WHaTeR

Water Harvesting Technologies Revisited: Potentials for Innovations, Improvements and Upscaling in Sub-Saharan Africa

Project funded by the European Commission
under the 7th Framework Programme
Project No. 266360

Factors influencing WHT uptake - A characterization of the WHaTeR study sites

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Identifier	WHaTeR_D7.2
Date	02-10-2013
Class	Deliverable
Responsible partners	IVM-VU
Annexes	
Distribution	PU
Overview	

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1. INTRODUCTION

In 2001, the AfDB, FAO, IFAD, IWMI and the World Bank identified the low level of investment in agricultural water in Sub-Saharan Africa as a major development issue which resulted in the set up of a collaborative programme, i.e., the Comprehensive Africa Agricultural Development programme. The synthesis report of this programme (Peacock et al. 2007) stresses the benefits of investments in agricultural water. In the WHaTeR project we focus on the potential of Water Harvesting Technologies (WHTs), which are defined as smaller-scale intervention technologies that induce, collect, store and conserve local surface runoff for agriculture in arid and semi-arid regions (Boers and Ben-Asher 1982). In this deliverable we describe the factors influencing the uptake and upscaling of WHT investments, specifically in the WHaTeR study sites, and give a general description of the sites.

Drechsel et al. (2010) conclude from an expert meeting on WHT uptake in Africa that no comprehensive assessments of the factors determining effective uptake exist. Also, while considering farmers uptake of conservation agriculture, Knowler and Bradshaw (2007) conclude that there are no universal variables explaining technology adoption and uptake. When reviewing the WHT literature certain communalities do, however, arise. For example, when the different factors influencing WHT uptake are framed in terms of costs and benefits, it becomes clear that WHT uptake is at least partially driven by the benefit-cost ratio For example, Walker and Ryan (1990) show that in semi-arid India, low farm gate prices, uncertain crop revenues and increasing opportunity costs of labour make investments in rainfed agriculture relatively unattractive, especially when compared to investments in irrigation that have a higher benefit-cost ratio. Clearly, this benefit-cost ratio may vary between farmers, regions and time periods: differences in soil type, slope and aridity explain why WHT makes sense in some regions and not in others, and between farmers the costs of WHT may differ based on the availability of labour (family size) and land: Shiferaw and Holden (2001) point out that WHT can incur substantial opportunity costs in terms of land use. Some WHT technologies take land out of production (where bunds are built within fields for example) and if farmers only have small plots this can be a substantial cost. An implicit assumption with regard to labour costs is that the farm-household's opportunity costs of labour are zero, especially in the dry season when agricultural activity is low. In many SSA regions the opportunity costs of labour are increasing, however, Fox et al. (2005) showthat in regions with higher opportunity costs of labour the returns to WHT investment are less. In fact, Moges et al. (2011) review the returns to investment of WHT structures in Ethiopia and conclude that due to high opportunity costs of labour, and disappointingly low benefits (caused by high seepage and evaporation losses of the constructed household ponds), returns to investments are in many cases insufficient to cover investment costs. Although many studies have indicated that WHT can generate substantial net benefits (Shiferaw and Holden 2001; Bekele and Drake 2003; Amsalu and de Graaf, 2007; Hatibu et al. 2006) benefits do not always materialize (technical design, local characteristics) and ultimately depend on rainfall.

Subsidization may improve the benefit-cost ratio of WHT investment for the farmer, but farmers still need to maintain investments in the long run. Amsalu and de Graaff (2007) indicate that, in Ethiopia, the perceived profitability of WHT is an important determinant of future maintenance; higher returns to investment affect maintenance positively, and off-farm employment has a negative effect. Hatibu et al. (2006) and Moges et al. (2011) argue that this is more likely to happen when WHT makes it possible for farmers to shift production to higher value (irrigated) cash crops. This also reduces the uncertainty of crop revenues from rainfed agriculture, another reason why the perceived cost-benefit ratio may be low (e.g. costs are certain, but benefits are not). Given that most smallholder farmers in semi-arid Sub-Sahara Africa are poor, with little means to invest in productivity improvement and a preference for investments that reduce risk, the availability of alternative investment options and the perceived uncertainty of investment returns are likely to be important factors determining WHT uptake. It is important to clarify what we mean with WHT uptake: subsidization will certainly aide the spread of WHT, but we only consider this as uptake when WHT investments are also maintained.

Subsidization as such may in fact reduce the likelihood that WHT are maintained: A key reason why farm households do not maintain WHT investments is that they expect the external investor to do this for them. Moges et al. (2011) indicate that in Ethiopia farmers expect the government to maintain investments and in India, Kerr et al. (2002) show that maintenance is less in projects where subsidization is high. Maintenance might also be less when farmers are not consulted during WHT implementation: Liu et al. (2008) explain how participatory WHT – that is when WHT implementation is planned, designed and implemented together with the farm households and/or wider community – this does not only increase local commitment but also helps overcome informational problems by making use of stakeholder knowledge regarding local context and the specific problems that need to be addressed. Thus, investments are better located, resulting in lower costs and higher returns. Sturdy et al. (2008) illustrate that participatory approaches and farmer-driven experimentation are essential for ensuring WHT relevance and adaptation to the local context, and Critchley (2009) discusses several studies that suggest that top-down technocratic approaches don't work and that farmers need to be involved in technology development and implementation.

The practice of many WHT projects in Africa seems rather non-participatory. Moges et al. (2011) describe how Ethiopia's WHT programme is top-down, technocratic and non-participatory. Bewket (2007) indicates that even in a project that presented itself as participatory, farmers were not truly consulted but merely persuaded to accept WHT investments on their land. In contrast to these examples, one of the most celebrated successes of water harvesting in SSA, namely the combination of stone bunds and *zaï* planting pits in Burkina Faso, was founded in participatory processes, and is renowned for its pioneering people-centred approach (Critchley, 2009). Barron and Noel (2011) explicitly compare WHT approaches between Africa and India confirming that the "soft component" of stakeholder participation and farmers' knowledge is indeed crucial for WHT success. Baiphethi et al. (2009) discuss the role of local institutions for successful WHT implementation, indicating that in South Africa farmers' groups played an important role in and making WHT a success.

The wider socio-economic and institutional context in which WHT investments are being considered influences the (perceived) returns to investment as well. 'Perceived' because factors like the availability of food aid may not directly influence the net returns to WHT, but when considering the options farmers may decide against WHT investments if they feel that their supply of food is sufficiently secured (Feder et. al. 1985). Also, in assessing the potential benefits, farmers are likely to consider the options available to them for increasing crop returns: Suri (2011) convincingly shows that smallholder farmers with little market access (e.g. high transportation costs, but also lack of access to credit, inputs etc.) are less likely to adopt new technologies, even if technically the potential returns are high. Duflo et al. (2011) illustrate something similar for the case of fertilizer, which also has low adoption rates in SSA. Here, lack of access to financial services (like credit and savings) constrain farmers in buying fertilizer when they need it, the analysis indicating that selling fertilizer coupons to farmers immediately post-harvest is much more effective than subsidizing fertilizer throughout the year. Also in the case of WHT adoption, missing or malfunctioning markets seem to seriously undermine uptake: Tabo et al. (2011) discusses how combined interventions in micro-dosing of fertilizer in planting pits and establishment of crop storage and savings systems (e.g. the *warrantage* system) helped to substantially improve farmer incomes and WHT uptake in the Sahel. The problem of missing or malfunctioning markets is especially relevant for the poor: Misselhorn (2005) concludes that poor market access is one of the main factors explaining food insecurity in Southern Africa, and in general poor household are usually constrained in their access to markets, which is an important reason why they remain poor (Duflo et al. 2011). Poor households are also faced by other constraints, like lack of assets, entitlements and property rights: Barbier (1990) illustrated the crucial role of land tenure security for adoption of conservation measures, and Shiferaw and Holden (2001) and Kabubo-Mariara (2007) analyze the role of land tenure in WH uptake.

Finally, lack of information and awareness is a reason that can explain low adoption rates. Critchley (1994, 2009) discusses the importance of agricultural extension and the role of farmer knowledge and farmer-to-farmer extension in WH adoption, underlining the important role of capacity building in uptake. Similarly, when farmers do not acknowledge that their yields are low and could be better, or to understand the problem of climate change and/or land degradation, they are unlikely to invest in WHT. Kato et al. (2011) report that in Ethiopia half of the farmers surveyed had made some investments to adapt to climate change. Hassan and Nhemachena (2008) show that for the whole of Africa, 50% of the surveyed farmers believe that temperatures are increasing and precipitation is becoming less, but only 20% of the respondents believe that soil and water conservation could help them adapt. Reij and Smaling (2008) find that innovations are mostly crisis-driven, but that market opportunities play a crucial role. This latter point is also concluded by Hassan and Nhemachena (2008); again underlining that for WHT uptake it is crucial that missing markets are addressed.

Summarizing, the literature suggests that there are 3 types of factors that influence WHT uptake: costs and benefits (e.g. aridity, rainfall characteristics, technical design, soil type, labour costs), contextual factors (e.g. market access, food aid, subsidization) and information (e.g. awareness, participation).

Although little can be said about the relative importance of the different factors, Drechsel et al. (2010) conclude that whereas the biophysical requirements for WHT are well-described, information about the socio-economic and institutional conditions for WHT uptake is lacking. In the WHaTeR project we have focused on the socio-economic factors influencing WHT uptake, collecting primary and secondary data with regard to the factors influencing the perceived costs and benefits of WHT, addressing knowledge constraints and institutional factors as well. For the characterization of the study sites, we will present some of this information (e.g. the findings of the household survey will be presented in deliverable 7.3) but for the main part we rely on the re-visit and field visit reports. We structure our analysis under the headings as suggested, e.g. costs and benefits, knowledge and awareness and socio-economic and institutional context. We include information about biophysical and technical WHT requirements under the heading of costs and benefits, given that these factors ultimately influence perceived benefits and costs. With regard to contextual factors we limit ourselves to the information available with regard to WHT implementation in the study sites. Given limited time and resources we have unfortunately not been able to analyse the wider socio-economic and institutional context of WHT in the study sites, and hence rely on existing publications and documentation to characterize the study sites in this respect.

Finally, in assessing the factors determining effective uptake and upscaling we have clearly focused on the factors explaining WHT uptake. This is to avoid overlap with the other work packages, specifically WP4 on environmental sustainability. In our analysis we did consider the potential for WHT upscaling in the WHaTeR study sites: for example, in the Ethiopian study site household ponds are being promoted, but upscaling may result in negative externalities downstream. Although we are still in the process of analyzing the potential downstream impacts of increased investments in household ponds, in characterizing the study sites and the WHT technologies considered we will also consider potential upscaling effects.

Table 1 presents the framework we propose to use for the characterization of the WHaTeR study sites. We start with a brief description of the study sites and the WHT technology considered. We then turn to the question of farmer awareness and the extent to which farmers are familiar with the technology introduced. We address the factors influencing the perceived costs and benefits of the technology, including technical and biophysical characteristics, labour and land requirements and the (un) certainty of benefits and costs. We end the characterization by considering the potential for WHT uptake and upscaling, by considering contextual factors like market access, institutional factors and WHT implementation process.

Table 1 Framework for the characterization of the WHaTeR study sites

Categories	Factors
1) Description study site	WHT technology, location, general characteristics study site
2) Knowledge and awareness	Knowledge of WHT and agricultural production, traditional knowledge, perceived climate change
3) WHT costs and benefits	Technical & biophysical factors, household characteristics, plot and crop production characteristics, importance of non-farm activities
4) Potential for WHT	Market access, institutional setting, WHT programs, upscaling potential, socio-economic developments

2. Characterization of the study sites

2.1 Burkina Faso

2.1.1. Description of the study site

In Burkina Faso the WHaTeR study sites have been selected on the basis of the countries' different agro-climatic zones. Traditionally, WHT investments in planting pits (zaï) and demi-lunes were made only in the Northern, arid to semi-arid regions, but INERA (the burkinabe partner in the WHaTeR project) has been actively promoting the use of these techniques also in the middle region and the south-west. The reason why INERA has been promoting WHT techniques in other regions is because of 1) the positive returns to investment and 2) the fact that climate change projections indicate prolonged dry spells and creating (temporary) problems of water scarcity also in the middle and even in the South. Hence, for the WHaTeR project INERA selected a village in the middle region of the country (Boukou) near the capital Ouagadougou, and a village in the South-west (Peni) to introduce WHT. For an assessment of the factors determining WHT livelihood impacts and uptake, an additional village was selected with better facilities and market access in the middle region (Malgretenga). Also, in the northern region two additional villages were selected for this work package to allow for comparison of the factors influencing uptake (Ziga and Kourou Magré).

Boukou and Malgretenga are located in the Bam Province in the middle of the country 12,0° N, 2,2° W. The average elevation is 300 meter above sea level (m.a.s.l.). The climate is Sahalian with 600 mm annual rainfall, mostly occuring during the rainy season from June to September (Ouedraogo et al., 2006). Average daily temperature ranges from 24°C in January to 33°C in April and the potential evaporation is far larger than yearly precipitation. The soils of the area are crusted and 60 to 90% of rainfall is lost to overland flow (Mando, 1997). The soils have a poor structure, with little organic material and nutrients. Peni in the South of the country 10,6°N, 4,3 °W located in the Houet province. The average elevation is 430 m.a.s.l.. The climate is southern Soudanian with an average precipitation of 1040 mm. The rainy season lasts from April to October and yearly rainfall is quite variable (Some et al., 2006). Average temperature ranges from 27 to 29°C. During an average year the rainwater availability is sufficient for the main crops during the growing season. The soils of the area vary between lithosols with no agricultural value, and tropical ferruginous soils which have better agricultural characteristics (Some et al., 2006).

The techniques studied for the WHaTer project in Burkina Faso can be categorized as *in soil* water storage techniques (e.g. Fox et al., 2005): planting pits capture and store rainfall at the micro, individual plant level, and demi-lunes capture and store run-off in the soil for several plants. Stone lines and grass strips reduce the speed of run-off, thus reducing soil erosion and increasing storage of water in the soil. Whereas stone lines and grass strips are usually multiple year constructions, zaï and demi-lunes need to be re-done every year. For all four techniques, material costs are (very) limited, but labour costs can be significant. These techniques are suitable for the northern province because they break the crust, enabling crops to grow where otherwise nothing would grow (e.g. Reij et al., 1996).

In the WHaTeR project we focus on assessing the factors determining the perceived costs and benefits of zaï and other WHT techniques, comparing the North with the Middle, and comparing households in villages with relatively good market access to households with poor market access. We decided to focus our analysis on these differences given that INERA indicated that farm households in the North seem to have a higher willingness to invest in WHT than households located in the middle, and because there are also indications that market access plays a role. Although we will present the results of this analysis in the next deliverable, D7.3: Paper on WHT uptake and upscaling, in this report we will characterize the study sites and review the literature with regard to the factors influencing uptake of zaï and other WHT techniques in Burkina Faso.

2.1.2 Knowledge and awareness

In terms of knowledge and awareness. INERA indicated that especially in Burkina Faso's Middle and South-West region lack of knowledge of WHT is an important reason for limited uptake. The importance of knowledge and awareness is confirmed by Sidibé (2005) who analyzed the determinants for the adoption of SWC in 230 households in northern Burkina Faso, concluding that the most significant variables for WHT uptake are training and small ruminants holding.

To assess the extent to which households were indeed unaware of WHT we conducted a short survey in the WHaTeR study villages before zaï, stonelines and grass strips were introduced by the project partner INERA. Interestingly, we found that especially in the middle (Boukou) households were generally aware of WHT, and of the added value of zaï and stonelines, possibly also because an NGO had implemented stonelines years before (see table 2). In the South-West people were much less familiar with WHT techniques, but they did indicate an interest and need for investments to restore the productivity of their land. Because of the low awareness with WHT we decided not to include Peni in our household survey, as respondents would not have WHT investments and would not be aware of the costs and benefits of WHT.

Table 2 Results baseline survey Burkina Faso WHT knowledge and awareness (n=100)

	Boukou	**Peni**
% that knows of the zaï technique	84%	30%
% that uses zaï on land	36%	18%
% that knows of stonelines	96%	8%
% that uses stonelines on their land	80%	6%
% that believes zaï increases crop yields	100%	78%
% that is willing to spend more labor on zaï	90%	80%
% that is willing to pay for mechanized zaï	98%	38%
% that believes zaï plus fertilizer increases yields	100%	98%
% that is willing to pay for fertilizer	60%	70%

2.1.3. WHT costs and benefits

Several studies have assessed the impact of zaï and demi-lunes technologies in Burkina Faso, most referring to the North. The range of crop yield improvements reported for planting pits is 19-48% (Roose et al. 1999). A couple of studies assessing the impacts of planting pits report much higher crop yield improvements, but these studies compare the situation with planting pits to a situation with no crop production at all (Hassane et al. 2000, Kambore and Reij 2004, Roose et al. 1999). This is not an outrageous comparison since in many Sahelian countries productivity is very low without planting pits due to highly degraded soils. The importance of soil fertility and manure application is underlined in most studies: crop yields increase up to 10 times when manure is added as well (Hassane et al. 2000, Roose et al. 1999, Fox et al. 2005, Fox and Rockström 2003).

The impacts of stone lines are comparable to those of planting pits, Zougmoré et al. (2004) reporting crop yield improvements of 12-18%. Like with planting pits, yields increase much more when investments are made also in soil fertility. Mixtures of water and soil conservation measures, like combinations of zaï with stone lines, and mixtures of bunds and grass rows, contour ploughing and infiltration pits, also report good yield improvements: Sawadogo et al. (2011) report 60-240% crop yield improvements for a combination of planting pits, stone lines and additional manure on formerly degraded lands. Fox et al. (2005) find in a comparative study of Burkina Faso and Kenya that water harvesting (WH) for supplemental irrigation (SI) improves self-sufficiency in staple food production. The analysis also suggests a strong mutual dependence between investment in WH for SI and fertilizer use. Except for Fox et al. (2005) none of the studies translated crop yield improvements into economic benefits. Although the analysis of Fox et al. (2005) focuses on household ponds, the analysis does give an indication of the factors influencing WHT costs and benefits in Burkina Faso. For example, the costs of WHT are largely determined by the opportunity costs of labor, which Fox et al. assume to be 0 in Northern Burkina Faso (because of high unemployment rates). This also explains why Fox et al. find very good returns for WHT in Burkina Faso, e.g. a net return of 390 USD/ha/year, as compared to 70 USD/ha/year in Kenya, a difference which can largely be attributed to higher opportunity costs of labor. Fox et al. also discuss the fact that WHT returns are variable due to the high variability of rainfall and the fact that during a drought (which they assume to happen with a probability of 10%) there are no returns at all. Farmers obviously know this, and although on the one hand WHT can help them mitigate the impacts of less rainfall, WHT also represents an investment with certain costs and uncertain returns. This may help explain why Barbier et al. (2009) find that in northern Burkina Faso, according to farmers, most of the new techniques have been adopted because of growing land scarcity and new market opportunities, rather than because of climate variability. Reij and Smaling (2007) find that innovations are mostly crisis driven, with market opportunities playing a crucial role. With regard to these market factors, Tabo et al. (2011) illustrate the role of market access in explaining low crop productivity in Burkina Faso. Tabo et al. argue that establishing crop storage and savings systems (the '*warrantage system*') helps to improve agricultural productivity, and increases farmers investments in WHT: which is why we selected two *warrantage* villages, Malgretenga and Kourou Magré.

Table 3 Overview of characteristics study villages in Burkina Faso

	Region	Warrantage	Total plot size (ha)	% off-farm	Educated HH
Boukou	Middle	NO	3,6	40%	80%
Malgretenga	Middle	YES	4,1	92%	44%
Kourou Bagré	North	YES	3,9	48%	74%
Ziga	North	NO	3,5	76%	46%

Considering the findings in table 3, there are differences between the study villages in terms of household involvement in off-farm employment, and education levels (education referring to whether the household has one or more household members who can read or write). At first sight, there are no clear difference between North and Middle, or between villages with or without *warrantage*, but when we consider the findings in table 4 it becomes apparent that when considering zaï investments there is a clear difference between the North and Middle.

Table 4 Characteristics WHT, land quality and well access between sites, Burkina Faso

	HH with:				Poor quality land	Access to well
	Zaï	Stone line	Other	No WHT		
Boukou	5%	30%	28%	37%	41%	10%
Malgretenga	2%	28%	10%	61%	41%	9%
Kourou bagré	28%	10%	48%	15%	33%	4%
Ziga	18%	18%	27%	37%	17%	4%

Table 5 WHT maintenance, input use and perceived crop losses, Burkina Faso

	WHT support	No WHT maintenance	Improved seeds	Use of fertilizer	Loses part of crop each 2 years
Boukou	30% from NGO	23%	19%	31%	48%
Malgretenga	19% from family	7%	46%	32%	54%
Kourou Bagré	26% from family	3%	66%	73%	42%
Ziga	41% from family	4%	11%	67%	30%

Interestingly, only in Boukou, where an NGO introduced and heavily subsidized the construction of stonelines, did a substantial number of respondents indicate that they did not maintain WHT investments on their land (see table 5), a clear indication of how subsidization may distort the actual willingness to invest in WHT: in fact, in Boukou this is also because the material for repairing stone lines does not come from the region, making the costs of maintenance very high. Use of fertilizer seems more common in villages in the North, and use of improved seeds more common in *warrantage* villages: both factors are likely to influence the perceived costs and benefits of WHT. As indicated before, we will present a full analysis of the factors influencing WHT uptake in our next deliverable, but the descriptive statistics already indicate that there exist great differences between the villages, especially with regard to market access (use of inputs, off farm employment etc), perceived land quality and education, which need to be linked to WHT investment and the characteristics of the land. In terms of perceptions, 85% of the respondents agrees that zaï increases returns in normal rainfall years (in Malgretenga this is 70%), half of the respondents would invest more in zaï if it could be mechanized and around 60% would invest more with better access to compost.

2.1.4 Potential for WHT

In terms of the wider set of factors influencing WHT uptake and its future potential, Mazzucato et al. (2001) analyze the role of social networks in Burkina Faso, concluding that "while farmers make few monetary investments in agriculture and land enhancing measures, they instead invest heavily in social networks that give them flexible access to resources necessary for agriculture and soil and water conservation, as well as allow them to spread risk and diversify their livelihood strategies thereby relieving the pressure on the land".

They actually recommend to increase the scale of WHT investment projects in order to "focus on how to strengthen local resource management networks and make them spread beyond the village level, rather than undercut them by focusing on an imaginary geographical entity such as the village in the '*Gestion de Terroirs*' approach". Unfortunately, we could not address the role of social networks in our analysis of the factors influencing WHT uptake, although in the household survey we did include questions about membership of village organizations and trust in others, including officials and villagers. Interestingly, whereas 80% of the respondents from Boukou and Malgretenga indicates trusting local authorities, only 60% of the respondents in Ziga and Kourou Bagré indicates the same.

Finally, we pay specific attention to perceptions of climate change, awareness of soil degradation and of the other factors influencing WHT uptake in our analysis, specifically relating to market access and the opportunity costs of labour. In terms of social organization we divided tasks with Workpackage 5 on livelihood aspects as they spent more time in the WHaTeR villages and include social organization in their qualitative analysis.

2.2 Ethiopia

2.2.1. Description of the study site

In Ethiopia the project focuses on two different types of water harvesting techniques, which are studied in two separate case studies. These are household and community pond in the Alaba region, and floodwater harvesting (or spate irrigation) in the Konso region (see figure 2). Lasage et al. (2011) describe the historical and policy context of water harvesting technologies in Ethiopia. Also, they describe the reasons for choosing Alaba and Konso region, and household pond and spate irrigation technologies. A practical reason is that both Konso and Alaba are located near the Ethiopian partner university, Arba Minch University. See table 6 for the description of the techniques.

Alaba site

The Alaba case study site is located 7,17° N, 38,06° E in the Southern Nations Nationalities and Peoples Regional State (SNNPR), 310 km south of Addis Ababa. It is a semi-arid, relatively flat region, located around the Blate river. The average elevation is 1800 m.a.s.l. ranging from 1550 to 2150 m.a.s.l..

Average precipitation is 940 mm per year (Climate explorer, 2013, Awassa station) There are two rainy seasons, one from March to May with an average rainfall of 240 mm and a standard deviation of 120 mm. The second rainy season, which is considered the main rainy season, is from July to September with an average of 320 mm and a standard deviation of 135 mm. Average temperature ranges from 17 to 20°C (Amha, 2006), and average potential evaporation is circa 1750 mm per year (Shewangizaw and Michael, 2010). The soils of the area are relatively fertile and during good rains farmers can harvest good yield even without fertilizer application. The total area of Woreda is 64000 ha of which 48000 ha (75%) are considered suitable for agriculture (Amha, 2006).

In Alaba household ponds and community ponds are the main WHT implemented, and hence we focus on these techniques in this case study. These ponds have been constructed as part of government programs (e.g. food for work) and as part of NGO projects. Ponds are a suitable technique because water is the main limiting factor for agricultural production. The land has gentle slopes and in combination with the rainfall intensity it generates sufficient overland flow to be stored in the ponds. The plot sizes are generally large enough to allocate a part of it as catchment area, and a part for the pond, leaving sufficient room for the (irrigated) crops .

Table 6: Description of selected water harvesting and soil and water conservation interventions (after Abebe et al. 2012).

Pond	Hand dug open reservoir to store water collected from local catchment. Seepage losses can be reduced by using lining (concrete or plastic). Sizes vary from 30 m^3 (individual household use) to 20,000 m^3 (community used). These are simple structures that can be constructed by untrained labourers. When lining is used, some expertise is necessary. Water is extracted using a bucket or foot pump. A roof may be constructed to reduce evaporation losses; then more correctly know as a cistern (Fox et al., 2005; Critchley, 2009). Implemented in Afar, Amhara, Oromia, SNNP, Somali, and Tigray regions.
Floodwater harvesting	Diversion of floodwater (spate flows) from beds of ephemeral rivers through open intakes, by diversion spurs or by bunds built across the river bed to spread over large areas as irrigation water and to be partially stored in the soil. Dry-planting is carried out. The intake structure often needs to be rebuilt after a flood. Normally communal activity requiring social organization. (Tesfai & de Graaff, 2000; van Steenbergen et al., 2010; van Steenbergen et al, 2011). Spate irrigation is on the increase in the semi-arid parts of the country: Tigray (Raja, Waja), Oromia (Bale, Arsi, West and East Haraghe), Dire Dawa Administrative Region, SNNP (Konso), Afar and Amhara (Kobe) regions.

Amha (2006) describes the Alaba region in her thesis about the impacts of household pond investment, underlining the highly eroded nature of Alaba woreda (woreda being the administrative unit, Alaba woreda comprising 76 villages) the scarcity of water in the dry season, especially given very deep groundwater levels (average depth of 200 meters). Traditionally, villages constructed communal ponds for dry-season livestock drinking and household water use. These ponds are being maintained with the help of NGOs in the region, and in addition to the community ponds the government has made large investments in the construction of household ponds, many households having been obliged to contribute labour. The mandatory, top-down character of the implementation process has affected the technical quality of the ponds (location, use of materials), but it has also implied that households that were not really interested in WHT still received a household pond on their land.

In the WHaTeR project we focus on assessing the factors determining whether households have maintained the ponds on their land. Thus, we define 'uptake' as the continued maintenance and use of WHT. Although we will present the results of our analysis of the factors influencing effective uptake in the next deliverable, in this report we will characterize the study site and describe the factors we expect to influence maintenance of subsidized household pond investments in the Alaba region.

In fact, given that we expected market access to play an important role in WHT uptake, we selected our study villages based on the distance to the main road. This indeed strongly coincided with the number of functioning household ponds: villages near to the road having many more functioning household ponds than in villages located further from the road. Table 7 gives an overview of the selected villages, and of the number of functioning and non-functioning ponds included in the study design. We used a stratified sampling approach to accommodate the interests and needs of the partner university, Arba Minch. In total, 300 households were surveyed, and the technical quality and location of the ponds was assessed.

Table 7 Villages selected for the household survey in the Alaba region, Ethiopia

	Village name	Number of households with functioning ponds	Number of households with nonfunctioning ponds
Close to the main road	Andegna Ansha	23	11
	Kufe	19	9
	Andegna Mekela	12	7
	Galato	19	9
	1st Ashoka	9	5
	Wanja	18	9
Total		**100**	**50**
Far from main road	1st Tuka	13	26
	2nd Tuka	9	18
	2nd Tuka	7	14
	Kobo Chobare	7	14
	Tefo Chufo	7	14
	Rokane Tefo	7	14
Total		**50**	**100**

Interestingly, half of the respondents indicates NOT to maintain their household pond, which might be related to the mandatory nature of the government investment program, the high subsidization rate, and poor site selection for the ponds. The interesting question for us to answer is what caused the other 50% of the households to do maintain their household pond: is this related to the technical quality of the pond, to household characteristics or to village characteristics like market access?

Table 8 Household pond investments in Alaba region, Ethiopia

Water harvesting technology the household invested in	Household pond, no lining	74%
	Household ponds, with lining	21%
	Vegetated bund	1%
	Other water and soil conservation	3%
	Other	1%
Who constructed the household pond?	Government	49%
	Household itself	26%
	NGO's	9%
	Household itself ánd government	12%
	Other	5%
How often a household maintain the household's pond	Never	53%
	Every year	26%
	Rarely	12%
	Sometimes	5%

Information from the focus group meetings indicated that market access and lack of facilities like credit, inputs and transport facilities pose serious constraints for farmers to diversify their cropping patterns and improve their livelihood. Field visits indicated that innovative, cash crop oriented farmers did maintain their ponds, and had in fact invested in additional ponds, but the analysis of the survey data will need to answer the question fully. Finally, we conducted a choice experiment in Alaba region, to ask farm households about the conditions under which they would be willing to invest in household pond (improvements). The results from this analysis will also be shared in the next deliverable, but here it is important to note that one of the characteristics of the Alaba region is poor market access and lack of facilities to improve agricultural productivity, a factor we expect to influence WHT uptake.

Konso site

The Konso case study site is located 5,25°N, 37,48° E in the Southern Nations Nationalities and Peoples Region, but more to the South. It is a more hilly region where the elevation varies between 500 and 2000 m.a.s.l. (Beshah, 2003) with the Sagan river running through.

Average precipitation is 620 mm per year, varying between 400 and 1000 mm. There are two rainy seasons, one from February to April with average rainfall of 220 mm, and one from October to November with an average rainfall of 320mm (Asfaw et al., 2013). Average temperature is 22,4°C with little variation throughout the year (Ocho et al., 2013), and average potential evaporation is circa 1700 mm per year (UNEP, 1997). The soils of the area are relatively fertile and during good rains farmers can harvest good yield even without fertilizer application. The district covers an area of 3000 km^2 and has 235000 inhabitants, of which 90% is rural population (Ocho et al., 2012). In most years, all wealth groups in Konso, including the better-off, receive food aid which covers on average 15% of their annual household food requirements.

In Konso the following types of RWH systems are practiced: terraces, stone bunds, household ponds, community ponds, sand dams and spate irrigation. On spate irrigation relative little information is available, while these systems are in practice for quite some time. The systems are relatively large and affect agricultural production of many households. This technique is relatively new for the Konso region (van Steenbergen et al., 2011)). The hydro-physical circumstances appear to be promising. There are several ephemeral rivers where flash floods occur during the rainy season. At several places these rivers flow through relative flat areas, where flood division structures can be constructed, to direct the water onto the fields.

Van Steenbergen et al. (2011) focus on the potential of spate irrigation in Ethiopia, suggesting that to transform spate irrigation in Ethiopia from subsistence to a business-oriented production system, it is important to promote cash crops including pulses and oil seeds as well as encourage investors to go for bio-fuel development and agro-forestry in the lowland areas where huge potential exist. Hence the choice to select this technique for further study within the context of the Whater project, focusing on technical improvements of the WHT.

2.2.2 Knowledge and awareness

Because of the huge government programs on soil and water conservation and rainwater harvesting in Ethiopia, knowledge and awareness of WHT do not appear to be a major constraint in the Ethiopian context. We did not test the validity of this assumption, however, but in the analysis we account for respondent perceptions of WHT returns and WHT potential and we will account for the technical quality of WHT investments and the extent to which farm households are capable of maintaining WHT. Education of the household is also a factor we account for, but unlike our approach in Burkina Faso we did not assess awareness and knowledge levels at the project's start.

2.2.3. WHT costs and benefits

With regard to WHT investments in general, Amsalu and de Graaff (2007) examine the determinants of farmers' adoption and continued use of introduced stone terraces in an Ethiopian highland watershed. Their findings indicate that the factors influencing adoption and continued use of the stone terraces differ: Adoption is influenced by farmers' age, farm size, perceptions on technology profitability, slope, livestock size and soil fertility, while the decision to continue using the practice is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Shiferaw and Holden (2001) point out that WHT has substantial opportunity costs in terms of land use; WHT require land to implement and especially when farmers have small plots this can be a substantial cost. They also show that although the societal benefits of soil conservation exceed the costs of implementation, conservation measures are unattractive for Ethiopian highland farmers because investments have few short term returns.

Typically, returns to household pond investments are higher than returns on *in soil* storage techniques like stone terraces and bunding, because household ponds allow for supplementary irrigation which allows farmers to shift to the production of higher value cash crops. Even when farmers don't change their cropping patterns, household ponds report the highest range of crop yield improvements, i.e. Fox and Rockström (2003) reporting improvements in the range of 44-71%, but Fox et al. (2005) reporting improvements of 150%, Hatibu et al. (2006) of 117% and Fox and Rockström (2000) even of 170%. For the Ethiopian context, Tesfaye et al. (2008) indicate that access to small-scale irrigation significantly enhances food security as use of pumps for supplementary irrigation allows farmers to grow vegetables and other high value crops. Moges et al. (2011) review ex situ rainwater harvesting structures and conclude that due to high opportunity costs and disappointing WHT benefits (caused by high seepage and evaporation losses) the returns to investments are in many cases insufficient to cover investment and labor costs.

Amha (2006) evaluates the impact of household pond construction in the Alaba region, indicating that the increased water availability from household ponds caused a shift in cropping patterns towards higher value crops (vegetables, fruit trees). An analysis of the determinants of household pond uptake indicated that larger households (labor availability), with relatively more assets (livestock, landholdings) and higher education levels were more inclined to have a household pond.

In the analysis no attention is paid, however, to the fact that household pond construction was heavily subsidized and government implemented, and it remains unclear whether households have a pond because they were well-connected or because they were most willing to invest, and if the location is suitable for a household pond. What Amha's analysis does indicate is that returns are most positive for farmers who managed to shift to higher value crops, which is why she concludes that effective uptake requires attention for crop marketing and market access. Interestingly, the focus group meetings indicated that farmers had stopped maintaining their ponds after the prices of vegetable crops (onion) dropped as a result of the fact that the market had been flooded with onions because all farmers with household ponds had started to produce the crop. Because of lacking market facilities, like information, storage facilities and transport, farmers were unable to adequately respond to the changed prices, which seems to have lowered the incentive to maintain the household ponds on their land. In our analysis of the household survey and choice experiment data we will assess whether this indeed explains uptake.

2.2.4 Potential for WHT

In Ethiopia, Moges et al. (2011) suggest that uptake of RWH systems by smallholders in Ethiopia is limited and the available information suggests that this is associated among others with poor planning and implementation, poorly functioning input and output markets and the lack of farmers' skills to use these systems effectively. Shiferaw and Holden (1999) consider famers decisions with regard to soil conservation. They conclude that "Pervasive market imperfections, poverty and high rates of time preference seem to undermine erosion-control investments. Lack of technologies which provide quick returns to subsistence-constrained peasants also seem to deter such investments". Bewket (2007) indicates that even in a project that presented itself as participatory, farmers were not truly consulted but merely persuaded to accept WH investments on their land. The limited attention to participatory and community-based approaches in parts of Africa – especially Ethiopia - is surprising given the experiences in India that indicate that participatory approaches are much more successful (Kerr et al. 2002) and efficient in terms of WH investment costs. Given that in the Alaba region we know beforehand that implementation has not been participatory and that farmers were not consulted about their interest to invest, we do not pay specific attention to the influence of project implementation on the outcomes, assuming that top-down implementation has affected WHT uptake in a negative way.

2.3 Tanzania

2.3.1. Description of the study site

The Tanzania case study is located in the lowlands of the Makanya River Catchment in northern Tanzania, in the Same District (4,8 to 4,3° S, and 37,5 to 37,5°East) near the towns of Bangalala and Makanya (4,3°S, 37,9°E). The elevation is below 735 m.a.s.l.. The region is characterised by a bimodal low-rainfall conditions of 500 mm per year. Average temperature ranges from 17 to 29°C (Tumbo et al., 2010). The western Pare lowlands are considered to have low agricultural potential. The average population density is 42 persons/km^2 (Tumbo et al., 2011).

The focus in Makanya watershed is on micro-dams and spate irrigation (floodwater harvesting). Micro-dams have proven to be suitable measures in the region, since their catchment wide introduction in the late 1990 and 2000s (Mahoo et al., 2012). Spate irrigation and flood diversion have been mentioned from the 1940s onward, larger scale adoption occurring since the 1990s and 2000s. The potential irrigated area is 700 ha. (Mahoo et al., 2012). For both micro-dams and spate irrigation, prior research has indicated several factors which should be studies in more detail to enhance water harvesting sustainability (e.g. develop village water plan, improve the structures, improve water scheduling and water use, etc.) (Mahoo et al., 2012). In the WHaTeR project several of these recommendations have been taken up, and improvements in the irrigation system have been made.

The analysis of factors determining water harvesting uptake will be based on the available literature, given that much has been written about the Makanya watershed already. Although while reviewing the literature it became clear that most of the available studies focus on the hydro-physical aspects of water harvesting, several studies address the socio-economic and institutional dimensions of water harvesting in Makanya watershed as well. We will discuss these studies in the following sections, addressing the findings with regard to knowledge and awareness, perceived costs and benefits and the potential for water harvesting in Makanya watershed.

2.3.2 Knowledge and awareness

Masuki (2006) elaborates the conditions for WHT adoption in the Pangani basin- the basin in which Makanya watershed is located. He argues that for the adoption of improved WHT practices it is crucial that indigenous knowledge is incorporated in the design and implementation of water harvesting structures and that it is important to share knowledge through farmer-to-farmer extension. Given that many projects have focused on Makanya watershed, and that WHT implementation seems to have been rather participatory, it seems that for the farmers in the Makanya watershed knowledge and awareness is not a problem. For the rest of Tanzania this may be different.

2.3.3. WHT costs and benefits

Hatibu et al. (2005) assess the costs and benefits of different WHT in Tanzania, and conclude that the more water is being harvested, the better the returns to investment are. Benefits are especially large when they allow farmers to shift from the production of subsistence crops to the production of cash crops, but this requires that sufficient water is harvested and that market access is guaranteed.

Senkondo et al. (2004) assess returns to water harvesting in the Makanya catchment and find that a) returns depend, at least partly, on the farmers location in the (irrigation) system and b) that returns are highly crop dependent, the highest returns being for farmers who were able to shift to high value market crops. This is in line with Hatibu et al. and underlines the importance of market access for boosting WHT returns. In their analysis, Senkondo et al. (2004) consider returns over a 10 year period at a discount rate of 10%, in line with the opportunity costs of capital in Tanzania. With regard to the opportunity costs of labor the authors use an average cost of hired labor of 1000 Tanzanian shilling (0.50 euro) per day. This seems rather low, given that the minimum agricultural daily wage in 2013 for Tanzania is 3800 shilling (http://www.africapay.org/tanzania/home/salary/minimum-wages), but this maybe be because of different reporting periods. Senkondo et al. (2004) compare returns for different crops (paddy, maize and onions) indicating that maize production without WHT is actually not economically viable. The reason that farmers still continue producing maize may actually be an indicator of limited alternative employment options, e.g. very low opportunity costs. Overall the analysis suggests that the benefit-cost ratio for maize farmers is most positive, but that returns are highest for onion crops. Overall, WHT has positive returns, even when accounting for capital and labor opportunity costs. Sensitivity analysis (e.g. varying in/output prices) suggests that results are robust, except for paddy.

Mutabazi et al. (2005) argue that water harvesting is also alleviating poverty as returns to labor are substantial. They compare returns across above and below average rainfall years and show that also in below average rainfall years water harvesting increases yields, and improves incomes. They mention that this has to do with the relatively good market access of Makanya watershed: '*Makanya village, where the study was conducted, is close to big marketing centres such as Dar es Salaam, Arusha and Nairobi, which are linked by the Dar es Salaam-Arusha-Nairobi highway. Therefore, improving the yield of the maize-lablab bean intercrop through better management of rainwater and agronomy would boost small farmers' incomes tremendously*'. Finally, in line with Hatibu and Senkondo they argue that the high returns are mostly because water harvesting gives farmers the option to shift to higher value crops (lablab beans) and that for the amount of returns the farmer's location in the irrigation system matters. Komakecht et al. (2011) discuss water management in the Makanya spate irrigation system saying that '*Spate irrigation systems pose institutional and technical challenges: collective action is challenged by complex upstream–downstream interactions between users within the system, and the high labor demands for regular reconstruction of temporary diversion weirs and intake structures*'. They conclude that in Makaya watershed effective institutional arrangements are in place.

2.3.4 Potential for WHT

Like discussed in the previous section, water harvesting in Makanya watershed has potential as it allows farmers to shift to the production of high value crops. Komakech et al. (2011) argue that there are a couple of technical issues that need to be addressed to ensure sustainability of the system (high sedimentation) and Chikozho (2005) who, contrary to Komakecht et al. (2011) suggests that institutional arrangements for water allocation are not effective and that more attention should be paid to up-downstream issues to ensure that downstream users get their fair share, and that environmental sustainability is not at risk.

Chikozho (2005) also discusses the need for institutional upscaling of water harvesting, e.g. from individual interventions to a scaling up of efforts at regional scale. Interestingly, Chikozo compares Pangani basin with Thukela basin, in South Africa, very near the WHaTeR site. He notes that whereas the water harvesting technologies used in the Pangani basin are largely 'homegrown' (e.g. farmers and extension workers know and developed these technologies), in South Africa they are externally introduced. This has implications for uptake: Chikozho notes that farmers in South Africa were skeptical and that it took quite some effort to convince them to try water harvesting on their land. In the Pangini basin, farmers are quite eager, and they even started to organize themselves around the water harvesting structures at village scale. This is a promising venue for upscaling, although Chikozho mentions that for successful upscaling these farmer organizations require better access to agricultural support facilities (information, credit etc) and other developmental interventions which should be discussed and co-designed.

2.4 South Africa

2.4.1. Description of the study site

The Potshini catchment is located in the Bergville District in KwaZulu-Natal, South Africa. The average elevation is about 1250 m.a.s.l. and it is a hilly terrain. The average monthly temperature ranges from 10 to 24°C. The mean annual precipitation estimated to be 700 mm/yr and mean annual potential evaporation between 1600 and 2000 mm/yr (Kongo and Jewitt, 2006).

It is predominantly a smallholder farming area, with crop production during summer, which constitutes approximately 80% of the total land in the catchment, and grazing. During winter, all the domestic animals (cattle and goats) are freed to graze on the smallholder farming land due to depleted pastures on the secured grazing lands on the upper slopes of the catchment (Kongo and Jewitt, 2006). The potential of WHT in the area is considerable. Earlier projects have reported successful results where smallholder farmers have managed to increase their crop production per unit area (Kongo and Jewitt, 2006). However, before extensive upscaling of WHT takes place it is important to fully understand the upstream-downstream impacts of WHT in terms of both water quality and water quantity. This will also be the focus on analysis in the Whater project.

Like in the case of Tanzania, the analysis of factors determining water harvesting uptake will be based on the existing literature. In the case of Potshini watershed, very few socio-economic studies were available, most of the research having focused on the hydro-biophysical aspects of water harvesting in the watershed. The water harvesting technologies considered in the WHaTeR project are small water storage structures (jojo's- plastic tanks) which harvest run-off from a micro area (farmer's homestead) and store it for supplementary irrigation and household water use. Most attention in the Potshini watershed focused, however, on conservation agriculture, e.g. investments in tillage improving soil fertility and the soil's water retention capacity and investments in gully plugs etc reducing soil erosion. Given the focus of the WHaTeR project, we will not be discussing these investments and their impacts here, but instead focus on the small water storage structures.

2.4.2. Knowledge and awareness

As discussed in the section on Tanzania, Chikozho (2005) notes that water harvesting was introduced externally, and that this hampered farmer uptake. Once the first (positive) results were visible, farmer-to-farmer extension greatly supported uptake. In South Africa in general, knowledge and awareness of water harvesting seems limited, few papers addressing water harvesting in South Africa.

2.4.3. WHT costs and benefits

For Potshini watershed, no socio-economic analysis of the returns to water harvesting were available, but two MSc thesis of the University of KawZulu Natal do shed light on water harvesting returns. Rotich (2012) assesses the cost-effectiveness of small water storage tanks, comparing building and maintenance costs for different materials and comparing costs with investment returns. The water storage system considered was designed to provide the full water requirements for an area 150-250 m^2 (depending on the crop type) for the driest year in 10, assuming zero rainfall at the end of summer (the wet season). Runoff design was based on design rainfall with 80 percent exceedance probability (i.e. 80% of rainfall events exceed this amount) for 0.5 hectare catchment area. Therefore, in years when there is rainfall in winter or early spring, a bigger area could be irrigated (provided infrastructure was in place) or there would be still be water available at the end of the growing season. Although costs differ substantially depending on the material used, underground storage tanks are cheapest because the storage achieved from the underground systems is much higher than the above ground systems, so the cost per unit of water stored is lower. The capital outlay is lower for the above ground tanks.

Farmers do not have to pay for the tanks, however, they only provide labor for maintenance. The opportunity costs of labor are very low, because of high unemployment rates, and many people receive government grants (pensions, child grants) as poverty is high. With regard to these grants, Sturdy (2008) notes that '*Government grants range from R200/person/month to R870/person/month, whereas a family in Potshini spends R941/year on average for agricultural inputs (note that $1 USD equalled approximately R7 at the time of the study). The largest expenditure, however, is that of funerals and ceremonies (weddings, coming of age, etc.), where R10,000 is a typical amount to spend*'.

In terms of returns, farmers in Potshini watershed produce mostly maize, the staple food crop, although few innovative farmers use the stored water also to produce vegetable crops. Both maize and vegetable production improved because of the storage tanks, both mainly benefitting household consumption as crop marketing is limited. Farmers generally have little experience with the marketing of their crops, and although Potshini watershed is rather well-connected, market facilities are poorly developed, transportation costs are high and people have no access to credit. The Famers Support Group have spent a lot of effort on connecting farmers to markets, however, and an increasing number of farmers has started to produce vegetables to sell on the market nearby.

2.4.4 Potential for WHT

Chikozho (2005) indicates that when evaluating the introduction of water harvesting in the region, farmers commented that they funds were lacking to make investments and further invest in the productivity of their land. This is reflected in the MSc research of Sturdy (2008) who indicates that farmers have few investment options as they basically have no access to capital, except for small savings groups. This is also because in South Africa access of small-scale farmers to finance or at least larger capital equipment or infrastructure is usually through state supported co-operative or group schemes, whereas the nature of the water harvesting investments in Potshini watershed is individual. Thus, most investments are initiated externally, which may create adverse incentives for uptake and maintenance.

Knowledge of agricultural production and awareness of water harvesting potential seem another constraint in Potshini watershed: most of the concerned farmers are laborers on the nearby commercial farms and in the mining sector most of their time, and during Apartheid they were hardly allowed to farm their lands. Still, few of the households concerned are full-time farmers, and because of high population density in Potshini watershed and resulting degradation problems, agricultural productivity is relatively low. With regard to the knowledge and awareness issue, Sturdy (2008) concludes that '*in Potshini, and in other subsistence farming communities in Southern Africa, hands-on, monthly workshops that focus on problems identified by the farmers themselves can be a successful pathway for facilitating adoption. Group workshops provide a venue for farmers to share concerns and knowledge, which is an important avenue for innovation dissemination because farmers tend to adopt innovations that have been tried and introduced to them by other farmers. Through such workshops, farmer leaders can be identified and motivated farmers can be chosen for individualized training or farmer experimentation, which have been successful pathways for fostering thorough understanding of innovations'*. In addition, the current incentive structures may not be conducive for farmer uptake of water harvesting investments and investments in agricultural productivity improvement, but it is beyond the scope of this project to address this issue in sufficient depth.

3. Discussion

The study sites cover a variety of biophysical and climatological circumstances. Hence, the WHT implemented at these sites are different. For the case studies described in this report, the main factors determining the choice of technique are the presence of a (ephemeral) river, soil characteristics, and intended use of water. If a river is present, floodwater or spate irrigation can be practiced. If there is no river, precipitation and overland flow are the main sources of water for the WHT. Depending on the permeability and fertility of the soil. Zai is practiced at location where a crust is formed at the top of the soil. Ponds are constructed mainly in areas where the soil has better agricultural characteristics when they are used for irrigating crops. Community ponds are mainly used for watering livestock, and hence soil characteristics are less important. Preferences from households and communities also play an important role in the selection of techniques.

When characterizing the WHaTeR study sites we find that, in line with the literature on water harvesting in semi-arid Africa (Bouma et al. 2012), farmer's knowledge and awareness, the perceived costs and benefits of rainwater harvesting, and the broader socio-economic context are indeed important factors influencing the uptake of water harvesting techniques.

First of all, in all of the sites farmers are mostly smallholder, subsistence farmers with little to no access to credit or input markets, and limited in their capacity to invest. Addressing the socio-economic constraints faced by most farmers seems crucial for water harvesting uptake, since farmers can otherwise not benefit from crop yield improvements and are less likely to maintain the (subsidized) investments made. The case of Burkina Faso shows that the facilities that are lacking can be as simple as storage facilities which limits farmers in storing their surplus harvest for household consumption, or to market the surplus harvest when prices are good. In Ethiopia, several papers point at the importance of market access, farmers with good market access using water harvesting investments to shift production to higher value (cash) crops to substantially improve their income. The same situation is found in Tanzania, here micro-dams and spate irrigation have starkly improved farmers livelihoods by allowing them to shift to the production of higher value crops. In South Africa, lack of market facilities seems to constrain farmers in making a shift towards cash crop production, but other factors seem to play a role here as well.

Second, especially when market access is lacking and farmers cannot use water harvesting to shift to the production of higher value crops, the benefit-cost ratio of water harvesting can be limited. There are three elements important for understanding this low benefit-cost ratio: (i) the costs of many water harvesting technologies are quite substantial, either in investment or in land and labor opportunity costs. Hence, even with substantial benefits, the benefit-cost ratio might still be low, (ii) many water harvesting investments have a long time horizon, ie investments reap benefits over the next 5-10 years. Poor farmers tend to have a short term horizon and although maintenance now might generate benefits for the next 5 years not earning off-farm income this year represents a real loss and (iii) benefits are uncertain, as for yields to improve because of water harvesting it is still necessary that it rains.

In drought years, WHT benefits may be limited, especially when investments generate no supplemental irrigation. Thus, adding uncertainty reduces the perceived benefit-cost ratio. Evidence from Ethiopia illustrates that a low benefit-cost ratio is actually the reason why water harvesting investments are not maintained, and in Burkina Faso increasing opportunity costs of labor seem to play an important role. In Tanzania, returns depend on crop choice and the location of the farmer in the irrigation system, whereas in South Africa farmers seem so deprived of means to invest in agricultural productivity that investments in water harvesting are mostly external and for reasons of food security.

Third, the characterization of the WHaTeR study sites indicates that (lack of) knowledge and awareness indeed plays an important role: Several studies pointing at the importance of consulting farmers to incorporate their knowledge and better target investments to their needs. Given that in the WHaTeR study sites farm households are currently well aware of the potential of water harvesting this is not a topic we can analyse in the course of the WHaTeR project, but the lack of knowledge and awareness will clearly be an important factor for an effective scaling up of experiences beyond the study sites.

Overall, there seems to be a business case for water harvesting investment, especially when it allows farmers to (partly) shift their farming practices from the production of subsistence to the production of cash crops. Clearly, this is not always possible as it depends on the amount of water that can be harvested and whether farmers have good market access. The business case for WHT in subsistence farming in dryland agriculture is more uncertain, studies being limited to crop yield improvement assessments without attention for investment costs. Also, in the face of increasing droughts the question arises whether water harvesting in dryland agriculture creates sufficient benefits in poor rainfall years: anecdotal evidence suggests that farmers may prefer to earn off-farm employment as opposed to investing in water harvesting, but this is a subject that requires further analysis.

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Bibliography

Abebe, A., Lasage, R., Alemu, E., Gowing, J., Woldearegay K.,(2012). Ethiopia chapter. In: Water Harvesting in Sub Saharan Africa: the state of the art. Critchley, W. and Gowing, J. (eds). Routeledge publishers, Oxon, UK, pp. 70-84. ISBN13: 978-0-203-10998-4

Amha, R., (2006). Impact assessment of rainwater harvesting ponds: the case of Alaba Woreda Ethiopia. MSc thesis, Addis Ababa University. 134p.

Amsalu, A. ,J. de Graaf (2006).Farmers' views of soil erosion problems and their conservation knowledge at Beressa watershed, Ethiopia, *Agriculture &Human Values* 3:99–108.

Amsalu, A. , J. de Graaff (2007).Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. *Ecological Economics* 61: 294-302.

Anley, Y., A. Bogale and A. Haile-Gabriel (2007). Adoption decision and use intensity of soil and water conservation measure by smallholder subsistence farmers in Dedo District, Western Ethiopia. *Land Degradation & Development* 18: 289–302.

Alemayhu, M., F. Yohanessi, P. Dubale (2006). Effect of indigenous stone bunding (Kab) on crop yield at Mesobit-Gedeba, North Shoa, Ethiopie. *Land Degrad. Develop* 17: 45–54 (2006).

Asfaw, A., Almekinders, C.J.M., Struik, P.C., Blair, M.W., (2013). Farmers' common bean variety and seed management in the face of drought and climate instability in southern Ethiopia. Scientific Research and Essays, Vol. 8(22), pp. 1022-1037, 11, DOI 10.5897/SRE12.732

Barbier, B., H. Yacouba, H. Karambiri, M. Zorome, B. Some (2009). Human Vulnerability to Climate Variability in the Sahel: Farmers' Adaptation Strategies in Northern Burkina Faso. *Environmental Management* 43: 790–803.

Barbier, E. (1990). 'The farm-level economics of soil conservation - the uplands of Java', *Land Economics 66*: 199-211

Barron, J., S. Noel, M. Malesu, A. Oduor, G. Shone and J. Rockström (2008). Agricultural water management in smallholder farming systems: the value of soft component in mesoscale interventions. SEI Project Report.

Barry, B., A.O.Olaleye, R. Zougmoré, D. Fatondji (2008). Rainwater harvesting technologies in the Sahelian zone of West Africa and the potential for outscaling. *IWMI Working Paper 126*, International Water Management Institute: Colombo, Sri Lanka: 40p.

Bekele, W. and L. Drake (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological Economics* 46: 437-51

Besha,T. (2003) Understanding Farmers Expanding Soil and Water Conservation in Konso Wolaita and Wello, Ethiopia Tropical Resource Management Paper 41 81-116

Bewket, W. (2007). Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. *Land Use Policy* 24: 404–416.

Bhatt, Y.; Bossio, D.; Enfors, E.; Gordon, L.; Kongo, V.; Kosgei, J. R.; Makurira, H.; Masuki, K.; Mul, M.; Tumbo, S. D. (2006). *Smallholder System Innovations in Integrated Watershed Management (SSI): Strategies of water for food and environmental security in drought-prone tropical and subtropical agro-ecosystems.* Colombo, Sri Lanka: International Water Management Institute.

Boers, T.M. and J. Ben-Asher (1981). A review of rainwater harvesting. *Agricultural Water Management* 5: 145-158.

Bouma, J.A., Barron, J. & Critchley, W. (2012). A review of the recent literature on water harvesting in SSA. In Critchley, W. & Gowing, J. (Eds.), *Water harvesting in Sub-Saharan Africa*. Earthscan.

Bouma, J.A. (2008). *Voluntary cooperation in the provision of a semi-public good- Community-based soil and water conservation in semi-arid India*. CentER Dissertation series 207, CentER graduate school, Tilburg University, Tilburg.

Bouma, J.A, van Soest, D.P. & Bulte, E.H. (2007). How sustainable is participatory watershed development in India? *Agricultural Economics,36*, 13-22.

Cheung, W.H., Senayb, G.B., Singh, A., (2008). Trends and spatial distribution of annual and seasonal rainfall in Ethiopia. International Journal of Climatology 28:1723-1734 DOI:10.1002/joc.1623

Critchley, W. (2009). Soil and water management techniques in Rainfed agrivulture – state of the art and prospects for the future. Background note. CIS, Amsterdam. 53p.

Critchley, W.R.S, C. Reij and T.J. Willcocks (1994). Indigenous soil and water conservation: a review of the state of knowledge and prospects for building on traditions. *Land Degradation & Rehabilitation* 5: 292-314

Deressa, T., R.M. Hassan, T. Alemu, M. Yesuf and C. Ringler (2009). Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. *Global Environmental Change* 19 (2): 248-255

Drechsel, P., A. Olaleye, A. Adeoti, L. Thiombiano, B. Barry and K. Vohland (2010). Adoption Driver and Constraints of Resource Conservation Technologies in sub-Saharan Africa. *Workshop report*. IWMI, West Africa Office, Ghana, FAO, Regional Office for Africa, Ghana and Humboldt University, Berlin, Germany.

Duflo, E., M. Kremer and J. Robinson (2011). How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya. *The American Economic Review*, 98 (2): 482-488.

Fox, P. and J. Rockström (2003). Supplemental irrigation for dry-spell mitigation of rainfed agriculture in the Sahel. *Agricultural Water Management* 61 : 29–50

Fox, P., J. Rockström and J. Barron (2005). Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya. *Agricultural Systems* 83: 231–250.

Graaff, de J., A. Amsalu, F. Bodna´r, A. Kessler, H. Posthumus and A. Tenge (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography* 28: 271– 280.

Hassan, R., Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis, *African Journal of Agric. And Res Economics* 2(1): 83-104

Hanjra, M.A., T. Federe, D.G. Gutta (2009).Pathways to breaking the poverty trap in Ethiopia: Investments in agricultural water, education, and markets. *Agricul.Water Management* 96: 1596–1604.

Hatibu, N., K. Mutabazi, E.M. Senkondo and A.S.K. Msangi (2006). Economics of rainwater harvesting for crop enterprises in semi-arid areas of East Africa. *Agricultural Water Management* 80: 74–86.

Hatibu, N., M.D.B. Young, J.W.G Owing, H.F. Mahoo and O.B. Mzirai (2003). Developing improved dryland cropping systems for maize in semi-arid Tanazania. Part 1: Experimental evidence for the benefits of rainwater harvesting. *Expl Agric.* 39: 279–292

Holden, S., B. Shiferaw and J. Pender (2004). Non-farm income, household welfare, and sustainable land management in a less-favored area in the Ethiopian highlands. *Food Policy* 29: 369–392.

IPMS, 2005.Alaba Pilot Learning site diagnosis and Program design.

Joshi, P.K., Wani, S., Joshi, L., Shiyani, L.R. (2005). Meta-analysis to assess impact of watershed program and people's participation, *Comprehensive assessment research report 8*, IWMI: Colombo

Kahinda, M., Taigbenu, A., Boroto, J. (2007). Domestic rainwater harvesting to improve water supply in rural South Africa, *Physics and Chemistry of the Earth*, 32 (15-18): 1050-1057.

Kahinda, M., Taigbenu, A. (2011). Rainwater harvesting in South Africa: Challenges and opportunities. *Physics and Chemistry of the Earth* 36:968-976

Kato, E., C. Ringler, M. Yesuf and E. Bryan (2011).Are Soil and Water Conservation Technologies a Buffer Against Production Risk in the face of Climate Change? Insights from Ethiopia's Nile Basin. *Agricultural Economics* 42 (5): 593-604

Kessler, C.A. (2006). Decisive key-factors influencing farm households' soil and water conservation investments. *Applied Geography* 26: 40–60

Knowler, D. and B. Bradshaw (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32 : 25–48.

Kongo, V., Jewitt, G. (2005). Preliminary investigation of catchment hydrology in response to agricultural water use innovations: a case study of Potshini catchment-South Africa. *Phys. Chem. Earth* 31: 976-987

Kosgei, J.R., G.P.W. Jewitt, V.M. Kongo and S.A. Lorentz (2007). The influence of tillage on filed-scale waer fluxes and maize yields in semi-arid environments: A case study of Potshini catchment, South Africa. *Physics and Chemistry of the Earth* 32: 1117-1126.

Lasage, R., J. Aerts, G.-C.M. Mutiso, A. de Vries (2008). Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya. *Physics and Chemistry of the Earth* 33: 67–73

Lasage, R., Gowing, J., Abebe, A., Alemu, E. (2011). Report on the revisit to Ethiopia in the context of WHaTeR project, Report W-11/12, Institute for Environmental Studies, VU University Amsterdam

Liu, B.M., Y. Adebe, O.V. McHugh, A.S. Collick, B. Gebrekidan and T.S. Steenhuis (2008). Overcoming limited information through participatory watershed management: Case study in Amhara, Ethiopia. *Physics and Chemistry of the Earth* 33 (2008) 13-21.

Maatman, A., H. Sawadogo, Schweigman and A. Ouedraogo (1998).Application of zaï and rock bunds in the northwest region of Burkina Faso; Study of its impact on household level by using a stochastic linear programming model. *Netherlands Journal of Agricultural Science* 46 (1): 123-136.

Magombeyi, M.S., A.E. Taigbenu (2008). Crop yield risk analysis and mitigation of smallholder farmers at quaternary catchment level: Case study of B72A in Olifants river basin, South Africa. *Physics and Chemistry of the Earth 33:* 744–756.

Mahoo, H.F., Kahimba, F., Mutabazi, K., Tumbo, S., Rwehumbiza, F., Reuben, P., Mbilinyi, B., Gowing, J., 2012. Tanzania: bright spots and barriers to adoption (In: Critchley, W. and Gowing, J. (Eds). (2012). Water Harvesting in Sub-Saharan Africa. Chapter 8. Earthscan, 118-133 pp

Makurira, H., H.H.G. Savenije, S. Uhlenbrook, J. Rockström and A. Senzanje (2007). Towards a better understanding of water partitioning processes for improved smallholder rainfed agricultural systems: A case study of Makanya catchment, Tanzania. *Physics and Chemistry of the Earth* 32: 1082-1089.

Mati, M.B. (2005). Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. *IWMI Working Paper 105*. Colombo, Sri Lanka: International Water Management Institute.

Mazzucato, V., D. Niemeijer, L. Stroosnijder and N. Röling (2001).Social Networks and the Dynamics of Soil and Water Conservation in the Sahel. *IIED Gatekeeper Series No. 101*.

Misselhorn, A. (2005). What drives food security in southern Africa? A meta-analysis of household economy studies. Global Environmental Change 15: 33-43.

Moges,G, H. Hengsdijk and H.C. Jansen (2011). Review and quantitative assessment of ex situ household rainwater harvesting systems in Ethiopia. Agricultural Water Management 98: 1215–1227.

Mutabazi, K.D., Senkondo, E.E., Mbilinyi, B.P.T., Mahoo, H.F., 2005. Economics of rainwater harvesting for crop enterprises in semi-arid areas: the case of Makanya watershed in Pangani river basin, Tanzania. Sokoine University of Agriculture,Tanzania.

Ngigi, S.N. (2003). What is the limit of up-scaling rainwater harvesting in a river basin? Physics and Chemistry of the Earth 28: 943–956.

Ngigi, S.N., H.H.G. Savenije, J. Rockström, C.K. Gachene (2005). Hydro-economic evaluation of rainwater harvesting and management technologies: Farmers' investment options and risks in semi-arid Laikipia district of Kenya. *Physics and Chemistry of the Earth* 30: 772–782.

Ngigi, S.N., H.H.G. Savenije, J. Rockström and C.K. Gachene (2005). Hydro-economic evaluation of rainwater harvesting and management technologies: Farmers' investment options and risks in semi-arid Laikipia district of Kenya. *Physics and Chemistry of the Earth* 30: 772–782.

Ocho D.L., Struik, P.C., Price, L.L., Kelbessa, E., Kolo, K.,(2012). Assessing the levels of food shortage using the traffic light metaphor by analyzing the gathering and consumption of wild food plants, crop parts and crop residues in Konso, Ethiopia, *Journal of Ethnobiology &Ethnomedicine*,8:30

Oweis, T., A. Hachum and J. Kijne (1999). Water harvesting and supplementary irrigation for improved water use efficiency in dry areas. *SWIM Paper 7*. Colombo, Sri Lanka: International Water Management Institute.

Pachute, J.S., S.D. Tumbo, H. Sally and M.L. Mul (2009). Sustainability of Rainwater Harvesting Systems in Rural Catchment of Sub-Saharan Africa. *Water Resour Manage* : 23:2815–2839.

Pachute, J.S. (2010). A package of water management practices for sustainable growth and improved production of vegetable crop in labour and water scarce sub-sahara Africa. *Agricultural Water Management* 97:1251-1258

Rajabu, K.R.M. (2005). The role of participatory problem analysis in performance improvement and sustainable management of rainwater harvesting (RWH) systems: A case study of Makanya village, Tanzania. *Physics and Chemistry of the Earth* 30: 832–839

Reij, C.P and E.M.A. Smaling (2008). Analyzing successes in agriculture and land management in Sub-Saharan Africa: Is macro-level gloom obscuring positive micro-level change? *Land Use Policy* 25: 410–20

Reij, C., Scoones, I., Toulmin, C. (Eds.), (1996). Sustaining the Soil. Indigenous Soil and Water Conservation in Africa. EarthScan, UK, p. 248.

Rockström, J. (2000). Water resources management in smallholder farm in eastern and southern Africa: An overview.*Physics and Chemistry of the Earth* 25: 272-283.

Rockström, J. and M. Falkenmark (2000). Semiarid Crop Production from a Hydrological Perspective: Gap between Potential and Actual Yields.*Critical Reviews in Plant Sciences*, 19(4): 319-346

Rockström, J. (2001). Green water security for the food makers of tomorrow: windows of opportunity in drought-prone savannahs.*Water Science and Technology* 43(4): 71-78.

Rockström, J., P. Kaumbutho, J. Mwalley, A.W. Nzabi, M. Temesgen, L. Mawenya, J. Barron, J. Mutua, S. Damgaard-Larsen (2009). Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research. *Soil & Tillage Research 103:* 23–32

Rockström, J., C. Folke, L. Gordon, N. Hatibu, G. Jewitt, F. Penning de Vries, F. Rwehumbiza, H. Sally, H. Savenije and R. Schulze (2004). A watershed approach to upgrade rainfed agriculture in water scarce regions through Water System Innovations: an integrated research imitative on water for food and rural livelihoods in balance with ecosystem functions. *Physics and Chemistry of the Earth* 29 : 1109-1118.

Rockström, J., J. Barron and P. Fox (2003). Water productivity in Rain-fed agriculture: Challenge and Opportunities for smallholder Farmers in Drought-prone Tropical Agroecosystems. Chapter 9 in *Water Productivity in Agriculture: Limits and Opportunities for Improvement* (eds J.W. Kijne, R. Barker and D. Molden) CAB International

Rockström, J. L. Karlberg, S.P. Wani, J. Barron, N. Hatibu, T. Oweis , A. Bruggeman, J.Farahani, Z. Qiang (2010). Managing water in rainfed agriculture—The need for a paradigm shift. *Agricultural Water Management* 97: 543–550.

Roose, E., V. Kabore and C. Guenat (1999). Zai Practice: A West African Traditional Rehabilitation System for Semiarid Degraded Lands, a Case Study in Burkina Faso. *Arid Soil Res and Rehab* 13 (4): 343-355.

Ryan, J. and D. Spencer (2001). *Future challenges and opportunities for agricultural land in the semi-arid tropics*. ICRISAT, Patancheru

Sawadogo, R. (2011). Using soil and water conservation techniques to rehabilitate degraded lands in northwestern Burkina Faso. *International Journal of Agricultural Sustainability* 9(1): 120-128.

Senkondo, E.M.M.,Msangi, A.S.K., Xavery, P., Lazaro, E.A., Hatibu, N (2004). Profitability of Rainwater Harvesting for Agricultural Production in Selected Semi-Arid Areas of Tanzania, *Journal of Applied Irrigation Science* 39 (1): 65 – 81

Shewangizaw, D., Michael, Y., (2010). Assessing the Effect of Land Use Change on the Hydraulic Regime of Lake Awassa. Nile Basin Water Science& Engineering Journal, Vol.3, Issue2

Shiferaw, B. and S. Holden (2001) 'Farm level benefits to investments for mitigating land degradation: empirical evidence from Ethiopia' *Environmental and development economics* 2: 335-58

Sidibé, A. (2004). Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural Water Management* 71: 211–224.

Skjeflo, S., Measuring household vulnerability to climate change—Why markets matter. Global Environ. Change (2013), http://dx.doi.org/10.1016/j.gloenvcha.2013.08.011

Some etal, (2006). Analysis of crop water use and soil water balance in Burkina Faso using CROPWAT.

Spielmann, K. A., M. Nelson, S. Ingram, and M. A. Peeples (2011). Sustainable small-scale agriculture in semi-arid environments. *Ecology and Society* 16(1): 26.

Staal, S.J., I. Baltenwecka, M.M. Waithakab, T. deWolffa and L. Njorogea (2002). Location and uptake: integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. *Agricultural Economics* 27:295-315.

Steenbergen, van F., A.M. Haile, T. Alemehayu, T. Alamirew and Y. Geleta (2011).Status and Potential of Spate Irrigation in Ethiopia. *Water Resource Management* 25: 1899–1913.

Stroosnijder, L. (2009). Modifying land management in order to improve efficiency of rainwater use in the African highlands. *Soil & Tillage Research* 103: 247-256

Sturdy, J.D., G.P.W. Jewitt, S.A.Lorentz (2008). Building an understanding of water use innovation adoption processes through farmer-driven experimentation. *Physics & Chemistry of Earth* 33: 859-72

Tabor, J.A. (1995). Improving crop yields in the Sahel by means of water-harvesting. *Journal of Arid Environments* 30: 83-106.

Teferaa, B. and G. Sterk (2008). Land management, erosion problems and soil and water conservation in Fincha'a watershed, western Ethiopia. *Land Use Policy* 27: 1027–1037

Tesfai, M. and L. Stroosnijder (2001). The Eritrean spate irrigation system. *Agricultural Water Management 48*: 51-60

Tesfai, M., de Graaf, J., (2000). Participatory rural appraisal of spate irrigation systems in eastern Eritrea. Agriculture and Human Values 17, 359–370.

Tesfaye, A., Bogale, A., Namara, R., Bacha, D., 2008. The impact of small-scale irrigation on household food security: the case of Filtino and Godino irrigation schemes in Ethiopia. *Irrig& Drain Syst* 22: 145-58

Tumbo, S.D., Mpeta, E., Tadross, M., Kahimba, F.C., Mbillinyi, B.P., Mahoo, H.F., 2010. Application of self-organizing maps technique in downscaling GCMs climate change projections for Same, Tanzania. Physics and Chemistry of the Earth 35, 608–617

Tumbo, S.D., Mutabazi, K.D., Byakugila, M.M., Mahoo, H.F.M., 2011. An empirical framework for scaling-out of water system innovations: Lessons from diffusion of water system innovations in the Makanya catchment in Northern Tanzania. Agricultural Water Management 98,1761– 1773

UNEP(1997). World Atlas of Desertification, 2nd edn., N. Middleton and D. Thomas (eds), London,

Van der Veen, A., and G. Tagel (2011).Effect of policy interventions on food security in Tigray, Northern Ethiopia. *Ecology and Society* 16(1): 18.

Van Steenbergen, F. Van., Lawrence, P., Salman, M. and Faurès, J.M., (2010). Guideliness on spate irrigation. FAO irrigation and drainage paper 65.FAO, Rome, 234pp.

Van Steenbergen, F. , Haile, A.M., Alemehayu T., Alamirew,T., Geleta, Y., (2011). Status and Potential of Spate Irrigation in Ethiopia. Water Resour Management 25, 1899–1913. DOI 10.1007/s11269-011-9780-7

Walker, T. and J. Ryan (1990). *Village and household economies in India's semi-arid tropics.* John Hopkins University Press, Baltimore

Wisser, D. Frolking, S., Douglas, E.M., Fekete, B., Schumann, A., Vörösmarty, C. (2010). The significance of local water resources captures in small reservoirs for crop production- a global-scale analysis. *Journal of Hydrology* 384:264-275

WOCAT (2007). Where the land is greener - case studies and analysis of soil and water conservation initiatives worldwide. H. Liniger and W. Critchley.

World Bank (2007). Agricultural water development for poverty reduction in Eastern & Southern Africa. Main Report. World Bank, Washington, D.C.

Zougmoré, R., A. Mando, L. Stroosnijder and E. Ouédraogo (2004). Economic benefits of combining soil and water conservation measures with nutrient management in semi-arid Burkina Faso. *Nutrient Cycling in Agroecosystems* 70: 261–269