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Procedure of Water harvesting technologies evaluation and selection

– Oum Zessar watershed Tunisia case study –

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SEVENTH FRAMEWORK PROGRAMME

Procedure of Water harvesting technologies evaluation and selection, Oum Zessar watershed Tunisia case study

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Objectives

Multi-stakeholder approach for the evaluation and selection of the most appropriate indigenous and introduced rainwater harvesting techniques in Oum Zessar watershed

Case study presentation

Oum Zessar watershed is located in the North of the province of Medenine and its area covers 36,530 hectares. The choice of this watershed was made due to its geographical situation and its hydrological, ecological and socio-economic functions. It has a strategic importance as its water table is used for drinking water by the governorates of Medenine and Tataouine. The Zeuss-koutine, the most important aquifer in Oum Zessar watershed, provides water for the drinking and the growing tourism sector that employ more than 16 % of the active population mainly in Djerba and Zarzis. It has also a high socio-economic importance with its agricultural sector. The area has a large agricultural potential based mainly on tree cultivation, breeding and fishing activities. Farming remains a vital activity in the study area. In fact, the farming activities contributes by more than 80% on the total household's income (Sghaier, et al., 2011).Oum Zessar watershed is characterized by the irregularity of the rain distribution which has important effects on natural resources and the development of agricultural production. On average the annual precipitation is about 157 mm, with +/- 20% variation .The coldest months are those of December, January and February with occasional freezing (down to -3 °C). June to August is the warmest period of the year and the temperature an reach as high as 48°C (in the shadow) (Ouessar, et al., 2008). The temperature is affected by the proximity to the sea and the altitude. The succession of dry years, the irregularity of rain and the occurrence of some intensive events are considered as the main physical factors of land degradation in the region. Furthermore, intensification of water and land use in the Oum Zessar watershed has leed to soil fertility decresae and water depletion. Yahyaoui et al (2002) argue that the piezometric level (PL) of Zess-Koutine acquifer has declined by 11.3 m between 1972 et 1999.The effects are less water for plant growth, lower biomass production and grain yield, and as a consequence of less protection of soils by vegetation. In fact, 19.8 % Oum Zessar watershed are affected by soil erosion (Sghaier, et al., 2011) . Oum Zessar watershed can represent the whole zone of the South East of Tunisia and therefore extrapolation of the case study results is possible under some acceptable assumptions.

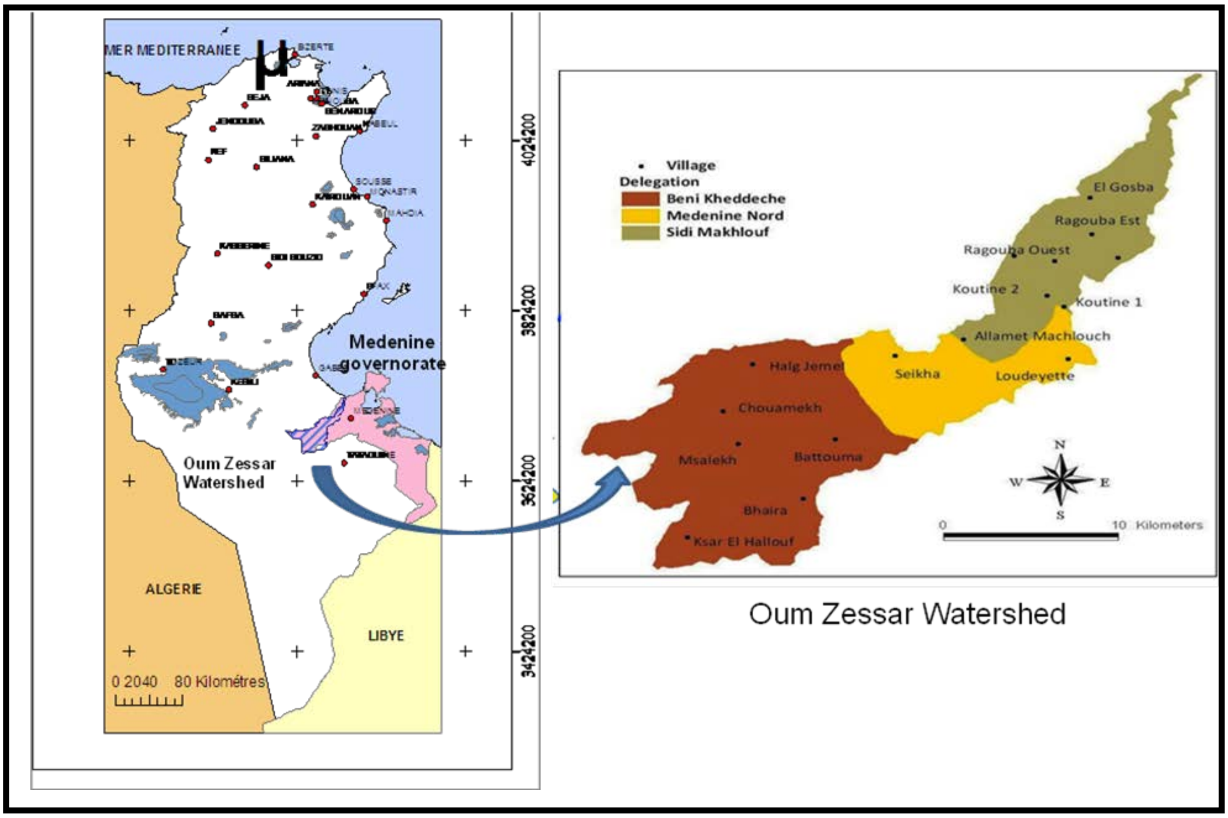


Figure1: Geographic location of Oum Zessar watershed (source: Sghaier et al, 2012).

General output

Given climate change, the demographic pressure and the growing of the different economic sectors selecting appropriate water harvesting technologies is a crucial challenge for the decision-makers in the Oum Zessar watershed. Based on local knowledge, the worldwide practices and the success stories the goals are the evaluation and the selection of the appropriate water harvesting technologies regarding their impacts on the environmental, social and economic dimensions.

Methods

Firstly based on the biophysical and socio-economic survey, literature review and semi-structured interviewing with stakeholders data on existing WHTs were collected. Secondly data related to the new water harvesting technologies were gathered from literature review and WOCAT data base. A multi-stakeholder participatory approach for the evaluation and selection appropriate techniques was applied. This approach employed Multi-criteria analysis (MCA). The central aim of the MCA application is to provide an explicit relative weighting system for indigenous and introduced WHTs impacts. A scoring method to evaluate effects of traditional an innovative WHTs, with different types and dimensions, on the sustainable development was applied.

Procedure of WHTs selection

The overall procedure of participatory WHTs selection in Oum Zessar watershed emphasis three distinguished steps:

The first steps of WHTs pre-selection process bring together scientists, representatives of local authorities, researchers or development professionals, and representative of civil society and NGOs during a one day workshop (04-12-2012). It consists of a multi stakeholders learning process in biophysical ad socio-economic impact of water and soil conservation practices in the OZ study site. The goal is to share understanding and a mutual learning on indigenous and innovative WHTs techniques to drive a range of WHTs alternatives. Through interaction between technical experts and scientists, it was increasingly recognised that by combining local and innovative WHTs, a more sustainable land management can be established. A variety of already implemented techniques during the last two decades has been presented and discussed. Other, based on WOCAT data base an innovative set of WHTs are presented by scientists. Technical experts argue that some new techniques recommended by scientists cannot be adapted to the local socio-cultural or biophysical environment. Finally output of the first step was an extended set of applicable indigenous and innovative news techniques regarding the biophysical and socio-economic context in Oum Zessar watershed.

The second steps follow up on what was discussed on the first workshop. It consists of preselecting a set of introduced and indigenous WHTs and a potential sub-watershed and/or private propriety for WHTs implantation. The qualitative participatory preselecting procedure, during a one day workshop (15-12-2012), included scientists, representatives of local authorities, researchers or development professionals, and representative of civil society and NGOs . The goal was to reach a consensus regarding a feasible and promising set of WHTs and potential sites for the implementation of selected WHTs based on the list presented and discussed during the first workshop.
Several criterias or decisive-key-factors were taken into account by scientists, decision makers and representatives of NGOs for the first pre-selection of WHTs and potential sites. The first set of selection criteria (table 1) are considered as biophysical and socio-cultural barriers to the applicability and adoption of WHTs. The criterias of selection are related to the pedology, hydrologic and topography characteristic of the oum zessar watershed, other the land use, land ownership and local knowledge are taken into account. Final output of the workshop was a restricted list of WHTs (table 2) .The previous WHTs implementation in the framework of several development projects and national program of water and soil conservation are taken into account. Connexions between pre-selcted water harvesting technologies and location are established. Indeed, each WH technology is affected to a potential site that consists of a sub-watershed or private propriety. In total three potential site and beneficiaries farmers are selected:

- Chaabat el anez, Béni-khdéche Up-stream of OZ waterhed
- Eloudayet, Medenine Nord Mid-stream of OZ waterhed
- Oued Moussa, Sid-Makhlouf Down-stream of OZ waterhed

Table1. Criteria for WHTs pre-selection.

Criteria (decisive-key-factors)
Biophysical criteria • Rainfall - Average yearly rainfall - Rainfall intensity • Pedology - Soil depth - Soil type - Stoniness • Hydrology - Runoff - Sediment transport - ect • Topography - Slope - Altitude - Groundwater depth
socio-cultural • Land use • Land tenure • Level of technical knowledge • Land use rights

Table 2. Pre-selected water harvesting technologies

Techniques	Origin	Definition/comments
Jessour	Indigenous	Jessour is an ancient runoff water harvesting technique widely practiced in the arid highlands (WOCAT Database) http://cdewocat.unibe.ch/wocatQT/qt_summary.php?lang=English&qt_id=239
Tabias	Indigenous	The Tabia earthen dyke is a water harvesting technique used in the foothill and piedmont areas. (WOCAT Database) http://cdewocat.unibe.ch/wocatQT/qt_summary.php?lang=English&qt_id=236
Cisterns	Indigenous	Cisterns are reservoirs used for storing rainfall and runoff water for multiple purposes: drinking, animal watering and supplemental irrigation (WOCAT Database) http://cdewocat.unibe.ch/wocatQT/qt_summary.php?lang=English&qt_id=235
Recharge wells	Indigenous	A recharge well comprises a drilled hole, up to 30-40 m deep that reaches the water table, and a surrounding filter used to allow the direct injection of floodwater into the aquifer (WOCAT Database) http://cdewocat.unibe.ch/wocatQT/qt_summary.php?lang=English&qt_id=234

Adapted recharge wells	Modified technique	
Gabion check dams	Indigenous	The technology of check dam is a technique consisting of binding different gabion cages filled with small stones together to form a complete flexible gabion unit. (WOCAT Database). http://cdewocat.unibe.ch/wocatQT/qt_summary.php?lang=English&qt_id=238
Zai planting holes	Introduced (Zambia)	Zai is an ancestral planting pit developed in the Yatenga province, North Western part of Burkina Faso (where average rainfall is about 600 mm, with recurrent droughts and where soils are heavily encrusted. (Fatondji et al., 2006). Fatondji, D., Martius, C., Bielders, C. L., Vlek, P. L. G., Bationo, A., and Gerard, B., 2006, Effect of planting technique and amendment type on pearl millet yield, nutrient uptake, and water use on degraded land in Niger: Nutrient Cycling in Agroecosystems, v. 76, no. 2-3, p. 203-217.
Retention ditches	Introduced (Ethiopia)	Retention ditches located in steep areas of Kenya, where runoff is captured and allowed to infiltrate. (Critchley et al., 1994). Critchley, W. R., Reij, C., and Willcocks, T. J., 1994, Indigenous soil and water conservation: A review of the state of knowledge and prospects for building on traditions: Land degradation & rehabilitation, v. 5, no. 4, p. 293-314

The Third step of WHTs selection process consisted of the final evaluation and selection of WHTs at the watershed level (big and medium techniques) and in each selected compartment of Oum Zessar watershed (Up-stream, mid-stream and downstream). The selection and evaluation involved scientists, representatives of regional and local authorities, representatives of civil societies and NGOs and land users (beneficiaries' farmers). This approach was flexible, in the way that we can introduce new technologies based on WOCAT database that can be assessed or evaluated together with the indigenous techniques. Using Multi-criteria analysis, the central aim is to provide an explicit relative weighting system for different WHTs impacts. Well balanced multi-stakeholders, scientist and actors group were invited. Different WHs alternatives were scored in order of their importance or stakeholder's preference regarding their impacts on sustainability dimensions (economic, social and environmental). The goal is to reach a final agreement on which options to select for implementation in Oum Zessar watershed. Further the on-site and off-side biophysical and socio-economic impacts of selected WHTs will be scientifically assessed using integrated modelling approach.

WHTs evaluation and section

Firstly a topology of preselected WHTs was done. WHTs presented on two axes typology matrix. The vertical axis concerns the scale from plot to whole watershed, and the horizontal axis is related to the times horizon from short term to long term.

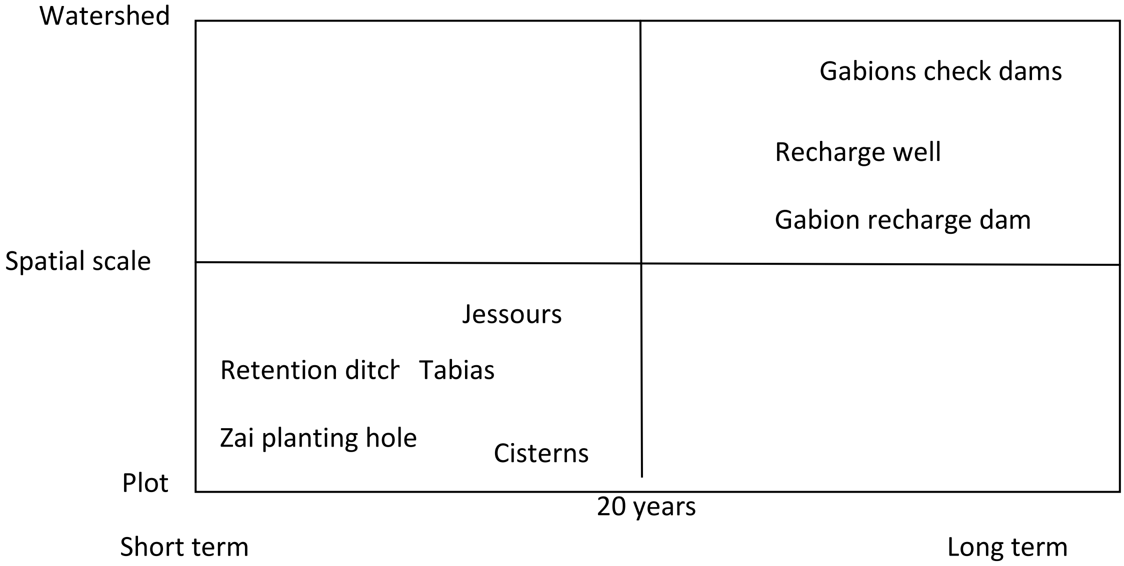


Figure1. Topology of preselected water harvesting technologies in OZ watershed

Given the spatial and time scale and the construction costs two groups of WHTs were identified:

Group 1 (Small and medium WHTs): Jessours, Tabias, Cisterns, Retention ditch and Zai planting hole

Group 2 (Large/big WHTs): recharge well, Gabion check dams and Gabion recharge dams

Considering criterias that have been discussed and validated by scientist and stakeholders (table 3) each group of WHTs was scored separately. Three working days with farmers and several semi-structured interviewing were made with stakeholders and scientists for WHTs selection and evaluation. For each sustainable development dimension a balanced set of indicators was chosen. This chose was made to facilitate the scoring exercise and to be sure that all participants shared the same understating. The scoring exercise started by explaining the different criterias by the facilitator and visualising the different preselected WH alternatives.

A scoring matrix (table 1, 2 on annexe 1) that contains different dimensions (economic, social and environment) WH alternatives and attributes has been prepared based on the output of previous workshops and the experiment choice proposed in the framework of WAHRA project. Using the scoring matrix stakeholder groups can score all alternatives against one attribute.

Table 3. Final list of criteria

Criteria
Environmental • Conserving water & soil • Groundwater recharge • Conserving biodiversity Economic • Increasing crop yields • Increasing farm income • Low costs of implementation & maintenance Social • Increasing employment opportunities • Increasing food security • Resolving interest conflicts

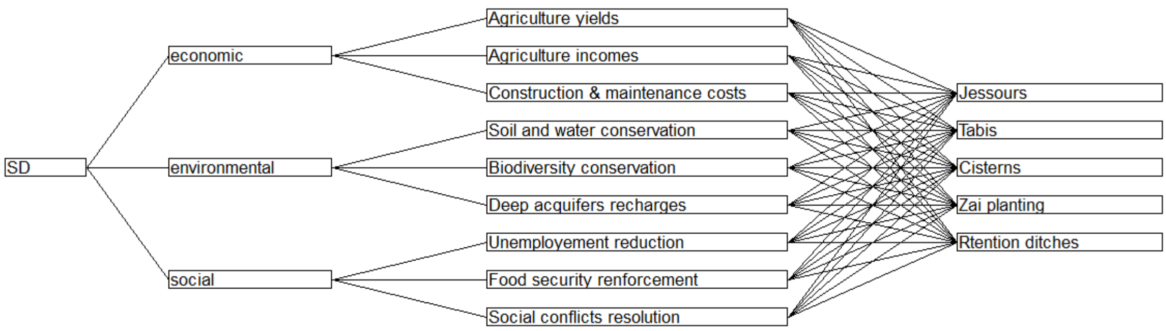
Multicriteria decision support

Multi-criteria analysis (MCA) deals essentially with complex decisions that involve a large amount of information, a number of alternative outcomes and criteria to assess these outcomes (Kuler.P, 2006). The central aim of the multi-criteria techniques is to provide an explicit relative weighting system for different criteria. The MCA techniques can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities (DCLG, 2009). Thus this analysis itself does not choose an alternative; it merely shows the contribution of criteria to the alternatives, based on the weights (preferences) that are given.
(Reidsma and al, 2008)
A standard feature of multi-criteria analysis is a performance matrix, in which each row describes an option and each column describes the performance of the options against each criterion. There exist several techniques and approach of Multi-criteria analysis, among other we can denote:
Direct analysis of the performance matrix, Multi-attribute utility theory, Linear additive model, Outranking methods, Analytic Hierarchy Process (AHP), And Simple Multi-Attribute Rating Technique (SMART). All MCA approaches make the options and their contribution to the different criteria explicit, and all require the exercise of judgement. They differ however in how they combine the data. (DCLG, 2009). The MCA techniques commonly apply scoring and weighting in two stages: Scoring: In this stage the expected consequences of each ranking are assigned a numerical score on the strength of a preference scale for each option for each criterion. The more preferred option scores higher on the scale and the less preferred lower. The most preferred option is associated with the highest value on the scale and the least preferred with the lowest. Intermediate values represent a constant linear expression.
Weighting: The assignment of numerical weights to define the relative scores for each criterion with respect to the objectives or overall objective of the exercise occurs during weighting. Relative scores will then be adjusted on the preference scale.
The Simple Multi-Attribute Rating Technique SMART

SMART (Simple Multi-Attribute Rating Technique) (Edwards, 1971) represents multi-attribute utility theory (MAUT) and is an extension of direct rating techniques. It is based on direct numerical rating values that are aggregated additively. There are many derivates of SMART by now, also including non-additive approaches. (Wolfslehner.B, 2007). The central aim of the Simple Multi-Attribute Rating Technique (SMART) application was the identification of the more appropriate climate change adaptation strategies that guaranties the sustainable development in the Oum Zessar watershed. The general approach of SMART consist of the a rank-ordering of alternatives for each attribute setting the best to 100 and the worst to zero and interpolating between. By refining the performance values with relative weights for all attributes a utility value for each alternative is calculated. (Wolfslehner.B, 2007).

First results of WHTs evaluation and selection

Preliminary results below are related to the scoring of the first group of WHTs in the up-stream watershed.



The figure 1: hierarchy of MCA application

The figure 2 shows the sustainability index related to each WHT alternatives. Jessours and Tabias are the most appropriate techniques contributing to the sustainable development in the up-stream watershed

Figure 2: Sustainability index OZ up-stream watershed

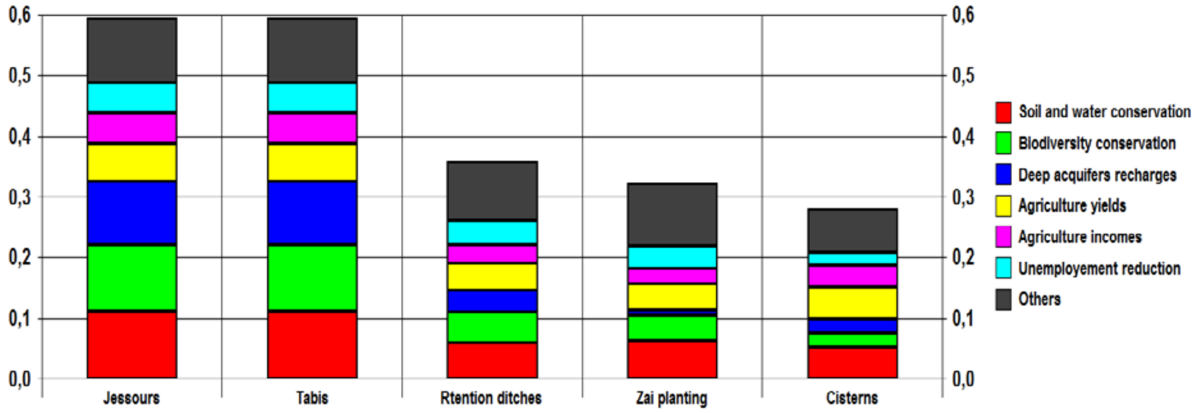


Figure2: WHTs contribution to sustainable development in OZ up-stream watershed

The figure 2 shows the contributions of each attributes on the sustainable development

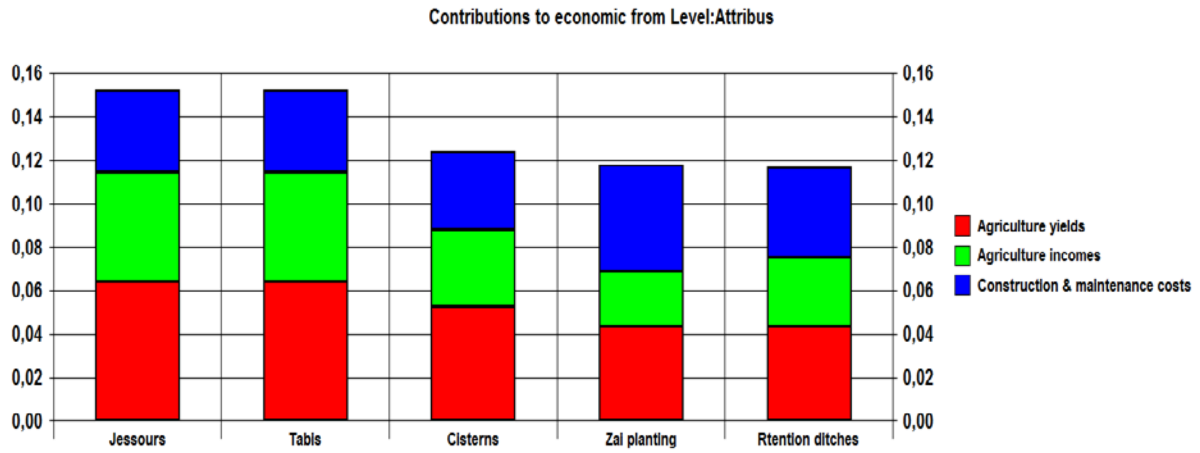


Figure 3. WHTs contributions to economic dimensions in OZ up-stream watershed

The figure 3 shows the contribution of each attributes on economics dimensions

Annexe 1: scoring matrix

Table 1: scoring matrix for small and medium WHTs

Name and surname: Affiliation : Location :

Scenario: medium years (rainfall between 50 et 100 mm)

Dimensions	S	Attributes	S	Jessour	Tabias	Citernes	Zai planting hole	Retention ditch »	Non CES
Economic		Increasing crop yields							Current situation
		Increasing farm income							
		costs of implementation & maintenance							
Environmental		Conserving water & soil							Current situation
		Conserving biodiversity							
		Groundwater recharge							
Social		Increasing employment opportunities							Current situation
		Increasing food security							
		Resolving interest conflicts							
		scale		S/M	S/M	S/M	S/M	S/M	S/M
		I chose							

S/M : small and medium techniques

Table 2: scoring matrix for big WHTs

Name and surname: Affiliation : Location :

Scenario: medium years (rainfall between 50 et 100 mm)

Dimensions	S	Attributes	S	Recharge wells	Gabions check dams	Gabin recharge Dams	Non CES
Economic		Increasing crop yields					Current situation
		Increasing farm income					
		costs of implementation & maintenance					
Environmental		Conserving water & soil					Current situation
		Conserving biodiversity					
		Groundwater recharge					
Social		Increasing employment opportunities					Current situation
		Increasing food security					
		Resolving interest conflicts					
		scale		L	L	L	L
		I chose					

L : Large WHTs techniques