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ORIGINAL PAPER

Conservatory Management of Natural Resources in the Naâma Region (Southwest Algeria)

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Abstract
This work was carried out in the Naâma area to determine the appropriate techniques for natural resource conservation of the agricultural holdings surveyed in this region. The results show that combining the mechanical methods (threshold in gabion, threshold in dry stone and hillside reservoirs) and the biological ones (setting in defense, reforestation, rustic planting, etc.) can give the best result to conserve the natural resources. The investigation carried out with farmers of thirty farms allowed us to determine some peasant of water and soil conservation techniques (WSCT) implemented in this area, notably basins, seguia, mulching, and dry stonewalls. On the other hand, some thresholds were practical and very well adapted to the physical conditions of this region. Still, they are partially degraded due to the influence of intense rainfalls and violent winds, which usually require normal controls after each hydrological event. The average cost to install a complete system of natural resource conservation in this area (torrential corrections and biological plantation) could be estimated from 1200 to 4000 DZD/m^3. The sensitization of people in the fight against any factor of land and environmental degradation is significant because this precious heritage that constitutes the land requests their participation in the various development programs on these steppe areas.

Keywords Conservation techniques · Gabion · Dry stonewall · WSCT · Naâma

Introduction

In Algeria, soil degradation is very advanced, and every year significant quantities are lost and moved by water and wind towards other places. Land degradation is a process that reduces the agricultural productivity of soils or reduces its effects as natural resources [1]. The triggering of this phenomenon was also due to the soil working [2]. Intensification of agriculture can lead to soil degradation and erosion, but land abandonment can also. Uncontrolled human, agricultural, pastoral, or forestry activities certainly play an essential role in accelerating the soil erosion process in its different forms (water and wind erosion) [3–8]. Neither fruit tree plantations, extensive cereal crops, nor grazed fallow land provides sufficient soil protection in the rainy season [9, 10]. The depleted and poorly covered soils are defending themselves against the aggressiveness of runoff [11, 12], to deal with this problem and maintain the environmental balance in the catchment area. The most appropriate method is the implementation of numerous techniques of water and soil conservation, which correspond to the whole range of mechanical, biological, cultural, and agronomic practices, as well as the sensitization of rural populations to improve the management of natural resources and the success of the conservation techniques implemented [13]. In this context, enormous studies about soil conservation and development have been undertaken in the Naâma steppe. These rich and fragile steppe areas have a continuous degradation process, which affects the regression of the vegetation cover, primarily through overgrazing, and under the risk of water erosion and silting phenomena, in both urban and rural areas as in road infrastructures and farms.

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Fig. 1 Geographical location of the Naâma area study

This work aims to propose a typology of water and soil conservation techniques (WSCT) in the Naâma region, with the erosion process. A survey within farmers and forest services was carried out to determine the dimensions, materials, implementation costs, and efficiencies of WSC and specify their links with the agro-ecological conditions of the region.

Material and Methods

Study Area

The province of Naâma is part of the high southern plains. It is lies between 32° 08′ 45″ and 34° 22′ 13″ north, and

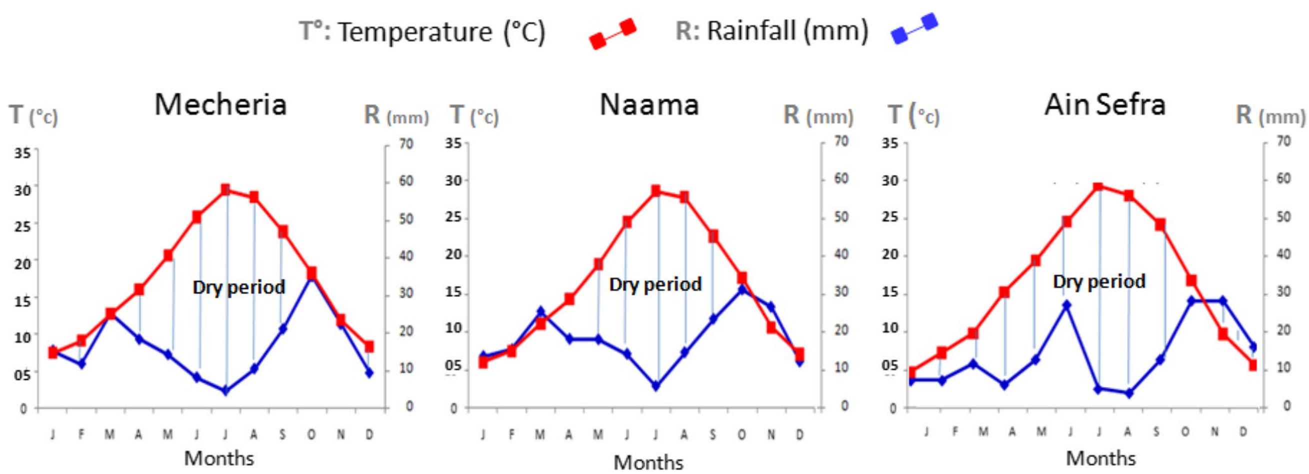

Fig. 2 Ombro-thermal diagram of Bagnouls and Gaussen between 1990 and 2014 in stations (Mécheria, Naâma, and Ain-Sefra) [17, 19]

between 0° 36′ 45″ and 0° 46′ 05″ west. It is located between the Tell and the Saharan Atlas, in its western part (Fig. 1). The region of bounds is:

- to the north by Tlemcen and Sidi Bel Abbes,
- to the east by El-Bayadh,
- to the south by Béchar,
- to the west by the Algerian-Moroccan border.

This province has a population estimated at 268,721 inhabitants (in 2016), with an average growth rate of 5.44% [14].

Vegetation

A steppe physiognomy describes the natural vegetation of the study area except in the mountains where the remains of primitive forests cut down by man and we find *Pinus halepensis* and *Juniperus phoenicea*. A part from these forest species, according to Pouget [15], the steppe vegetation often appears monotonous, based on esparto grass (*Stipa tenacissima*, *Lygeum spartum*) and/or perennial chamaephyte (*Artemisia herba alba*, *Artemisia campestris*, *Helianthemum hirtum*), and according to FAO [16] any removal or degradation of the vegetation cover or plant residues that protect the soil on the surface is the main cause of wind erosion.

The appearance of the steppe changes with the rainfall gradient and the nature of the soil. For example, the southern Oranian steppe is dominated by the following plant formations:

- Esparto grass steppe (*Stipa tenacissima*);
- Sagebrush steppe (*Artemisia herba alba*);
- Spartum steppe (*Lygeum spartum*);
- Halophyte steppe (*Hammada scoparia*);
- Psammophyte steppe (*Retama raetam*, *Thymelaea microphylla*).

Climate

The regional hydrological regime in the region of Naâma can be divided into two main seasons: a cold and relatively wet season and a hot and dry season. The examination of the climatic data allowed us to establish the ombro-thermal diagrams for this region. So, based on the two climatic stations of Mécheria and Naâma indicate 7 to 8 dry months, generally from March to October (Fig. 2); however, the station of Ain-Sefra located in the south of Naâma (Fig. 2) showed a long duration for the dry season (10 to 11 months), ranging from January to October [17–19].

The rainfall quotient is applied to the Mediterranean and Northern Sahara countries and considers the annual variation of temperatures. Climatic data revealed that the three stations of Naâma, Mécheria, and Ain-Sefra are classified on the upper arid and cold winter periods.

Potentiality of Water Resources in the Region Naâma

The region of Naâma has a significant essential wealth of surface water resources but above all underground (rivers and wadis, reserves of chotts El-Chergui and El-Gharbi, underground water reserves…) [20]. It contains significant underground water potential that has been little exploited, especially in the steppe plains around the chotts (El Chergui and El Gharbi), in the Naâma syncline, and the valley of Ain-Sefra-Tiout [20, 21]. It has relatively large water resources and benefits from many natural assets: heavy rains, a mountain water tower with large infiltration areas and snow-capped peaks, perennial rivers, and large underground aquifers continental intercalary (Albien) [21].

Naâma region has relatively large water resources and many natural advantages: rather large rains, a water tower mountainous with large areas of infiltration and the snowy peaks, perennial rivers, and primary groundwater [22].

Methodological Approach

The steppe constitutes a fragile environment for the degradation of the vegetation cover and the anthropic effects of land use constitute supplementary factors that generate erosion. To achieve our objective in the study area, we adopted a global working approach based on four components:

- The choice of sites in coordination with the administrative services of Naâma;
- The operations of exploration, observation in the field, and the collection of data;
- The analysis of different systems of WSC to evaluate their effectiveness.

The Choice of Sites

The choice of sites was based on some parameters, such as water and soil conservation techniques. The implementation of these systems was created by public services or developed by farmers. We reported that the forest conservation services and the High Commission for the Development of the Steppe (HCDS) of the province of Naâma as well as the district of the forests of Mécheria and Ain-Sefra take care of this mission.

Exploration and Observation Trips

Some surveys of a few selected sites gave us a global overview of the different techniques used in the study area. Direct observation in the field has led us to understand the conditions of works carried out, the dimensions of structures, and the dimensions of structures, and they enabled us to see the efficiency of some anti-erosive systems.

Survey with Farmers

We conducted surveys on 30 farms over 3 months. They were carried out using a questionnaire which was established to collect as much information as possible about the farm, farming practices, traditional and modern conservation techniques, and the constraints experienced and problems faced by farmers.

Results and Discussion

Erosion is a complex phenomenon that contributes to the disappearance of good soils under wind and water. The risks of erosion in the Naâma region are mitigated by applying water and soil conservation techniques (WSCT).

Mechanical Installations

Torrential Correction

Table 1 shows some works about the torrential correction used for water and soil conservation in the Naâma region.

Table 1 Some anti-erosion works installed on the Naâma region [23]

Technique	Region	Disclaimers	Efficiency	Year	Cost (DZD)	Sustainability
Gabion sills	Oued Founassa (Djeniene-Bourezg)	L: 10 m l: 2 m H: 1 m V: 20 m^3	Very effective	2010	1400–4000	Sustainable
	Oued Ouarka	L: 30 m l: 8 m H: 1 m V: 240 m^3	Effective	2010	1400	
	Ben yakhou (Ain-Sefra)	L: 68 m l: 2 m H: 1 m V: 204 m^3	Very effective	2010	4000	
	Hassi-labyad	L: 1000 m l: 1 m H: 1 m V: 1000 m^3	Effective	2015	4000	
	M'ssif (Naâma)	L: 1000 m l: 1.50 m H: 1 m V: 1500 m^3	Moderately effective	2013	1950	
	Djeble Antar (Mécheria)	1) L: 40 m, l: 5 m, H: 1 m 2) L: 45 m, l: 4 m, H: 1 m 3) L: 50 m, l: 3 m, H = 1 m V: 530 m^3	Effective	2010	3000	
	Asla	L: 38 m l: 8 m H: 1 m V: 304 m^3	Effective	2007	1400–4000	
Dry stone sills	Asla	L: 100 m l: 1 m H: 1 m V: 100 m^3	Effective	2010	1200	
	Ouarka	L: 9 m l: 2 m H: 1 m V: 18 m^3	Effective	2007	1200	Weak

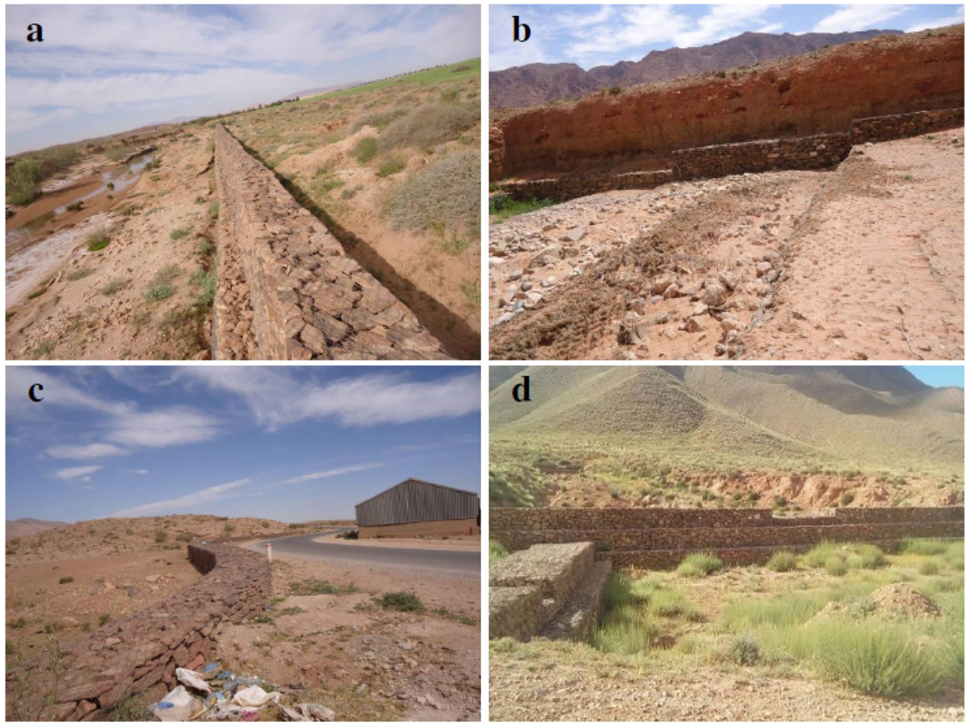

Fig. 3 Gabion sills to control erosion in the different sites of the Naâma region (**a** Messif, **b** Ouarka, **c** Hassi Labyadh, **d** Djebel Antar)

Fig. 4 Dry stone sills in the region of Naâma (**a** Ouarka, **b** Asla)

Table 2 Effectiveness of three types of thresholds on gullying [24]

Type of sill	Gabion	Dry stone	Wire mesh
Sediment capture	Very fast	Fast	Fast
Sustainability	Fragile	Fragile	Most sustainable
Cost (FF)	500 FF/m^3	400 FF (or 75%)	125 FF or 25%

L length, *W* width, *H* height, *V* volume, *DZD* Algerian Dinars.

The two techniques used according to the data provided by the forest services are gabion walls and dry stone walls. Each system has its characteristics in terms of size, efficiency, and durability.

According to Tacnet et al. [24], a system is considered adequate if its capacity to protect soil is in line with its design objectives.

Gabion walls are efficient and moderately durable, with a high cost (labor costs, building materials, transport, etc.), and require maintenance that determines their lifespan (Fig. 3).

The field trips allowed us to observe that gabion sills are used to fix gullies, mainly near roads, to limit sand's advance and slow down runoff into agricultural lands, especially near the streams. According to Roose et al. [25], these gabions fix the sediments very quickly (in 2 or 3 floods). Still, they can also be raid destroyed promptly under the piping phenomenon, tunnels dug by the falling energy of runoff water if energy dissipaters do not defend them. The majority of the observed gabion walls are perfectly adapted to this region's

Table 3 Hydraulic systems used in the Naâma region during the period 2002–2006 [29]

Daira	Commune	Type	Number	Capacity (m^3)	Height (m)	Year of completion
Mécheria	Ain Benkhelil	Water bund	2	550,000		2004
		Retained	1	2,517,535	5.8	2006
		Hill reservoir	9	510,000	3 and 4.5	2004–2006
		Diguette	1	90,000	3.5	2006
	Mécheria	Water bund	1	80,000	5.50	2004
		Diguette	1	90,000	3.95	2005
	Biodh	Water bund	3	505,000	5 and 6.57	2005
		Hill reservoir	9	335,000	2 and 5.50	2003–2006
M Ben Amar	M Ben Amar	Retained	1	2,036,737	7.82	2004
		Hill reservoir	6	245,000	3 and 4.50	2004–2005
	Kasdir	Water bund	4	2,043,360	1 and 5.20	2003–2006
		Retained	1	1,000,000	5.85	2004
		Hill reservoir	6	187,000	1.50 and 4	2004–2006
		Diguette	1	133,000	3.73	2005
Asla	Asla	Water bund	2	44,952	6.5	2003
		Hill reservoir	5	213,000	1.5 and 5.84	2002–2006
Naâma	Naâma	Water bund	2	208,000	6.59 and 7.70	2005–2006
		Diguette	1	36,000	2.60	2005
		Waterhole	5	164,000	1 and 5.60	2003–2006
Ain Sefra	Ain Sefra	Diguette	2	388,660	3.50 and 4.25	2006
	Tiout	Hill reservoir	2	106,896	5 and 5.50	2005
		Hill reservoir	4	150,092	4 and 5.75	2004–2005
		Diguette	1	78,888	5.52	2005
Sfissifa	Sfissifa	Water bund	5	1,382,025	5 and 6.50	2004–2006
		Retained	1	9,642,250	10	2006
		Hill reservoir	4	211,253	4 and 6.55	2004–2006
		Diguette	3	194,364	4.40 and 7.50	2004–2006
Moghrar	Dj Bourezg	Water bund	2	245,000	5 and 6.25	2006
		Diguette	2	105,000	4.70	2004–2005
	Moghrar	Water bund	1	55,000	4.50	2006
		Diguette	6	446,000	2.67 and 7	2004–2006

climate and soil conditions. Adaptability is a concept recently introduced for torrential correction [6], which consists of characterizing the capacity of torrential correction structures to be convenient to the conditions of the natural environment while playing its role. The survey leads us to say that the weirs are adopted only for some anti-erosive systems.

The dry stone walls implemented in Asla, Ouarka, and Oued Ouarka sites are less expensive than gabion sills but

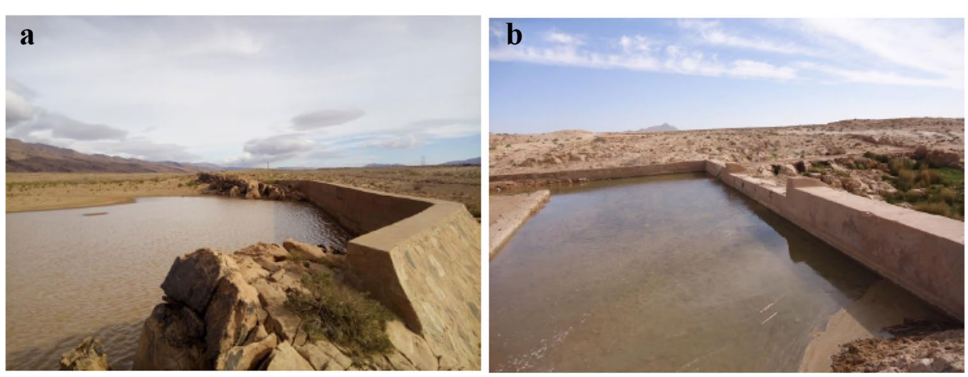

Fig. 5 Diguette in the Naâma region (**a** Founassa, **b** Messif)

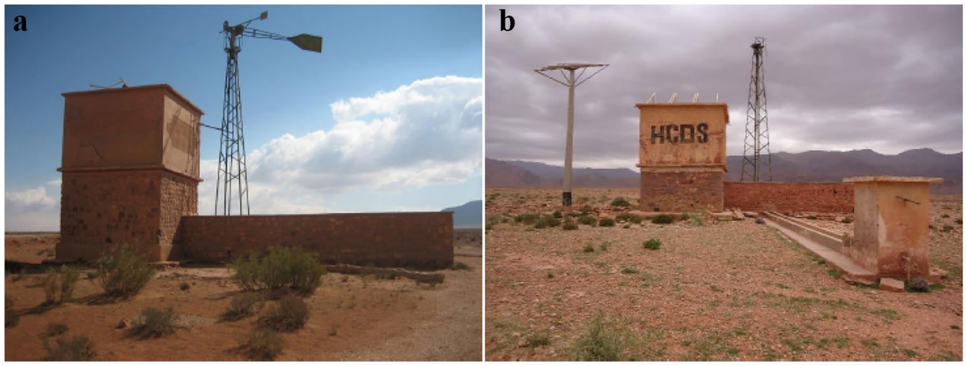

Fig. 6 Drilling carried out by HCDS services completely degraded (**a** Moghrar; **b** Tiout)

require time and qualified personnel to collect stones and build walls. Sogetha [26] said that the dry stone walls constitute a barrier for the sediments and a filter that passes water, and also minimize the speed of surface water flow, which increase the infiltration of water towards the soil, and decrease the suspended fine soil particles mobilized from upstream slopes (Fig. 4).

The dry stone weirs visited on the different sites in the Naâma region were fragile and had a very short lifespan. They were built with weak stones that decompose rapidly under the effect of water and climate conditions. The small stones used to realize the weirs system were moved by water (high flows), and the structures were quickly destroyed. According to Burchard [27], the quality, form, and size of stones used to construct weirs are parameters that determine the lifespan of these systems (Table 2).

In Naâma region, Melalih [28] confirmed that gabion sills are the most used (96%) for WSCT, while the rest (4%) are with dry stone cordons.

Hydraulic Weirs In the Naâma region, the High Commission carried out work about water and soil conservation (Table 3) for the development of steppes during the period 2002–2006, which was generally based on systems: hill reservoir, diguette (bund, small dam), and water bund.

Table 4 Biological management used in the province of Naâma [23]

Biological management	Cultivated surface (ha)
Green band and belt	2145
Reforestation and shade grove	2058.5
Dune fixation	13,127
Pastoral plantations	564
Fruit plantation	3014
Fencing	422,000

The different observed water and soil conservation techniques are mainly realized with mechanical structures that store sediments and slow down runoff flows. Dikes and canals realized parallel to the contour lines were made with soils, stones, and beaten earth [30]. Dikes in small dams are probably the most common system for artificial water storage (Fig. 5).

The mobilization of surface water through three hilly reservoirs across the province's territory is generally intended for irrigation and livestock watering [21].

These structures can trap large quantities of water and sediments [31].The water diversion and collection channel system called seguia (irrigation by canal), observed in Messif region, is made by a cemented and arranged stones that allow water to be distributed on the agricultural land (Fig. 6).

These hydraulic systems (dykes, dams, boreholes, etc.) are effective structures that control rainfall and runoff, which can be used later to irrigate farmland or even for livestock watering.

Biological Developments The conservation strategies used to protect steppe areas in the Naâma are mainly the defense of rangelands, reforestation, fodder plantations, dune fixation, and the development of arboriculture (Table 4).

The biological developments carried out in the Naâma region differ from one commune to another. We found that the fixation of dunes alone, which covers 13,127 ha, and a fruit plantation covering 3014 ha, constitutes an important component of agrarian space and land management. According to Boucherit et al. [32], the development of fruit arboriculture in mountain areas is likely to stabilize erosion processes, restore the plant cover, and open a new way of agricultural diversification and a new source of income.

The cultivation of fodder species to meet the needs of the livestock started from an exciting idea that has deteriorated under the influence of overgrazing and other biological techniques. The development of species production must

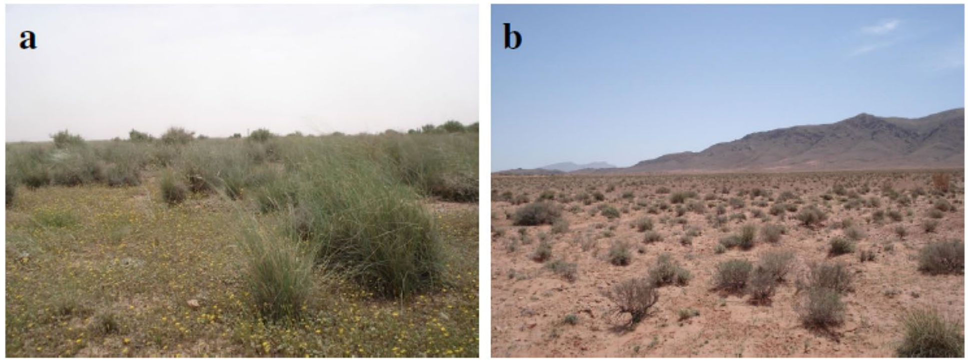

Fig. 7 Biological management (**a** Abdelmoulah; **b** Zaboudja)

necessarily involve land improvement work and soil amendment to enrich them and increase their yields [33].

The decrease in the vegetation cover in this steppe promoted the movement of dunes under the wave action and wind erosion.

Thus, silting and dune movement affecting the steppe regions are the desertification problem's locomotive parameters. A continuous regressive evolution reflects the degradation of plant groups in arid and semi-arid environments under natural and anthropogenic conditions [34, 35].

According to Benkhalfoun and Adjadj [36], the choice of plant species is mainly based on the following criteria:

– Ecology of the plant species and their adaptability with the soil and climate.

In coordination with the citizens of these rural areas, the presence of goals in the area guarantees the success of these plant species and the project (Fig. 7).

According to the work of Benaradj and Boucherit et al. [37–39], on the steppe of Naâma, the biological techniques

Table 5 Results of the survey carried out on 30 farms

Questions	Data	
Surface (ha)	S < 5 ha	43%
	5 < S < 10 ha	50%
	S > 10 ha	7%
Type of operation	Individual	73%
	Group	27%
Tillage	Tillage	96.67%
	Half-direct	3.33%
Installation of anti-erosion systems	Traditional (e.g., basin, dry stone)	86.67%
	Modern (e.g., gabion sill)	13.33%
Mulching	Yes	13.33%
	No	86.66%
Fallow land	Yes	3.33%
	No	96.66%
Use organic manure	Yes	83.33%
	No	16.66%
Raising animals	Yes	63.33%
	No	36.66%
Water	Drilling	66.66%
	Well	20%
	Hill reservoir	6.66%
	Source	3.33%
	Wadi	3.33%
Water use (irrigation, watering of livestock)	Irrigation	100%
Installation of hydraulic works	Traditional	26.67%
	Modern	73.33%

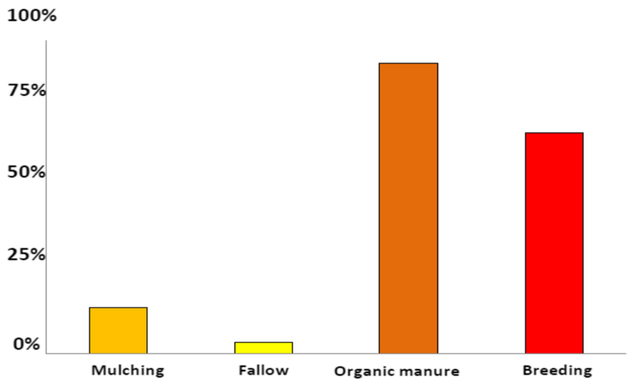

Fig. 8 Some biological techniques practiced in this area

of defending have a positive impact in terms of biological ascent. The setting in defense allows a quantitative and qualitative increase of the floristic richness, a development of the pastoral species, particularly the therophytes. These results show significant phytomass and relatively high vegetation cover. The floristic composition is very diverse. Defending has an improving aspect of the soils; it has been demonstrated that this regeneration translates into a remarkable improvement in the soils' physical (texture) and chemical (organic matter) characteristics.

Result of the Survey with Peasant

Peasants lead a simple life, often expressed by adopting a traditional livestock way to address immediate needs. The cultural practices still present preserve an important agro diversity.

Based on the survey conducted with farmers and their own lifestyle environment, the results reveal a certain

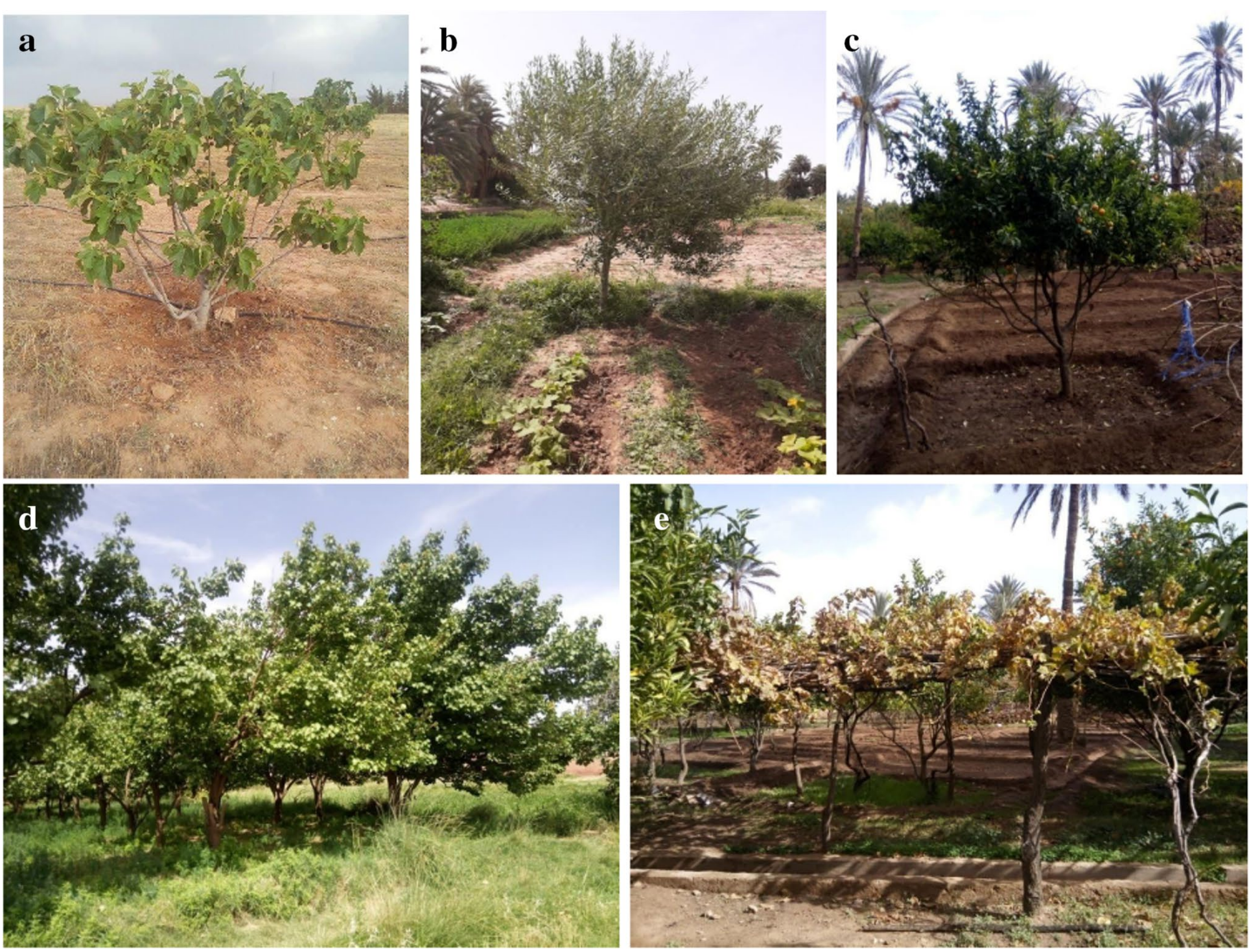

Fig. 9 Half-moon basin around fruit trees in Naâma (fig tree, olive tree, orange tree, apricot tree, vine tree)

heterogeneity in terms of the area farmed and the availability of means of production and the WSCT used (Table 5).

To get a clear idea about agricultural farms in the Naâma region, a questionnaire was performed with farmers who are ages over 50 years old.

Thus, more than 50% of the surveyed agricultural farms are average sizes between 5 and 10 ha. The legal nature of land ownership is individual (73%). Most farmers (73%) carry out superficial tillage, especially for annual and biennial crops, while deep tillage is reserved for arboriculture. However, some farmers prefer semi-direct tillage without tillage.

It should be noted that tillage practices directly bear the potential for wind and water erosion and soil quality, especially as it relates to the maintenance of soil organic matter. This includes the depth, direction, period of tillage, the type of equipment used, and the number of passes. Tillage is considered a way to limit erosion if it is realized in the best way, with vegetation cover on the soil surface. Barthes et al. [40] estimate that runoff and soil losses are higher in plowed plots, lower in no-till, and intermediate in shallow tillage.

Summer fallow and mulching are practiced less than 15%. Fallow is a very traditional technique and has a marked influence on erosion reduction if it is managed well [41]. Indeed, according to Wischmeier and Smith in Roose [42], even low-dose mulching (2 to 6 t/ha) can reduce erosion problems by 95%, whereas burying biomass as green manure can only reduce them by 5%.

Nicou [43] found a better effect when burying crop residues than leaving the residue on fields. On the other hand, when we make the tillage operation, we can create naked soil, aggravating erosion.

Furthermore, FAO [44] has pointed out that biological techniques (soil cover, use of fertilizers, mulching, cover crops, rotations, etc.) are more efficient than mechanical techniques, which are very expensive and difficult to maintain. Therefore, these types are aimed at stabilizing watercourses, watersheds and mitigating excess precipitation.

Pastoralism is the main activity in this area, where 63.33% of farmers practice animal breeders, and 83.33% use organic manure for land enrichment as fertilizers. It should be noted that no soil or water analysis has been carried out (Fig. 8).

Techniques Developed by Farmers

In the field, we can see that farmers are aware of soil degradation and try several times to develop techniques to safeguard this heritage. The various WSCT carried out by farmers are created to store and manage rainfall and prevent soil loss caused by runoff.

The most widespread practice in the study area is the plantation of arboriculture on steep slopes and the installation of small infiltration basins at the foot of the trees, either circular or half-moon shaped, to facilitate infiltration towards the roots (Fig. 9).

Fig. 10 Traditional irrigation system by seguia (**a** Asla, **b** Moghrar)

Fig. 11 Gully erosion corrected by a gabion sill (**a** face, **b** profile)

All these elements and indicators can promote the development of agricultural productivity in this region. This can be done without omitting opportunities to announce the availability of water for the population. The availability of this element can contribute to the settlement of rural people and improve their living conditions and economic activities (mainly agro-pastoral) [22].

Regarding the irrigation water sources, we indicate that water comes from several sources: 70% from drilling, 20% from traditional wells, and 10% from ponds. Thus, the farmers practice traditional systems for irrigation of their crops through canals and seguia (Fig. 10), which cause considerable water losses. For example, in the region of Tiout (south of Naâma), the farmers are receptive to water management because they use a traditional distribution system [45, 46]. In contrast, farmers with sufficient financial means use drip and sprinkler systems for irrigation.

Techniques Put in Place by the Public Authorities

In the region of Naâma, and precisely on agricultural lands, WSCT structures implanted were adapted according to some conditions, such as the relief and the availability of stones. Whether through the system of dry rocks or gabion walls, they have been built after a request made by farmers and sent to the forest services of the province of Naâma, where they explain the constraints and problems encountered on their farms (Fig. 11).

A public technical authority deals with all applications with the coordination of farmers benefiting from these

Fig. 12 Different WSCT introduced by forest conservation services in the province of Naâma (**a** Messif; **b** Asla)

Fig. 13 Stone cordons in the agricultural land of Mécheria

anti-erosive systems. This WSCT was mainly realized with gabion sills (Fig. 12), for the main reason is to protect farmlands against flood risks.

Currently, we indicate that in the majority of farmlands visited, we found the most practiced WSCT by farmers on their cultivated fields, which are the cordons of stones. The implementation of this system by farmers is primarily free and without any technical assistant (Fig. 13).

Conclusion

The steppe is a rich and fragile environment due to the degradation of the steppe vegetation cover and the irrational use of lands, which are the factors generating erosion.

This study was interested in the WSC techniques applied in the Naâma region. The surveys were conducted with farms in different areas (Asla, Mécheria, Ain-Sefra) to determine the state of the two anti-erosion systems (mechanical and biological).

The survey diagnostic of these systems on the study region shows that the weirs (made with gabion and dry stone) are not put in place for all anti-erosive systems. These WSCT are characterized by shortcomings (implementation without prior study, no determination of priority areas for intervention, lack of monitoring, and maintenance due to the lack of awareness of rural societies). Sustainability consists of involving the populations more closely for the action.

Surveys with farmers confirm that lot of lands in this region were degraded and gullied after each rainfall. They are ready to develop traditional conservation techniques, e.g., basin and seguia, to minimize erosion. These systems help to save and keep what remains of good agricultural lands. Therefore, it is necessary to prioritize these methods and strategies of soil and water conservation because they are the best way to keep the agro-ecological conditions and socio-economic characteristics of the Naâma region. So, to have the desired results, it is essential to take into account a set of diseases such as:

– The state of soils: texture, depth, structure, etc.
– The aspect of surface: slope, relief, porosity, and land on the surface;
– Climatic context: temperature, hail, rainfall, and insolation.

Finally, water and soil conservation is therefore essential to protect the natural resources of this region. This technique of land use and of erosion treatment lead to the protection of soil and water and at the same time to increase rates of agricultural productivity.

Declarations

Conflict of Interest The authors declare no competing interests.

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