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WAHARA

Water Harvesting Technologies (WHT) in Africa - a literature review focused on Tunisia and Burkina Faso

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1. Introduction: context of this literature review

The purpose of this literature review is to establish an exhaustive list of Water Harvesting Techniques (WHT) found to be applied in North and West Africa, more specifically in Burkina Faso and Tunisia. This review of techniques is done within the framework of the WAHARA project (Water Harvesting for Rainfed Africa: *investing in dryland agriculture for growth and resilience*). This European project aims to assess the up scaling potential of a variety of WHT thanks to a strong focus on 4 sites (Ethiopia, Zambia, Burkina Faso and Tunisia), which represent a large variety of Agro-climatic conditions (from (sub-) humid in Zambia to arid in Tunisia). To be highly relevant and have a greater potential to be integrated beyond the selected sites, the WHT of interest should present the following advantages: flexible, adaptable, understandable by local population and low-cost of implementation. In this context this literature review will be mainly focused on the French sources found for the two francophone sites within the WAHARA project, respectively Burkina Faso and Tunisia. The study will also take in consideration some WHT in neighbours' countries such as Mali, Morocco and Cameroon.

Since *Water Harvesting,* is a very broad term, we considered the following definition to present it: *a wide variety of interventions to use rainfall through collection and storage, either in soil or in man-made dams, tanks or containers bridging dry spells and droughts. The effect is increased retention of water in the landscape, enabling management and use of water for multiple purposes* (Boers and Ben-Asher, 1982; Bruins et al., 1986; Pacey and Cullis, 1986; Reij et al., 1988; Critchley and Siegert, 1991; and Boers, 1994. UNEP (2009)).

This literature review will be divided in three main parts. The first one will present the methodology of research followed to find relevant publications. This section will also include a translation table concerning the terminology of techniques (French/English) as this study focuses mostly on the French publications. The second part will deal with the results of the review according to 5 categories of WHT regrouped in tables to give a quick overview, the main characteristics of the WHT considered and respective Agro-Ecological data. A summary of these techniques by country is presented in the last part of this review: a useful tool to assess the potential of up-scaling for each WHT.

2. The methodology of research

This literature review is based on three main components: database research, own sources and *grey* literature documents.

1. Database research

Academic publications have been searched through the following database: the Scopus Electronic database. Articles have been selected in Life Sciences, Physical Sciences and Social Sciences domains, from 1985 to the actual period thanks to various combinations of specifics keywords (reflected in table 2, next page).

2. Keyword selection and combinations

Keywords have been selected through the categories of WHT, existing and defined according to the table 1.2 of the WAHARA project proposal, wherein WHT are classified regarding the provenance of the water harvested (source of water) and the type of buffer considered.

In total 6 buffer types have been identified for each 7 principal sources of water (Table 1 below):

Table 1 : Summary of table 1.2 from the WAHARA project proposal

Principal source of water	Buffer types
Rain	Soil storage (in situ), Soil storage (ex situ), Conveyances structures, Reservoirs, Tanks (containers), Ground water recharge.
Atmospheric (dew,fog)	
Runoff (overland flow)	
Runoff (concentrated flow)	
Stream flow	
Ground water	
Waste water[1]	

The methodology of research was based on various combinations of three selected keywords (Main keyword + Specific keyword + Location keyword), shown in the table 2 next page.

[1] *Waste water will not be considered in the research due to the characteristic of this source of water (sanitation issues, etc). Moreover the use of this water source is not very much developed as yet in the countries of interest (personal discussion with Mr. de Graaff)*

Table 2 : Keyword combinations

Main Keywords	AND	Specific keywords	AND	Location keywords
Water harvesting Rain water Runoff water Ground water Stream flow Fog water		Technology Conservation Management Micro-catchment Reuse /Recharge/Retention Blue water Infiltration Irrigation Stream flow Fog Pit/Pond Roof/road top Reservoir Tank Aquifer recharge Dam Bund/Strip/Ridge/Contour Soil storage Conveyance structure Spreading structure Collection		Tunisia Burkina Faso Africa

All combinations presented in table 2 did not always supply relevant scientific publications or no publications at all. When coupled with the location keyword *Tunisia* or *Burkina Faso*, the combination keyword displayed a small amount of publications but highly relevant when records, whereas the location keyword *Africa* displayed an important amount of articles but much broader and sometimes with an overlap with the previous research.

Results of the database research

In total we selected 26 articles via the Scopus Electronic database on the basis of more than 80 records.

3. *Grey* literature and other sources

Besides the database research, some relevant *grey* literature sources have been found by using similar combinations of keywords on the Internet (in French and English). In addition to that, various references have been collected thanks to personal discussions during the review. Some of them are the basis of the literature review (*i.e* **Ennabli, N.** 1993. *Les aménagements hydrauliques et hydro-agricoles en Tunisie*)

4. WHT : translation of terminology (EN/FR)

Since this review is focused on the two francophone sites of the WAHARA project, it was essential to display both English and French names of the techniques inventoried along the research. Below the table 3 presents a translation of the main terms found at the end of the review of WHT. The table 4 (next page) presents some soil moisture conservation methods that are usually combined with some WHT in order for agricultural purposes.

Table 3: Terminology of WHT[2]

Techniques names (French)	Techniques names (English)
Banquette en terre à extrémité déversante	Contour bench (with draining system)
Banquette de terre à rétention totale	Contour bench (with total retention)
Bourrelets	Planting pit
Micro-bassin	Micro-basins
Galleries filtrantes	Filtering Channel
Billons	Contour ridge
Digue de bas fonds	Dyke (of bottom valley)
Terrasse	Terrace
Puits de recharge	Recharge wells
Inondation dirigée (épandage de crues)	Spate irrigation
Cordons pierreux	rock/stone bunds/line
Diguettes filtrantes	Stone dykes
Haie/brise vent	Hedgerow barrier
Boulis (mare surcreusée)	Artificial pond
Zai	Planting pit
Billons cloisonnés	Tied ridges
Demi-lune	Half moon
Diguettes en terre	Earth dikes/dams
Fossé ados	Bench terrace
Muret	Little wall
Reservoir	Reservoir
Bande enherbée	Grass strips
Plantation d'arbres	Tree planting
Terraces de diversion	Diversion terraces
Micro-barrages	Micro-dams
Reservoir collinaire	Hill reservoir
Collecte des eaux pluviales (toit)	Roof top harvesting systems
Banquette de terre	Earth bund
Collecteurs de brume	Fog collectors
Micro barrages de sable	Micro sand dams
Lit rocheux	Rock bed
Barrage de retenue	Check dam
Barrage souterrain	Undeground dams
Barrage de sub-surface	Sub-surface dams
Seuil d'épandage	Stone-weirs

[2] *Sources for translation: 1-FAO report: Water harvesting in western and central Africa,2001., Ghana p 9-10. 2-http://webworld.unesco.org/water/ihp/db/glossary/glu/aglu.htm.*

Techniques names (French)	Techniques names (English)
Hoffra	Planting pit
Enclos-Tabias	*Tabias* system
Mescat	*Mescat*
Majel/ Fesquia	Cisterns
Jessours	*Jessours*
Seguia	Conveyance structure
Foggaras	Conveyance structure
Mgoud	Conveyance structure
*Chereb (*épandage direct*)*	Natural flooding
*Seguis (*épandage direct*)*	Natural flooding
Matfia/Khattara	Cisterns

Table 4: Soil moisture conservation methods

Techniques names (French)	Techniques names (English)
Scarifiage	Scratching
Sous-solage	Sub-soiling
Buttage/billonage	Ridging
Paillage	Mulching
Régénération naturelle assistée (RNA)	Natural Regeneration assisted
Jachère protégée	Protected fallow
Le Nakr	-
Le tombeau de Zaafrane	-
Le Ghout	-
Les Garaats	-

3. Results of the review by category of WHT

The results of this literature review will be presented according to 5 categories of WHT:

1-Micro-catchment to collect water at farm and field level;

2-Macro-catchment methods to collect water at the watershed level;

3-Flood water harvesting methods;

4-Atmospheric water harvesting methods;

5-In situ soil moisture conservation methods.

1. Micro-catchment methods to collect water at farm and field level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
FR	**Lamachère, J.M. Serpantie, G.**	1991	Burkina Faso **(South Sahelian, annual rain: 400 to 700 mm)**[3]	Soil storage in-situ	Runoff	Tied stones lines (*Cordons pierreux isohypses cloisonnes*)	Plot 2: stones lines "isohypses" 20m space in between two lines. Plot 3: idem + labour work	3 years monitoring (1986-1987-1988) 1 site: Yatenga (Bidi region) 3 plots soil: sandy and sandy clay slope: 2,5% monoculture of Mil	Labour work enhances greater infiltration of runoff and rain water. Result: discharge flow: 36 % reduction, runoff volume: 13 % reduction compare to the reference plot.
FR	**Vlaar, JCJ.**	1992	Burkina Faso **(South Sahelian, annual rain: 400 to 700 mm)**	Soil storage in-situ	Runoff	Stone dykes (*Diguettes filtrantes*)	Partial cost of realisation: 240 000 F CFA (without labour cost).	Description of the technique	Between 80 and 160 mandays to realise a field treatment of 1 ha
FR	**Ennabli, N.**	1993	Tunisia **(South, annual rain < 200 mm)**	Soil storage in-situ	Rainfall/ Runoff	*Hoffra*	Technique similar to the *Zai*.	Jerba, South Tunisia	
FR	**Ennabli, N.**	1993	Tunisia **(centre: annual rain 200 to 400 mm)**	Soil storage in-situ	Runoff	Earth dykes + "draining-off" (*Banquettes en terre à extrémité déversantes*)		Widespread technique (Djebel Orbata, Gafsa region)	Economic technique but silting issues.
FR	**Ennabli, N.**	1993	Tunisia **(centre: annual rain 200 to 400 mm)**	Soil storage in-situ	Rainfall	Bourrelets	Technique similar to the half moon.	Widespread in Tunisia (mostly in Central Tunisia), Djebel Mnara-Garaat Sidi Khlifa	
FR	**Ennabli, N.**	1993	Tunisia **(Arid to semi-arid)**	Soil storage in-situ+ cistern	Rainfall/Runoff	Enclos-Tabias	A decantation reservoir is installed before the cistern (few m3). Cistern about 100m3 minimun (conic, prismatic shape)	3 sites: Adar plain (between Gabès and Matmata), Kerkennah island and Kairouan region	Adapted to flat terrain. Dykes, 1 to 2 m high (earth, stone, or vegatation+earth). Systems which have shown a great efficiency. The cistern is installed to cope with strong dry spell.
FR	**Ennabli, N.**	1993	Tunisia **(Arid)**	Soil storage Ex-situ	Runoff	Mescat + Mankat	Mescat (impluvium), Mankat (flat cultivated area)	Sahel North de Sousse 1 site: Chott Meriem 4 plots	Ideal surface ratio of 1,5 between Mescat (3/5) and Mankat (2/5).

[3] *Agro-Ecological-Zone and/or average annual rainfall of site(s) considered in the study. (source: http://www.fao.org/ag/AGP/AGPC/doc)*

1. Micro-catchment methods to collect water at farm and field level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
FR	**Ennabli, N.**	1993	Tunisia **(Arid to semi-arid)**	Tank	Rainfall/ Runoff	*Majel/ Fesquia.* (Cisterns)	Decantation + storage, stone-faced underground basins. communal use or private	Widely spread in Tunisia	Cisterns with various types of impluvium (from soil to roof) mostly for drinking water purposes
FR	**I.N.E.R.A**	1996	Burkina Faso **(Sub-Sahelian: annual rain 400 to 700 mm)**	Soil storage in-situ	Runoff	Stone dykes/rock lines (*Diguettes filtrantes/cordons pierreux*)		Assessment efficiency between PDS and FEER systems associated with stone dykes Central Plateau 2 sites: Kirsi (sandy soil) and Nioniogo (clay loam)	The PDS rock line system has a greater retention capacity than the FEER system. When coupled with stone dike the water repartition is better on the plot.
EN	**Van Loon, E. Stroosnijder,L.**	2000	Burkina Faso **(North Sudanien rain : 790 mm)**	Soil storage in-situ	Runoff	Hedgerow barrier system	Species: *Agave sisalana, Ziziphus mauritana, Andropogon gayanu, natural vegetation.*	30 years of rainfall data 1 site: Experimental farm (Gampela) Various plots with different treatments Sandy loam+ clayed in deep layer slope of 1.5 to 2.5 %.	Combination of natural vegetation + alley length of 15 m was found to minimize both runoff and evapotranspiration from the system. 10 m alley in the case of *Andropogon* species.
FR	**Some, L. Kambou. F. Traore, S. Ouedraogo, B.**	2000	Burkina Faso **(Sub-Sahelian: annual rain 400 to 700 mm)**	Soil storage in-situ	Runoff	3 types of Rock lines (*cordons pierreux*) :	"système à trois pierres" (FEER), "système pierres dressées avec sous-solage" (PDS), "pierres alignées")	Central Plateau, Yatenga Village of Sabouna (Nord Ouahigouya)	FEER system: 20 à 22 m3 of stone/ha whereas 12 m3 for the PDS rock line system. "Pierres alignées" system is the most simple but less filtration which induce more runoff.
FR	**Gadelle, F.**	2001	Burkina Faso **(Semi- arid)**	Soil storage In-situ	Runoff/rainfall	Artifical pond: *boulis*	The earth digged out is used to create a small dam dowstream and dykes on the side (generally with *Acacia senegal, Acacia nilotica ou Prosopis juliflora* and herbaceous species)	Description of the technique	Costly, high rate of evaporation, destinated to water the cattle. Slope between 1/7 and 1/10.

1. Micro-catchment methods to collect water at farm and field level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
FR	**F. Gadelle**	2001	Burkina Faso, Niger **(semi-arid)**	Soil storage	Rainfall	*Zai*		Description of the technique	Ratio: impluvium area/hole area 7/1 to 20/1.
FR	**F. Gadelle**	2001	Niger, Gambia, Nigeria, Burkina Faso **(semi-arid)**	Soil storage	Runoff	Tied ridges (*billons cloisonnés*)		Description of the technique	Recommended to design tied ridges horizontaly with a special plough often found in Nigeria.
FR	**F. Gadelle**	2001	Burkina Faso, Niger **(semi-arid)**	Soil storage	Rainfall	Half-moon (*demi-lunes*)		Description of the technique	Diamètre variable de 1,0 à 2,5 m, with or wihtout stones.
FR	**F. Gadelle**	2001	Various countries	Soil storage	Rainfall	Earth dykes or earth dams (*Diguettes isohypses/diguettes divergentes*)		Description of the technique	"Diguettes isohypses": recommended in Sahalian zones. When the rainfall parttern is greater, "diguettes divergentes" are recommended. Disavantage: fragile structures.
FR	**F. Gadelle**	2001	Burkina Faso, Niger **(semi-arid)**	Soil storage	Rainfall/runoff	Bench terrace (*fossé ados*)	A good ratio of sandy-clayed soil is needed	Sites: Ader Doutchi Maggia (Niger) Projet GERES (Niger + Burkina Faso)	In Burkina Faso, most bench terraces designed within the project GERES (1960), have not been conserved (no maintenance). In Niger, thanks to the additions of stones better conservation.
FR	**F. Gadelle**	2001	Burkina Faso, Niger **(semi-arid)**	Soil storage	Runoff	Little wall (*Muret*)	Filtration of water (structure dispersed in the field). Recommended for Soudan-Sahelian + Soudan zones	Description of the technique	Technique widely spread in Burkina Faso but low efficiency with only one layer of square stones. Often needed to be consolidated. High level of maintenance.
FR	**F. Gadelle**	2001	Various countries (but not Gambia)	Soil storage	Runoff	Rock lines (*Cordons pierreux*)	Recommended for Soudan-Sahelian + Soudan zones	Description of the technique	Technique widely spread in Burkina Faso but low efficiency with only one layer of square stones. Often needed consolidation. Much maintenance.

1. Micro-catchment methods to collect water at farm and field level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Fox, P. Rockstrom, J.**	2003	Burkina Faso **(Sub-Sahelian: annual rain 400 to 700 mm)**	Soil storage Ex-situ	runoff/gully flow/rainfall	Farm pond, *Zai*	Storage volume of 150 m3. Hand dug (7 m x 7m x 3 m) used for supplemental irrigation.	3 years study (rainy seasons 1998–2000) 1 site: located in the Tougou basin (Yatenga region). 1.8 ha catchment area. Rainfed sorghum cultuvation 0.1 ha irrigated	High volume of water loss by seepage of harvested water (1998, 89%; 1999, 44%; 2000, 75%). Seepage surpassed irrigation volume requirements all 3 years. Supplemental irrigation from the pond was found to increase the yield of an average of 59% for non fertilised crop and 50% for fertilised crop.
EN	**Fox, P. Rockstrom, J. Barron, J.**	2005	Burkina Faso **(Sub-Sahelian)** and Kenya **(semi-arid)**	Reservoir	Runoff	Reservoir + 2 manual foot-pumps	300-m3 reservoir: operational size (to construct and to manage)	3 Years study 1998–2000 2 sites: on-farm experimental Tougou basin (Yatenga region, Burkina Faso) /Mwala (Machakos district, Kenya) 4 reservoir types sealing tested: cement/thick (4 mm) rubber tarpaulin thin (1 mm) plastic sheeting/ self-sealing	The thin plastic sheeting as reservoir sealant was found to be the lowest cost strategy under local labour conditions. The WH system is economically viable if combined with improved soil fertility management (i.e fertilizer application)
FR	**Ganaba, S.**	2005	Burkina Faso **(Dori station, annual rain: 461mm/ Sebba station, annual rain : 515 mm (period :1992 to 2003)**	Soil storage	Runoff/rainfall	Half-moon, stones lines, stones dykes, Tied ridge	Perenial vegetation associated: *Acacia nilotica, Acacia tortilis, Balanites aegyptiaca, Leptadenia hastata, Ziziphus mauritiana.*	Study based on 2 floristic inventories: August-september 1999-2003 6 agropastoral units: Falagountou, Sampelga, Kabo-Gountouré, Boundoré, Koréa and Dori Nord.	Half-moon + sub-soiling: great density and floristic composition (greater repartition of humidity in the soil than other combination of techniques)
EN	**Kablan, R. et al**	2008	Mali **(Sudanian annual rain: 500 to 1300 mm)**	Soil storage in-situ/groundwater recharge	Rainfall/runoff	*Amenagement en courbe de niveau* (developed by the Institut d'Economie Rurale (IER) and CIRAD) (Gigou et al., 2006)	Permanent ridges :1m wide/ height 0.5 m + waterways to drain excess of water	2 years study (2003-2004) 1 site: Siguidolo village (Konobougou) Soil type: Alfisols ACN and no-ACN comparison	ACN soil profile stored 17% more water on the average than no ACN in 2003. The deeper layer (horizon 80-160 cm) was found to have an higher moisture content.

1. Micro-catchment methods to collect water at farm and field level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Al Ali, Y. et al**	2008	Tunisia **(annual rain of 366 mm (1993-2006)**	Soil storage in-situ/ groundwater recharge	Runoff	*Contour bench*		2 year study (2004–2006) 1 site, located in the El-Gouazine watershed: 2 terraced plots (3000 m2) with 2 modalities: 1 left fallow (several years) 1 was tilled.	Ploughing in combination with contour bench reduced runoff by 75% but erosion per millimetre of runoff was about twice as much on the tilled soil as on the fallow.
EN	**Barry, B. Olaleye, A.O. Zougmoré, R. Fatondji, D.**	2008	Burkina Faso **(Kirsi: Sub-sahelian Saria: North Sudanian)** Niger **(3 sites rain: 500 to 700 mm)**	Soil storage in-situ	Runoff	Zaï/tassa,stone row,grass strips, half-moon	*Zaï* construction is hard work and is done by hired labor at the rate of 5 FCFA/hole. 79 380 F/ha (mean distance of 0,8 m)	3 sites in each country Burkina Faso (Kirsi, Saria and Pougyanou) Niger (Sadore, Damari and Kakassi)	Comparison between Water Use efficiency of WC techniques combined with additional treatments (compost,mulching,fertilizer, manure) The smaller the spacing between stone rows, the higher the organic carbon content and higher the water holding capacity. Zaï technique with manure significantly improved water use efficiency the 3 sites (Niger)
EN	**Previati, M. et al**	2009	Tunisia **(annual rain : of 300 mm, 35 years)**	Soil storage In-situ	Rainfall/Runoff	Micro-basins (soil and stones walls)	Slopes between 5 and 33% and vegetation cover between 1 and 20%. Micro-basins areas: 7 to 33 m2. Precisions on tillage	January to December 2003 Hilly region of Central Tunisia 15 farm with micro-basins 15 soil profiles/3 depths per set of soil. 4 different soils (Cambisols,Kastanozems, Arenosols, and Calcisols).	Water stock higher inside the micro-basins than outside the micro-basins (variations due to the soil type and seasons). Cambisols (fine particules) are the most interesting (water stock of 30% is measured).The Kastanozems soils presented no advisable benefits in water storage capacity.
EN	**Sanou,J. Zougmoré, R. Bayala, J and Teklehaimanot, Z.**	2010	Burkina Faso **(Sudanian, annual rain : 800 to 1000 mm)**	Soil storage in-situ	Rainfall/Runoff	Boundary tree planting		Dry season and wet season 2007 1 site : Farmed parkland at Nobére (100 ha) 8 isolated trees of each 2 species selected randomly	Soil infiltrability found to be higher below the edge of tree crowns. Soil infiltrability increased from tree trunks to crown edges (compaction factor) field. Trees on farms help to conserve soil moisture by increasing soil infiltrability in the area at the edge of tree crowns.

1. Micro-catchment methods to collect water at farm and field level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Kagamebga, W. F.**	2011	Burkina Faso **(North Sudanian, annual rain: 700 to 900 mm)**	Soil storage in-situ	Rainfall/Runoff	Half-moon, sub-soiling, Zai		2 years period Gampela (near Ouagadougou) 2 sites : 2 fields trial 10 treatments	Half-moon technique was found to produce a significantly higher growth and survival rate. The most effective measure between sub-soiling and Zai.
FR	**Keddal, H.**	2011	Morroco	Cisterns	Rainwater	Rooftop systems	Systems with underground cisterns	Technical overview of various rooftop systems	Costly.
FR	**Kharmouch, M.**	2011	Morroco **(Sub-humid, annual rain 600 to 800 mm)**	Soil storage in-situ	Runoff	Earth dike (*banquette de terre*)	Fruit species on planted on the bund.	1 site: Taliouk (province of Khémisset)	
FR	**Nrhira, A.**	2011	Morroco **(Arid, annual rain : 100 to 400 mm)**	Cisterns/ basins	Rainwater	Matfia/Khattara	Maftia are placed inside or outside the house	Souss-Massa-Draa Region	Systems realised for domestic use and cattle but also small scale irrigation. Métfias/Khetara repartition map (region).

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2. Macrocatchment methods to collect water at the watershed level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
FR	**Roose,E.**	1991	Burkina Faso/Mali **(Soudan-Sahelian, annual rain : 600 to 1200 mm)**	Soil storage in situ	Runoff	Diversion terraces, micro-dams	Inventory of existing techniques and critical analysis.	Plateau Mossi and Ziga (Burkina Faso) région de Koutiala (Mali)	Critical analysis of case studies. In the Soudan-Sahel zone. Permeable micro-dams lead to the natural formations of progressive terraces are better adapted to reduce erosion and conserve water than diversion terraces.
FR	**Roose,E.**	1991	Burkina Faso **(Soudan-Sahelian, annual rain : 600 to 1200 mm)**	Soil storage Ex-situ/ Ground-water recharge	Runoff/rainfall	Hill-barrage (without outlet) (*Barrage collinaire*)	Supplemental irrigation	1 site : Ziga	Used within the community to water cattle and to irrigate small gardens.
FR	**Ennabli, N.**	1993	Tunisia **(centre: annual rain 200 to 400 mm)**	Conveyance structures	Ground water	*Galleries filtrantes*	Only one earthen canal still functional and enhance to divert the water from the gallerie to garden (Thélepte)	1 site: Bou HAYA	Systems disposed under a sandy river bed (Oued). Technique similar to undergrounds dams in gabions with pumping device such as in Burkina Faso and Sénégal).
FR	**Ennabli, N.**	1993	Tunisia **(South, annual rain < 200 mm)**	Soil storage Ex-situ	Runoff	*Jessours*		1 site: Matmata region (south-ouest of Tunisia)	
FR	**Ennabli, N.**	1993	Tunisia/ Sahel **(centre: annual rain 200 to 400 mm)**	Conveyance structures	Runoff	*Seguia*	Bring water to field (cf meskat)/ convey water from Oasis	Source of Torzeur-Nefta	Water from different sources are conveyed to a unique place by Seguia: *cuvette de rassemblement* (collection)
FR	**Ennabli, N.**	1993	Tunisia **(centre: annual rain 200 to 400 mm)**	Conveyance structures	Ground water	*Foggaras*	Inflitration losses around 10 to 20% of the total discharge drained (mostly located in the downstream part of the system).	2 sites: Oasis d' El Guettar (800ha, alimented by 60 foggaras) and Souk El AHAD (Kébili)	Systems abandoned since the aquifer recharge was not sufficient. Hard labour to construct but systems were very efficient.
FR	**Dridi, B. et al**	2001	Tunisia **(centre: annual rain 200 to 400 mm)**	Soil storage in-situ/ reservoir	Runoff	Contour ridges, hill reservoir (*reservoir colinaire*)		1 site: Merguellil catchment (central tunisia)	Mean storage capacities of areas with hillside reservoirs (38 mm) and contour ridges (85 mm) . More than 90% of the runoff is retained in contour ridges-controlled areas.
FR	**Gadelle, F.**	2001	Various countries	Soil storage/ GF recharge	Runoff	Dykes (*digue de bas fonds*)	Enhance rice cultivation + cash crops		> 1 m high with spillway (cement) Widely spread in Sahelian countries

2. Macrocatchment methods to collect water at the watershed level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Fonteh, M. and Nji, A.**	2001	Cameroon **(Sahel, annual rain 967 mm)**	Soil storage In-situ	Runoff	Micro sand dams	In lowland area	Mandara Mountains region	Very little maintenance
EN	**Fonteh, M. and Nji, A.**	2001	Cameroon **(Sahel, annual rain 967 mm)**	Reservoir	Rainfall\ runoff	Rock bed	For domestic consumption.	3 isolated villages of the Mandara Mountains around Mokolo (Mayo Tsanaga Division)	Expensive.
EN	**Fonteh, M. and Nji, A.**	2001	Cameroon **(Sahel, annual rain 967 mm)**	Ground water recharge	Stream flow/runoff	Check dams	Wells are constructed downstream the dam.	Mandara Mountains region	Between 1985-1995 a total of 753 biefs were constructed in the Mandara Mountain region (*Charniaux, 1995*)
EN	**Nasri, s. et al**	2004	Tunisia **(Centre, annual rain : 141 mm, period 1935-1996)**	Soil storage Ex-situ, tank	Runoff	*Tabias* + Cistern	Average slope of the catchment 9%, cistern equipped with an overflow outlet. System placed at the foothill or piedmont.	4 years study (1995–1999) 1 site: Bou Hedma catchment (district of Mezzouna) 4 tabias systems in cascade 1 cistern (35 m3, 1/3 in the slope, catchment area for this cistern is 3 ha) used for watering cattle + domestic uses.	Efficiency of the local surface runoff water collection of the system was significantly high. The water stored behind the *tabias* infiltrates in two or three days and recharges the soil water storage. This traditional system of soil banks installed in a 0.26 km2 catchment reduced the runoff to almost zero.
FR	**Nasri, S. Lamachère, J. M. Albergel, M.**	2004	Tunisia **(annual rain of 366 mm, 1993-2006)**	Soil storage Ex-situ	Runoff	Contour benches (*banquette de terre à rétention totale*)	Average lenght: 100 m; average heigh: 1,50 m; distance between: 25 m. Surface sub-catchement implemented with the measure: 43 %. Maximal retention capacity of the measure: 260 000 m3	1994-2000 1 site: d'El Gouazine watershed (18,1 km2). Model for 12 flooding event.	Runoff coefficient after implementation of contour benches, 1 à 3 % (20% to 30% before) for rainfall between 30 et 50 mm. The global runoff coefficient range from 1 to 9 % for autumn flood (september/october) and from 0,3 to 0,6 % for the winter and spring flood events (november to may).
EN	**Ouessar, M. et al**	2004	Tunisia **(South, annual rain: 150 to 230 mm)**	Various	Various	Terraces, Tabias, Gabions, Jessours, Cisterns, Recharge wells		1 site: Oued Oum Zessar watershed Summary of WHT in the study sites and economic analysis of these techniques.	Gradual increase in the infiltration volume to the aquifer as a function of the progress of the water harvesting works implementation. In 1975, the watershed renovated partially: GF recharge : 285L/s. In 2000, strategies implemented GF recharge: 447L/s.

2. Macrocatchment methods to collect water at the watershed level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Schiettecatte et al**	2005	Tunisia **(Monthly rain: 0 to 40 mm, period 1969–2000)**	Soil storage Ex-situ	Runoff	Jessours	Impluvium (80 000 m2) Terrace (2750 m2)	3 years water balance assesment 1 site : Wadi Oum Zessar watershed Amrich jessr Olive trees Field Rainfall simulation: inflitration and sediment transport. Runoff and erosion estimation.	Jessours important role in reducing transport of water/sediment. Dry years technique very efficient for olive trees. Off-site impact may be decreased by reducing the (CCR) ''catchment-to-cropping ratio'' by constructing a downstream terrace which collects part of the runoff overflow from the upstream terrace. For an average annual rainfall of 235 mm, CCR should be at least 7.4.
EN	**Mekki, i et al**	2006	Tunisia **(North, annual rain: 450 mm, 90 years)**	Reservoir	Runoff	Dam, hill reservoir	Reservoir area: 3.7 ha (storage capacity: 145 000 m3)	Monitoring overland flow and blue water production during 2 cropping seasons (2000-2002) Cap Bon, north east of Tunisia 1 site: Kamech catchment-hill reservoir (2.6 km2) Intensive agricultural activity 11 plots with various land use and soils (4 types)	The water harvesting capacities (blue water production) for a farmed catchment in semi-arid areas, is function of land use and management practices (proportion of surface runoff and soil infiltration will vary).
FR	**Nasri, s.**	2007	Tunisia **(annual rain of 366 mm, 1993-2006)**	Soil storage in-situ	Runoff	Contour benches (*banquette de terre à rétention totale*)	Slope < 25% Maximal retention capacity : 228 m3 /100 m	9 years impact monitoring (1997–2006) 1 site : El Gouazine watershed 14 contour bench in cascade (2.48 ha) Assesment of 2 modalities for inter-row: Fallow/culture	After 9 years of implementation: 31% reduction of the initial stocking capacity (siltation canal upstream of contours benches + mechanical erosion). To avoid overflow, weirs with dry stones (or cemented) should be placed on the contour bench.
EN	**Baccari, N. et al**	2008	Tunisia **(annual rain of 366 mm, 1993-2006)**	Soil storage in-situ	Runoff	Contour benches (*banquette de terre à rétention totale*)		8 years monitoring 1 site: El Gouazine watershed (18,1 km2)	After 8 year of implementation: Average risk of bench breakage (21% or 1.5 breaks/km) 3 main causes: -Presence of gypsum clay (8.5 breaks /km); -Hydrographic network (80% of breaks on or near the network); -Very high slopes, greater than25% (3.5 breaks /km).

2. Macrocatchment methods to collect water at the watershed level

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Giovanni, F. et al**	2008	Mali **(Sahel, annual rain 129 mm)**	Ground water recharge	Runoff	Underground dams/sub-surface dams	Gabions advantages: cheap, easy to make ubiquist for soil type.	1 site selected/17: region of Kidal Satellite image/remote sensing	Apart the methodology of selection, this article presents 2 examples of small dams in the Kidal region: Underground dam (gabions in Tedeini) and mixed structure underground+ surface dam (stones + cement mortar).
EN	**Abouabdillah, A. et al**	2010	Tunisia **(centre: annual rain 200 to 400 mm)**	Soil storage in-situ/ reservoir/ ground water recharge	Runoff	Reservoirs, dams, contour ridges, inter-row		1 site: Merguellil catchment Simulation of actual water balance using SWAT-2005 model including the water harvesting systems. 2 senarios generated: -contour ridge removal (impact assesment) -olive tree planting (between contour)	Contour ridges contribute to the retention of high quantity of sediment+ surface runoff reduced by 32 %. Planting the olive trees between contours could improve its yield.

2. Macrocatchment methods to collect water at the watershed level

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3. Flood water harvesting methods

EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
FR	**Ennabli, N.**	1993	Tunisia **(Arid to semi-arid)**	Conveyance structures	Stream flow	Mgoud	Flood diversion dike	4 regions: Plaine de Gamouda, Gatis Gafsa and le Kairouanais	
FR	**Ennabli, N.**	1993	Tunisia **(centre: annual rain 200 to 400 mm)**	Soil storage Ex-situ/ Groundwater recharge	Stream flow	Chereb (*épandage direct*)	Natural without infrastructures (located in upstream part)	Present from Ceddada to Djebel Hediffa	Natural zone located at the inlet of gullies (expansion zone) which divert storm water to fields: low-cost.
FR	**Ennabli, N.**	1993	Tunisia **(centre: annual rain 200 to 400 mm)**	Soil storage Ex-situ/ Groundwater recharge	Stream flow	Seguis (*épandage direct*)	Natural without infrastructures (located in lowland part). Ideal slope (3 m/m) with regular shape.	Gafsa zone: ségui de Mehamlet (Sebkat Sidi Mansour ect tributary) + Djebel Orbata	Plains located between 2 mountainous entities which divert storm water to fields. Technique with a lot of potential in the country: low cost and few labour
FR	**Gadelle, F.**	2001	Various countries	Soil storage Ex-situ/ Groundwater recharge	Stream flow/runoff	Spate irrigation (*inondation dirigée*)	For short flood	Description of the technique	
FR	**Gadelle, F.**	2001	Niger **(Sudano Sahelian)**/ Mali **(Sudanian)**	Soil storage Ex-situ	Runoff	Stone-weirs (*seuil d'épandage*)	The weir can divert the entire flow	Koré (Niger) Yélimané (Mali)	Costly compare to the efficiency.
FR	**Gadelle, F.**	2001	Mostly Mauritania	Soil storage Ex-situ/ Groundwater recharge	Stream flow	Flood plain inondation (*Barrage de retenue*)		Description of the technique	

3. Flood water harvesting methods

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4. Atmospheric water harvesting methods

FR/EN	Authors	Year	Location	Buffer	Water source	WHT	Remarks	Methods/sites	Results
EN	**Marzo, M,V. Sánchez Megía,J,L.**	2008	Morroco **(Desert, annual rain < 150 mm)**	Tank	Fog water	Fog collectors (standard type)		18 months analysis Ifni region of Morrocco (Tiznit province) 2 mountainous sites -Boulaalam (300 m a.s.l) -Boutmezguida (1,225 m a.s.l.) 4 Fog collectors	The results show that it is possible to obtain an average of 7.1 l/m2/day at the inland site whereas only 1.9 l/m2/day on the coast.

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5. Soil moisture conservation methods

FR/EN	Authors	Year	Location	Buffer	Water source	SWC	Remarks	Methods/sites	Results
FR	**Ennabli, N.**	1993	Tunisia **(Centre annual rain: 200 mm)**	Soil storage in-situ	Rainfall/runoff	*Le Nark*	*Nark's* fields are surrounded by little walls (cement, 1 to 1,5 m) to avoid lateral runoff.	Site: Kerkenah islands Annual rainfall 200 mm Shallow soil layer (up to 1 m) the deeper layer is a loam crust (0,2 to 0,6 m) which limit agricultural practices. Farmers brake the loam crust + add earth to create a planting pit (1X1X1 m): Vineyard/ Fig tree.	The tree is not limited anymore to develop its root system + limitation of evapotranspiration (EP). To reduce entirely the EP farmers can use dry algae on the top the *Nark* (screen protection).
FR	**Ennabli, N.**	1993	Tunisia **(Centre annual rain: 200 to 400 mm)**	Soil storage in-situ	Rainfall/runoff	*Le tombeau de Zaafrane + Tabias*	Species with high economic value : Figuier de Barbarie (Prickly pear cactus)	Zaafrane Region, S-W of Kairouan Technique works better in sandy soils Hole (*Tombeau*) dimensions (0,5X1,5X0,5 m), a layer of 0,2 m thick of cactus is realized. Impluvium is made (few m2) around the *tombeau* to trap runoff water.	Figuier de Barbarin (Cactus inerme) consolidates the Tabias, plays also the role of hedgerow system, fence (cattle), traps and collects the rainfall and limits the runoff and erosion. Food for cattle and population.
FR	**Ennabli, N.**	1993	Tunisia **(Desert, annual rain: 20 to 100 mm)**	-	Groundwater	*Le Ghout*	Widespread in the Souf region	Souf Region (desert) Digging the sandy soil close the aquifers in order to plant Date palm: basin creation.	Roots of species go easily in the ground until they reach the groundwater level. The groundwater depth (7 to 15 m) + mobile aquifer to be efficient. High level of maintenance to avoid the siltation by the sand: high labour activities.
FR	**Ennabli, N.**	1993	Tunisia **(Arid to semi-arid)**	-	Groundwater/ rainfall/runoff	*Le Garaat*	Lowland with various dimensions (generally rounded shape)	Various sites: Sejenane (N-W), Ichkeul (N-E), Zaafrane (in Kef), Tarf Echna (Bou Arada). The *Garaat* has no fixed size: the rainfall + runoff + aquifer depth will delimit the contour. A central core and fields surrounding (up to 100 km2)	In dry period the contour of the *Garaat* is highly productive cereals especially (20 to 30 q/ha) + grazing land. In humid period, the area of the *Garaat* can be X 10 and the yield doubled. This system has an important economic value.
FR	**Belemvire.A et al**	2008	Burkina Faso **(Sub-Sahel)**	Soil storage in-situ	Rainfall/runoff	*Jachère protégée* (Protected fallow)	Description of the technique in plateau	Fallowing enhance the protection of a site from human disturbances: regeneration of the vegetation cover and modification of the vegetation structure.	In the central Plateau of Burkina Faso, this technique is not well expanded due to the high population density of the region, farmers does not have enough field to implement the measure. (Sawadogo, H.,2011)
FR	**Belemvire.A et al**	2008	Burkina Faso **(Sub-Sahel/ North sudanian)**	Soil storage in-situ	Rainfall/runoff	*Régénération naturelle assistée (RNA)*	Description of the technique	Management of trees and shrubs (useful species for populations). Reconstitution of the vegetation covers on fields.	Trees and shrubs contribute to decrease the runoff discharge and reduce soil erosion. Diversification of income for local population but hard work for maintenance. Adoption rate low: 31% (Ouédraogo et Lompo, 2006).

5. Soil moisture conservation methods

FR/EN	Authors	Year	Location	Buffer	Water source	SWC	Remarks	Methods/sites	Results
FR	**Sawadogo, H.**	2011	Burkina Faso **(Sub-Sahel/ North sudanian)**	Soil storage in-situ	Rainfall/runoff	*Le paillage* (mulching)	Description/ applicability of the technique	Covering the soil with a layer of 0,2 m of dry vegetation (3 to 6 t/ha) Vegetation used generally: *Loudetia togoensi* and *Butyrospermum parkii.*	Technique simple + easily implemented by local farmers. Enhances fertilization of soil coupled to the termite's action: higher porosity and permeability in soil. Reduces runoff with the layer of vegetation but more exposition to parasites. Adoption rate in Plateau central region: 34% (Ouédraogo et Lompo, 2006)
FR	**Sawadogo, H.**	2011	Burkina Faso **(Sub-Sahel/ North sudanian)**	Soil storage in-situ	Rainfall/runoff	*Le billonnage* (Ridging)	Description/ applicability of the technique	Technique to prepare the soil in *billons* in order to make plant cultivation at the top. Most of the time mechanization is necessary, also could be done by hand-made.	Advantages: Economy of labour + increase in fertility of properties for the soil: OM + manure concentrated close to the plant. If the *billons* are placed toward the wind direction: limiting the wind erosion.
FR	**Sawadogo, H.**	2011	Burkina Faso **(Sub-Sahel/ North sudanian)**	Soil storage in-situ	Rainfall/runoff	*Le sous-solage* (Sub-soiling)	Description/ applicability of the technique	Technique to break the crust of the top-soil layer (silted) to increase the inflitration capacity. Depth: 0,15 m according the level of farmer equipment (0,3 m according to Vlaar,1992) Technique often associated with contour bench.	Maintenance: Annual labour to conserve infiltration properties. Technique easily adaptable in all Agro-climatic regions + high or low slopes terrains with stable soils (sandy soil less recommended) Advantage: allow the possibility to use this method in dry period. The limiting factor is the mechanization (tractor is not owned by a lot of farmers).
FR	**Sawadogo, H.**	2011	Burkina Faso **(Sub-Sahel/ North sudanian)**	Soil storage in-situ	Rainfall/runoff	*Le scarifiage* (scratching)	Description/ applicability of the technique	Scratching the first layer of top-soil by using a mechanical method. Soil preparation + weed control	A regular scratching during the growing season avoids the development of weeds and increases temporarily the infiltration capacity of the soil. This technique is applicable and effective for light soils. Advantage of the technique: time saving to realize + labour input acceptable.

5. Soil moisture conservation methods

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4. Summary of Water Harvesting Techniques by country

Table 3: Summary of WHT's found in Tunisia

Technique	Watershed Suitability			Function			
	Upper	Middle	Lower	Soil conservat	Recharge	Retention	Reuse
Hoffra		●	●	●	●	●	
Banquettes en terre à extrémité déversantes	●	●		●	●	●	
Bourrelets		●		●		●	
Enclos-Tabias			●			●	
Mescat		●		●	●		
Majel/ Fesquia (cisterns)		●	●			●	
Contour bench	●			●	●		
Micro-basins	●	●				●	●
Jessours	●			●	●		
Galleries filtrantes			●				●
Seguia		●					
Foggaras			●		●		●
Contour ridge	●	●		●	●	●	
Reservoir collinaire	●					●	●
Digue de bas fonds			●		●	●	
Banquette de terre à rétention totale	●	●		●		●	
Terraces	●	●		●	●		
Recharge wells			●		●		●
Inter-row system		●	●	●	●		
Mgoud		●					
Chereb (épandage direct)	●				●		●
Seguis (épandage direct)			●		●		●
Spate irrigation (*inondation dirigée*)		●			●		●

Table 4 : Summary of WHT's found in Burkina Faso

Technique	Watershed Suitability			Function			
	Upper	Middle	Lower	Soil conservat	Recharge	Retention	Reuse
Cordons pierreux	●	●		●	●	●	
Diguettes filtrantes				●	●		
Hedgerow barrier	●	●			●		
Boulis	●	●	●			●	●
Zai		●	●	●	●	●	
Billons cloisonnés	●			●		●	●
Demi-lunes		●		●		●	
Diguettes en terre	●	●		●		●	
Fossé ados	●			●		●	●
Muret	●	●	●	●	●	●	
Reservoir	●	●	●			●	●
Grass strips	●			●		●	●
Tree planting	●	●		●			
Diversion terraces	●	●		●		●	
Micro-dams	●	●		●	●	●	
Reservoir collinaire	●				●	●	●
Spate irrigation (*inondation dirigée*)		●				●	

Table 5: Some WHT's found in Morocco

Technique	Watershed Suitability			Function			
	Upper	Middle	Lower	Soil conservat	Recharge	Retention	Reuse
Roof top harvesting systems		●	●			●	●
Banquette de terre	●	●		●		●	●
Matfia/Khattara (Cisterns)		●	●			●	●
Fog collectors	●					●	●

Table 6: Some of WHT's found in Cameroon

Technique	Watershed	Function

	Suitability						
	Upper	Middle	Lower	Soil conservat	Recharge	Retention	Reuse
Micro sand dams			●	●	●	●	●
Rock bed	●	●	●			●	●
Check dams	●	●		●	●		

Table 7: Some of WHT's found in Mali

Technique	Watershed Suitability			Function			
	Upper	Middle	Lower	Soil conservat	Recharge	Retention	Reuse
Underground dams		●	●		●	●	●
Sub-surface dams	●	●	●		●	●	●
Stone-weirs (*seuil d'épandage*)		●	●	●		●	●
Barrage de retenue	●	●	●	●		●	●

5. Conclusion

We reviewed 34 different sources and we inventoried a total of 57 techniques (respectively 47 WHT and 10 SWC techniques) which are applied by local communities in the two francophone countries (study sites) of the WAHARA project (Tunisia and Burkina Faso). This literature review shows that those countries have a large set of actual and indigenous knowledge concerning Water Harvesting Technologies and a great potential of adaptability throughout Africa. There is a need to find more data concerning the cost of those technologies in order to better argue on the feasibility of implementation. Moreover, the adoption rate of each WHT is also an important parameter to take in consideration for the up-scaling process of the technologies.