usually not considered. Moreover, the best roof system will depend on many factors, such as weather and rainfall. However, those with smooth sloping roofs harvest 50 % or more than flat rough roofs (Mun & Han 2012). In addition, Fewkes (2012, p.179) recommend those, which are chemically inert, such as slates.

The final decision on which design technique should be implemented will depend on the specificities of the area where it will be installed. Keyline systems have proven to be a complementary tool for agriculture practices; nonetheless, there is still a need for further research to support them. More abundant scientific literature exists on rooftop systems, supporting their usage and a longer tradition as domestic water service providers. However, there are still elements that need to be evaluated, such as the water use for irrigation in green roofs.

RWH Challenges

RWH systems face several challenges. The most important is the provision of good water quality for the drinking water supply. In addition, there are other challenges that have prevented wider scale RWH implementation. In this paper, they have been divided into technical and quality issues, legislative, economical aspects, and lack of awareness.

Technical and quality issues

Quality is the main challenge posing health concerns in RWH systems. In certain case studies, they attribute low quality as a result of a lack of monitoring (WWAP 2016), which represented, for instance, high numbers of cases of diarrhoea in a project implemented in Thailand (Salas 2009). Thus, authors with practical experience, as König (2009), have recommended maintaining the collecting surfaces and storing facilities free from pollutants and mosquito breeding – to avoid cases of malaria, dengue, and other diseases. Another suggestion came from Fewkes (2012), who argued for storing facilities designed to overflow at least twice a year to facilitate particles removal. Moreover, in order to improve or reduce water pollution levels, a study by Helmreich and Horn (2009) promoted solar and membrane technologies, and slow sand filtration systems. These methods allow water disinfection, and microbiological quality improvement. Furthermore, the most important technical challenge is rainfall variability (König 2009; Salas 2009; Sharma 2009). Currently, there are technologies that try to measure and predict rainfall, and thus try to improve the systems' design, however, this is not an easy task. Accordingly, scholars such as Sharma (2009 p. 24) go as far as to name this 'the greatest water challenge'.

Finally, further research on water access to downstream users is needed (Dile et al. 2013; Falkenmark et al. 2001), as it is believed that harvesting water might result in a decrease for downstream users (Barron 2009). Specifically, a case carried out in Saurashtra region, India, showed that although RWH have benefits, a rapid unmonitored adoption could potentially affect downstream users (Cortesi, Prasad & Abhiyan 2009). Given the above, increasing infiltration, and thus rising aquifers is preferable over direct storage. At the same time, refilling aquifers will help the whole downstream system to have a balanced water supply. Nonetheless, aquifer recharge is only possible on a certain scale, on community or catchment level, and mostly not very efficient on an individual basis with small patches of land.

Legislative issues

A UK study shows that there is a negative impact in the technology implementation, when there are low or no water quality standards in place, and/or no public health associations' action (Fewkes 2012). The legislation to back up the development and implementation of RWH systems is lacking in most countries, and in rural areas of South Africa DRWH it is even illegal (Mwenge Kahinda, Taigbenu & Boroto 2007). This absence of legislations has rendered into an insignificant transfer of knowledge and best practices among countries. Sharma (2009) argues that one reason for this is the fact that structural and institutional functioning of governments in place do not relate to the actual need of local institutions. An active policy support should be brought together with technical know-how and capacity building, as the study by the Stockholm Environmental Institute and the UNEP suggested. Moreover, according to Sanches Fernandes, Terêncio and Pacheco (2015), the most important challenge for RWH systems to be implemented in a higher number is the lack of inclusion within countries' water policies. Without government intervention, citizens lack awareness of the systems, and thus do not implement them or force the creation of laws that promote among others financial incentives to acquire them (Lee et al. 2016). One way to tackle this is to mainstream RWH systems into national policies, and, as suggested by the Stockholm Environmental Institute and UNEP study (2009), to include rainfall as part of the water management plans, as it has been done in Germany and Australia, which are currently examples of best practices.

Economic issues

There is a need for financial incentives to increase RWH systems usage, an initial investment subsidies by local governments (König 2009; Fewkes 2012). For instance, a study by the Australian Bureau of Statistics (ABS) established that the main reason for not having installed a rainwater tank lied in the perception of a high cost (Rahman, Keane & Imteaz 2012). Another example of this is a study carried out by Roebuck (2011), where he shows that in order for DRWH to be cost effective in urban areas there is a need for a type of household allowance. Moreover, other relevant economic aspects are the countries' low water tariff. For instance, in Malaysia, as it was presented by Ern Lee et al. (2016), the installation cost of RWH systems is much higher than local water tariffs, resulting in a negative cost-benefit trade. Thus, authors such as König (2009), recommend providing subsidies to supply the initial step for the system's installation, as was the case of the Gansu Province in China. At a larger scale, specifically for companies, Fewkes (2012) proposed a tax incentive, which enhances the usage of these systems within companies.

Lack of awareness

Furthermore, these financial incentives should go hand in hand with awareness of the systems potential for the users. However, as Rahman, Keane & Imteaz (2012) explained, users do not welcome these systems, or lack the motivation to implement them, as they do not see benefits over the long term, or in general there is no involvement (Helmreich & Horn 2009). Another perspective was presented by a case in Malaysia, in which water abundant perception has prevented households to see the need to implement these technologies in their homes (Lee et al. 2016). Or as Fewkes (2012) portrayed it, possible users simply lack knowledge and access to information on how the water cycle and water recycling cycle works, and thus do not understand water finite aspect. Thus, to engage changes in users' mind-set, it is important to raise awareness of the benefits these systems provide, water finite aspect as a natural resource, and the need to create a connection between governments and local authorities, in terms of actions within a community.

In order to overcome these challenges, governments need to work together with local communities, to understand their direct needs, and to embed local knowledge. The first step towards this is the inclusion of rainfall in legislations, followed by a promotion and increase of awareness of the systems' functioning and utility, as part of schools and universities' curriculum. These are essential for the propagation of the systems at a wider scale, and for maintaining the systems' standards, resulting in better water quality and no-health risk for users.

RWH Benefits

Best practices can be found in rural and urban areas around the world, as the application of RWH systems provide synergies between human well-being, development and improvement, and ecosystems' regeneration and maintenance. These synergies translate into direct and indirect social, economic, and environmental benefits.

In terms of social gains, a study carried out by Barron (2009) points out the importance of RWH to provide communities with an opportunity to develop their religious and spiritual rituals. In addition, Sharma (2009) states an improvement in communication between residences and the study by the Stockholm Environmental Institute and the UNEP (2009) added a progress of equity and gender balance in these communities. Sharma (2009) describes the economic gains as the increase in the number of jobs available and formation of microfinance and working groups, which influenced poverty reduction (Dile et al. 2013; Falkenmark et al. 2001) and resulted in an increment on farmers' income (Vohland & Barry 2009), benefiting the achievement of the Millennium Development Goals (Barron 2009). Examples of this come from cases in India and China, where the installation of RWH systems has provided farmers with added value to their crops by diversifying them to the inclusion of vegetables and fruits (Sharma 2009; Sturm et al. 2009; WWDR 2016), and to having other types of livestock (König 2009). For example, in India specifically, RWH implementation helps farmers to move from small grazing animals - sheep, goats - to large dairy animals - buffaloes, cows - (Sharma 2009), this due to a larger yield in vegetation available, reduction in soil erosion, and more water available for livestock management. Finally, at the ecosystem level, it has helped available species to diversify and vegetation to spread (Sharma 2009; Zhu 2008). Salas (2009) even goes so far to argue that RWH methods are key allies for climate change adaptation and mitigation. In addition, these changes helped to improve soil conservation, reduce cases and/ or intensity of floods, and increase the ecosystem biodiversity (König 2009; Sanches Fernandes, Terêncio & Pacheco 2015; Su et al. 2008). In countries such as Germany, Australia and Japan, implementation of DRWH has resulted in a reduction of the so-called urban heat island effect, and has promoted a reduction of CO_2 production by cutting back the use of energy (Salas 2009). Furthermore, RWH systems have advanced and increased biodiversity through the implementation of green roofs and green facades and have allowed the re-composition of soil through infiltration systems.

Hence, although the most vital effect of these water efficient technologies has been to enable access to drinking water, they have additional indirect positive effects on: users' livelihood, communities, and ecosystems. The key idea behind these systems is that they are decentralised from the main water system supplies, which empowers users and provides more freedom when making decisions. In addition, they embed local knowledge, skills, materials, and equipment, which make them easy to build and to maintain (Helmreich & Horn 2009).

Best Practice

RWH technologies have been developed differently, regardless of their collective similarities. Moreover, countries with successful cases still observed major challenges, such as the systems scale-up, and understanding downstream users' effects (Dile et al. 2013; Falkenmark et al. 2001). Nonetheless, they stand as best practices that if properly analysed and understood could be replicated in places with similar environmental, social, and economic conditions. For this paper, two best practices are presented below, one set in the Province of Gansu in China and another one in the North-eastern region of Brazil.

China: the revival of a millenary technique

Although China has a more than 4000 years long history in the usage of RWH methods (Falkenmark et al. 2001), it was not until the1980s that a joint strategy between the Provincial Government and the Gansu Research Institute for Water Conservancy (GRIWAC) with the aim to secure economic stability of a whole region, caused a mega-scale reproduction of the systems in the country (Falkenmark et al. 2001; Woltersdorf, 2010; Zheng; Zhu 2008; Zhu et Li 1999). The project founded was named '121 Project', and it consisted of a simple RWH system: one piece of water collection field subsystem, two storage subsystems, and one land to plant cash crop, with a water supply and irrigation subsystem (Zhu 1998; Zhu 2008). The region was chosen due to its economic, social, and environmental settings: extreme conditions of dryness, water shortage, low agricultural productivity, soil erosion, high poverty level, fragile ecologic environment, and low yield-investment ratio (König 2009; Zhao et al. 2009; Zhu 2008). The emphasis was set on water as the backbone of development, as agriculture is the main source of income and the region is totally dependent on natural and non-constant rainfall (Zhu 2008). The introduction of the methodology was an easy task, as it was based on an improved tradition of the local people to harvest rainwater for their daily use. Their previous system, however, was mainly based on natural soil, so collection efficiency was very low (Falkenmark et al. 2001; Zhu 2008).

Now, more than 30 years later, the region went from its local government having to dispatch trucks to transport water from far away to supply drinking water to more than 1.2 million people meeting their daily water needs through decentralised systems (Zhu & Li 1999). In addition, the project's main purpose still resonates: to enhance the utilisation of rainwater efficiency to promote economic and social prosperity (Zhu 2008). The success of the 121 Project made it replicable in regions with similar weather conditions - semi-arid, drought prone, and sub-humid- in China (Woltersdorf, 2010). In fact, seventeen provinces in China have adopted rainwater harvesting - providing around 15 million people with drinking water and irrigating around 1.2 million ha of land - by building 5.6 million tanks with a total capacity of 1.8 billion m^3 (König 2009; UNEP 2001).

Brazil: integrating RWH systems in the North-east

The semi-arid north-eastern region of Brazil has faced droughts and loss of crops due to insufficient rainfall (Gnadlinger 2007). In this region, annual rainfall can vary from 200 to 1,000 mm (UNEP 2001), being concentrated within a few weeks during a year, and accompanied with a high rate of evaporation -3,000mm a year (König 2009). In addition, Brazil has an uneven distribution of its freshwater sources. This situation made people of the north-east collect rainfall in hand-dug rock and river bedrock catchments (UNEP 2001) to have some access to water. Nonetheless, this traditional collection lacks efficiency, as in the case of the Gansu Province, but its usage made easier the introduction of improved techniques. As it was the case with the rainwater cisterns and subsurface dams introduced in the1970s by EMBRAPA, the Brazilian Agricultural Research Agency. This pilot project counted with the support of NGOs, grass-root organisations, and communities, and started to slowly change the situation in the region. Finally, in 1999 the idea of water management scaled-up, with the creation of ASA, an association of more than 1000 grass-root organisations. This changed the lives of over 5 million Brazilians (UNEP 2001) with the establishment of the Program "P1MC -1 Million Cisterns," and its complementary program "P1+2 -One piece of land and two types of water" (Gnadlinger 2007). Both programs are receiving funding from governmental organisations and the private sector (König 2009). The goal of *1 Million Cisterns* is to supply drinking water to 1 million rural households, which would equal 5 million people (Gnadlinger 2007). The water is collected in tanks made of pre-cast concrete plates or wire mesh concrete (UNEP 2001), and until August 2012, more than 500,000 cisterns were constructed by the project (ABCMAC). Furthermore, its complementary program provides 2 sources of water, one for human consumption and the other for food production (Gnadlinger 2007).

The improvement in the health level these two projects brought to the region, by enabling access to better drinking water quality and time saved for women, as they no longer have to cover long distances to fetch water over to their homes, has made people in the north-east see the benefits RWH systems provide them. Locals have accepted RWH systems, and have come to understand the need to manage water (König 2009). Because of this, RWH systems functioning and utilisation are now an integral part of educational programs in this region, and its usage is spreading in Brazil, especially within urban areas (UNEP 2001).

These two best practices show the importance of joining effort between governments and communities, to establish legislations, policies, and cost-sharing of RWH systems. The key elements for the projects' success can be enumerated as:

- Recognition of water as a key element for development by both government and local people
- Direct involvement of government through financial support in form of subsidies
- Decentralisation of solutions and systems
- Direct participation of technical exchange by farmers/locals – i.e. inclusion of previous knowledge and compatibility with local life-style
- Diversification of farmers' income-sources

Conclusion and Literature Gap

In this brief literature review, rainfall as a water supply source, and RWH methods dynamic and flexibility were presented as key factors for RWH systems to be an integral part of human settlements and farming. This long tradition has been continuously present in rural areas, while it has just started to regain importance in the urban ones. Moreover, the importance of RWH methods resides in their service provision, by going further than just the supply of drinking water. The systems help to overcome changes in water demand and challenges in water scarcity and variability of rainfall, while providing social, economic, and environmental benefits to users and ecosystems, in the form of income growth and diversification, sustainable forms of agriculture, climate change mitigation and adaptation.

In countries, which are currently examples of best practices, namely Australia, Germany, and Japan for urban areas, and China, India, and Brazil, among others for rural ones, the implementation of these systems came out of the basic need to access water. The reason for their success resides in the involvement of local governments to act together with local communities to put in place policies, legislations, and provide financial support that lowers the systems' initial cost. Specifically, the Gansu Province case in China is an example of the recognition of water as a key element for development. As presented above, many scholars considered this the first step towards the adoption and spreading of RWH technologies. Moreover, studies reinforced the importance of educational programs that explain water cycle and systems usage and importance, as it has happened in the North-eastern region of Brazil. Further inclusion in the curricula of schools and universities is crucial for making RWH a standard approach in all land use designs – from domestic over on-site to catchment-wide systems. Subsequently, technical exchange and capacity building are needed to promote legislative changes. Thus, to fully gain the benefits of RWH systems, society still needs to overcome challenges on quality and technical aspects, legislation, lack of awareness among possible users, and presence of economical support. To overcome them, the main element claimed by most of the studies was to have rainfall embedded within local water policies, strategies and plans, and to create parallel to it an initial cost-sharing strategy among users and governments.

The future and further development of RWH systems is optimistic, if the suggestions made by the authors are met. There is still a need for research, specifically in terms of downstream users' effects, and understanding and enumerating the differences of each system according to their context, to be able to properly transfer and scale them up. RWH are methods of adaptation to changes that are taking place right now, and techniques that enhance ecosystems services. As scarcity of water continues to grow, so does the need to look for more sustainable methods to interact with nature. RWH systems will be seeking to fulfil this task.

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