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REPORT ON THE ASSESSMENT OF POTENTIAL OF WATER HARVESTING

Authors: M. Ouessar, R. Hessel, M. Kirkby, M. Sghaier, C. Ritsema

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SEVENTH FRAMEWORK PROGRAMME

WP1: The potential for WH in an array of biophysical and human environmental settings in rainfed Africa

D1.4 REPORT ON THE ASSESSMENT OF POTENTIAL OF WH

by

M. Ouessar, R. Hessel, M. Kirkby, M. Sghaier, C. Ritsema

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1. Introduction

Only a small fraction of the rainfall falling in arid and semi-arid areas percolates into deeper soil or rock layers to recharge an aquifer. Another small fraction is used for transpiration of vegetation or of agricultural crops. Runoff can be a significant percentage of rainfall, but usually the majority of the precipitation evaporates from the often bare soil or from surface depressions. To feed the growing population in the dry areas of the world, more irrigation is needed but the quantity of irrigation water is extremely limited. The "classical" sources of irrigation water are often at the brink of overuse and therefore untapped sources of irrigation water have to be sought for. To increase agricultural production in dry areas, the necessity exists to think about the utilisation of the evaporative portion of precipitation to be used for agricultural purposes before it is released to the atmosphere (Oweis et al., 1999). Since time immemorable, farmers in dry areas collect surface runoff of precipitation, using various types of water harvesting (Prinz, 1996).

Water harvesting (WH) has many facets, but here we are concerned with schemes for domestic water and crop growth in rainfed Africa. Urban systems have their greatest value where piped water is not available, collecting relatively clean rainwater from roofs and paved areas for domestic use, and perhaps to irrigate garden plots. In rural environments, rooftop water harvesting can make for a safe source of water at the doorstep, increasing time available to especially women and children to engage in productive, education and social activities by reducing time required for fetching water as well as limiting occurrences of water-related diseases (Van Steenbergen et al., 2009). In rainfed agriculture, rainfall is the most prominent random parameter beyond farmers' control. In arid climates, where crop water needs often exceed total rainfall, WH can enable agriculture by concentrating water from a larger area without the need of depleting groundwater resources. This role can be extended to semi-arid and dry sub-humid climates, where it is not the amount of rainfall that limits rainfed production but rainfall variability (Andersson et al., 2011). WH technologies (WHT) can be especially useful to bridge dry spells that might occur during the growing season (Ngigi, 2003; Adekalu et al, 2009), and has been found to significantly increase water use efficiency if used for supplemental irrigation (Oweis & Hachum, 2006).

In spite of several thousand years of experience in water harvesting, huge potential still exist especially in many dry African countries where rainfed farming is still dominant and the associated risks of recurrent droughts and climate change are increasing. This makes assessment of the potential for WH all the more urgent.

Based on the already achieved tasks (1 to 4, described in deliverables 1.1-1.3) within WP1, this report intends to assess the potential of WH at both African continent as well as study site scales.

2. Specific aims

The specific aims of this document are:
* Exploring of the possibilities of WH at the African continent,
* Assessment of the potential of WH in the study sites.

3. Method

At the African continent scale

Deliverable 1.3 showed that there is a very large number of WHT that are already being used in Africa. However, many of these WHT have been developed locally and are therefore not always known outside the area where they were developed. Although WHT developed in some location should not be implemented elsewhere without first considering their suitability and the need for adaptation, general criteria can be developed that do provide some guidance on which WHT could potentially be used where in Africa. These criteria should cover both bio-physical ones and socio-economic aspects.

Bio-physical aspects

One of the most important requirements for WHT is of course that they are effective from a bio-physical point of view, meaning that water is actually harvested and stored for later use, e.g. to bridge dry spells or even to grow crops outside of the rainy season. This effectiveness can be assessed e.g. by observing changes in yield and by determining water use efficiency. Literature indicates that there is also a relationship between WHT and nutrient management; if both are applied yields are likely to be higher than if only WHT or only nutrient management is applied (e.g. Rockstrom et al., 2002, 2009; Biazin et al., 2012; Wakeyo & Gardebroek, 2013).

At continental scale, any approach that is used to assess whether WHT would be useful is by necessity a simplified approach as it is not possible to take local circumstances into account at this scale. Furthermore, such an approach should make use of existing data sources and remote sensing wherever possible. Mati et al. (2007) elaborated an advocacy tool which can show in spatial domains the expansive opportunities for RWH in Africa with focus on ten selected countries. They produced a GIS database which captured the main factors associated with RWH: rainfall, topography, soils, population density and land use. Similarly and within this project, Kirkby et al. (2012) (University of Leeds, WP4) developed a better interactive continental quick scan tool for water harvesting potential (deliverable 4.1). The tool is based on matching potential to needs using four main parameters:

- Climatic statistics: Potential and need for WH and WH groundwater recharge,
- Topography and soil quality: Upstream Runoff, % good cropland, % grazing land
- Population pressure: Density Rate of growth, non-agricultural income,
- Economic inputs: Potential for investment in groundwater exploitation, fertiliser & machinery, etc.

The tool could be used at Africa-wide survey as well as at point survey.

- Africa-wide survey

- Uses Climatic Research Unit interpolated climate data,
- Uses FAO, World bank and other data available from internet,
- Makes an initial analysis of climate to assess general need for and suitability of water harvesting,
- Based on ratio of rainfall to potential evapotranspiration during the 4-5 months of growing season for rainwater agriculture,
- Because part of rainfall is lost to runoff, Ratio needs to be greater than about 1.5 for water harvesting not to be required.

- At-a-point survey

- Mines the same data-sets to provide approximate default values for any point, defined by latitude and longitude,
- These data can be updated with local knowledge,
- Also takes account of potential for water harvesting from neighbouring areas.

Socio-economic aspects
As is the case for any technology, especially if it is firstly introduced, and as reported by many authors (e.g. Goel & Kumar, 2005, Kahinda & Taigbenu, 2011; Hanjra et al., 2009), socio-economic aspects are of vital importance for the success or failure of WHT.

However, as socio-economic conditions vary much at continental as well as at regional scales, and as these conditions cannot be captured in simple maps, except for very basic data such as population density, it is not possible to include socio-economic aspects adequately in the Quick scan tool developed in WAHARA. Therefore, socio-economic aspects need to be considered at smaller scale, e.g. at the scale of study sites. In this respect, the Quick scan tool would provide some indication about what WHT could be suitable from a bio-physical point of view, while a deeper assessment of socio-economic situation at study site scale can then narrow down and determine which of these WHT would be suitable from that point of view.

At the study site level

As described in the study site descriptions (included in deliverable 1.1), WHT are already being used in all WAHARA study sites. Furthermore, the stakeholder workshops (reported in deliverable 1.2) revealed that stakeholders in the study sites are aware of the role that WHT could play.

Bio-physical aspects
Continental assessments such as those performed by the Quick scan tool cannot take local (bio-physical) conditions into account, and therefore a choice for a certain type of WHT should always consider these conditions to determine whether local conditions are sufficiently accounted for. To give just one example, slope angle calculated from a continental DEM provides and average that might not at all be applicable to a particular location within the study site. One way of considering local circumstances too is by using the WOCAT database (see WP2 work), since this database describes how WHT work in a particular case. Nevertheless, as circumstances for that particular case will be different from the circumstances in the area where WHT are to be implemented, adaptation is always needed. This adaptation is a continuous process that over time should result in an optimal suitability of a certain WHT to the site-specific conditions. Hence, to improve WHT it is possible to look at innovative WHT (from elsewhere), or at WHT that are already applied in the region but that could be improved further. The second type might need less adaptation as these WHT were already, at least partially, adapted in the past. In WAHARA, it was agreed that 2-3 WHT would be selected, adapted and implemented in each study site, and that 1 of these would be innovative. These innovative WHT could come from other WAHARA study sites, from the WOCAT database, or from researchers.

Socio-economic aspects
Stakeholders indicated that they are aware of the importance of WHT (deliverable 1.3) and that they were willing to collaborate with the WAHARA project. In task 1.4 a household survey was conducted. The stakeholder workshop in combination with this survey provide information that can be used to determine to what extent the different WHT fit into the livelihood strategies and farming practices of stakeholders, and to determine also what are the main socio-economic challenges and constraints for implementation of WHT in the study sites.

4. Results

Continental scale

Figure 1 shows the results from the application of the quick scan tool at the continental scale.

Figure 1 shows the ratio of rainfall to potential evapotranspiration during the 4-5 months of the growing season under average annual weather conditions. It indicates that the study sites in Tunisia, Ethiopia and Burkina Faso are within the range of 0.2 – 1.5, indicating that WHT would be both possible and beneficial. Study site descriptions (included in deliverable 1.1) confirm that WHT are being practiced in all these sites. The study site in Zambia would, according to the map, not need WHT, but one has to keep in mind that this map cannot take local conditions into account, that in years with below average rainfall the need to use WHT is larger, and that the Quick scan tool does not take the distribution of rainfall during the growing season into account. In Zambia, dry spells during the growing season are one of the main causes for crop failure; this makes the use of WHT a necessity despite high values of the ratio rainfall to potential evapotranspiration.

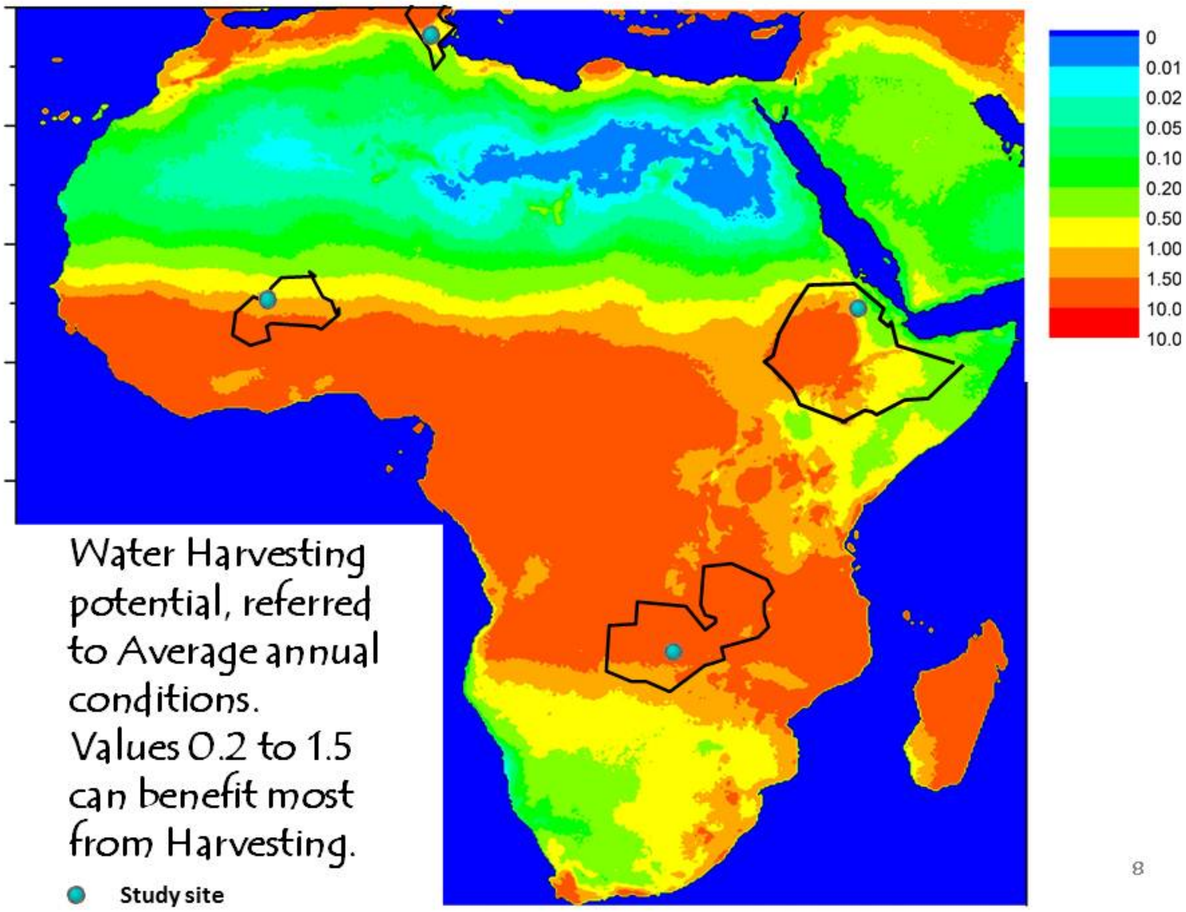

Figure 1. WH potential in Africa based on average annual conditions.

Deliverable 1.3, and the reports supporting that deliverable, presented a large number of WHT that are currently used in Africa, indicating that WHT are available for most regions of Africa. In effect, WHT is also practiced in areas that have ratios of rainfall to potential evapotranspiration that are well below 0.2. Under these circumstances it is still possible to grow a crop, but the lower the ratio is, the larger is the collecting area in comparison to the cultivated area. For such regions, WHT is often the only way in which it is still possible to grow crops.

Although a range of potentially suitable WHT exists, the knowledge about such WHT is not always widely available. Effective ways are needed to share this knowledge. WOCAT can play a crucial role in this, although WOCAT information is more likely to reach e.g. NGOs, and extension services than the actual land users. It should also be kept in mind that it is generally the socio-economic factors that determine whether or not measures are adopted. Hence, bio-physical effectiveness alone is not sufficient, and neither is providing proof of such effectiveness to land users. Adoption can only be achieved in a participatory process in which socio-economic and political issues are taken into account as well.

Study site scale

Previous work (deliverables 1.1-1.3) showed which WHT are currently used in the WAHARA study sites, and what the attitude of stakeholders towards WHT was. Based on what stakeholders said they thought important in WHT, study site teams made a pre-selection of WHT that would potentially be useful for the study site. This pre-selection included some WHT that are already practised in the area, but that could be adapted and/or adopted more widely, and it also included some WHT that are new to the study site (based on the other study sites of WAHARA in combination with the WOCAT database). The following tables summarize the outcomes of the discussion among the study site teams but the final selection of WHT will be done by the local stakeholders during the selection workshop of WP2 (as reported in Deliverable 2.3). For each potential technique, the study site team identified some main attributes:

- Level of technology cost: in order to know if the technique requires high or low technological inputs and therefore the cost level,
- Scale: Farm or watershed levels,
- Principle: Form of harvesting of the water
- Position: Position in the watershed (upstream/mountain, middle stream/piedmont, downstream/plain).
- Innovation/origin: If the technique is a traditional/already know or if it is newly introduced from other parts of the country or from elsewhere.
- Remark: Any relevant remark.

Tunisia:

Technique	**Innovative (Yes/No)**[1]	**Level of Technology/ Cost**	**Principle**[2]	**Scale of effect/impact**	**Where to apply (landscape position)**	**Origin (adapted from)**	**Remarks**
Tabia	No	Low	Spreads diverted flood water	farm level	Flat /Piemont area	Indigenous	
Jessour	No	Low	Collects runoff from slopes	farm level	Hillside	Indigenous	
modified recharge wells	Yes	Medium	Injection of floodwater into the	Sub-watershed	Hillside	Tunisia/ Saudi Arabia	

[1] No if already applied in study site, Yes if a) from WOCAT database, b) from other WAHARA sites, c) significantly adapted from existing WHT or d) new WHT suggested by researchers

[2] Principle describes very briefly how the WHT works, including e.g. whether it depends on other WHT, and what effect it has.

			aquifers				
Deep trenches	Yes	low	Infiltration of local runoff	farm level	Flat area	Ethiopia	
Subsurface irrigation (Stone pockets)	Yes	low	Infiltration of local runoff	farm level	Flat area	Tunisia	
Zai pits	Yes	low	Infiltration of local runoff	farm level	Flat area	Burkina Faso	
Hillside cisterns	Yes	Medium	bench terraces guide water to cisterns	slope	Hillside	Tunisia/India	

The techniques that will be selected in Tunisia will be applied in the upstream, middle, downstream of the watershed and will be integrated with the national plan and involve other sectors.

Ethiopia: Potential WHTs

Technique	Innovative (Yes/No)	Level of Technology/ Cost	Principle	Scale of effect/impact	Where to apply (landscape position)	Origin (adapted from)	Remarks
Hillside cisterns	Yes	Medium	Bench terraces guide water to cisterns	Slope	Hillside	Tunisia/ India	
Stone faced vs. soil faced trench bunds	No	Low	Trench bunds enhance soil and water conservation	Sub-watershed	Any topography (flat to hilly)	India/China	To be compared
Percolation /sediment storage ponds	Yes	Medium to High (depending on size)	By plugging a gully it stabilizes the channel and enhances water storage	Sub-watershed	Flat to medium slopes	China/India	
Gully treatment	No	High to medium	By plugging a gully it stabilizes the channel and enhances water storage	Along stream channels	Flat to medium slopes	China/India	
Infiltration pits	No	Low	Enhances infiltration	Sub-watershed	Any topography	India/China	
Mulching: stone,	Yes	Low	Improve soil fertility	Farm level	Flat	India/China	

biological or a combination							
Cactus/Moringa plantation on farm boundaries	No	Low	Improve soil fertility	Farm level	Flat	Indigenous +China	
Sub-surface dams	Yes	Medium to high depending on size of subsurface dam	Improve subsurface water storage	Farm level	Flat	India/China	

Zambia:

Technique	Innovative (Yes/No)	Level of Technology/ Cost	Principle	Scale of effect/impact	Where to apply (landscape position)	Origin (adapted from)	Remarks
Reduced tillage	Yes	low	Improves soil structure and soil water conservation. Furrow left by the Ripper collects water	farm level	Anywhere in the watershed	Indigenous/ Magoye Ripper	
No tillage	Yes	low	Reduces evaporation and enhances infiltration. Improved soil structure and organic matter content increase soil water storage	farm level	Flatlands	Indigenous	Used in combination with direct planting, availability of new planter makes no till an option
Strip tillage	Yes	low	Improves soil structure and soil water conservation. Furrow left by the Ripper	farm level	Anywhere in the watershed	Indigenous/ Magoye Ripper	Adaptation of Magoye ripper for moist soil

			collects water				

Burkina Faso:

Technique	Innovative (Yes/No)	Level of Technology/ Cost	Principle	Scale of effect/impact	Where to apply (landscape position)	Origin (adapted from)	Remarks
Zai Forestry	Yes	low	Shallow pit that collects runoff and increases infiltration	farm level	Flat/hillsides	Indigenous	Application of Zai for growing trees
Half moons	No	low	Bund that collects runoff and increases infiltration	farm level	Flatlands	Indigenous	
Dykes		low	Dyke collects runoff and increases infiltration				
Grass lands (Tapis Herbache)		Medium	Improves infiltration	Farm level	Hillsides/ flatlands	Indigenous	
Banka		low	Pond that collects and stores surface water	Farm level	Farm level	Indigenous	Based on natural banka

These tables show that for all 4 study sites, a number of potentially suitable WHT have been identified. Thus, all study sites have potential for WHT. The tables also show that the listed WHT are a mixture of technologies developed locally and technologies from elsewhere (e.g. in other WAHARA study sites).

The stakeholder workshops showed a clear tendency to adoption of known and or improved technologies rather than technologies brought in from elsewhere (deliverable 1.3). This is likely due to a combination of factors, such as:

1) Stakeholders can only chose WHT that they know well enough. A challenge therefore is to provide sufficient thrustworthy information about innovative WHTs. The WOCAT database, films (Metameta videotheque for example) and other illustrative documents can be very useful.
2) Stakeholders want to minimise risk and are therefore inclined to select WHT that have been proven to be effective. Demonstration of already undertaken successful experiences can help much.
3) Stakeholders might not be convinced that WHT brought in from elsewhere are applicable in their area. A challenge therefore is to adapt such WHT to such extend that stakeholders will consider it to be worth a try. Starting only with limited ‘innovative’ farmers can be a first phase in the adoption of newly introduced WHT

5. Conclusion

Huge potential exist in Africa for surface WH as well as groundwater recharge. Most of the study sites belong to areas with high potential. The teams have the tendency of adopting already existing WH techniques as they do not need extension efforts from the researchers. However, they are very reluctant about the introduction of new techniques from elsewhere as this process is somewhat risky and may need some time to be completed. In WAHARA, 2-3 WHT will be test-implemented and monitored in each of the study sites. At least one of these will be an innovative WHT for each country. This will allow stakeholders to see such an innovative WHT, which will make them more familiar with it and which makes things more concrete, thus hopefully provoking a process of adaptation in which the introduced WHT is adapted to better fit local circumstances.

6. References

Adekalu, K.O., J.A. Balogun, O.B. Aluko, D.A. Okunade, J.W.Gowing, M.O. Faborode, 2009. Runoff water harvesting for dry spell mitigation for cowpea in the savannah belt of Nigeria Agricultural Water Management 96, 1502–1508

Andersson J.C.M, A.J.B. Zehnder, J. Rockström and H. Yang (2011). Potential impacts of water harvesting and ecological sanitation on crop yield, evaporation and river flow regimes in the Thukela River basin, South Africa. Agricultural Water Management, 98(7): 1113-1124. doi:10.1016/j.agwat.2011.02.004.

Biazin B., G. Sterk, M. Temesgen, A. Abdulkedir, L. Stroosnijder, 2012 Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa – A review Physics and Chemistry of the Earth 47–48, 139–151

Goel, A.K., R. Kumar, 2005. Economic analysis of water harvesting in a mountainous watershed in India Agricultural Water Management 71, 257–266

Hanjra, M.A., T. Ferede, D.G. Gutta, 2009. Reducing poverty in sub-Saharan Africa through investments in water and other priorities Agricultural Water Management 96, 1062–1070

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

Kirkby, M. Fleskens L., B. Irvine 2012. Continental-scale quick-scan tool development. Presentation at the research workshop of WAHARA project, Wegeningen.

Mati B., T. De Bock, M. Malesu, E. Khaka, A. Oduor, M. Nyabenge, and V. Oduor 2007. Mapping the Potential of Rainwater Harvesting Technologies in Africa. World Agroforestry Centre (ICRAF), Netherlands Ministry of Foreign Affairs and Swedish International Development Cooperation Agency) (SIDA).

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.

Oweis, Th., Hachum, A. 2006. Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. *Agricultural Water Management*, 80: 57-73.

Oweis, T., Hachum, A., Kijne, J., 1999. Water harvesting and supplementary irrigation for improved water use efficiency in dry areas. SWIM paper No. 7. International Water Management Institute, Colombo, Sri Lanka.

Prinz, D., 1996. Water Harvesting: Past and Future. In: Pereira, L. S. (ed.), Sustainability of Irrigated Agriculture. Proceedings, NATO Advanced Research Workshop, Vimeiro, 21-26.03.1994, Balkema, Rotterdam, 135-144.

Rockström, J., Barron J., Fox P., 2002. Rainwater management for increased productivity among small-holder farmers in drought prone environments Physics and Chemistry of the Earth 27, 949–959

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
Van Steenbergen F., A. Tuinhof. (2009). Managing the Water Buffer for Development and Climate Change Adaptation. Groundwater recharge, retention, reuse and rainwater storage. Wageningen, The Netherlands: MetaMeta Communications.
Wakeyo, M.B., C. Gardebroek, 2013. Does water harvesting induce fertilizer use among smallholders? Evidence from Ethiopia Agricultural Systems 114, 54–63