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Guidelines for Adaptation of Water Harvesting Technologies

Authors: Piet Stevens, Mohamed Ouessar, Hamado Sawadogo, Kifle Woldearegay, Silenga Wamunyima

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Guidelines for adaptation of water harvesting technologies

WAHARA Work Package 5 deliverable 3

Authors:
Piet Stevens, Mohamed Ouessar, Hamado Sawadogo, Kifle Woldearegay, Silenga Wamunyima

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Introduction

This document follows through on WAHARA Work Package 5 deliverable 2, which focused at water harvesting (WH) adaptation. WH adaptation is the innovative process of farmers making novel water harvesting concepts work for them, or making existing ones work better or respond better to changing working conditions. One of the observations made was that there can be no WH adoption without WH adaptation. Not only is a good adaptability of WH technologies critical for their successful outscaling, but also for their robustness under altering natural or socio-economic conditions. WH adaptation, i.e. making WH technologies suitable, should help productivity increases in African rainfed agriculture to come about quickly enough and make them last long enough.

The first and most important guideline for WH adaptation is: use common sense. The second would be: use local know-how. These and other guidelines are worked out in the text below. They were written for farmers, local communities, extension workers and other local community facilitators who are looking to improve local rainfed farming conditions by applying innovative WH solutions from somewhere else.

The guidelines were developed with the type of technologies in mind that are within WAHARA's scope, i.e.:

- Low-cost interventions
- Intended to conserve and/or control natural water resources (notably rainfall, run-off, flooding)
- Buffering water through storage and recharge on or below the surface
- Enabling water use for multiple purposes (e.g. crop growing, livestock production, farm household water needs)
- Can be independent units or embedded in a larger system

The guidelines presented in this document were to be evaluated by stakeholders in the study sites, resulting in deliverable 5.4. Feedback from stakeholders has been used to adapt earlier drafts of Deliverable 5.3, resulting in the current final version.

Adaptation

The principle on which water harvesting is based is universal and simple: water always and automatically flows to the lowest point that it can reach. All WH technologies make use of this natural phenomenon to capture rainfall water running off a slope and conserve it for useful purposes. However, the working conditions differ from place to place and change from time to time. As a consequence, adaptations need to be made to ensure that a WH technology performs well when introducing it from somewhere else or when adjusting one to a changing working environment.

Adaptation of a water harvesting technology is about making that technology work under new conditions. This may involve small things like adjusting some dimensions of the technology, e.g. constructing a longer dam or changing the distance between ridges. Or the adaptation is as big as changing steeply sloping land into terraces, or sensitizing people in the community to accept the new WH idea and helping them change certain traditions.

So, adaptation of a WH technology is about making adjustments to its original design and/or to the working environment. The latter can be the natural environment, notably the surface conditions of the land and the vegetation. It may be that the socio-economic environment as well needs to be adapted. For instance, changes in the agricultural system, e.g. introducing the production of high value crops, or by strengthening a community's capacity to implement the new WH system, e.g. through education and logistical support.

In fact, normally the conditions are wide-ranging, in many cases interconnected and sometimes conflicting. Some conditions vary even within a single farm field, such as the water infiltration characteristics of the soil. Moreover, the real challenge is to make the new WH technology not just to work but to be *worthwhile*; the desired benefits must be realised for all or most of the intended beneficiaries without taking a lot of time and within the limited available resources. As a consequence, adaptation can be a quite complex process. It means that it is practically impossible to prescribe WH adaptation on a case by case basis. Therefore, rather than providing an exact working model, these guidelines only go as far as advising on a general working approach; they explain what should be taken into account when adapting new WH technologies from elsewhere, but they do not give instructions for specific cases.

The following strategy is advised for a WH adaptation project, in short:

1. Implement the project in logical steps including consultation, selection of an innovative WH solution, and planning and executing its introduction taking into account the requirements for adaptations (see Chapter 3)
2. Work with the locals (see section 'The stakeholders'):
    a. They know the local situation best
    b. Local ownership needs to be built:
        i. Their problems need to be solved, their views be heard and acted upon
        ii. They need to welcome the solutions and remain informed, consulted and motivated
        iii. They need to participate and contribute in the actual implementation
3. Secure guidance by experts (see section 'Professional guidance')
4. Site for the ex-situ WH construction works. A suitable location must be found for the WH technology to work well. A clear idea of the approximate/exact location is needed and of the amount of flexibility as to the spatial planning for introducing WH
5. Assess the feasibility and profitability of the intended WH project as accurately as possible
6. Mobilise resources: local (as much as possible) and external (as much as necessary). Consider: finance, expertise, labour, tools, machines and equipment, building materials, clearance by the authorities, policies, services
7. Learn and improve by doing and observing, with consideration given also to possible negative effects such as conflicts between stakeholders within the locality or down-stream (see section 'Step-wise WH development')
8. Ensure to have:
    a. A thorough understanding of the local conditions and dynamics
    b. Clarity of the problem or the desired benefits for which a WH solution is sought
    c. A good understanding of the WH principles and technical options to match them with what is needed and what is possible, with adaptation.

Steps in WH adaptation

Adaptation is already important when merely reflecting on potentially suitable options; after all, whether or not a promising but alien technology should be considered is highly determined by how adaptable it is to the new environment as well as by how easily the environment itself can be adjusted to the new technology. In fact, a solid adaptation project should involve the following steps:

1. *Consultation*. Reference is made to WAHARA report 4 (Ouessar, Hessel, Sghaier, & Ritsema, 2013). All interested parties will need to be informed, possibly sensitized. They need to discuss, brainstorm and decide about new WH solutions, whether one is required and if so, how generally these could be adapted to tackle local water challenges in agriculture. Perhaps the issue is an *opportunity* (rather than a problem) that could be exploited by introducing a new WH technology. The initiative can come from farmers, from extension staff or researchers, from the local or national government, or anybody else in the

community. The meeting(s) should be realistic about what can be done and manage the ambitions. The outcome would be consensus about the need for WH innovation, the direction of the next steps and who will be involved in these. For technologies that need to be realised by or for a community, the consultation step will be more encompassing than for those that are implemented on a farm-by-farm basis

2. *Selection*. Refer to WAHARA report 17 (Sawadogo, Hessel, & Ouessar, 2013). Pre-selecting and assessing likely solutions and selecting the most promising one is the next step. The need and options for adaptation having a bearing on the selection should be mapped out. The farmers directly concerned together with one or more experts and possibly other key stakeholders decide on a WH technology for which the necessary adaptations will be possible. Their meetings should be used for further learning about WH as well. To be most effective, the group should be not too large. Other interested parties not involved in these meetings should be kept informed; the selected WH technology might need to be adjusted after having heard their views. This is especially important if there are concerns about negative impacts. The technology should be replicable, within the reach of many and not causing unsurmountable conflicts in the community

3. *Planning*. The selection step is followed through by preparing for the realisation of an adapted WH technology. Mostly the same people that are involved in the selection will be occupied with this as well. In fact, the selection and planning may best be done repetitively in a few rounds. As in the selection step, interested parties not present in the activity will be informed and their suggestions be used to improve the plan. It should contain the critical technical, organisational and financial details needed to serve as a guiding tool during implementation. Depending on the type of technology and level of expertise, the plan can be more or less rudimentary

4. *Implementation*. When the consultation, selection and planning are done well, this should smoothen the actual work in the field to lay out the selected WH technology with the necessary adaptations. The group of people directly involved should be limited to those strictly needed for the necessary labour, expertise, tools and supervision at the different stages of implementation

5. *Optimisation*. Experience with a WH technology being implemented might show that further adaption is desirable. Also it may occur that the technology successfully applied in the past needs adaptation, e.g. due to changes in local conditions such as reduced rainfall. Hence, the process should not end when the technology is implemented; performance should be continuously monitored, and the technology adapted if and when necessary.

The consultation and planning steps require basic project planning, management and group organisation expertise that normally is available, e.g. through the local agricultural extension service. Therefore they are not worked out further in this document. The selection step and jointly the implementation and optimisation steps get some more attention below.

Selecting a WH technology for adaptation

Based on WOCAT[1] experience, a participatory and replicable selection methodology was worked out under WAHARA work package 1 as presented in WAHARA report 17 (Sawadogo, Hessel, & Ouessar, 2013) to identify a number of WH technologies for testing at the WAHARA study sites in Burkina Faso, Ethiopia, Tunisia and Zambia (not more than 3 was recommended). Usually, farmers or local communities embarking on the introduction of adapted WH technology will aim for just one.

[1] https://www.wocat.net/

Generally, the range of WH options will depend on:

- The scale of application (e.g. farming household, a particular area or farmer group, village, town)
- The local traditions, and the formal rules and regulations, e.g. related to water use rights, land tenure. They may limit the choice, but also provide opportunities, while some common practices may need to be adapted, e.g. communal grazing arrangements
- The ambitions and capacities of those involved and the resources and facilities that they have access to
- The other limitations and opportunities of the natural and socio-economic situation. The checklist of natural and socio-economic indicators in Appendix 1 can help to identify these, based on comprehensive knowledge of the local situation.

Referring to the various selection stages described in WAHARA report 17, the following is suggested:

1. *Pre-selection*. From the consultation with the stakeholders it should be clear why a new WH technology is required and what issue(s) it should address. If there is more than one issue, they should be prioritised. A long-list should contain water harvesting technologies that are most likely going to provide the sought-for solutions. This can be done in two stages:
    - Professionals who are very familiar with both WH technologies and the local situation prepare a recommended list of technologies
    - They explain their choices in a meeting with the stakeholders' workgroup. The list is adapted and concluded by the meeting based on its suggestions and discussions. In their deliberations, the participants will be guided by the experts.

    At both stages, when brainstorming about the WH options, the technologies with a shortcoming that immediately would rule out further consideration should be discarded:

    a. Make a list of the major local benefits that the technology must provide, bearing in mind the outcome of the stakeholder consultation. Table 1 provides examples of *benefit* criteria from which can be borrowed from. Lists of *general* criteria are also referred to in WAHARA report 17. The criteria agreed by the stakeholder workshops held at the four WAHARA study sites can be found in WAHARA reports 14, 15 and 18 (Arbi, Ouessar, & Sghaier, 2013; WAHARA Research Team of Mekelle University, 2013; Sawadogo, et al., 2013 respectively).
    b. Assess applicability; check if the WH technology would be potentially suitable for the local conditions. Local conditions might differ so much from the conditions for which the technology was intended that it cannot be used at all and therefore does not need to be considered in the selection process. For example, a WH technology suitable for gentle slopes is not practical in a mountainous area, and a technology meant for sub-humid conditions does not need to be considered in an area with very little rain. Furthermore, the applicability of WH technologies also varies within an area. An obvious example would be check dams, which are only useful in places where water concentrates, so in valleys and river beds. Also refer to Appendix 2.
    c. Evaluate the technology's viability; check if it can likely be adapted to the local natural and socio-economic conditions and live up to the expectations within the locally available (or obtainable) means and capacities (see Table 3 for an overview of general WH adaptation conditions). There is no need to compare the different technologies in detail yet, but if there is an obvious difference, it should be noted, as this information may help in the final selection. For the same reason, any benefits that the technology may give beyond what is expected and would make it more useful, can be noted as well

d. As soon as the stakeholders reveal a critical drawback or a 'non-negotiable' for a particular technology (i.e. it is unsuitable and the problem cannot -or not easily enough- be solved), drop it from the list
e. Try and end up with a short-list of not more than 5 WH options.

In the unlikely event that the previous procedure does not leave a single technology on the list, try and look again for other potential WH technologies that may have been overlooked. Possibly reconsider some of the earlier discarded ones (the sifting may have been too rigorous?). On the other hand, it might be possible that a WH solution has *not* the highest priority; perhaps other solutions need to be considered first.

2. *Selection*. From the short-list of potential WH solutions that remained after pre-selection, one technology should be selected. Table 1 (with instructions in Text box 1) will help comparing the options and decide which WH solution promises the most acceptable balance between risk and performance[2]. Note that the balance between risk reduction and productivity enhancement can vary between stakeholders, so should be confirmed. Making use of the general guidelines provided in WAHARA report 17, it is a simple and concretely worked out alternative to the -all different from each other- scoring systems used at the study sites as described (but not worked out as a fully detailed set of guidelines) in WAHARA reports 14, 15 and 18. Note that that Table 1 is already filled in as an example; three WH technologies (Magoye ripper, Zaï and Stone lines) are evaluated according to a range of criteria[3]. Also note that in this example, not the technology that scored highest on benefits ended best, but the one with the lowest score for risk.

[2] Also refer to WOCAT, and to (Kaushali & Fleskens, 2015)
[3] WOCAT documentation contains many possible criteria, as well as potential benefits and disadvantages

Text box 1. Scoring WH technologies for local suitability

Directions for completing Table 1.

Table 1 contains a list of criteria for the suitability of a WH technology in a new situation. The need and possibilities for adaptation are taken into account. Follow the steps below to score and compare the short-listed WH technologies, which will allow singling out one for implementation:

1. The list is divided into risk (including cost) criteria and benefit criteria. Check their relevance for the local situation. If necessary, a criterion can be rephrased, split up into two or more, be removed and a new one be added. Note that a particular risk can change over time; e.g. certain useful services are expected to become available soon. In such a case either an overall assessment is made or, if necessary, the risk is rephrased and divided into more than one criterion. The list can be as long as the stakeholders need it to be. However, between them the criteria should not overlap in meaning. Furthermore, a long list of criteria complicates the selection process and makes it more time-consuming. If the decision was taken to restrict the number of criteria it is suggested that these still cover the different main WH aspects, such as technical, economic, environmental and social. Possibly borrow from the overview of WH adaptation conditions (Table 2). Other sources are WOCAT and the WAHARA reports mentioned above. Ensure that all relevant aspects are considered by including *economic*, *ecologic* and *socio-cultural* criteria.

2. As some criteria can be more important than others, they may need to be ranked. This can be done in the column under the heading *Priority*. Attach a priority score to each criterion as follows: 3 = high priority, 2 = medium priority, 1 = low priority. Criteria with (more or less) the same priority should get the same priority score

3. Fill in the names of the pre-selected WH technologies, designating a column to each one of them

4. Subsequently, for each criterion, determine how well the criterion applies to the separate technologies. Accordingly, score each technology as follows: 3 = applies very well with the criterion, 2 = applies somewhat, 1 = does not apply with the criterion. If two or more technologies do not differ much from each other, give them the same score. Fill in the scores for each technology

5. Multiply the score by its priority and note down the result in the table as well. Consider all the criteria one by one. Once all the WH technologies have been scored in this manner for all criteria, calculate and fill in the average risk score and the average benefit score for each technology

6. Then, under Selection result, calculate the benefit/risk ratio by dividing the average benefit score by the average risk score. Fill in for each WH technology

7. Finally, compare the benefit/risk ratios and decide which WH technology should be selected. Normally, the technology with the highest ratio would go through. If this is felt realistic, select that technology. A technology that it is less risky or promises more important benefits than another one may be preferred even if they have (about) the same benefit/risk ratio.

Table 1. Scoring WH technologies for local suitability

Risk criteria	Score: Magoye ripper	Score: Zaï	Score: Stone lines	Priority		Score x priority: Magoye ripper	Score x priority: Zaï	Score x priority: Stone lines
Technical design is difficult to understand, use and/or maintain and/or not safe	2	1	1	3		6	3	3
Technical design is difficult to adapt	1	1	1	3		3	3	3
Technology not suitable for the climate conditions	1	1	1	3		3	3	3
Technology doesn't easily comply with the required land surface and/or soil conditions	2	2	1	3		6	6	3
The soil layer is thin or places that can hold enough surface water are far				0		0	0	0
Financial costs are high during construction/maintenance	1	1	2	3		3	3	6
Requiring a lot of labour	1	2	3	3		3	6	9
Reducing the arable surface	1	1	3	1		1	1	3
Requiring a lot of changes in the farming system	1	1	1	1		1	1	1
Requiring fairly drastic changes in local customs	2	2	1	1		2	2	1
Requiring commitment of the community	1	1	1	0		0	0	0
Requiring political will and/or government clearance and/or protection	1	1	1	0		0	0	0
Requiring donor support	2	1	2	1		2	1	2
It takes time before benefits can be expected	1	1	1	3		3	3	3
Difficult to access the necessary inputs, finance and/or other private and public services	3	1	1	2		6	2	2
Difficult to access markets for selling farm produce	1	1	1	2		2	2	2
Sensitive to climate and/or other changes beyond people's control	1	1	1	1		1	1	1
Causes damage to the natural environment	1	1	1	1		1	1	1
Causing problems in the community, locally and/or neighbouring (e.g. downstream)	1	1	1	1		1	1	1
					Average risk score:	**2.3**	**2.1**	**2.3**

Benefit criteria	Score: Magoye ripper	Score: Zaï	Score: Stone lines	Priority		Score x priority: Magoye ripper	Score x priority: Zaï	Score x priority: Stone lines
It improves water availability and/or water security	3	3	2	3		9	9	6
It stimulates diversification in farming	3	1	1	2		6	2	2
It reduces risk of crop failure/stabilizes yields between years	3	3	2	3		9	9	6
It increases farm production	3	3	2	2				
It produces more income	3	3	2	3		9	9	6
It creates employment	1	1	1	1		1	1	1
Many people in the area will benefit	1	3	2	3		3	9	6
It is beneficial to many women	3	2	1	2		6	4	2
It is attractive for the youth	3	2	1	2		6	4	2
It is useful in other areas	3	3	3	1		3	3	3
It will give the benefits over many years	3	3	3	3		9	9	9
It reduces damage to the land	3	3	3	3		9	9	9
It improves biodiversity (vegetation, wild life)	1	1	1	1		1	1	1
It has important other natural and/or socio-economic benefits	2	2	1	1		2	2	1
					Average benefit score:	**5.6**	**5.5**	**4.1**

Selection result *WH technology:*	***Magoye ripper***	***Zaï***	***Stone lines***
Benefit/risk ratio (= average benefit score / average risk score)	**2.4**	**2.7**	**1.8**
The technology to be selected		**x**	

Adapting a WH technology

The WH technology selected for introduction will need to be adapted so it can work in the local situation and provide its intended results. Assess in the following steps what needs to be changed and how:

1. Review the critical conditions that make the WH technology work. Check against the relevant indicators (see list of indicators in Appendix 1)[4]
2. For those of the above conditions that are not met, assess which aspects of the design and the working environment need to be changed and how, so to still make the WH technology work. Ensure that this is possible within the available means and the other local conditions. Care should be taken not to discard options with a bias towards technical (or other) criteria; the art may be to look with an open mind to the options first, and then consider if and how they can be adapted
3. Identify other, supportive changes that can or should be made[5].

An example is given for the WH technology *Stone lines* (in this simple case social issues such as land tenure, policies, local customs and tradition, culture and religion are not considered):

1. *What are the critical conditions making the Stone lines work?*
    a. There are stones/rocks of the correct sizes available nearby
    b. Slopes are not too steep
    c. Local labour can be mobilized
        - Farmer provides manual labour and basic tools
        - Local farming community can provide manual labour and basic tools as well
        - Productive inputs/local market are available to make effort worthwhile
2. *What to do if any of the above is different?*
    a. Use soil instead of stones
    b. If few stones available:
        - Use soil and reinforce with stones
        - Reduce area covered with bunds
        - Maximize distance between bunds
    c. Ferry stones from further away: truck needed
    d. Adapt distance between bunds to steepness of slope, dig in stones on steeper slopes
    e. Adapt lay out to local farming practices (crop types, mechanisation)
    f. Consider safe water drainage facility if risk of flooding: protected spill way, diversion dyke, discontinue bunds
    g. Labour: hire, rotate shifts to work on each others' fields
    h. Concentrate on most productive fields to guarantee household food security or where cash crops can grow profitably
3. *What to consider otherwise?*[6]

[4] Also refer to WOCAT questionnaire for *Technologies*
[5] Also refer to WOCAT questionnaire for *Approaches*

a. Sensitization of community
b. Organize participants
c. Training on principles, how to lay out the works, how to use and maintain it
d. Technical guidance
e. Incentives
f. Enhance community acceptance
g. Prevent potential conflicts: grazing rights, use of communal materials, renumeration of services provided, reduced run-off of water to neighbours' fields, equitable access to benefits
h. Integrate in local agricultural development efforts, link with service providers (inputs, finance, insurance, markets, mechanisation)
i. Change local customs: limit free access of cattle by controlled grazing, fencing, cut and carry
j. Testing of the system on a small scall, monitor and decide on any changes needed.

When considering the adaptations to be applied, it should be noted that some characteristics of the WH technology or of the working conditions, without being changed, actually facilitate the adaptations. A general overview of this is given in Table 3 (in the column headed *Aspects facilitating WH technology adaptation*). In the other columns of the same table, an overview of the aspects that can be changed is given as well as what the impact of the changes would be. Using the table and updating it for the local situation and the selected WH technology, helps to estimate not only what room for adaptation there is, but also whether the changes are worthwhile, i.e. whether they will make the new, adapted water harvesting technology produce enough of the intended benefits.

[6] Some of these aspects may need to be defined in more detail; a good assessment of certain details may actually be crucial for successful adaptation, but difficult to accomplish! Perhaps it is good to refer back to the consultation and planning steps with stakeholders to further discuss these considerations after a choice for a certain WH technology has been made

Table 2. Conditions for water harvesting adaptation			
Aspects determining the adaptability of the WH technology			
Category	**Aspects facilitating WH technology adaptation**	**Aspects that can be changed**	**To accommodate for what**
Design of the WH technology	Already existing WH structures and available WH expertise (to build, use and maintain WH systems) Concept is suitable for a wide range of biophysical and socio-economic environments Simplicity of the design makes it easier to adjust; indicators of simplicity of the design: • All who need to understand it do understand • The design is not complicated more than necessary • It doesn't require a high level or high variety of skills • It requires (mainly) locally available skills, manpower, tools and materials • It can be made quickly • It can be easily expanded and replicated (e.g. modular design) • It is easy to add new things or to integrate other technologies Reasonable financial costs make technical adjustments feasible; consider: Investments, variable and labour costs (including for maintenance), payback amount, payback time during construction/use/alterations	Particular specifications: • Dimensions • Choice of materials • Order of construction in time • Design alterations/choice of design options Know-how: • Understanding and skills of local stakeholders to implement WH	· Required WH capacity; the envisaged volumes of water that can effectively be harvested, transported and stored · Application level; integration of complementary farming technologies (e.g. irrigation, mechanisation, modern farm inputs, high-value agricultural commodities), other water uses than farming, more and other beneficiaries · Other aims/benefits · Financial costs; capital investments, running costs at each phase of development of the WH technology (design, construction, use) · The limitations and opportunities of the working environment
Aspects determining the adaptability of the working environment			
Category	**Aspects facilitating WH technology adaptation**	**Aspects that can be changed**	**To accommodate for what**
Climate	Knowledge about the key climate conditions and their trends help establish: • Best overall design, including choice of alternative options • Design specifications	Climate cannot be changed (unless by long-term mitigation on a global scale, which is outside the scope of WH adaptation)	Not applicable
Land	Effective runoff from WH catchment area Knowledge about the key topographic, soil and geological conditions help establish: • Location • Best overall design, including choice of alternative options • Design specifications	Surface - slope (terracing), topography (afforestation, de-stumping and cleaning surface to become more suitable for desired farming systems) Soil - structure, organic matter content, coverage, nutrient content (reduced/zero tillage, mulching, conservation farming, integrated soil fertility management) Rock bed - unpractical to change	Create room for WH technology Make WH technology (more) effective and efficient by: Adjusting for run-off intensity Making land (more) suitable for rain water catchment Making land (more) accessible/suitable for farming Increasing infiltration rate and water holding capacity of the soil Increasing productivity of the soil

Table 2. Conditions for water harvesting adaptation (continued)			
Aspects determining the adaptability of the working environment (continued)			
Category	**Aspects facilitating WH technology adaptation**	**Aspects that can be changed**	**To accommodate for what**
Natural environment (other than Climate and Land)	Ecosystem services: • Adequate amounts and quality of local building materials make WH construction and adaptation easier • Agricultural potential of the natural environment that justifies investing in WH and WH changes	Optimise maintenance, build resilience, and expand ecosystem service delivery: • Water reserved for natural vegetation and wildlife • Pollution; limit and control • Protect against (excessive) mining of the environment (i.e. extraction larger than natural regrowth) • Space reserved for natural vegetation and wildlife; size, location, quality, access Use of ecosystem services: • Knowledge; strengthen, document, use • New ecosystem services; introduce, exploit	• A broad natural sustainability base for the preferred WH system and changes • Better chances for successful and efficient implementation and maintenance of the WH system and changes
Agricultural system	Individual rather than communal farming practices can make integration of a WH technology into the farming system less complicated Productive farm assets and methods may help the WH technology to be financially or economically more feasible, hence justify certain adaptation efforts Synergies between different components of the agricultural system (e.g. livestock for manure, draft power for soil tillage)	Farming skills training, research, extension and information services Farm enterprise annual crops, trees, livestock, aquaculture, forestry Commodities crop type and variety, livestock/fish breeds Production units - fields number, shape, length and width, fencing Mechanisation level manual, animal draft power, motorised Irrigation have it - yes or no, adjust it - type, size	Productive farming assets make the WH technology (more) compatible and financially and economically feasible Match production unit size to water catchment capacity Adapt production unit shape to make the WH technology more effective/efficient
Socio-economic environment (other than Agricultural system)	Trade-offs, income, food and nutrition security, spin-offs in employment, skills, economic and social development, education, health, community strength and stability, cultural pride Necessary technical know-how and experience available for implementation, community organisation, financial management, use, maintenance	Acceptance Sensitization; information, testimonies, exposure, demonstration Participatory planning Use of local capacities; labour, skills, input supply, other services Alternative uses of the WH technology for other beneficiaries; introduce/add/improve Capacity building Skills at each phase (design, construction, use) for technical know-how, management, facilitation (community organisation, governance), use and maintenance Labour force, tools and equipment, building materials Enhancing overall benefits Productivity and sustainability of rainfed farming (introduce/reorient/improve) Statutory land tenure; introduce, reinforce Services for marketing, farm input supply, training, information, financing, risk reduction (insurance) Multiple uses for WH technologies; introduce/add, make more effective, efficient	A more flexible or diverse use of the WH system and larger community acceptance, participation and know-how will facilitate decision taking, increase local ownership and local participation, and improve the likelihood for a WH technology to be effective and sustainable Enhancing complementary services for greater farm productivity and income can help justify the additional costs of a WH technology

Participation, facilitation and learning

This last chapter highlights a few important organisational aspects that if taken into account will facilitate an effective and efficient conducting of the entire adaptation process:

- Involvement of the beneficiaries and other stakeholders aimed at good representation while maintaining manageable working groups
- Facilitation of the work through expert guidance and support
- Making progress in manageable steps.

1.1. *The stakeholders*

Ownership of the WH activities and results requires the participation of all interested parties in their respective roles. Their contributions will make WH introduction and adaptation cost-effective, help produce the relevant results and increase impact and sustainability.

In the case of WH technologies that are limited to individual farms such as planting pits, stone lines, jessour, tabia, percolation/sediment storage ponds, soil improvement measures and conservation tillage methods, the people directly involved would be:

1. The farmer or farmers (both men and women) on whose fields the WH activities will be implemented. Depending on the number of farmers targeted in an area, their farmers' association may be involved as well
2. The local extension officer or another qualified person to work closely with the farmers and take the role of facilitator. His or her work will include informing and training farmers and other members of the community, keeping working links with other experts and service providers and arranging for any formalities required in conjunction with the local authorities and the government.

Technologies such as cisterns, bench terraces, check dams and recharge wells go beyond the individual farm level; they are laid out on communal land and involve or affect the local community. At this application level, the adaptation process will be more complex and the technical and community development skills and oversight required be more critical[7]. Consequently a larger and probably more varied group of farmers, other community members, experts and service providers will play a role. They may include:

1. The intended beneficiaries. Depending on the technology, these may be different types of farmers intending to use the WH facilities for different farming enterprises, or include other community members as well, for instance if the stored water is meant for general household use too
2. Other women and men who are supposed to work with the new technology and/or have to adapt their livelihood because of it and/or are affected in one way or the other by the introduction of the new WH system
3. Professionals working with the community to inform, advise, train and/or support the people involved, maintain linkages with public, private and commercial service providers and manage the adaptation process
4. Organisations such as farmers associations to represent the farmers and rural development programmes in the area that may support the community's WH initiative
5. Local authorities and government services that are needed for official permits, oversight and other formalities as well as for their specialist expertise and facilitation.

[7] If individual farms are small but their total number is big, WH projects may be more complicated and might need the involvement of community leaders and other stakeholders as well

Note that a participatory approach is gender balanced; women as much as men should not only be kept informed but also invited to share and have everybody benefitting from their know-how and preferences as well as take part in decision making and implementation. Moreover, time schedules for meetings and work in the field should as much as possible respect the usually busy agendas of women who run a household. Similarly, appropriate considerations may need to be made for other subgroups/minorities/categories, such as large versus small farmers, subsistence versus market orientation, farmers versus pastoralists, and youths versus the elderly.

Generally, it will be useful to link the WH adaptation project with the official agricultural or rural development plan for the area and to mobilize support from public services, including from development programmes, farmer organisations and NGOs. Usually it is a good idea too to create working links with the private sector such as traders and processors of agricultural commodities, agro-dealers and financial service providers (including banks and insurance companies); their services may be needed to strengthen the feasibility and sustainability of the WH investments.

Interested parties not directly participating need to be kept informed about the progress, especially if community-level WH works are concerned. However, also for the introduction of farm-level WH technologies, it is good strategy to keep the general public updated through information and exposure. It can help strengthen the community members' acceptance for WH initiatives by individuals in their midst, prevent conflicts and be instrumental for a wider uptake of innovative WH technologies as well.

1.2. Professional guidance

The professionals mentioned in this document to guide the WH adaptation process are important. Their task is to facilitate, i.e.: inform, sensitize and train farmers and other stakeholders, link them to support organisations and service providers (including related to policy making/implementation, lobby organisations) and provide them continuously with advice and support. Most likely the facilitators will be subject matter specialists, agricultural extension or research officers, or community development staff assigned to the area by the government. The farmers and other stakeholders should try and get the most out of them.

It is important that these experts are conversant with the relevant WH technologies and equipped with at least the basic means to perform; i.e. WH instruction and information materials as well as means of communication and transport and access to funds to operate. The farmers/community, being the beneficiaries of their services and owners of the project, should arrange to contribute to these logistics as much as they possibly can.

It may be important that the local experts receive refresher training in the practical aspects of WH adaptation as some of them may actually lack this expertise. Lead farmers and community leaders should have access to such courses as well. Furthermore, linkages to other service providers such as agro-dealers, traders, bankers and union officials, will prove useful not only for their specific services but also to add to the expertise of the local government officer. Integration into the national agricultural investment plan and linkage to a (possibly donor supported) development programme or fund may prove to be indispensable for securing, even if temporarily, some of the above essentials.

1.3. Step-wise WH development

The introduction and adaptation of a new WH technology follows a learning curve, which should not be too long. The following methods will help the stakeholders working with satisfaction to produce results sooner than later.

Training and exposure

An important activity is to update the farmers and other participants on key technical and management aspects. For instance, the WH principles should be explained, the technology's lay-out, use and maintenance be demonstrated, and the participants be exposed to how and *how not* to do things and be given the chance to make mistakes and learn through exercise; seeing a success is motivating, seeing a failure is instructive. When discussing critical conditions and adaptations, it will be good to refer to examples of wrong/unsuccessful adaptation. When done in a formal training course for groups, besides being educational, the course will be useful to strengthen the common purpose among the participants as well. However, a training course alone is not enough; it should be followed up with continuous advice, support, refreshing of knowledge and repetition of important topics.

Demonstrations and the locals meeting with colleagues who have gone through some WH experiences already can be extremely instructive and motivating. Such exposure visits should be hosted by people able to tell the story right and emphasise the critical details, preferably from different angles, so including not only WH subject matter specialists but also farmers, agricultural extension officers, representatives from the community and the authorities. Pay attention to the gender angle too. If outings are not do-able, try and compensate for this with a good alternative, e.g. invite some key people from elsewhere to present and/or use video or other visual materials.

Learning by doing

Often when still learning, it makes sense to apply an iterative approach, i.e. learning by doing step by step. It involves trying out, observing and reflecting on the results at every stage, allowing for useful new ideas to come in from participants or people being consulted and deciding how to go from there, based on what was learned. This same process can then be repeated every time at a more developed level until the result is achieved.

This practical approach stimulates participation, maximises the use of local knowledge and ingenuity and produces visually motivating outputs. It helps keeping the project manageable, as long as the group of participants is kept small but representative and all the skills required are available at each particular stage. Also, the step by step method reduces risk; not much time and resources nor the participants' interest are lost in the process, provided the steps are not too small and many; they should be as big as can be handled at any stage. It is also vital not to lose direction by monitoring the process and maintaining consensus and clarity about the originally intended result. The WH subject matter specialists and other facilitators should ensure this throughout the project.

It is best to start small, if possible. For micro-level WH technologies this can be done by testing the technology on part of the farm, or even a field, as it allows comparison between conventional and new practice under the same circumstances, and adapt and expand thereafter depending on what was learned from the first experience. Volunteers should start trying on one or more test sites selected for the highest potential for success. For macro-level WH technologies, this may be less practical although it could be possible to test on a limited scale. However, for these larger investments, the preparatory stages, i.e. consultation, selection and planning, and the training, demonstrations and guidance aspects, will be more substantial than for micro-level cases.

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Appendix 1. Checklist of indicators for the suitability of a WH technology

The required value (or range of values) or the preferred target of each indicator is determined by the WH technology[8]

Category	Indicator type	Indicators
Design of the WH technology	Principle and structural design	Degree of simplicity, scalability, replicability
	Flexibility	Ability to integrate with agricultural operations and farming systems and other (WH) technologies
	Costs - for investment, maintenance, use	Cost types and levels, financing options, payback period
	Inputs - for construction and maintenance	Time, labour, tools, machines and equipment, materials - locally available or imported
	Know-how - for construction, maintenance and use	Skill types and educational and experience levels required
	Safety	For workers, users, public
Climate	Rainfall	Monthly amounts, intensity and variability within and between years against monthly agricultural water needs
	Evaporation	Monthly amounts against monthly agricultural water needs
Land	Soil	Texture, structure and thickness of soil layers, agricultural production potential, spatial variability
	Topography	Space, slope, surface crust, surface roughness, various other features of or on the surface (such as stones, rock outcrops, anthills, gullies, stream beds)
	Vegetation	Types, densities, spatial variability
	Aquifer	Depth, volume, distance to natural surface water, types of surface water
Other natural	Wild life	Biodiversity, risk of pests, fungal diseases and nematodes, and dangerous animals
	Disasters	Probability of earthquakes and storms
Agricultural	Agricultural objectives	Productivity levels (e.g. land, labour, farm, area)
	Agricultural system	Subsistence, market-oriented, commodities (crops, livestock), access to markets, level of organization of the agricultural sector and of empowerment of farmers
	Production types	Use of traditional and modern inputs, level of mechanisation, use of irrigation (type, extent), agricultural land use intensity, drought resistant/tolerant, groundwater recharge
	User rights	Land, water, grazing, forests
	Farmer organisation	Types, membership, services
Socio-economic (other than Agricultural)	Socio-economic objectives	Number and types of beneficiaries, shared values (e.g. food and nutrition security, skills development, employment creation, income generation, gender equality, youth employment), sustainability, community acceptance, activities in competition with farming (e.g. gold panning, migration)
	Social capacity	Level and types of community organisation, skills and resources
	Financial	Risks, costs and benefits (types, volume, quality, timing), profitability, growth potential
	Formal system	Policy, rules and regulation, law enforcement, permits, directives from government and local authorities (e.g. with respect to land tenure, land use, water rights, construction, safety, pollution, natural environmental protection), policy balance between food and cash crops
	Services	Government, private commercial, community, microfinance and credit institutions, warrantage (inventory credit), insurance, farm inputs, equipment, infrastructure, transport, marketing services, research and development, training, information
	Trade-offs and spin-offs	Competing claims (e.g. on land and water use), down-stream impacts (e.g. on water availability and quality, water and wind erosion), competing claims (e.g. between farmers and herders),

[8] E.g. refer to data available with WOCAT

Appendix 2. Database of WH technologies and their key bio-physical suitability criteria

Water harvesting techniques	**Suitability indicators**						
	Slope (%)	***Land use***	***Soil properties***	***Annual rainfall (mm)***	***Topography***	***C:CA ratio***	***Limitations***
In-situ rainwater harvesting							
Mulching	0-5	Cultivated land	Impermeable soil	200-800	Low topographic relief	Not applicable	Not suitable in areas with high rainfall
Conservation tillage	0-5	Cultivated land	Impermeable soils	200-800	Low topographic relief	Not applicable	Problem of compaction, flooding or poor drainage
Micro-catchment systems							
Negarim micro-catchments	1-5	Cultivated land, bare/shrub land	Thick soils (at least 1.5 metre deep)	100-400	Even and uneven micro- catchments	1:1-25:1	Cannot be mechanized
Meskat systems	2-15	Cultivated land	All agricultural soils	200-400	Even and uneven micro- catchments	2:1	Lack of uniformity in water distribution in the cropping area
Contour bench terraces	20-60	Bare/shrub land, cultivated land	All agricultural soils except shallow ones	200-600	Even and uneven micro- catchments	1:10	High construction and maintenance costs, cannot be mechanized
Semi-circular bunds/half-moons/triangular bunds	0.5-5	Bare/shrub land, cultivated land	All soils not shallow and saline	200-750	Even topography	3:1	Cannot be mechanized, require regular maintenance
Pitting systems (e.g. Zaï pits/ Chololo pits, Tassa, etc.)	0-5	Bare/shrub land, cultivated land	All agricultural soils	350-600	Even and uneven micro- catchments	1:1-3:1	Demand heavy labour during preparations
Contour ridges /furrows	0-5	Bare/shrub land, grazing land, cultivated land	All agricultural soils not heavy and compacted	350- 750	Even topography	2:1-3:1	Not suitable in heavy and compacted soils, or high rainfall
Trapezoidal bunds	0.25-1.5	Bare/shrub land, grazing land, cultivated land	Agricultural soils with good constructional properties	250- 500	Area within bunds should be even	10:1-30:1	Limited to gentle slopes.
Contour stone bunds with/ without trenches	0-2	Bare/shrub land, grazing land, cultivated land	All agricultural soils	200-750	Even and uneven topography	variable	Only possible where abundant loose stone is available
Contour earth bunds with/ without trenches	0-5	Bare/shrub land, grazing land, cultivated land	Thick soils (at least 1.5 metre deep)	200-750	Even without rills	variable	Not suitable for uneven or eroded land
Eye brows	1-50	Bare/shrub land	Shallow to medium soils	200-600	Even and uneven topography	3:1-20:1	Not effective in very low rainfall areas, cannot be mechanized

Source: Grum, et al., 2015

Appendix 2. Database of WH technologies and their key bio-physical suitability criteria (continued)

Water harvesting techniques	Suitability indicators						
	Slope (%)	*Land use*	*Soil properties*	*Annual rainfall (mm)*	*Topography*	*C:CA ratio*	*Limitations*
Micro-catchment systems (continued)							
Fanya Juu terraces	5-16	Cultivated land	Moderately deep loamy soils	500-1000	Hill slopes and footsteps	variable	Loss of land for terrace bund, high labour input
Runoff strips	0-5	Bare/shrub land, grazing land, cultivated land	Thick soils (at least 1metre deep)	200-750	Even topography	Less than 2:1	Distribution of water across the strip may not be uniform
Inter-row systems (road catchments)	0-5	Bare/shrub land, cultivated land	Thick soils (at least 1metre deep)	200-750	Even topography	1:1-5:1	Lack of uniformity in water distribution across the cropping area
Macro-catchment systems							
Jessour systems	Moderate to steep slopes	Bare/shrub land, cultivated land	All agricultural soils	less than 250	Even and uneven topography	100:1-10,000:1	Breakdown can occur if no proper maintenance is made
Hillside conduits	Catchmen t (>10), crop area (0-10)	Bare/shrub land	All agricultural soils	200-600	Hilly or mountainous areas	10:1-100:1	Excess water need to be disposed
Water spreading bunds	Less than 1	Bare/shrub land, cultivated land	Floodplains with deep fertile soils.	100-350	Even topography	variable	Bund breakage are possible in the first season
Micro-dams	Moderate to steep slopes	Bare/shrub land, grazing land, cultivated land	Soils suitable for irrigation	200-750	Not necessarily even, narrow gorge	variable	Expensive structures, suitable topography and geology for reservoir
Cisterns	3-15	Bare/shrub land, grazing land	Deep soils	200-750	Not necessarily even	variable	High construction cost, need stable catchment, siltation and water quality problems
Sub-surface dams	0.2-15	Along streams near cultivated land	Sand bed with shallow rock (2-3 metre from bed)	200-750	Not necessarily even	variable	Difficulties in site selection and calculating water storage
Check dams	Less than 15	Along streams beds (1st to 3rd stream order) nearby cultivated land, 0-700 m distance	Fine loam with less infiltration rate	200-750	Even and uneven topography	variable	Can silt up quickly and need maintenance, improper design causes bank erosion
House hold/farm ponds	0-10	Bare/shrub land, cultivated land	Sandy clay loam with moderate infiltration rate	200-750	Not necessarily even	variable	Siltation/deposition, water loss due to infiltration for porous media
Percolation ponds	0-10	Bare/shrub land, grazing or grass land, along stream beds (2nd and 3rd stream order)	Clay loam, sandy clay loam with moderately high infiltration rate	200-750	Not necessarily even	variable	Need regular maintenance to reduce siltation

Source: Grum, et al., 2015