Rainwater harvesting: A suitable poverty reduction strategy for small-scale farmers in developing countries?

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Using Botswana as a case study, the paper examines the factors that determine the suitability of rainwater harvesting (RWH) in small-scale agriculture in developing countries and proposes a decision-making matrix that may be used to assess the technology for increasing crop production and reducing poverty. This study indicates that current potential for increases in crop production through the use of RWH in both Botswana and developing countries as a whole is uncertain; primarily because of impacts of long-term climate variability, alterations to rural livelihood strategies as a result of economic development, and other structural constraints. In summary it is shown that the suitability of RWH for increasing crop production and reducing poverty in developing countries depends on factors related to climate and ecology, farming practices, availability of assets, livelihood strategies, national governance, and community and catchment institutions.

Keywords: rainwater harvesting, appropriate technology, water resources management, small-scale farming, Botswana

We need to offer the poor real technology choice over affordable, appropriate and accessible options. It is not hi-tech or low-tech but right tech (Coventry, 2003: 1).

Where RWH is a traditional method of agricultural water management systems have fallen into disrepair

Within the small-scale agricultural sector it is claimed that with the use of rainwater harvesting (RWH) there is a potential to double current crop yields (Rockström et al., 2002) and lift farmers out of the poverty trap (Barron, 2009). Nonetheless, technologies have failed to be adopted on a wide scale despite the undertaking of a significant number of pilot projects and research (Oweis and Hachum, 2006). Furthermore, in regions where RWH is a traditional method of agricultural water management it has been observed that systems have fallen into disrepair and been abandoned (Kumar et al., 2008).

The suitability, adoption, and sustained use of any technique for agricultural use depends on a wide range of factors and must be accessible, affordable, and appropriate for the target community.
(Coventry, 2003). Therefore RWH technologies should not be viewed as a panacea for small-scale agriculture and although some systems have been successfully used by smallholder farmers in parts of the developing world for thousands of years (Pacey and Cullis, 1991), the same technology may not prove equally effective in all areas. We argue that existing promotion programmes largely ignore the complex environment that RWH systems must fit into (Scoones et al., 2007) and although researchers have successfully identified factors, such as climatic characteristics, availability of resources, livelihood strategies, policies, and institutions, that influence the sustainable use of RWH (Kundhlande et al., 2004; Baiphethi et al., 2009), implementation frameworks have remained overly focused on the technical dimensions of RWH (see Hatibu and Mahoo, 1999; AfDB, 2007).

Broader recognition and incorporation of non-technical factors into promotion frameworks might usefully ensure that the technology is only advocated where suitable. In the light of this, the aim of this research is to propose a decision-making matrix that may be employed by those considering the implementation of RWH schemes in developing regions.

**Literature review: Critical issues for rainwater harvesting**

RWH technologies have been traditionally used by farmers in many marginal regions of the developing world and so are undeniably relevant in certain circumstances. Yet the dynamic and marginal context within which these technologies subsequently fit is often ignored (Pacey and Cullis, 1991; Scoones et al., 2007) and fundamental factors which contribute to the success or failure of a scheme are inadequately addressed. Although researchers have successfully identified factors that affect RWH (Kundhlande et al., 2004; Baiphethi et al., 2009), issues regarding the sustainability of the technology are also often not addressed. We argue there is a need to compile a wider range of factors into a decision-making matrix for those working with RWH in agriculture.

**The challenges to crop production in marginal regions**

RWH is thought to be particularly suited to the application of supplemental irrigation in arid and semi-arid areas where yield losses are high owing to moisture stress. In these areas, the high variability of rainfall presents the greatest challenge to crop production (Barron, 2009) and there is an opinion that in some areas rainfall is simply too erratic for RWH to sustain crop yields successfully, particularly when not distributed in line with the crop-growing seasons (Oweis and Hachum, 2006). High potential evaporation in these areas also
The suitability of RWH for agriculture is dubious in the context of long-term climate variability. The suitability of RWH for agriculture is considered particularly dubious when considered in the context of long-term climate variability. Predictions of decreasing and more stochastic rainfall in many developing regions may cause difficulties, and farmers may view the growing uncertainty in rainfall as too worrying to invest in the technology (Boyd and Turton, 2000). It is possible RWH may provide farmers with the ability to overcome the increased risks involved in crop production associated with climate variability, but more in-depth research needs to be conducted to determine this.

The majority of small-scale farmers in developing countries are located in areas with less than ideal conditions for growing crops, where low and erratic rainfall is coupled with poor soils (Kundhlande et al., 2004). Smallholder farmers often work with infertile soils, or soils where nutrients are gradually depleted by a process of nutrient mining which means that initial increases in crop yields may be unsustainable in the long term (yet this is often overlooked; FAO, 2003). Soil characteristics including high infiltration rate and low water-holding capacity (Rockström et al., 2002) also present problems.

Understanding the priorities of resource-poor, small-scale farmers

The availability of resources such as finances, land, and labour are widely cited as constraining factors to the adoption of RWH systems by farmers (Pachpute et al., 2009). Many RWH systems demand a high initial input, which can present problems for some families, particularly those that are extremely poor, nomadic, or headed by women (Pacey and Cullis, 1991; Kumar et al., 2008), even where the willingness to replicate these systems is substantial (Nijhof et al., 2010). In some cases the key resource that farmers lack may be the knowledge and skill to collectively manage their farmland effectively; therefore even with the provision of RWH it is possible that production levels may remain low (Barron, 2009).

In marginal areas RWH cannot be considered as a stand-alone activity, as the suitability of RWH for agriculture and poverty reduction in developing countries also depends on the synchronization of the technology with other farming and livelihood strategies. Several argue that RWH may be unsuitable for small-scale farmers as it contradicts household level strategies such as land use extensification (Jodha, 1990) and diversification (Boyd and Turton, 2000). Possible future trends in livelihood strategies, such as temporary urban migration, are also important as these relate to the appropriateness of RWH for small-scale farmers in the long term. If crop production is regarded with increasingly low priority in the livelihood strategy, insufficient
resources may be allocated to allow for the adoption of the technology (Hatibu and Mahoo, 1999; Boyd and Turton, 2000).

**The role of governance and institutions**

Any government policy that has a significant influence on livelihood strategies of farmers, such as those regarding economic development, welfare, agriculture, investment, and land tenure, will affect the adoption and sustainability of RWH (Boyd and Turton, 2000; Kumar et al., 2008). In areas where the government provides incentives for farmers, the adoption rate of RWH schemes appears to be higher (Tumbo et al., 2010), although some forms of political intervention, such as social support, have been found to be detrimental to the success of RWH projects (Jodha 1990).

Institutions, such as farmer cooperatives, are a key factor to ensuring that RWH techniques move from being a simple disseminated technology to a sustainably adapted and managed technological package capable of reducing poverty. A lack of emphasis on institutions may minimize the impact of any government policies or investments designed to encourage RWH (Baiphethi et al., 2009), although the introduction of formal institutions and legal frameworks by governments may also reduce the effectiveness of traditional and informal arrangements in RWH and reduce rates of adoption and use of schemes (Boyd and Turton, 2000). Nevertheless, institutions can play a primary role in learning and knowledge exchange, development of best practices, farmer support, and the management of RWH systems (Nijhof et al., 2010) and may help provide the poorest households with resources needed for the adoption of the technology.

**Beyond rainwater harvesting: Dynamic and complex systems**

Any benefits accrued by RWH schemes implemented in one area may result in significant negative trade-offs in others. To maximize reductions in poverty and land degradation, societal and ecological demands need to be considered in combination with crop production, as hydrology and ecosystems in semi-arid and arid areas are highly sensitive to changes in green water flow and small changes to rainfall and runoff levels may be large in a relative sense (Falkenmark, 2007).

Further, ecological systems in much of the developed world are transient and chaotic in nature and RWH schemes cannot be designed without due consideration of this. Ecological systems in semi-arid and arid regions can be classified as non-equilibrium and conditions across even small areas are unstable (Scoones et al., 2007). Non-equilibrium systems are controlled by external, non-linear factors, which lead to a continual transition between different stable environments, vastly...
different from the ‘idealized reality’ often assumed during technology transfer processes (Scoones et al., 2007).

**Methods**

The findings of this research are drawn from both primary and secondary qualitative data. The primary data collected from a series of interviews conducted during fieldwork, provide in-depth information on the context of RWH within Botswana specifically. The secondary data provide a comprehensive summary of past research and experience in the field of RWH within Botswana, the southern African region and the developing world as a whole.

**Approach**

Grounded theory was used as the basis for this research, therefore data collection and analysis was driven by concepts identified in existing theories. Following the process of theoretical sampling, the preliminary collection of secondary data was used to generate categories that shaped the interview guide and the collection of primary data. The interviews led to the identification of further themes via a process of coding and additional secondary data was collected where necessary until all themes were considered ‘saturated’.

**Data collection and analysis**

Since the identification of farmers with direct knowledge or experience of RWH in small-scale farming was problematic, participants with views on RWH were identified through a process of snowball sampling. This comprised the identification of an initial set of participants relevant to the research topic who were then used to establish contact with other relevant groups or individuals; it is particularly useful for situations where no specific sampling frame exists. For the purposes of this study, an initial list of potential participants was compiled with the use of secondary data and these individuals were then used to establish contact with other relevant organizations and individuals with knowledge and experience of RWH.

A total of 12 individuals were interviewed, representing ministries, NGOs and institutions in Botswana, the traditional Batswana farming community, and academic institutions in South Africa. Analysis of the interviews was carried out in several stages. After preliminary coding conducted manually, the software package NVivo was used to conduct more extensive and systematic coding using word-based techniques examining word repetition and the analysis of the context within which key words were used.
Although efforts have been made to ensure the validity of this research, it is possible that insufficient triangulation of data obtained from the NGOs, government ministries, and research institutes with that of traditional farmers may reduce the validity of the insights gained. Furthermore, the small size of the total sample may limit the transferability of conclusions drawn, although it is anticipated that the depth of data obtained compensates for this to a certain extent.

Case study: Botswana

Botswana is a landlocked country in southern Africa encompassing approximately 582,000 km² (FAO, 2005) with a population of just under 2 million (GoB, 2009). The country has a semi-arid to arid environment with a mean annual rainfall of 416 mm (FAO, 2005), although in the east where the majority of small-scale crop production is carried out mean rainfall is 200–550mm. Rainfall in Botswana is erratic and may become increasingly so if predictions of a future reduction in rainfall levels and decrease in rainy days become realized (Batisani and Yarnal, 2010). Potential evaporation is about four times the average annual rainfall at approximately 2,000 mm (FAO, 2005) and soils are characteristically sandy and infertile across much of the country (FAO, 2003). An analysis of the risks associated with crop production as a result of these climatic and ecological factors provides a key contribution to the formation of the matrix.

Economic growth has led to rapid urbanization with formal employment becoming a major source of income in some areas, particularly in the southeast of Botswana (Rethman and Muhangi, 2009), but arable farming is still said to provide an important contribution to livelihoods across the country (BIDPA, 2001 in CAR, 2007).

Water scarcity in Botswana is high, but water availability is not the only factor affecting arable farming. The Government of Botswana attributes low production to a number of factors such as poor farm management, inadequate arable land, an ageing farming population, inadequate market access, damage to crops by livestock, and a lack of community level institutions (GoB, 2009). While we did not research all of these factors, we draw on them to inform our RWH adoption matrix.

Evidence from other research (Rahm et al., 2006) indicates that the Government of Botswana has a significant influence on crop production. In particular, the well-developed social support system is said to have led to the development of an enduring belief within the rural population that the government will provide come what may. Furthermore, land allocation policies have provided farmers with plots that are unsuitable for crop production in some cases (Borhang, 1992).
and the drive for rapid economic development by the government has created more competition for labour and finances (CAR, 2007). We consider these factors will influence the intensity and durability with which rainwater harvesting is adopted.

Domestic RWH systems have been traditionally used in Botswana for many years for homestead supply (Pacey and Cullis, 1991), but views regarding the suitability of the technology for agricultural production vary (cf. FAO, 2003; Mati et al., 2006). Despite the implementation of several government-led schemes involving RWH and attempts to assist small-scale farmers through extension services, RWH performance on traditional farms has been poor, with only 30 per cent of potential yields achieved (Rockström et al., 2010). Little examination of these RWH schemes has been conducted and one of the objectives of this research was to determine the range of factors that led to low levels of adoption of RWH by small-scale farmers in Botswana.

Results and discussion: The proposed matrix

The findings indicate that RWH is currently used by some small-scale farmers in Botswana, but that systems have not been widely adopted. Systems are built either independently by farmers, or through government-led schemes implemented by the Ministry of Agriculture (MoA). Many participants referred to the use of traditional methods of RWH involving natural or man-made earth pans to provide water for both pastoral and arable farming, particularly in the west of Botswana where it was reported they often provide the only source of water. Other methods of water collection reportedly used were sand rivers, hafirs (underground reservoirs), and small earth dams. However, there was mixed opinion over the extent to which these methods of water collection are continuing to be utilized by small-scale farmers.

Evidence presented illustrates that dryland agricultural systems are inherently risky and that the suitability of RWH for increasing crop production and reducing poverty ultimately depends on the potential the technology holds for reducing the risk involved in arable farming, without restricting benefits gained from other important livelihood sources. Drawing on both literature and findings from primary research in Botswana, key requirements needed to ensure the suitability of RWH in any particular context have been determined and divided into those affecting initial adoption and those affecting longer-term sustainability of RWH. These requirements are outlined in the following sections and summarized in a decision-making matrix in Table 1.
Table 1. Decision-making matrix for the suitability of RWH systems in agriculture

<table>
<thead>
<tr>
<th>Time frame</th>
<th>Factor</th>
<th>Initial adoption</th>
<th>Longer-term sustainability</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Adequate data on rainfall, evaporation, and soil properties to allow for effective design of systems</td>
<td>Sufficient availability of water to maintain wider ecosystems in region despite presence of RWH systems</td>
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<tr>
<td></td>
<td></td>
<td>Potential rainfall and runoff volume and distribution compatible with crop water demand</td>
<td>Minimal effects of long-term climate variability on ability of RWH to provide adequate water</td>
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<td></td>
<td></td>
<td>Soil with good water-holding capacity (and sufficient structure if required for any construction in association with RWH system)</td>
<td>Rainfall patterns offer opportunity for enhancement via RWH with little excessive drought or floods (see next point)</td>
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<td></td>
<td></td>
<td>Soil nutrient level capable of sustaining crop growth in at least the short term</td>
<td>Increasingly high unpredictability of rainfall, or failure to provide weather forecasts, to allow for timely farming practice and efficient use of water harvested may impact on use</td>
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<td></td>
<td></td>
<td>Traditional use of RWH in crop production and Labour and equipment investment acceptable</td>
<td>Combined use of RWH with soil conservation methods and application of fertilizer</td>
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<td></td>
<td></td>
<td>Costs and benefits compare favourably with livestock keeping</td>
<td>Optimization of farm management skills to decrease limitations on crop production caused by factors other than water availability (e.g. seed sowing)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate availability of finances, materials, and labour required for adoption through subsidies and assistance from appropriate institutions</td>
<td>Fits wider farming systems in location</td>
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<td></td>
<td></td>
<td>Adequate land availability and land tenure Knowledge and understanding of RWH</td>
<td>Adequate availability of land suitable for long-term crop production close to homestead</td>
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<td></td>
<td></td>
<td>Low input demand for adoption</td>
<td>Low input demand for maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Availability of finances, materials, and labour required for maintenance through subsidies and assistance from appropriate institutions</td>
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<td></td>
<td></td>
<td></td>
<td>Possession of skills to adapt RWH system to meet specific needs of farm/catchment</td>
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<tr>
<td></td>
<td>Livelihood strategies</td>
<td>Crop production high priority in livelihood strategy</td>
<td>No detrimental impact on wider livelihood strategy (e.g. diversification)</td>
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<tr>
<td></td>
<td></td>
<td>Significant reduction in risk of crop failure with implementation of scheme</td>
<td>Provides consistent boost to household income and nutrition</td>
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<td></td>
<td></td>
<td>Rapid return on initial investment</td>
<td>Sustained high priority of agriculture in livelihood strategy</td>
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<td></td>
<td></td>
<td>Lack of conflict with other current livelihood strategies (e.g. pastoral farming)</td>
<td>Low competition for resources from other livelihood strategies (e.g. formal employment)</td>
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<td></td>
<td></td>
<td>Crop prices attractive to draw farmers towards production</td>
<td>Markets for crop produce remain predictable and transparent</td>
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<tr>
<td></td>
<td>Community and catchment</td>
<td>Government with high capacity to implement relevant policies and schemes</td>
<td>Catchment-level institutional linkages between upstream and downstream users to monitor and manage water supply and demand within both agriculture and other sectors</td>
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<td></td>
<td>institutions</td>
<td>Presence of local-level institutions to implement farmer-centred research and extension</td>
<td>Community-level institutions to allow for farmer participation in planning, training, cost sharing, continual evaluation, and improvement of systems</td>
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<td></td>
<td></td>
<td>Assistance of community/village leaders in adoption issues</td>
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<td></td>
<td>National support programmes</td>
<td>Incentivized policies and schemes, including grants and subsidies</td>
<td>Complementary policies encouraging the increased importance and growth of small-scale agriculture and crop production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Policies encouraging independence of rural population from government</td>
<td>Provision of infrastructure to increase access to markets</td>
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<td></td>
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<td></td>
<td>Social protection income for households and drought food aid does not undermine attractiveness of RWH</td>
</tr>
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</table>
Climate, land, and ecology

A common agreement among the majority of participants was that traditional methods of RWH used by farmers (natural and man-made earth pans) have successfully maintained agricultural water availability in the past, but no longer provide farmers with enough water for the entire growing season; as a result they are being abandoned by some farmers. Insufficient rainfall was the most frequent factor cited for the abandonment or non-adoption of RWH by small-scale farmers, more than half of the participants were of the opinion that the volume of water collected does not provide adequate irrigation to crops. Furthermore, participants commented that they believed the evaporation to rainfall ratio was increasing, resulting in the loss of a significant proportion of rainfall harvested that would otherwise be available for crop consumption, particularly in traditional systems where water is lost through evaporation from surface storage in pans. Nonetheless, a number of participants were of the opinion that rainfall levels in Botswana are sufficient to provide water to meet crop demand for the duration of the crop growing season.

This research confirms that one of the greatest risks to rain-fed crop productivity is high rainfall variability. The ability to reduce the reliance on stochastic rainfall is the key to the suitability of any technology aimed at increasing productivity (Rockström et al., 2002) and in some semi-arid and arid areas the variability of rainfall may be too great for certain types of RWH to provide sufficient benefits. Moreover, RWH must enable crop water demand to be met both in the short and long term, maintaining a lowered level of risk in arable farming even in the context of long-term climate variability.

However, water is only one of the many barriers to crop production (Rockström et al., 2002; Barron, 2009) and climatic factors need to be considered closely with wider ecological issues, as these can also have a marked influence on yields. For example, areas with unfavourable soil characteristics, such as low moisture-holding capacity, or low fertility may not be suitable for RWH (Rockström et al., 2002) and data collection in Botswana reiterated the importance of combining RWH with soil conservation measures if crop production is to be most successful (Rockström et al., 2002; AfDB, 2007). Other ecological issues, such as sufficient availability of water to maintain wider ecosystems in any region despite the presence of RWH systems, also need consideration (Falkenmark, 2007).

Farming practice

Findings from this research highlighted that ineffective management may restrict crop production despite increased water availability; therefore the adoption and sustained use of RWH may be limited
Regardless of rainfall level unless improvements to farming practices are also made, such as crop selection and pest management (Rockström et al., 2002). Inputs such as labour and equipment required for RWH must also be comparable with those of current farming practices, and costs and benefits must compare favourably with livestock keeping. These issues are expanded upon below with reference to household livelihood strategies.

Additionally, although data gathered from Botswana was unable to confirm that the presence of RWH in traditional farming increases the likelihood of the uptake of new RWH strategies, literature suggests that this has proved to be the case in other projects (AfDB, 2007). As a result it may be possible to conclude that RWH may be more suitable for use in crop production in areas where it has been used traditionally and fits with the wider farming systems.

**Availability of assets**

In many cases marginally productive farming practices in Botswana were linked to a lack of knowledge among individuals (Respondents B, C, and N). This was attributed to the unavailability of adequate training and support at both an individual and group level within the farming sector. Similarly, poor performance of agriculture in other developing countries associated with the loss of traditional knowledge regarding optimal farming practice has led to a reduction in adoption and use of RWH (Boyd and Turton, 2000) as a result of the reluctance of farmers to invest in activities where returns are unreliable.

A lack of resources, including finances, skills, labour, and land, was acknowledged to be a key constraint to the adoption of RWH by the poorest farmers (Pachpute et al., 2009) and although government schemes in Botswana were unsuccessful, the provision of grants and assistance from governments or NGOs has been shown to reduce the barriers to technology uptake (Tumbo et al., 2010).

Our research found that an important factor affecting the adoption of RWH systems in Botswana was the reluctance of farmers to dedicate their labour to implementing the systems. According to the participants, problems regarding labour availability were primarily attributed to a lack of willingness to work on farmland among the rural population. The availability of labour for RWH construction and maintenance appeared to be further restricted by poor community cohesion within farming areas and a lack of willingness to work at group level.

Interviewees gave mixed opinions regarding the influence of the availability of financial capital on RWH schemes, but the majority stated it to be a barrier to the initial adoption of the technology even when systems are heavily subsidized by the government. A lack of
financial resources was also found to lead to an inability to purchase fencing to protect against damage to crops by livestock, which was said to reduce the adoption of RWH by small-scale farmers as the risk of crop damage remained too great. Grants and loans were said to be available for farmers through the Citizen Entrepreneurial Development Agency (CEDA), but the stringent and rigorous application process appeared to cause problems in gaining access to these for some.

An inability of some individuals to obtain a plot of land also posed problems, which in some cases was said to be due to elders retaining family crop land that would have traditionally been passed to younger generations. It was possible for individuals to obtain a plot through the Land Board, but the process was said to be lengthy and convoluted. Moreover, it was reported that the Land Board had in some cases allocated land unsuitable for crop production, which was therefore seen by farmers as not worthy of investment in potential crop-enhancing technologies such as RWH.

Livelihood strategies
Evidence suggested that crop production must generally be allocated with a relatively high priority level within the household livelihood strategy and not have a detrimental impact on a household’s wider livelihood strategy in order for sufficient resources to be allocated for the adoption and sustained use of RWH. In Botswana pastoral farming was seen to be an important part of livelihood for the majority of the rural population and as a result small-scale farmers were reluctant to invest in crop production technologies such as RWH. We argue that unless changes occur, RWH adoption and use rates may continue to remain low because of competing demands for resources between arable and pastoral farming.

The competition for land, water, and labour resources between crops and cattle was a recurring theme in the interviews and evidence indicated that the needs of cattle are generally prioritized over those of crops at both household and community level because of the higher value attributed to cattle through greater potential income (CAR, 2005). The conflict between pastoral and arable farming poses perhaps the greatest barrier to the use of RWH in countries where livestock make a large contribution to livelihoods, and competition for land, water, and vegetation may lead to the failure of RWH systems unless an appropriate system that allows the co-existence of cattle and crops can be implemented (Pacey and Cullis, 1991).

Continuing changes in rural livelihood strategies in developing countries also appear to limit the potential adoption and use of RWH. All participants spoke of a general trend away from agrarian livelihoods in rural Botswana and traditional farming households
appeared to be abandoning their cropland and moving towards other livelihood strategies, for example pastoral farming. This trend is compounded by low prices and a lack of an accessible market for traditionally grown crops, such as maize, compared with high prices and a large, accessible market available for cattle.

Furthermore, economic development and an increase in availability of formal employment are leading to a reduction in the importance of farming in rural livelihood strategies, and the investment in non-farm income is seen by farming families as having greater potential for reducing livelihood vulnerability than those within the farming sector. In Botswana high economic development and a rapid increase in formal employment in recent years has led to migration from rural areas, particularly among young Batswana, and farming is no longer seen as an attractive career option. Such changes in the relative importance of different livelihood strategies have resulted in fewer resources allocated to RWH (Hatibu and Mahoo, 1999; Boyd and Turton, 2000) and if the importance of farming continues to decrease into the future, the potential for widespread adoption of RWH and an increase in crop production may be low.

**Community and catchment institutions**

Insufficient institutional capacity at the local level in Botswana was reported to have limited both short- and long-term adoption of RWH. Participants believed that the number of institutions available to assist farmers has declined significantly in the past few decades and in addition those that remain appear not to work efficiently. NGOs, farming organizations, and cooperatives that encouraged the adoption of RWH schemes among farmers in the past have witnessed sharp falls in funding from donors, explained by Botswana’s achievement of middle-income status (CAR, 2007). This, it was said, led to the collapse of many such organizations with the consequence that group organization has become a problem across the whole agricultural sector. If RWH is to have the potential to increase small-scale crop productivity on a widespread basis, the capacity of existing institutions, such as the MoA extension scheme, needs to be improved and new institutions created at the community and catchment level.

We argue that the suitability of RWH in small-scale agriculture may be greater if both informal and formal institutions exist at local level, as this will ensure the sustainable utilization of RWH (Kundhlande et al., 2004). Community and catchment institutions provide a platform for ensuring benefits are shared equally among all users and allow for the training of farmers and sharing of experiences (Nijhof et al., 2010).
National support programmes

Participants confirmed that impacts of incentivized government schemes aimed at increasing the adoption of RWH in Botswana, such as the Arable Lands Development Plan (ALDEP), have been limited. Furthermore, the increased drilling of boreholes to provide access to water resources infrastructure in rural areas under the current Integrated Support for Arable Agricultural Development (ISPAAD) scheme is said to reduce the perceived need for RWH among farmers and increased dependence on the government for water supplies.

In accordance with research in other similar regions (Jodha, 1990; Boyd and Turton, 2000), extensive drought relief schemes in Botswana including the provision of food to rural populations have reduced not only the uptake of technologies such as RWH in crop production, but involvement in arable farming in general. Reductions in arable farming are also said to have occurred as a result of an emphasis by the Government of Botswana on growth of the formal employment sector, commercialization of agriculture, reduced support for small-scale farmers, and a focus of support on pastoral farming.

The potential benefit of schemes involving subsidies and grants specifically for the purpose of RWH adoption has already been discussed, but if the use of RWH is to be sustainable on a large scale it is suggested that these incentives need to be accompanied by complementary policies that encourage the growth of RWH and small-scale agriculture. This may include policies comprising improvements to rural infrastructure to allow market access for farmers (Rockström et al., 2010).

Conclusion

There is a widespread literature that argues rainwater harvesting has the potential to lift farmers out of the poverty trap through the improvements it can provide to agricultural productivity (Rockström et al., 2002; Barron, 2009). However, in many areas empirical evidence on short- and long-term adoption does not support this contention and, in contrast, improvements to livelihoods due to RWH for agriculture have been low or not sustained (Hatibu et al., 2006).

The findings from this research indicate that the factors that affect the adoption of RWH in Botswana and by extension other developing countries in the sub-Saharan region are categorized as: hydro-ecological factors; availability of assets; rural livelihood and income strategies; local institutional capacity; and national support programmes. We suggest these affect the short-term adoption and longer-term success of RWH, and accordingly need to be analysed when considering the implementation and uptake of RWH in small-scale agriculture.
In Botswana these factors have been shown to occur within the context of a dynamic and interdependent environment where farm management skills are variable and the incentives to increase crop production are uncertain.

We particularly observe that farmers prefer, within the economy of Botswana (with its robust international meat markets), to cope with variable and low rainfall through livestock grazing rather than rainwater harvesting for agricultural production. This demonstrates that farmers have the ability to carefully consider trade-offs and technologies for benefiting from intractable soil moisture conditions. It is their livestock that puts in effort to integrate the benefits of photosynthesis across the landscape rather than their own energy and skill (see Shackleton et al., 2001 for background discussion on livestock-based livelihoods in Southern Africa).

On the basis of this research the current potential for increases in crop production in Botswana through the use of RWH appears to be limited and potential for the future is uncertain. This is primarily due to impacts of long-term climate variability on rainfall and evaporation and alterations to rural livelihood strategies as a result of economic development. With appropriate adaptation of systems and the development of community-level institutions to provide in-depth training to farmers, potential may improve, but it is possible that the prevalence of livestock and pastoral farming may present too great a barrier to be overcome in some developing countries.

It is recommended that the proposed matrix is tested by its application to several additional case studies within a range of different contexts. This will allow for further analysis, elaboration, and weightings of the factors that determine the suitability of RWH for increasing crop productivity and poverty reduction in developing countries. This process will lead to the refinement and expansion of the decision-making framework proposed here into a more comprehensive implementation framework.

**References**


