





Water management and the agricultural development constraints in the Algerian Sahara: Case of the M'Zab Valley

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Abstract: In Algeria, modern agriculture was introduced in the Saharan region through the implementation of the law n° 83–18 of August 13, 1983, relating to access to agricultural land ownership (Fr. Accession à la Propriété Foncière Agricole (APFA) in French). This law was hugely successful and sparked a real enthusiasm for this type of activity, which resulted in an expansion of agricultural areas at the M'Zab level, similar to that observed in other Saharan regions. Over the past decades, the agricultural area has declined markedly (–0.4%), which was due to multiple causes, including ecological problems, such as urban discharges and the rise in the water level. So far, little research has been done to assess the agricultural situation and irrigation in this region. The objective of this work is to analyse and discuss the constraints and impacts of water and agricultural management on sustainability of the ecosystem in the Saharan environment. This work is based on extensive research, which has been carried out in the M'Zab region on the oasis system and its evolution. It was enriched with dozens of direct surveys, performed among farmers working in agricultural areas. The results show that agricultural development and the sustainability of farms in this region face several technical and social constraints, the most important of which are the workforce-related problems and water management. Several measures have been recommended to be taken not only to preserve the ecosystem but also to give significance to the large investments made by the public authorities.

Keywords: agricultural development, Algeria, irrigation, management, M'Zab valley, workforce, water

INTRODUCTION

The expression 'land use system' was introduced by FAO in the 1970s [BOUMA 1997] because many countries had developed their own systems of land evaluation, which made the exchange of information difficult, and created a need for standardisation. In 2012, more than 324 million ha of land were equipped with irrigation facilities worldwide, which accounted for 21% of the areas covered by arable land and permanent crops. In North Africa, it oscillated between 17.1 and 25.6%, whereas in sub-Saharan Africa, it oscillated between 2.4 and 3.4% [FAO 2016]. In the Saharan region, water was essential for the development of agricultural areas, since the presence of this resource was fundamental for the practice of irrigated agriculture and, in

particular, for palm tree farming. The main factors which conditioned the localisation, establishment, and structuring of the cities in the vast Saharan territories were not only the wadis, which constituted extensions of cities, but also the water cycle [BENYOUCEF 2009].

Few researchers had worked on the Saharan areas and the Algerian oases before the 1990s, with the exception of geographers such as Jean Dubief [1953–1965], who studied the hydrology of the Sahara. Since the 2000s, Algeria has been implementing a policy aimed at improving national food security, developing certain priority agricultural sectors and land. This has been done through various national plans shaped to the rhythm of fluctuations in oil revenues. These programmes (BrE) were sometimes carried out in partnership with foreign

companies and researchers in the hydraulic and agricultural fields [BESSAOUD *et al.* 2019]. This has contributed to the development of the Saharan areas [ZEGAIT 2020]. The different types of activities developed there have their origin in land exploitation [GAFSI 2007]. Today the challenge consists in ensuring the sustainability of agricultural holdings, in particular, of the most important ones, which extend over several hundred hectares. These holdings have mobilised significant water reserves and boreholes, pumps, and irrigation pivots, which required exceptional financial resources. Their impact on the appearance of the Saharan space is considerable, as they profoundly modify landscapes, especially near urban areas and along major highways, which constitutes an obstacle to the cultivation of certain crops [KOUAMÉ *et al.* 2013]. On the other hand, mismanagement of water resources in these agricultural areas, for example, through an over-exploitation of deep aquifers, has had serious consequences for the environment and the ecosystem. This was manifested in rising water levels, pollution of aquifers, and salinisation of the farmland, but, above all, it has affected a community managed resource [YELKOUNI 2005].

This situation has resulted in the abandonment of family farms, which led to instability in the family structure and in the social structure [COLIN 2004]. This method of land management illustrates how sensitive this question is. The exploitation of these spaces must follow specific management principles for each area, while the traditional systems must be restored and preserved [COTE 1998; REMINI *et al.* 2012; ZELLA *et al.* 2006]. This system of succession, whose direct socio-economic implication is the management of the land heritage by the family, has been highlighted by many researchers. The hydraulic revolution in the Saharan agricultural lands brings a new approach to water management, in particular, with respect to irrigation. Alternatively, purified wastewater should be considered a new water resource, which is currently seldom applied to irrigate newly cultivated areas [DUBOST 2002].

The study addresses several questions, including: how does community land management lead to the abandonment of farms

by young people in M'Zab Valley? How do abandonments of farms occur in M'Zab Valley? What are the impacts of the abandonment of farms, caused by mismanagement of natural resources, on the community? and, finally, does the water problem arise due to insufficient water supplies, mismanagement of water supplies, or both? In this context, the aim of our work is to establish the actual scale of the problems related to agricultural activity and the functioning of ecosystems, as well as to assess the impact of irrigation water and its consequences on the degradation of the ecosystem in the M'Zab Valley, with a view to proposing interventions.

MATERIALS AND METHODS

STUDY AREA

The M'Zab valley is part of the Ghardaia Province, it is situated 600 km south of the capital city and is considered to be one of the great oases of the Algerian Sahara (Fig. 1). It has an arid and dry climate, which is characterised by low rainfall ($<90 \text{ mm}\cdot\text{y}^{-1}$), occasionally accompanied by torrential floods. These floods contribute to the leaching of the surface water located in the alluvium [DUBIEF 1953]. Temperatures in the summer may exceed 45°C , while winters are mild, with an annual average temperature between 8 and 12°C . Winds in the valley are relatively frequent and irregular. They play an important role in the formation of ergs and regs [DUBOST 2002]. Their speed is important from April to July. The sirocco and sand winds occur in this period, accompanied by very strong evaporation with an annual average of around 2500 mm [YAMANI *et al.* 2016].

STRUCTURE OF THE AGRICULTURAL SYSTEM

The agricultural sector of the M'Zab Valley comprises two farming systems. The old palm grove (Photo 1a), characterised by a high density of the plantation, old palm trees, traditional



Fig. 1. Location of the study area; source: own elaboration

irrigation by gullies, and poorly structured and highly fragmented farms (0.5–1.5 ha). This system features tiered crops of date palms, fruit trees, market gardening, and fodder intercrop. The agricultural development areas (Photo 1b) can be subdivided into two types. The first is the semi-oasis agricultural development, which is a small piece of land, with an average area of 2–10 ha, based on the extension of old palm groves, and organised according to an improved oasis system. It is characterised by localised irrigation, optimum density, regular alignment, and structured operations. The second is the business agricultural development, which is a major development, mobilising significant investments, and based on the exclusive use of deep groundwater. It is characterised by the large size of plots of land (up to 500 ha), a greater role of mechanisation, the use of localised irrigation or sprinkling, cultivating open fields, date palm (*Phoenix dactylifera*), and arboricultural orchards. The herds of animals associated with crop production, especially sheep and cattle, are significant. The dominant crops in M’Zab valley are date palms, which account for 75% of practical crops, followed by vegetable crops, which make up 15% of the total. The date palm cultivation heritage of the valley has 150,000 productive palm trees which yield average annual produce of 50,000 Mg of fruit. According to [HOUCHEM 2018], the old palm groves are in decline. They are affected by chaotic urbanisation and their development prospects are uncertain. The new palm groves are dominated by palm cultivation, which prevents the cultivation of other crops, potentially more important for the security of food supplies.

production, irrigation method, land status, agricultural system, marketing, etc.). These areas were selected on the basis of field observations performed over several years in a hundred oases in the M’Zab valley. Other interviews involved a dozen institutional subjects (local communities, agricultural and water services) and were performed to collect data on existing farms, as well as the subjects’ opinions on the new dynamics of oasis agriculture. Like any other scientific research that focuses, above all, on concrete observations, our approach consisted of analysing the facts and drawing relevant conclusions.

RESULTS AND DISCUSSION

The results of several investigations show that, due to various causes, the problem of agricultural development in the M’Zab valley relates to the type of workforce and water management.

LEVEL OF EDUCATION

The results of the surveys show that the level of education of the farmers in the region is modest (they attended a primary, religious school that called Zaouïa). As a result, we infer that it is practically impossible for these people to keep even rudimentary accounts of their agricultural holdings (Fig. 2). The low level of farmers’ education constitutes an obstacle to the adoption of crops which are newly introduced in the region and require advanced technical skills [BENSAHA *et al.* 2019].

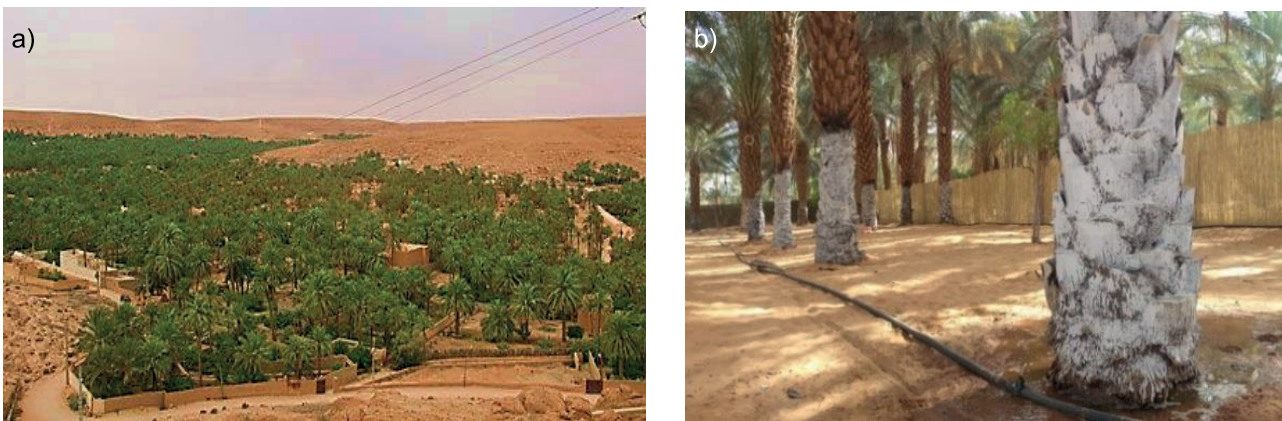


Photo 1. Structure of agricultural system: a) old palm grove, b) agricultural development (phot. R. Zegait)

RESEARCH METHODOLOGY

In order to deliver a diagnosis of the management of irrigation water and agricultural areas in the M’Zab valley and to analyse the positive and negative aspects of irrigation water management, which supports the development of the oasis, extensive research has been carried out in the M’Zab region on the oasis system and its evolution. It was supplemented with dozens of direct surveys carried out among farmers working on agricultural development farms located in the Kaf Edoukhan area, and approximately thirty surveys carried out among farmers living in the old palm groves of M’Zab valley. These surveys focused on farmers (origin, social status, motivation, constraints, etc.) and their farms (surface area,

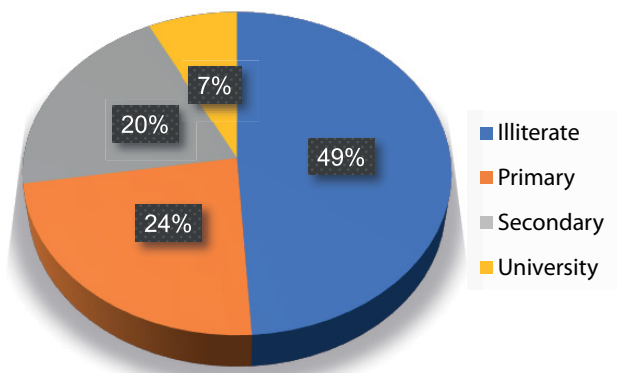


Fig. 2. Educational level in analysed region; source: own study

THE WORKFORCE

Family and temporary labour are still present in these farms with a respective share of 98.66 and 46.98%, with the exception of remote farms, which rely on non-family labourers, whose professional qualifications are usually low (Fig. 3). These workers tend to have no professional training. According to BENSАHA *et al.* [2015], these various orientations of young people away from family farms encourage their parents to resort to hiring foreign labour.

The economic transformations and the change in young people’s attitudes have an impact on their daily lives. This creates the need to seek labour force outside of the family network [GAFSI 2007]. Financial difficulties and the dispersal of most of the labour force on family farms, due to internal quarrels between stakeholders, have led many planters to employ external labourers to carry out work in the fields [BENSАHA *et al.* 2015]. Children constitute a family workforce that can, in principle, take over the farms.

Also, many agricultural workers are not protected by national labour laws, are paid low wages, and work in unsafe conditions [HURST *et al.* 2005]. Finally, providing employment in agriculture in M’Zab Valley is another major challenge, as the percentage of people employed in agriculture remains very low, while other sectors of the economy are not developing.

MANAGEMENT OF IRRIGATION WATER IN THE M’ZAB VALLEY

The irrigated area (IA) in the M’Zab valley is spread over 5286 ha where the mobilisation of water is ensured mainly by the application of wells and, occasionally, boreholes. It accounts for 68% of the total area. The irrigation method is gravitational and is applied on approximately 90% of the irrigated area, followed by

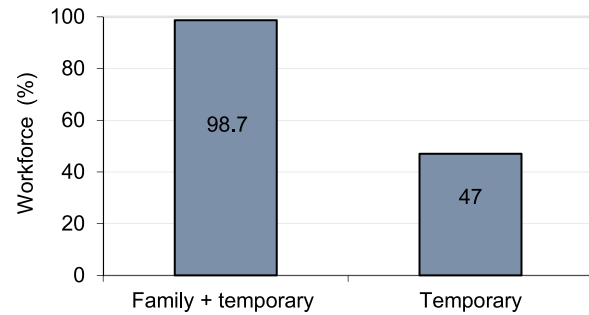


Fig. 3. Use of the workforce; source: own study

the drip irrigation method, applied on 10% of the area. The mobilisable volume of irrigation water is around 85.3 Mm³ and is supplied by 1,535 water points. This translates into an annual average of 16,137 m³·ha⁻¹, with a very heterogeneous distribution between municipalities (Tab. 1). With the extension of the utilised areas, the agricultural sector offers great prospects for development [DSA 2015].

ASSESSMENT OF IRRIGATION WATER LOSS

According to the estimates of the National Hydraulic Resources Agency (Fr. Agence Nationale Ressources Hydrauliques – ANRH), the M’Zab valley features more than 93 boreholes with a daily output exceeding 0.19 Mm³·d⁻¹, where 0.13 Mm³·d⁻¹ intended for irrigation account for 68% of all drilling. Research results indicate that 89.5% of operators use submersion irrigation. The advantage of this irrigation system consists in the fair distribution of water at the right time, while its downside is the loss of water (Photo 2).

Table 1. Characteristics of the irrigation system

Commune	IA (ha)	Drilling (CI)		Well (phreatic)		Total volume (Mm ³ ·y ⁻¹)
		number	volume (Mm ³ ·y ⁻¹)	number	volume (Mm ³ ·y ⁻¹)	
Ghardaïa	1 591	13	13.46	457	14.41	27.87
Bounoura	923	7	5.58	310	9.77	15.35
El-Attuef	993	12	14.50	283	7.50	22.00
Daya	1 779	13	12.23	440	7.90	20.13
Total	5 286	45	45.77	1 490	39.58	85.35

Explanations: IA = irrigation area, CI = continental interlayer.

Source: DSA [2015].



Photo 2. Irrigation water points: a) traditional well, b) drilling (phot. R. Zegait)

It can be noted that the high efficiency of the irrigation system in the Saharan regions, featuring the sandy loam-type soil, is around 60% and 85% for localised irrigation [KHADRAOUI 2010]. This translates into an infiltrated water layer of around $17.16 \text{ Mm}^3 \cdot \text{y}^{-1}$.

On the other hand, the irrigation relies on traditional wells catching the superficial groundwater in the alluvium, under the bottom of the valley. Their depth hardly exceeds 50 m. Their refilling is ensured thanks to the infiltration of rains in the flooding periods and extra irrigation, improved by ingenious devices such as dams, delaying the flow of floods or low walls concentrating and directing the runoff onto the limestones in the valley flanks. We have identified around 1,500 irrigation wells. The total volume extracted from these wells was estimated at $0.11 \text{ Mm}^3 \cdot \text{d}^{-1}$ [DSA 2015], i.e. $39.58 \text{ Mm}^3 \cdot \text{y}^{-1}$ with arbitrary and uncontrolled use. The infiltrated water layer is around $15.84 \text{ Mm}^3 \cdot \text{y}^{-1}$ (Fig. 4).

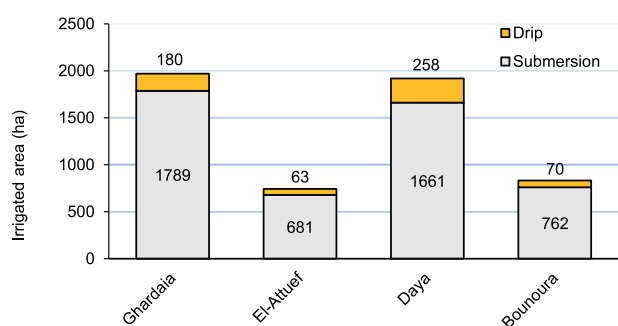


Fig. 4. Irrigation system; source: own study

The water balance of the groundwater in the M'Zab valley showed that a significant excess of water in the order of $1.51 \text{ Mm}^3 \cdot \text{y}^{-1}$ emerges where the flow entering into the system ($43.08 \text{ Mm}^3 \cdot \text{y}^{-1}$) is extremely high when compared with outflows ($41.57 \text{ Mm}^3 \cdot \text{y}^{-1}$) [ZEGAIT 2020]. This assessment clearly shows that irrigation water is responsible for 77% of the problems involving excess water, which arise from irrational water management.

It should be noted that numerous water leaks are observed along the irrigation network, from the Albian borehole to the terminal pipes. These losses add up with those resulting from the infiltration of the cooling basins.

Furthermore, poor maintenance has resulted in the emergence of cracks and rust in the pipes. The application of rational management of irrigation water in the M'Zab valley, involving the integration of modern techniques and the use of purified water in agriculture, will reduce annual losses of irrigation water in the valley by 85 Mm^3 by 2050 [ZEGAIT 2020]. This minimisation would strongly contribute to the rebalancing of the ecosystem of the oasis in the M'Zab valley. To the local people, land represents the basis of all wealth. It is also fundamental for the very existence of their society. Finally, the irrigation systems in the studied region are in most cases defective and require major restoration, in order to allow for more efficient irrigation and better management of water supplies. This induces a low level of water storage, and permanent silting up of the basins which require frequent maintenance. In the long term, it causes a waste of labour force and time. This is combined with considerable water losses through infiltration into the sandy soil.

NOTES ON WATER MANAGEMENT IN AGRICULTURAL AREAS

The management of collective facilities is exceedingly difficult in the absence of a specialised state service, which generates many problems among farmers and leads to the rapid deterioration of facilities [BENSAHA 2009].

The inadequate management of water resources manifests itself in the following field observations:

- significant and continuous loss of water due to infiltration through traditional irrigation canals, called Seguia; excessive doses of irrigation in the earth, and multiple leaks in the supply networks;
- poorly organised water towers;
- extensive illicit operations and tapping beyond the flow rates of many boreholes;
- poor uptake of collective facilities by the beneficiaries.

On the other hand, the water shortage is largely due to:

- diverting of water between farmers: it has been noted that farmers located upstream tend to steal water towers that serve those located downstream from the borehole and a little further;
- extension of existing farms and creation of new farms; each Albian borehole is designed to irrigate a specific area.

It is important to note that the perpetual demand for water and the growing number of farmers cause conflicts between the operators, in this case over the diverting of water. These conflicts manifest themselves very seriously from the beginning of the summer season. To remove this constraint and reduce its impact on agricultural output, we offer guidelines for environmental interventions.

The absence of farmers is reported at 63.09% of the farms surveyed, more than three-quarters of which are new, where the beneficiaries are not yet organised to start this activity (irregular presence/lack of food or value) or simply have not acquired such habits [BENSAHA *et al.* 2016]. As a result of the aid received, an economy of solidarity is developing between the victims of the traditional system, with controversial outcomes. The suitability of the land for cultivation has been affected by inappropriate land-management practices in the study area.

Given that 2/5 of the farmers in this area produce exclusively for their own consumption (Fig. 5), there are good reasons to reflect on the future of these farms [BENSAHA *et al.* 2016].

The palm tree, therefore, remains the main crop in the areas where water is scarce. We have noted huge quantities of date palm rejects (Djebbars) planted in the development areas, due to the abandonment of the plots. When water is scarce, the farmers

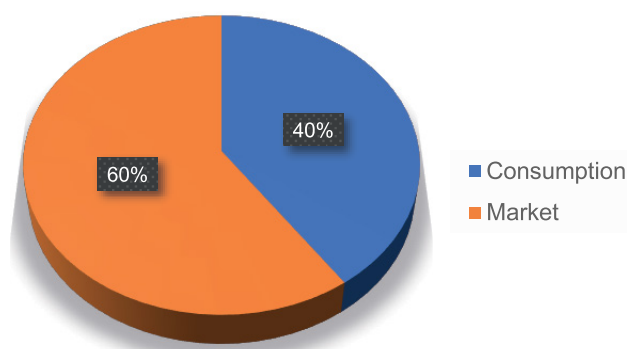


Fig. 5. Product destination (marketing); source: own study

are unable to diversify their crops. Similarly, the presence and/or abundance of other crops depend on the availability of water. This abandonment of farms is certainly a voluntary act, as young people need to seek independence.

In the light of the various investigations carried out by the public authorities and all the partners linked directly or indirectly to the development program, we have drawn the following conclusions:

- there is a problem of under-exploitation of the production units;
- investments are unprofitable;
- there are no action plans for effective promotion of agricultural entrepreneurship;
- mechanisms and conditions for acquiring the means of production are discouraging;
- farmers fail to master the markets.

In addition, due to the disengagement of the State from water management and maintenance of facilities, they are left in the hands of associations and experience:

- insufficient support from the departments concerned in terms of programming and implementing management rules and maintenance work;
- low productivity of crops;
- the small size of the farms allocated to the farmers and lack of opportunities to extend the production capacity, which do not allow them to generate income sufficient for maintaining the farms and achieving profitability.

CONCLUSIONS

The M'Zab valley is regarded as one of the great oases of the Algerian Sahara. It has an arid and dry climate. In recent years, it has seen a marked decline in agricultural land. The first part of this piece of work was devoted to the analysis of the effects of farmers' and workers' education on agricultural development.

The results show that the low level of education among farmers constitutes an obstacle to the adoption of crops that were newly introduced in the region and require advanced technical skills. The agricultural workforce is a major challenge in the M'Zab valley, as economic transformations and changing attitudes among young people have an impact on their daily lives, making them open to the opportunities of employment outside of the family. Secondly, we considered the effects of irrigation water management in the M'Zab valley.

The results show that there is a significant excess of water in the order of $1.51 \text{ Mm}^3 \cdot \text{y}^{-1}$, as the flow entering into the system ($43.08 \text{ Mm}^3 \cdot \text{y}^{-1}$) is extremely high in comparison to outflows ($41.57 \text{ Mm}^3 \cdot \text{y}^{-1}$). This assessment clearly shows that irrigation water is responsible for 77% of the problems involving excess water, which arise from irrational water management. The management of agricultural areas in the M'Zab valley is challenging to those involved in supervision and development, as well as to farmers. These examples demonstrate that there is a real problem in the common management of land in this locality. This can be accounted for by the complexity of the strategies weighing on those responsible for implementing the legislation relating to the development and organisation of facilities. This problem, far from being fortuitous, is growing more urgent in this community.

In this situation, we recommend organising awareness-raising and training days for farmers to improve their adaptation to new agricultural and irrigation techniques, as well as developing and popularising modern irrigation methods that improve the efficiency of irrigation systems, and the introduction of localised irrigation methods that would reduce the incidence of abandonment of farms. The management of areas should be based on consultation between the project manager and the operators, with the view to removing all constraints weighing on the improvement of farmers' production conditions. It is only on this condition that these interventions by public authorities can contribute to sustainability. It is important to be aware, however, that this crisis, like previous social crises, has an impact on all the parties involved.

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