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Opportunities and Challenges for Groundwater Artificial Recharge by Surface Water Harvesting in Libya

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Abstract: This paper discusses the surface water harvesting in Libya, the opportunities and challenges and obstacles faced during investment and development in this field. The research was based up on limited relevant literatures from water institutions, even of wide interest of Libyan water institution but the lack of their integration make the data collection is not easy. Libyan experience in groundwater artificial recharge by surface water harvesting was discussed, which are mostly related to direct percolation from the lakes of the constructed dams. In addition the suitable sites for groundwater artificial recharge were also proposed in this paper.

Key words: Water Harvesting · Artificial Recharge · Libya

INTRODUCTION

Libya, lies on the north coast of Africa as indicated in Figure (1), between Egypt to the east, Tunisia and Algeria to the west and Niger, Chad and Sudan to the south; while to the north it is bounded by the Mediterranean Sea. It has an area of 1,759,540 km^2.

Climate: In Libya the climatic conditions are influenced by the Mediterranean Sea to the north and the Sahara desert to the south, resulting in an abrupt transition from one kind of weather to another. The following broad climatic divisions can be made [1]:

- The Mediterranean coastal strip with dry summers and relatively wet winters;
- The Jabal Nafusah and Al Jabal Al Akhdar highlands experiencing a plateau climate with higher rainfall and humidity and low winter temperatures, including snow on the hills;
- Moving southwards to the interior, pre-desert and desert climatic conditions prevail, with torrid temperatures and large daily thermal variations. Rain is rare and irregular and diminishes progressively towards zero.

Fig. 1: Libya Location map

Precipitation is low and the vast majority of the country is desert as in Figure (2), only a few areas in Libya have sufficient precipitation (above 200 mm per year on average) to allow agricultural use. These areas are located in the north, with focus in two distinct regions, Tripolitania in the west and Cyrenaica in the east.

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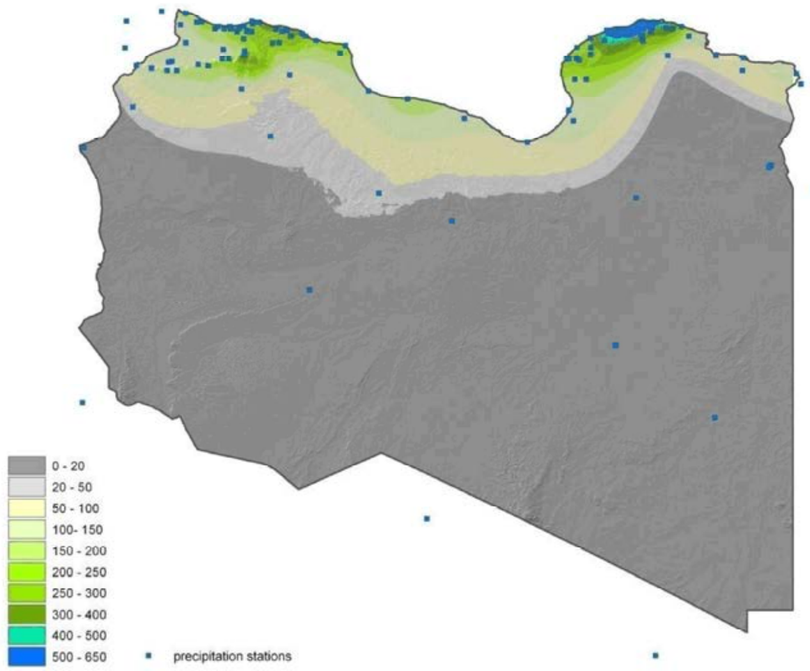

Fig. 2: Average annual precipitation in Libya [2]

The spatial pattern of precipitation is one of very fast decline from north to south. Most of the precipitation falls in late autumn, winter and early spring and shows high variability from year to year [2].

Water Resources: One of the serious problems that many countries are facing today is water shortage; even though over 70% of the earth surface is covered by water. In the last few years, domestic water shortage has increased worldwide. This is due to the increase in the overall water demands and competition among the various consuming sectors resulting from rapid population increase and change of consumption patterns due to rising standards of living standard [3].

Libya is located in one of the driest and semi-driest regions in the world, with small total annual rainfall and high evaporation rates. No significant surface water resources are available; groundwater is the main source of water. On the other hand, Libya population growth rates are among the highest in the world [4], which is associated with escalating water demands for domestic and municipal usages, as an input in the other productive activities, such agriculture and industry. The Large increases in water demand with very little recharge have strained Libya's groundwater resources resulting in serious declines in water levels and quality, especially along the Mediterranean coast where most of the agricultural, domestic and industrial activities are concentrated [3].

Surface runoff resulting from winter storms is less than 200 Mm^3/yr. Along with direct infiltration from rainfall; wade runoff contributes to the recharge and coastal and inland aquifers by an estimated annual volume of 650 Mm^3. About 60 Mm^3 are yearly accumulating behind dams for direct agricultural, industrial and domestic uses. Generally, however, surface water represents less than 3% of total water use in the country. Groundwater on the other hand accounts for more than 97% of water supply for all purposes. Aquifer systems varying in age from Cambrian to Quaternary underlie practically all the surface area of the country at different depths that could exceed 1000 m below surface. Few of these aquifers are renewable, while those belonging to the great sedimentary basins in the central and southern parts are not renewable at present. Their exploitation is in fact a mining process that takes into consideration both hydro-geological and economic constraints [4].

Water Harvesting: Water harvesting has been an indigenous practice in Libya since hundreds of years [2].

Table 1: Total capable for storage [7]

Area	Total capable for storage Mm^3	Controlled In 1977 Mm^3	Controlled in 2009 Mm^3	Expected to be Controlled in the future Mm^3
Jiffara Plain	87	10.10	25.50	47.30
Musrata Al Khomas	27	13.50	17.40	20.76
Ghdams Basin	16	-	-	13.10
Central Libya	3	0.90	1.80	2.10
Al Jabal al Akhdar	45	13.60	15.95	35.90
South Al Jabal Al Akdar	11	-	-	-
Tobrock	11	-	-	1.35
Total	200	38.10	60.65	120.51

Table 2: The constructed dams in Libya [7]

No	Wadi	Area	Reservoir capacity Mm^3	Average annual design storage Mm^3 year
1	Wadi Mejenin	Bin Ghasheer	58	10
2	Wadi Kaam	Zliten	111	13
3	Wadi Ghan	Giryan	30	11
4	Wadi Zaret	Rabtah	8.6	4.5
5	Wadi Lebda	Alkhoumes	5.2	3.4
6	Wadi Qattara	Benghazi	120	12
7	Wadi Qattara II	Benghazi	1.5	0.50
8	Murqus	Ras Al Hilal	0.15	0.15
9	Bin Jawad	Bin Jawad	0.34	0.34
10	Zaza	Tukrah	2	0.80
11	Derna	Derna	1.15	1.0
12	Abu Mansur	Derna	23.7	2.0
13	Wadi Tabrit	Zliten	1.6	0.50
14	Wadi Al Thiker	Zliten	2.4	0.50
15	Wadi Jarif	Sirt	2.4	0.30
16	Wadi Zabid	Sirt	2.6	0.50
17	Wadi Zahawuiyah	Sirt	2.2	0.70
18	Wadi Shouka	Jufrah	3.65	0.20
Total			376.49	61.39

Table 3: Dams on contract for construction in Libya [7]

No	Wadi	Area	Reservoir capacity Mm^3	Average annual design storageMm^3 year
1	Wadi Bu Shyba	Giryan	5.5	2.58
2	Wadi Ar Ruman	Giryan	3.75	1.4
3	Wadi Tlal	Sirt	8.7	-
4	Wadi Al Hammar	Benghazi	19.5	5.85
Total			37.45	9.83

Since the Roman times water harvesting techniques were applied extensively in North Africa. Archeological research by the UNESCO Libyan Valleys team revealed that the wealth of the "granary of the Roman empire" was largely based on runoff irrigation [5]. The team excavated structures in an area several hundred kilometers from the coast in the Libyan pre-desert, where the mean annual precipitation is well below fifty millimeters. The farming system here lasted well over 400 years and it sustained a large stationary population, often wealthy, which created enough crops to generate even a surplus. It produced barley, wheat, olive oil, grapes, figs, dates, sheep, cattle and pigs. The precipitation is variable, falling in just one or two rain storms, often separated by droughts several years long. (There is no evidence of climatic change since Roman period [6].

Due to the water resources scarcity, Libya was invested in the development of the surface water resources where seven areas as indicated in Table (1) selected as areas that capable for storage by water harvesting. Numerous institutions was involved, the main was Libyan General Water Authority (GWA) which carried out many action plans regarding studying, design and construction of water harvesting as shown in the Tables (2,3,4 and 5).

Table 4: Proposed dams in [7]

No	Wadi	Area	Reservoir capacity Mm^3	Average annual design storage Mm^3 year
1	Wadi Al Khalij	Derna	5	2.5
2	Wadi Al Mualaq	Derna	6	3
3	Wadi Ashahbuon	Trahuna	3.3	1.02
4	Wadi Az Zgadnah	Trahuna	1.9	0.62
5	Wadi Turgut	Qarabouli	8.4	2.08
6	Wadi Qraim	Qarabouli	2.6	0.62
7	Wadi Ghanima	Qarabouli	2.4	0.63
8	Wadi Bani Walid	Bani Walid	10.40	7.20
9	Wad Atmisalah	Bani Walid	9.3	3.25
10	Wadi Mansour	Bani Walid	4.25	1.80
11	Wadi Mimon	Bani Walid	3.40	0.85
12	Wadi Nalut	Nalut	5.90	1.25
13	Wadi Bu Ar Rasef	Al Hrabah	15.00	2.28
14	Wadi um Al Qrab	Ar Hybat	10.00	1.55
15	Wadi Jenawen	Jadou	5.00	0.89
16	Wadi Tobrock	Tobrock	2.35	1.35
17	Wadi Swakh	Giryan	6.00	2.60
18	Wadi Bu Aysha	Giryan	2.80	1.30
19	Wadi Al Bab	Benghazi	31.30	8.80
20	Wadi Sirt-Bin Jwad	Sirt	1.25	1.25
Total			136.55	44.84

Table 5: Main aquifer characteristics of Al Jabal Al Akhdar (GWAE, 2002)

Aquifer	Average Depth below the ground level meters	Main constitutes
Quaternary	From 10 to 50	Fluvial deposits
Miocene	From 100 to 150 meters	Marly limestone
Oligocene	From 200 to 250 meters	Calcarenitic limestone
Eocene	From 250 to 350 meters	Nummlitic limestone
Upper cretaceous	From 250 to 350 meters	Dolomitic limestone

The Wadies considered as priority in the construction of dams for water harvesting those their runoff is flow to the Mediterranean Sea the objectives of water harvesting are as follows:

- Harvesting water before it reaches the sea
- Protect cities and villages, residential and agricultural and industrial projects of the dangers of floods
- Exploitation of water that can be harvested in agricultural and domestic purposes
- Protect the soil from erosion
- Artificial recharge of the groundwater.

To achieve the above objectives GWA has constructed major dams on the most important wadies in Libya with total storage capacity of 389 Mm^3 and the average annual storage volume of about 6 $Mm^3$of water as indicated in Table (2). Also GWA has finished and design and contracted for the construction of other dams as shown in Table (3) also expected an action plan for study and implementation of dams on other wadies as indicated in Table (4).

Also there were many initiatives and actions plans related to surface water harvesting in Libya were proposed. The most recent is the agreement of cooperation between the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Agricultural Research Center (ARC) in 2007 to boost collaboration for five years through the support of a trust fund from Libya to launch an integrated program of research-for-development in Libya covering three major areas water harvesting, improving cereal productivity and improving small-ruminant productivity [2] and even Rainwater harvesting has been practiced but its contribution to domestic water supply has been very limited [8].

Libyan experiences for the artificial of the groundwater is limited only in the construction of dams as shown in figure (3) the Schematic of type of artificial recharge in Libya, from example in Qattara dam in Cyrenaica province Figure (4) and Kaam dam in Tripolitania province Figure (5) despite the lack of periodical periodic monitoring for groundwater quantity and quality, the field investigations and questionnaires

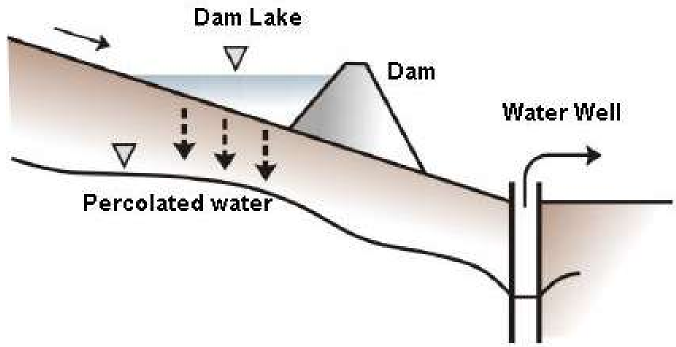

Fig. 3: Schematic of type of artificial recharge in Libya [9]

Fig. 4: Wadi Qattara

Fig. 5: Wadi Kaam

from farmers and stakeholders indicated the changes that have occurred in the groundwater after construction of dams and during rainy seasons.

Possible Sites for Artificial Recharges: There are many factors to be considered when determining if a particular site will be receptive to artificial recharge and each artificial recharge technique has its own characteristics and thus, the method of site determination will differ from other techniques [10]. The most important criteria for the suitable sites of groundwater recharge is the precipitation, the amount of the runoff, slope and type of the rocks, Tertiary and upper Cretaceous carbonate rocks are the main constitutes of the aquifers in Al Jabal Al Akhdar

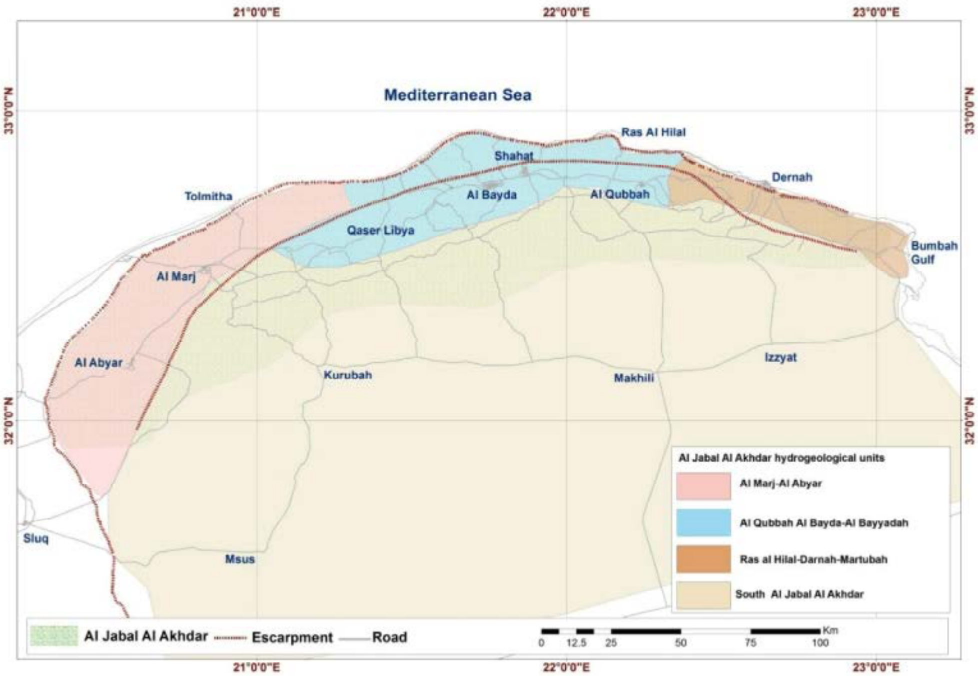

Fig. 6: The spatial extension of Al Jabal Al Akhdar hydrogeological units [14]

area, while perched aquifers generally occur locally in Quaternary deposits. The lithological natures of those aquifers are predominately made of chalky and calcarenitic limestone, in addition to karst processes playing the main role in the presence of water bodies in the whole area, in which they are expressed by development of macrokarstic features. Groundwater flow is mainly related to a system of micro fissures and micro pores. The recharge of the aquifers is due to the direct infiltration of rainfall and to the seepage of runoff water along the wadi beds. The natural outlets of the aquifers are either springs, or in the case of the northern flank to the sea [11]. The hydrogeological units in the Al Jabal Al Akhdar are illustrated in Figure (3), these are:

- Al Marj-Al Abyar
- Al Qubbah Al Bayda-Al Bayyadah.
- Ras al Hilal-Darnah-Martubah.
- Northern boundary of South Al Jabal Al Akhdar.

The boundaries of these units is not defined precisely due to lack of detailed studies, limited exploratory drilling and the lack of integration between the data and information between the different institutions working in the area.

According to GWAE [12] those hydrogeological units share common carbonate rocks.Table (1) illustrate the aquifers in the area defined by their geological age. The depth to the aquifers varies due to the geological setting. The Eocene and Upper Cretaceous aquifers has the high potential as water resources in term of quality and quantity and their spatial extension is mainly around the middle parts of Al Jabal Al Akhdar [13].

Therefore Al Jabal Al Akhdar considered as promising area for artificial recharge in which the surface water resources are represented mainly by the wadis, where the hydrographic network reflects the morphological features of both flanks : to the north the valleys are short and deeply cut and reach the sea after a few tens of kilometers and to the south, the valleys are wide and flat and they progressively disappear as valleys and become large spreading zones at the breaking slope of the Al Jabal Al Kadar [15]. Figure (7) illustrates the layout of the wadis in the area where the hydrological divide in the middle of Al Jabal Al Akhadr represents the boundary of the flow directions for the runoff in the rainy seasons. The lack of the periodical hydrological measurements led to difficulties in evaluating and estimating the exact amount of surface water resources. However, previous hydrological studies, although for short periods, indicated that around 7, 400, 00, 000 m^3/year of water are available as surface water which can be collected by using different methods of surface water harvesting [14].

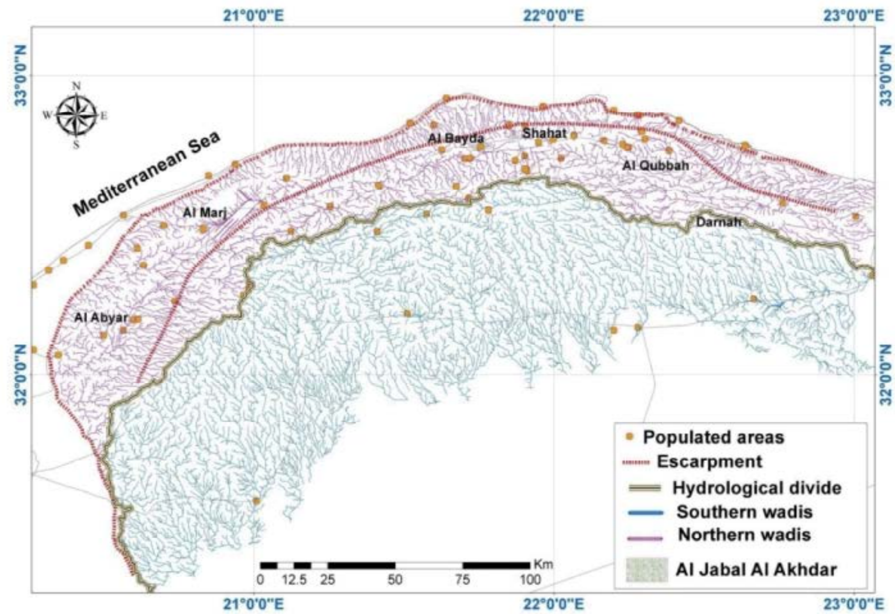

Fig. 7: Wadis map of Al Jabal Al Akhdar [16]

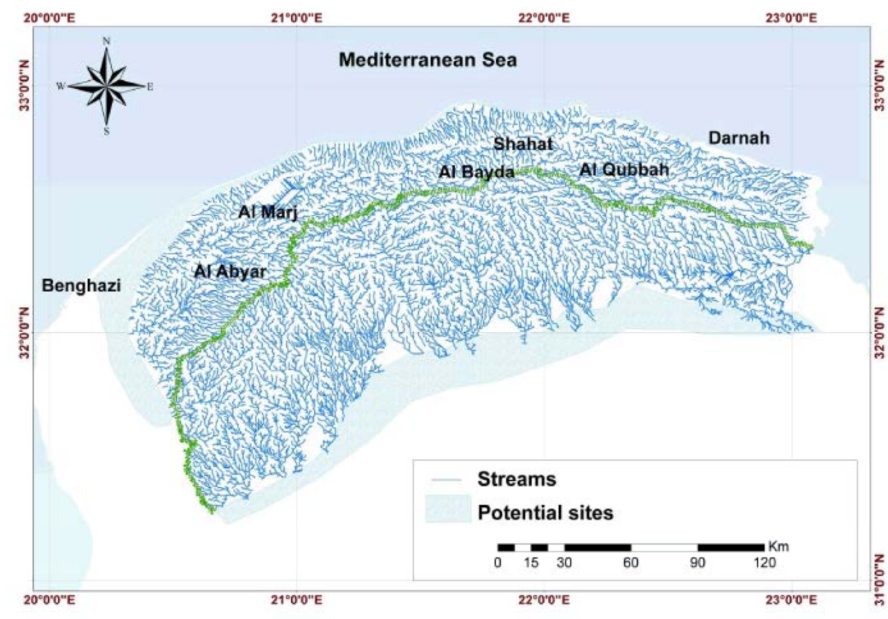

Fig. 8: The potential sites for ground artificial recharge in Al Jabal Al Akhdar Al Jabal Al Akhdar.

As indicated in the Figures (8) the northern parts of Al Jabal Al Khadar where the coastal plain is considered as the potential site for the artificial recharge in addition to the Sothern flanks of Al Jabal Al Khadar can considered as the potential site for the artificial recharge where the consultant office Franlab in 1976 delineate the Wadies and select dams locations to be constructed for water harvesting and artificial recharge.

Challenges and Constraints: According to [8, 13] there is increasing water scarcity in Libya due to escalating demand driven by population growth and urbanization and uneven distribution of water resources and quality degradation, therefore surface water resources as other water resources faces many challenges and constraints, which can be concluded as in the following [13] :

Institutional:

- Centralization in planning and financing
- Limited budget and financial resources
- The overlap of water institutions
- The lack of coordination between the water institutions
- Organizational instability
- Limited structuring among the functional levels
- Inadequate institutional capacity at regional and local levels
- Limited experience in integrated management
- Less participations of the stakeholders

Human:

- Socio-economic dimensions are insufficiently reflected
- Less in capacities in surface water management
- Limitation in skilled labor and insufficiently prepared for coping with future challenges
- Absence of an organized long-term approach to awareness raising activities
- Lack of financial incentives to workers in water institutions

Technical and Environmental:

- Lack of Monitoring of surface water resources
- Lack and quality of data

CONCLUSIONS

Through the above discussion it is clear that surface water in Libya confined to northern areas which considered as small amounts but can be developed and invested with regard to the proposed dams. The groundwater artificial recharge can be conducts in the promising area in oriented comprehensive experimental program started as pilot project in properly selected site.

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