

# THE ROLE OF ARTIFICIAL IMPOUNDMENTS IN IMPROVING AGRICULTURAL PRODUCTION IN THE SEMI-ARID REGIONS OF NORTHERN MOROCCO

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**ABSTRACT.** At the end of the last century, the Rif mountains of Morocco have experienced significant changes in the level of agricultural activity, especially it concerns the increase in cannabis cultivation, which is characterized by high water requirements. For that reason, a number of Artificial Impoundments (AIs) have been constructed in the Tangier-Tetouan-Al Hoceima (TTA) region, where by August 2017 there were more than 1400 of such structures. This requires to a study the efficiency and potential negative effects of such noticeable development. It has been shown that these hydraulic structures have provided additional positive value to the agricultural sector, especially to the proscribed industry of cannabis cultivation. Regarding other effects, the present study has found that their impact on the hydraulic and hydrographic aspects at the moment is very limited and that the only major constraint for their application is related to the issue of security, which arises from the fragile geological structure that is observed in the majority of the region.

**KEY WORDS:** Rif Mountains, the Tangier-Tetouan-Al Hoceima region, hydro-agricultural development, Artificial Impoundments, cannabis

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## INTRODUCTION

The construction of dams is considered among the many water practices of ancient times. It is spread in different parts of the world. The total actual volume of the water impoundment in the world's artificial reservoirs today is 10,800 km<sup>3</sup> (Chao and Li 2008; Chao 1988). Also, their types vary between large dams (Buttress Dam, Embankment Dam, Storage Dam...) and small ones like AIs. The latter kind (also called artificial ponds), which constitute the subject matter of the present study, are considered among the many artificial hydraulic structures that are built separately from the hydraulic networks and are refilled with water during the periods of precipitation through surface runoff (Ministère de l'écologie, du développement durable des transports et du logement 2012) and/or from the groundwater or rivers in order to be used during the summer season (Directions Régionales de l'Environnement, de l'aménagement et du logement 2012). The functions of these AIs are numerous as they are used to breed fish (Keshavanath et al. 2001), for recreation and aesthetic purposes (Callihan 2013), for extinguishing fires and so on. Along with that, the irrigation of farmlands in the Mediterranean region is considered to be the most important function of these AIs (Casas et al. 2011). It also helps to improve landscape amenity in highly anthropized horticultural areas (Bonachela et al. 2013).

The growing propagation of AIs has made it necessary to frame it legally to avoid all deficiencies that are likely to be caused. In France, for example, the first laws to control

these AIs date back to 1968. Since 2007, new rules have appeared via the water law that founded a much more secure system for declaration and permission (Dunglas 2014). But as far as Morocco is concerned, the water law number 36-15 (fourth chapter, article 62), which concerns the pricing and use of rainwater, is considered among the clearest provisions in the law about the AIs since «the owners, users and the estate possessors have the legal right to collect, use and price rainwater that falls on their estates...and the technical conditions are determined by an organising text to establish, manage and maintain the edifices for collecting and storing rainwater» (la loi n°36-15 relative à l'eau promulguée par Dahir n°1-16-113 du 10 Août 2016).

These AIs provide a lot of benefits as they help to irrigate reasonable surfaces of farmlands. However, the problem is that these AIs are costly both at the financial and property levels. Regarding the financial level, the establishment of such AIs requires large sums of money and only those whose incomes are high can afford them. And as far as the property level is concerned, the Rif Mountains are known to have small agricultural holdings. This problem is found also at the global level as the AIs are estimated to occupy between 0.1% and 6% of farm area worldwide (Downing et al. 2011). Hence, despite the beneficial aspect of these AIs, they will without doubt make the problem bigger. On the other hand, we should not forget that they may have negative social, environmental and ecological effects since they will inevitably disrupt the equilibrium that is specific to the management of water. Also, these AIs are constructed haphazardly and over geological

structures generally characterized by their fragility (the risk of collapsing). The problem gets much more complicated as these Als are constructed in most of the cases, especially in the Chefchaouen province, to irrigate the cannabis fields, which in itself represents a problem/constraint that even the state has not been able to deal with. In general, this study aims to describe, interpret and analyse the spatial distribution of these Als in relation to the geological, topographical and hydrological characteristics as well as administrative divisions to show the scope of their effectiveness in terms of irrigation water security and also demonstrate the negative effects that accompany them in the TTA region. In order to find a temporary interpretation to this problematic, we hypothesize that these Als are considered to be good and beneficial water projects and that their current impact on the capacity of the large dams and the sustenance of the groundwater is minor.

**MATERIALS AND METHODS**

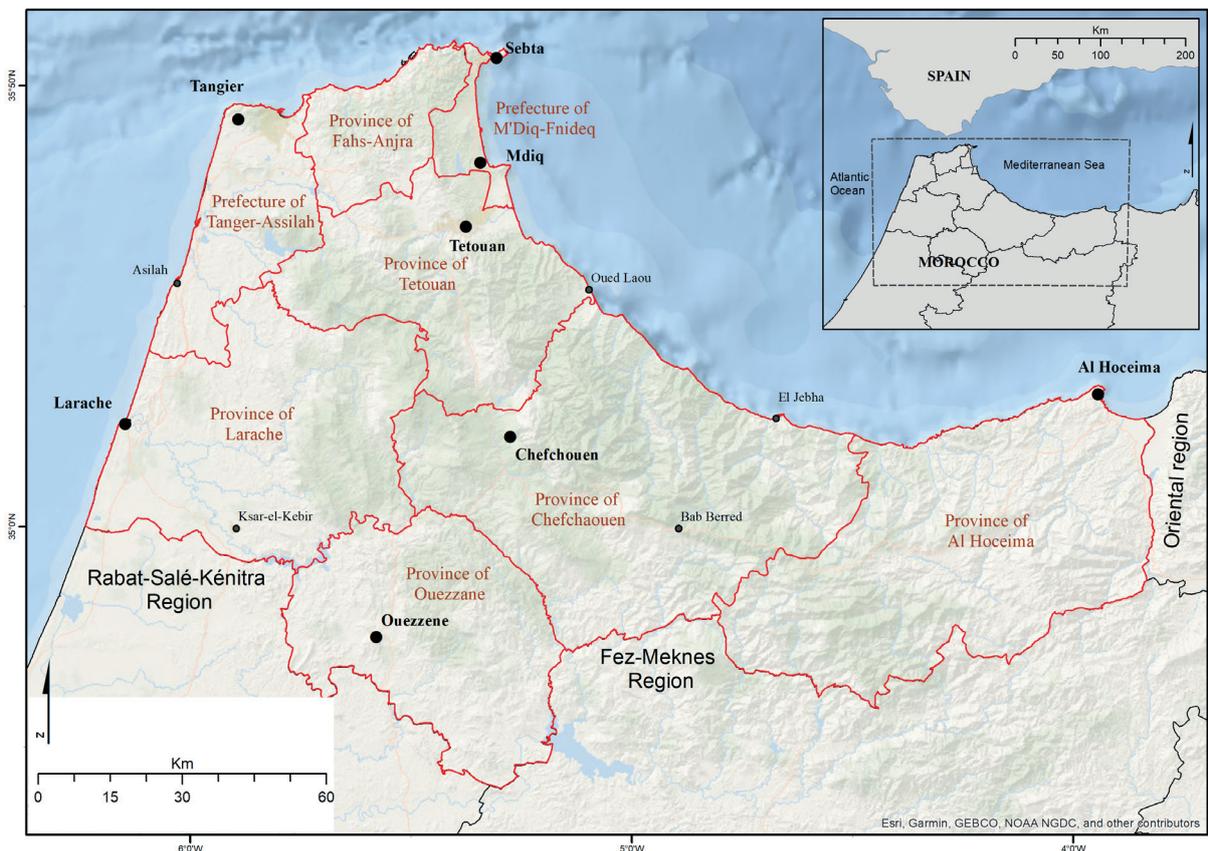
**Study Area**

The area of study (Fig. 1) is the TTA region, which is located in northern Morocco, bordered from the north by the Mediterranean Sea, from the south by the Rabat-Sale-Kenitra and Fes-Meknes regions, from the east by the Oriental region and from the west by the Atlantic Ocean. It is one of the twelve regions of Morocco. The TTA region includes six provinces and two prefectures whose population is about 3,556,729 inhabitants according to RGPH 2014, 40.20% among them are rural. Despite the mountainous topographic relief, the rural area of this region depends mainly on the agrarian economy. It is worth mentioning that in the last few years the Rif has witnessed great change concerning the types of the adopted agriculture that has been accompanied by an obvious change in the adoption of irrigation sources for the lands, as some farmers resorted to the technique of collecting water from many sources in the basin (Als).

**Materials and Methods**

For this study, we have used a scientific method, which includes description, interpretation, analysis and statistics. Testing of the hypothesis was conducted using the mapping technique, which allowed to localize the studied Als, register their distinguishing properties such as area and depth as well as estimate the quantity of the water stored. Moreover, to cover the research problem a bit further, it was also necessary to go to the field to take some photos and review the available literature on the topic. It should be noted, that there have been many previous studies, especially in the European countries. To digitize the Als, we used The Map-Tools application that offers several utilities under Google Maps (<http://tool-online.com/index.php>) such as import-export text, DXF, KML files. The coordinates and the surface area of Als were identified using the website indicated. These data were then exported to GIS (ArcGIS 10.2) to build a database comprising the subsequent columns: FID (the name primarily used in shapefiles), surface area, bottom area, maximum depth, minimum depth, average depth, maximum volume, minimum volume, average volume.

To estimate the volume of the water in these Als, it is necessary to know the depth and the area of the top and the bottom. The area of the top is very easy to determine, unlike the bottom area and the depth of the AI. For this reason, we have worked on a sample of 50 cases conducting interviews with the owners of these water projects. Then by generalizing the calculations about the other Als, we have finally achieved a result presented in Table 1. As for the volume of water that can be stored in these Als, it was calculated using simple equation ( $\text{Volume} = \text{length} * \text{width} * \text{height}$ ) and since the area of the top is always different from that of the bottom, they were added to each other to obtain the average.



**Fig. 1. Study area location**  
 (Source: the official maps available through the website (ANCFCC: <https://www.ancfcc.gov.ma/>))

**Table 1. Distribution of Als according to the area and depth**

Area* (m <sup>2</sup> )		Depth (m)		
Top	Bottom	Average	Minimum	Maximum
> 10000	> 2500	18	15	21
8000–9999	2000–2499	14	13	15
7000–7999	1750–1999	12.5	12	13
6000–6999	1500–1749	11.5	11	12
5000–5999	1250–1499	10.5	10	11
4000–4999	1000–1249	9.5	9	10
3000–3999	750–999	8.5	8	9
2000–2999	500–749	7.5	7	8
1500–1999	375–499	6.5	6	7
1000–1499	250–374	5.5	5	6
900–999	225–249	4.5	4	5
800–899	200–224	4	3.5	4.5
700–799	175–199	3.5	3	4
< 600	< 150	2.5	2	3

\* The bottom area of 84% Als (The survey sample) nearly equal a quarter of its top area.

Source: the field survey, August 2017

## RESULTS

### Spatial Relationship Between the Als and Structural Units

The geological conditions are an issue of great importance for the study of dams. Geologically, the Rif area is characterized by its torsions, creepy folds and overlays. According to many geologists, the Rif may be divided into three principal regions: the internal Rif, the flysch unit and the external Rif.

The internal Rif includes three small units: Ghomarids, Sebtds and the «*Dorsal Calcaire*», which in total occupy about 13% of the geological area of the region (Fig. 2). The first two units are characterized by the metamorphic rocks that date back to the Paleozoic and Mesozoic Era (Azzouz et al. 2002). Their rocky formations are marked by very poor water permeability and their immense sensitivity to erosion. As for the «*Dorsal Calcaire*», it constitutes from limestone and dolomite formations with the occasional inclusion of marl. Regarding the hydrological behaviour, these units are characterized by their high water permeability.

It is generally noticed that this region is marked by a semi-complete absence of the Als (1% of the Als in the TTA region) (Fig. 2 & Fig. 3). This can be explained by the hydrological factor: there is an abundance of water resources flowing from the «*Dorsal Calcaire*» springs, which are converged towards downstream into the *Ouad Lou* and *Elkanar* rivers and provide an important source of water for irrigation of a large agricultural area.

The flysch unit (Early Cretaceous to Earliest Miocene) represents about 22.67% of the total area of the study region (Fig. 2). This field is considered by Durand-Delga and others (2000) as turbiditic deposits that consist of calcareous clay and sandstone (Nold et al. 1981). This geological unit in terms of hydrological behaviour is characterized by its little permeability. Also, the sensitivity to erosion differs according to the degree of rock resistance, which weakens when the marl prevails and increases in

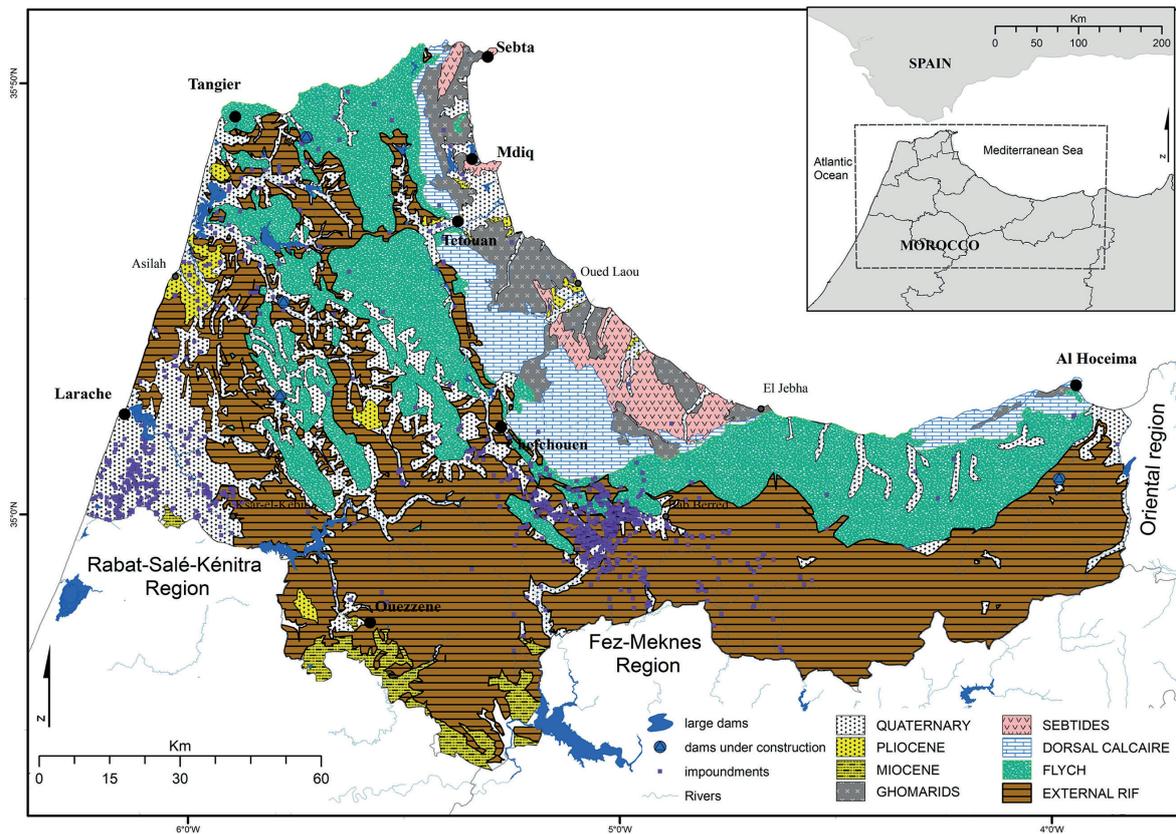
the presence of the sandstone. A great number of Als (238) have been constructed within this unit, which constitutes 16.95% of all the Als in the region, with a density that reaches 0.07 Als/km<sup>2</sup>.

The external Rif (Middle-Upper Triassic to Upper Eocene) occupies a large area of the Rif's chain territory, representing 43.33% of the total area of the region (Fig. 2). This unit includes various types of rock such as marl with the presence of limestone, schistose, sandstone and quartzite formation, which are characterized by the little water absorption and increased exposure to different kinds of erosion. This unit includes the largest number of Als constructed in the region (594), which corresponds to 42.30% (Fig. 2 & Fig. 3). As for the distribution of the Als within these geological units, it is related to hydrological, socio-economic and historical factors which will be clarified later.

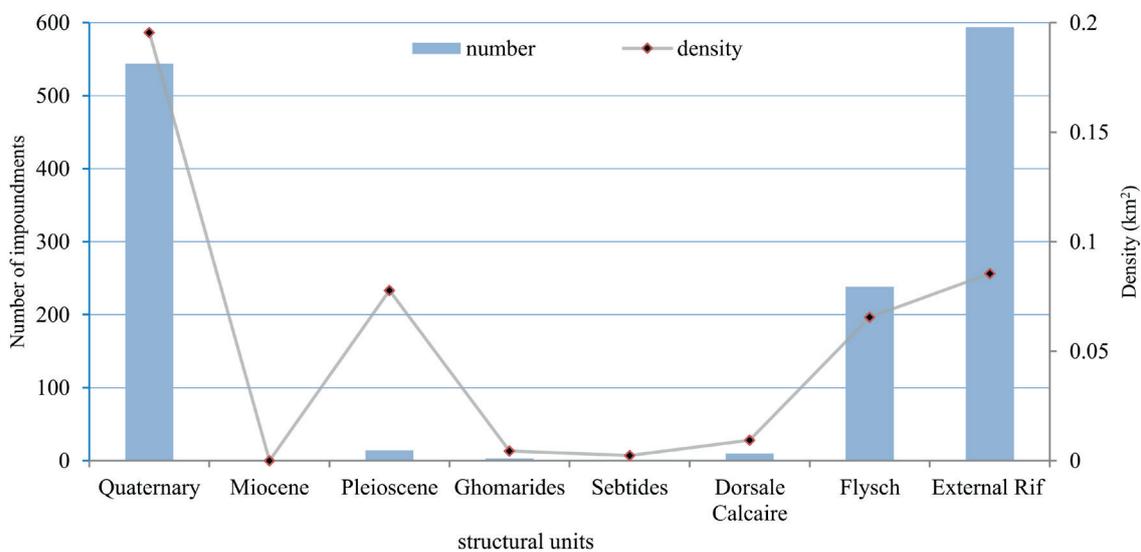
In addition to these principal geological units, formations that go back to the Pliocene Epoch can be found in the study area. Besides, we also find Quaternary deposits which are formed of clay and sand of red colour (El Ouahabi et al. 2014). These formations are mainly present in the Loukkos area, which in its turn is characterized by a large propagation of Als (544), that corresponds to 38.74% of the total number of Als in the region with the highest density (0.2 Als/km<sup>2</sup>) (Fig. 2 & Fig. 3). The prominent presence of such water projects may be caused by the fact that despite the Loukkos area has been developed since the year 1970 within the framework of the national policy of hydro-agricultural managements (El Kellouti 2004), the traditional water sources of the area (Ouad El Makhazin dam, the groundwater of the R'mel aquifer and the Dradar...) are not sufficient to satisfy the irrigation and other needs within the cultivated farming lands most of which are characterized by a flat and vast area.

### Distribution of the Als According to the Relief

The topographical analysis, especially in mountains, is without a doubt extremely important when studying the water structures, particularly those located at the slope and altitude. The division of



**Fig. 2. Structural units and location of Als**  
 (Source: Modified from geological map of Rif (1/500 000))



**Fig. 3. Number and density of Als according to the structural units**  
 (Source: Compilation based on the map's database – Fig. 2)

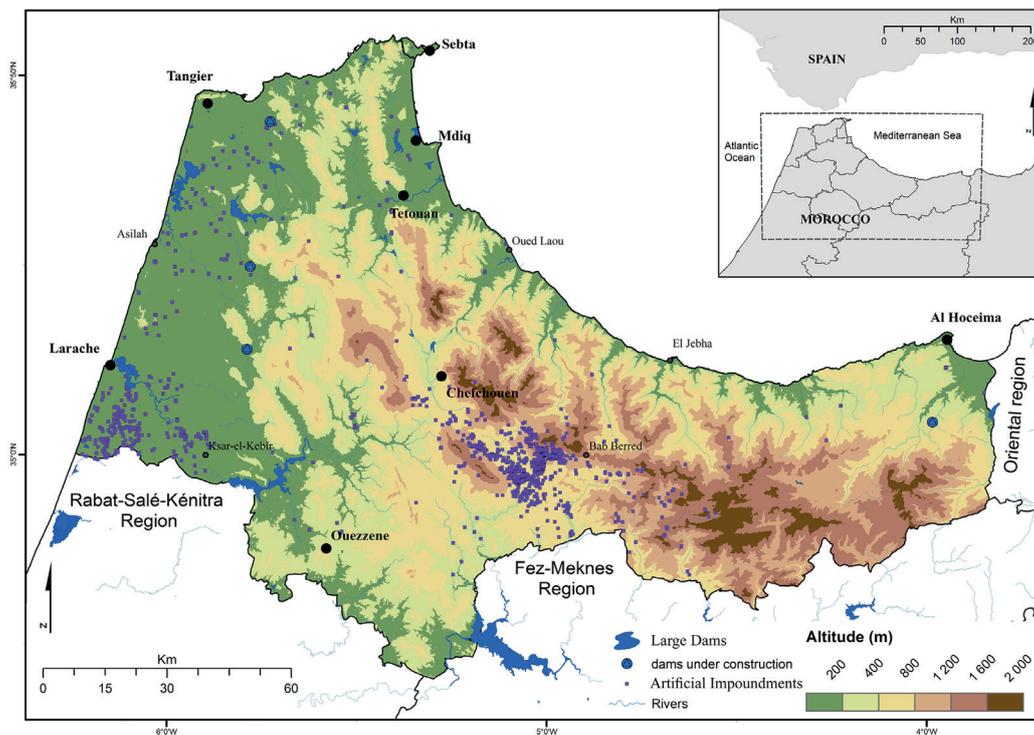
the study area according to the altitude categories has shown that the elevation of half of the TTA region area exceeds 400 metres above sea level and in more than one third it exceeds 800 metres (Fig. 4). In general, the elevation increases from the west to the east. Comparing the distribution of Als with the altitude classes it can be seen that more than one third of the Als in the region were constructed at an altitude between 800 and 1200 metres with a density that reaches 0.12 Al/km<sup>2</sup> and that more than one fourth is found at an altitude which does not exceed 200 metres with a density estimated at 0.15 Al/km<sup>2</sup> (Fig. 5).

Regarding the slope (Fig. 6), in more than half of the territory of the region (54%) it exceeds 5% and in one fifth of the area the steepness exceeds 10%. The Fig. 7 reveals that some peasants constructed the Als on steep slopes exceeding 15% (5 Als). 60 Als

were built on slopes ranging between 10% and 15%, meanwhile, the highest presence of such water projects in their number and density corresponds to the slope of less than 5%. This is normal if we consider the absence of the farmlands and its narrowness on one hand, and the danger that construction of the Als within the area with steep terrain may cause on the other hand, especially given that the majority of the studied region formations are fragile and unstable and that their surface is extremely broken up as a result of the erosion of the rivers.

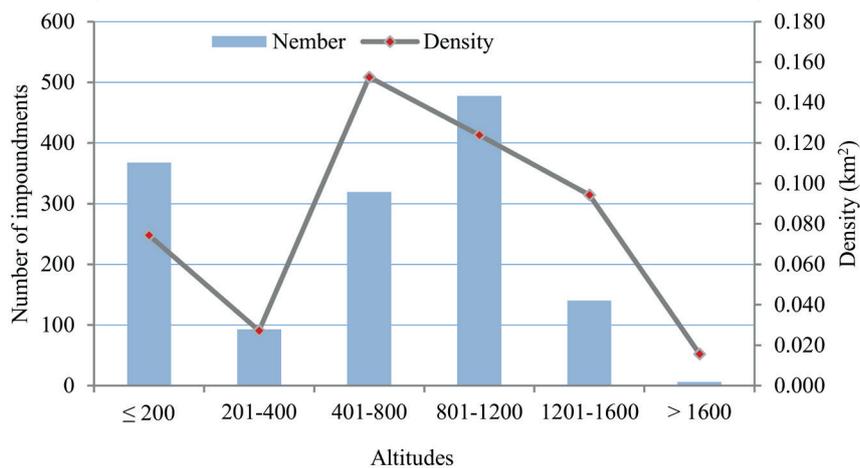
**Distribution of the Als according to the watersheds**

It is impossible to study the effect of the hydrological factor on the distribution of Als without taking into consideration



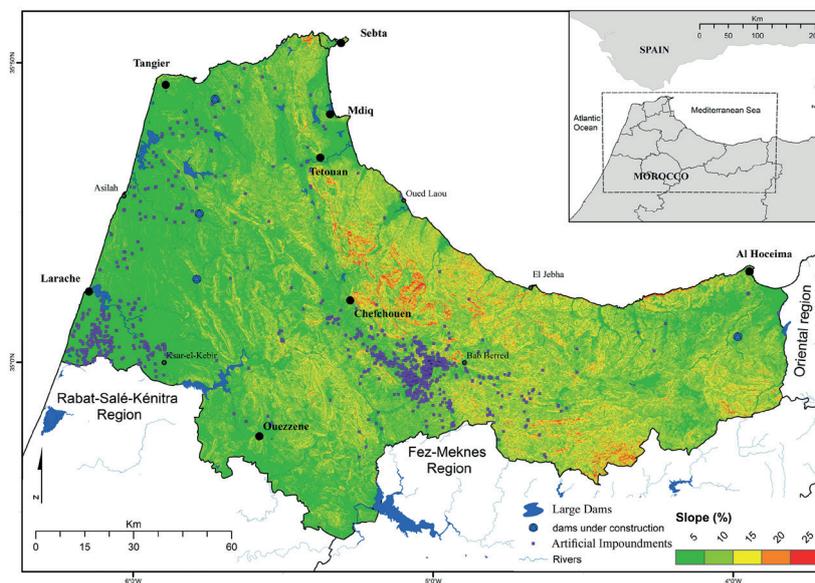
**Fig. 4. Elevation and location of AIs**

(Source: Modified from SRTM elevation data at 90 m resolution)



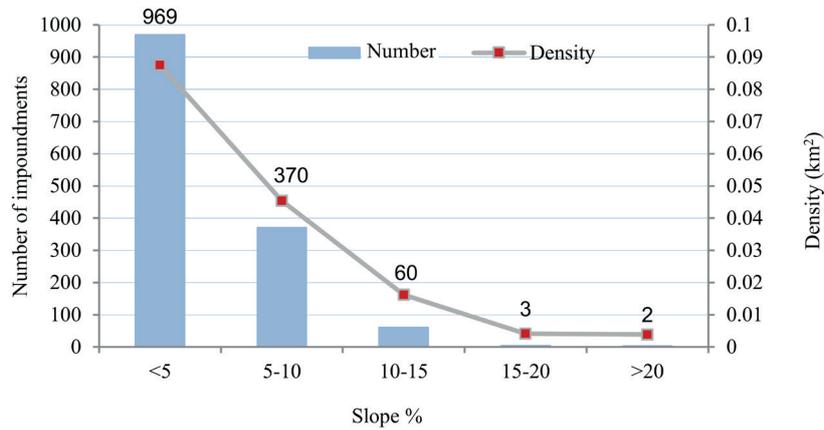
**Fig. 5. Number and density of AIs according to the altitude**

(Source: Compilation based on the map's database – Fig. 4)



**Fig. 6. Slope and location of AIs**

(Source: Modified from SRTM elevation data at 90 m resolution)



**Fig. 7. Number and density of Als according to the slope**  
 (Source: Compilation based on the map's database – Fig. 6)

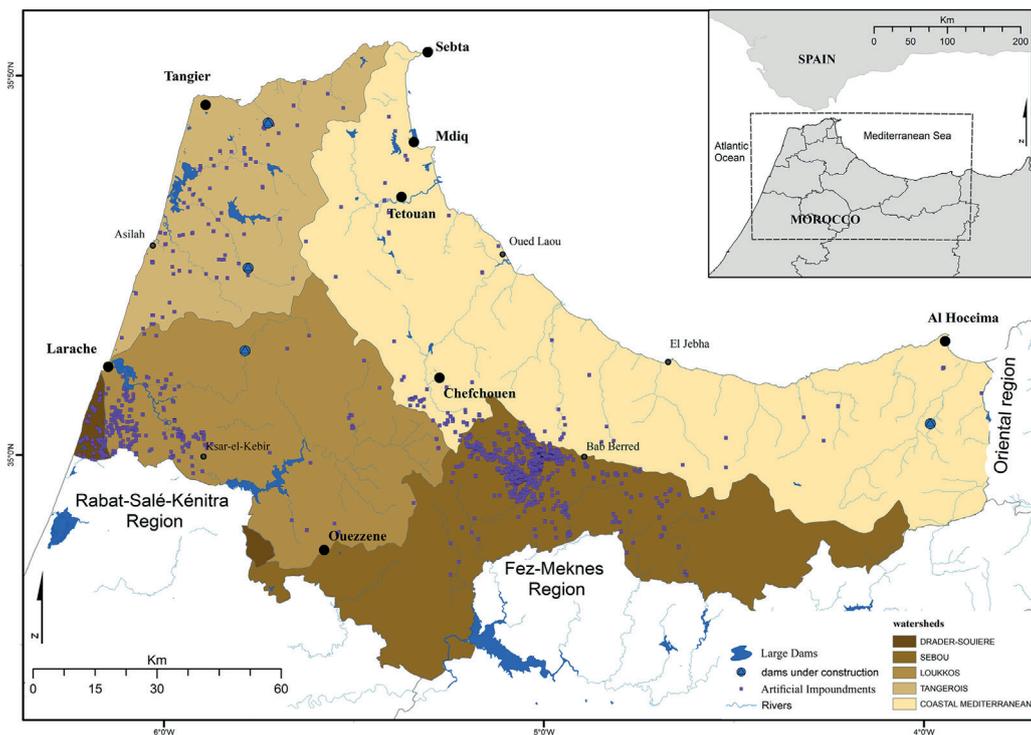
both climatic factors, particularly the factor of rain and snow precipitations, and hydrological factors. Concerning the climatic factors, the amount of rainfall in the TTA region varies significantly since precipitation generally decreases from west to east and registers its highest level (more than 1000 millimetres per year) in the centre (the province of Chechaouen) (Salhi et al. 2019) due to the exposure of foothills to the Atlantic influences, which also coincides with the wide development of the Als. Meanwhile, considering hydrological factors, the geological and geomorphological evolution has contributed to the extension of some groundwater aquifers, the most prominent of which are: «Dorsal Calcaire», R'Mel, Martil-Aiila, Oued Lou, Ghiss-Nkkor, Sherf Elaqab. 250 Als, about 17.80% of the total number of Als in the region, were constructed on these geological formations, which are mostly water absorbent and permeable. Among these formations, the majority of these Als (233) corresponds to the R'Mel aquifer, which is because this is predominantly an agricultural area. However, the water stored in this aquifer and obtained from other sources is not sufficient to satisfy the increasing irrigation needs, particularly within the recurring dry periods in the last few years. In general, these figures indicate that more than 8 out of 10 Als were built on geological formations

impervious to water. In other words, they were built mainly in areas depending mostly on surface water resources.

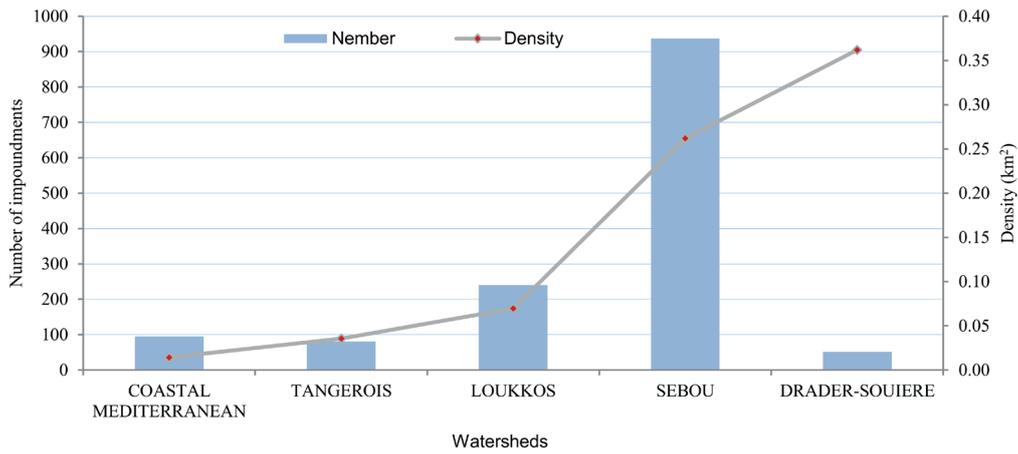
In TTA region there are 5 large watersheds (Fig. 8) but all of them except for the Tangérois watershed are shared with the other regions: the Sebou watershed, for example, is shared with the regions of Fes-Meknes and Rabat-Sale-Kenitra.

The comparison of the area of these watersheds with the distribution of the constructed Als has shown that 2/3 of them were built within the Sebou watershed, which is followed by the Loukkos watershed with 17.09%. However, regarding the density of the Als, as it is shown in Fig. 9, the Dradar Sweer watershed is characterized by the highest density with an average of 0.36 Als/km², which is followed by Sebou with 0.60 Als/km². Hence, the question is whether the difference in the distribution of these Als regarding their number and density is related to the hydrological properties of the region watersheds.

There is no doubt that the hydrological factor is present and controls the distribution of Als in the study region. The main reason is that the areas that are characterized by the absence of underground water tables, as it has been mentioned previously, are the ones that are marked by a large proliferation of these water



**Fig. 8. Watersheds and location of Als**  
 (Source: Modified from SRTM elevation data at 90 m resolution)



**Fig. 9. Number and density of AIs in different watersheds**

(Source: Compilation based on the map's database – Fig. 8)

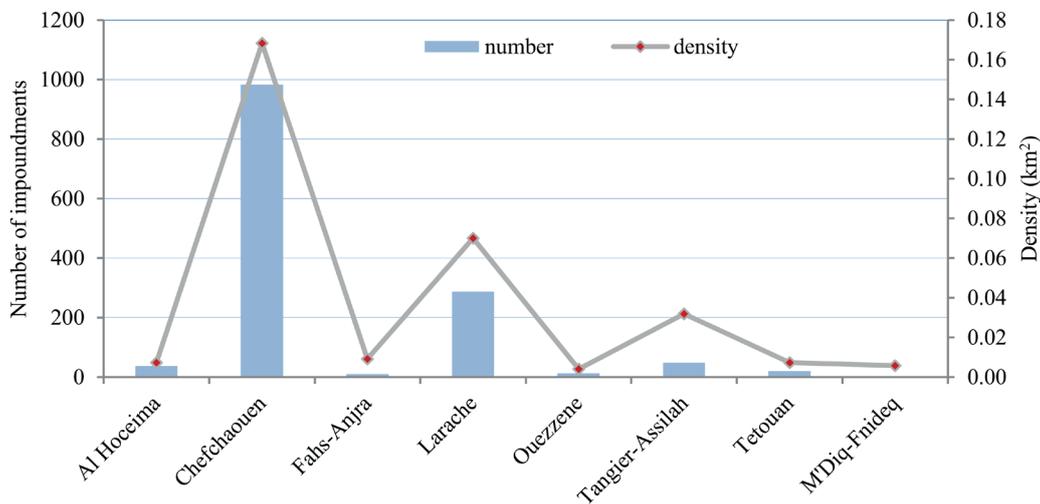
projects. These areas are characterized by a high surface runoff discharge during the rain periods (the wet season) and an almost complete depletion in the dry seasons, which forces peasants to resort to the construction of AIs to remedy the deficit during the dry periods. However, from the maps of the distribution of AIs, it can be observed that they are present in some areas but not in the others even if they are similar in the climatic and hydrological conditions. This means that the hydrological factor is not the only controlling one but there is a combination of some other natural and human (historical and socio-economic) factors as it will be subsequently clarified.

**Distribution of the AIs according to administrative division**

The two provinces combined, Chefchaouen and Larache, have the largest share of the AIs in the region (9/10 of the AIs) (Fig. 10), the highest number and density of AIs is observed in the first province with a percentage of 70.08%, which is followed by the second one with 20.44%. However, besides the differences between the provinces, there is also variation present within the provinces themselves and as we found out that about 8/10 of the AIs were built in just four out of 28 rural communes in the province of Chefchaouen: Bni Salh (368 AIs), Bab Bered (197 AIs), Ouad Elmelha (107 AIs), Bab Taza (104 AIs). These communes are also marked by the highest density of the AIs with 3 AIs/km<sup>2</sup> in the Bni Salah commune, which rises to about 5 AIs/km<sup>2</sup> in some areas such as Bni Aammar village (rural commune of Bni Salah). As for the province of Larache, half of its water projects are exclusive to the Ouamra commune (149 AIs) which has

the highest density of 0.45 AI/km<sup>2</sup>, followed by Oulad Ouchih commune 0.35 AI/km<sup>2</sup>.

The dominance of the two provinces of Chefchaouen and Larache can be primarily explained by their great dependence on the agricultural economy from two different perspectives: in the first province, the prohibited agricultural activities (cultivation of cannabis) is widely practiced while in the second province there is a predominance of different kinds of allowed agricultural products like bananas, citrus fruits and sugar cane. All these agricultural products require a significant amount of water. However, if the conclusion about the importance of the water projects in the province of Larache is really significant because it is the only province that includes several large investments in different agricultural activities, the proliferation of AIs in the Chefchaouen Province due to cultivation of cannabis is questionable because there are other provinces where this forbidden agricultural product is practised. Still, as it has been mentioned previously, in the province of Chefchaouen these hydraulic structures are concentrated within particular areas, which means that there were factors that have contributed to their creation, namely the absence of water resources and more specifically groundwater, which has led to the necessity to look for adaptable methods to deal with the shortage of water. However, the implementation of these adaptable procedures, particularly the AIs, require great financial resources and this is what can distinguish some of these regions over others as the cultivation of cannabis, agriculturally and commercially, for a long time has contributed to the accumulation of significant financial resources that made it possible for their owners to invest in such



**Fig. 10. Number and density of impoundments according to the prefectures and provinces**

(Source: Compilation based on the map's database – Fig. 1)

hydro-agricultural projects. In connection with this, the AIs are always based in some particular areas and we can point out that the AI Anassar village (rural commune of Bab berred) was the first to practice these water techniques. This is due to the fact that this area for a long time depended on a small dam upstream of the village which was used communally, but its collapse in the last few years made the population to continue the irrigation of their lands relying on dams, but this time independently. For this reason, this practice has spread noticeably, changing the geographical landscape in the region as it is illustrated in the photo (Fig. 11).

DISCUSSION

The capacity of the AIs in the TTA region exceeds 7 million m<sup>3</sup> (Table 2). There is a clear dominance of the AIs in the Sebou watershed, in which store 2/3 of the total volume of water in the AIs is stored. Then there are the AIs of the Loukkos watershed with a volume that exceeds 1.3 million m<sup>3</sup>. This results from the high number of these water projects in the two watersheds compared with the rest. In comparison, the volume of water in these AIs combined exceed the capacity of many large dams such as Nahkla (4.33 million m<sup>3</sup>), Aljomoua (5.05 million m<sup>3</sup>), Sidi Driss

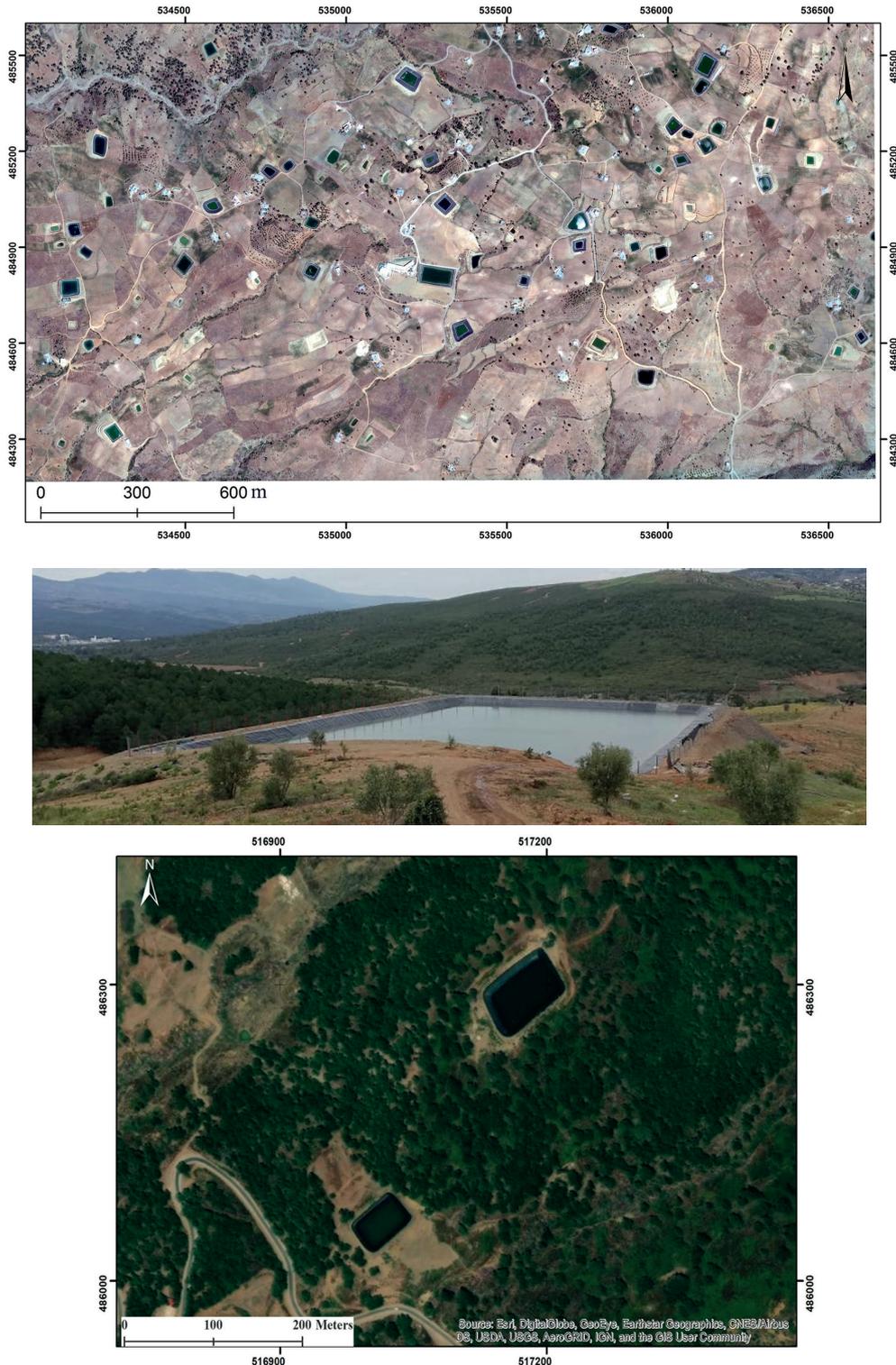


Fig. 11. Examples of AIs in the Tangier-Tetouan-Al Hoceima region

- a - Al Anassar village (rural commune of Bab berred)
- b - Ben zid village (rural commune of Bab taza)
- c - the north of Fifi center

(Source: A and C – Bing Map hybrid, 2017, B – shootin 02-04-2019 by Mustapha Hmamou)

dam (2.2 million m<sup>3</sup>), considering that the majority of these Als are refilled with water twice a year, the volume of stored water in them also exceeds the volume of Asmir dam in August 2017 (11.4 million m<sup>3</sup>), the regular capacity of which reaches 40.7 million m<sup>3</sup> (Royaume du Maroc, Ministère de l'Équipement, du Transport de la Logistique et de l'eau 2017).

While the large dams integrate numerous functions, including irrigation of the farmlands, providing the cities and villages with drinkable water and producing hydroelectric energy, the functionality of the Als is limited to irrigation of the agricultural land. As many studies have found out, one hectare of agricultural land needs an average of 5836 m<sup>3</sup> of water per year (Aahd et al. 2009). This means that these Als if we take into consideration

the effect of evaporation, which is between 1000 and 1400 millimetres per year (Lahlou 2000), can on average irrigate more than 1370 hectares, which is more than 2/3 of the Chefchaouen province area. Also, it is necessary to point out that the number of Als capable of irrigating more than one hectare has reached 364, 3/4 of which are located in the Chefchaouen province. Regarding the cost-effectiveness, one irrigated hectare yields more than five tons of raw cannabis.

Besides the contribution Als make to the development of the local agricultural product, they can also have other positive roles, they can be resorted to in case of a fire outbreak and also they contribute to the diminution of the water flow hostility during the periods of rainfall. They also have other positive effects on the local

**Table 2. Distribution of Als according to the watersheds and its volume of water**

Watersheds	Numbers of Als	Capacity (one thousand m <sup>3</sup> )		
		Average	Minimum	Maximum
COASTAL MEDITERRANEAN	95	241	212	270
TANGEROIS	81	656	603	709
LOUKKOS	240	1585	1393	1777
SEBOU	937	6059	5494	6624
DRADER-SOUIERE	51	131	116	147
Total	1404	8672	7817	9527

Source: the field survey, August 2017

**Table 3. The impacts of Als on the capacity of the large dams**

Large dams	C (M/m <sup>3</sup> )	V. S m <sup>3</sup>	Als				I-LD %
			N	A.V (K/m <sup>3</sup> )	Min. V (K/m <sup>3</sup> )	Max. V (K/m <sup>3</sup> )	
Ibn Battouta	29.1	13					0.000
9 April	300	131.8	2	9.6	8.6	10.5	0.003
The Tanger Mediterranean	22.1	19.7					0.000
Hassan Ben El Mehdi	28.8	4.7					0.000
Smir	40.7	11.4					0.000
Nakhla	4.32	2.86	1	1.6	1.4	1.9	0.037
Moulay Bouchta	11.6	11.6	1	0.2	0.1	0.6	0.004
El Jomaâ	5.05	2.72					0.000
Moh.Ben Abde krim Al Khattbi	11.6	1,8					0.000
O. El Makhazine	672.9	385.3	21	76.96	69.1	84.9	0.011
Al Wahda *	3522.5	1790.6	943	6403.5	5780.9	7026.1	0.182
Kharroub**	185		2	12.8	11.7	13.8	0.007
Oued Martil**	120		2	0.9	0.9	1.0	0.001
Dar Khrofa**	480		2	35.7	33.4	37.9	0.007
Total	5433.67	2375.48	974	6541.0	5906.1	7176.7	0.120

C (M/m<sup>3</sup>): Capacity (million m<sup>3</sup>), V. S m<sup>3</sup>: the volume of the stored water in August 2017 (million m<sup>3</sup>)

Number: N

A.V: The Average volume:

Min. V: The minimum volume

Max. V: The maximum volume

K/m<sup>3</sup>: 1000 m<sup>3</sup>

I-LD: Impacts on large dams %

\*- dam outside the Tangier-Tetouan-Al Hoceima region

\*\* - dam under construction

Source: Compilation based on the mapping database of this research

animal and plant environment (the amphibians and the birds) (Fang et al. 2009; Casas et al. 2012; Ferreira and Beja 2013) and can produce beautiful landscapes. However, they can also have different negative effects that should be taken into consideration, namely concerning the environmental and socio-economic aspects (Fuentes-Rodríguez et al. 2013; Casas et al. 2015). These Als may provide new habitats for macroinvertebrates (Abellán et al. 2006), change the geographical landscape (Montginoul and Erdlenbruch 2009), along with their negative effect on the security of people and animals (the recurrent cases of drowning accidents) and the construction of the Als in forests (Fig.11-c). However, the most dangerous negative impact is related to their quantitative and qualitative effect on the hydraulic and hydrographic features of the watersheds. These Als divert and delay downstream water flow and modify the groundwater interaction (Smith et al. 2002). Moreover, the consumption of water will increase in the presence of these hydro-agricultural structures and thus, its saving will not be possible (Loubier et al. 2011).

There are ten large dams in the TTA region with a retaining capacity that reaches 1.1 billion m<sup>3</sup>, by August 2017 the refilled volume has reached 584 million m<sup>3</sup> (Royaume du Maroc, Ministère de l'Équipement, du Transport de la Logistique et de l'eau 2017). Along with that, there are some dams that are in the process of construction and also dams located outside the region which are refilled from its river basins such as the *Wahda* dam.

As for the effects of the Als on the large dams, the *Wahda* dam comes in the first place with 943 Als built in the upstream watershed. They can store about 6.4 million m<sup>3</sup>, which is the equivalent of 0.18% of the reservoir capacity of the dam (3.5 billion m<sup>3</sup>) and 0.35% of the volume of water stored during the year 2017. It is followed by the *Ouad El Makhazine* dam in the upstream of which 20 Als were constructed with a load capacity around 77 thousand m<sup>3</sup>, 0.01% of the reservoir capacity of the dam and 0.02% of its stored volume in August 2017. As for the other remaining large dams that are either already built or currently under construction, only very few Als have been constructed by August 2017 (Table 3).

From these figures, we can conclude that the effect of the Als on the capacity of large reservoirs is meagre/insignificant as it does not exceed 0.12% of their total storage capacity. Thus, the factors that cause a decline in the filling of these large reservoirs are related to the recurrence of the periods of droughts. On the other hand, it is worth pointing out that the surface water is still not fully exploited as it ought to be, especially within the Mediterranean watershed. Especially given the fact that the volume of

the reservoirs in this area does not exceed 90 million m<sup>3</sup>, while the average annual runoff from the Mediterranean watersheds is about 1.8 billion m<sup>3</sup>. Considering that the volume of water discharged from these watersheds exceeds 40% of the annual rainfall (Royaume du Maroc, Agence du bassin hydraulique du Loukkos 2007), the share of water stored in these reservoirs remains low (less than 15%).

## CONCLUSIONS

Taking into account all discussed above, it is clear that the Als can be considered to be useful water projects for the mountainous areas both economically and socially. The water discharged from the mountains and particularly from the dams in the form of drinkable or industrial water or water for irrigation or producing electricity does not benefit fairly these mountainous areas (Boujrouf 2002). Besides, their impact on the retaining capacity of the large dams is low, especially considering that the Rif mountains are among the rainiest areas at the national level, even despite the fluctuations in the rainfall temporal distribution, as the volume currently stored within the Als does not exceed 0.12% of the retaining capacity of the large dams. In addition to that, their effect on the groundwater recharge in the TTA region is considerably limited as most of the rocks in the study area are impermeable.

This kind of private hydro agricultural structures can be considered an ideal solution to maintain the population's stability due to the absence of the large dams in the upstream watersheds. Generally speaking, these solutions, despite their high costs, are less harmful from both the environmental and social perspectives, especially compared to the solutions that include drillings, which have spread greatly in the region during the last few years. On the other hand, we should not forget that the studied water projects are highly dependent on the climatic conditions, particularly rainfall and snow, as refilling of these Als is determined by the surface water runoff. Thus, in the case of recurring droughts, pumping of groundwater still has to be used, which can consequently create conflicts within the population. In addition to that, the complexity of the administrative procedures at the level of granting construction permits leads to the illegal propagation of these Als, which means that their effects will not remain minor. ■

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