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Evaluation of hydro-agricultural techniques and assessment of know-how implemented by traditional societies: Case of the region of Béni-Snous in the city of Tlemcen – Algeria

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Abstract

In the past, rural society has always been able to implement some forms of community management of space, water and land that have served as a support for the survival of populations that are often too large for the available resources. The mountainous region of Béni-Snous offers a wide variety of strategies for water and soil fertility conservation management; it presents a form of adaptation of man to the strong physical constraints and thus constitutes a hydro-agricultural and cultural heritage which unfortunately has not yet aroused all the interest it deserves and of which one can be inspired. The ingenuity of these traditional systems, which have survived throughout history, challenges us to analyse and study these systems more seriously, particularly from the technical and organizational side. Our study was conducted in this context. The present work aims to evaluate the traditional systems of water and soil fertility conservation management, which are encountered on the mountains of Béni-Snous, which is characterized by a semi-arid climate. These systems represent a kind of creativity that is, at the same time, practical, organizational and social. The assessment of the state of water and soil management and conservation structures showed that 78% of them are currently functional and valorised. Given their importance, all mobilization and water management structures are still functional; they showed a good cost-effectiveness ratio.

Key words: *Béni-Snous, community management, cost-effectiveness, evaluation of hydro-agricultural techniques, water and soil fertility conservation management*

INTRODUCTION

Water and soil are the most valuable assets for man. These delicate resources are undergoing unprecedented qualitative and quantitative degradation. Despite the development of different strategies for the preservation and management of these resources, the degradation process continues to grow due to the climate change and human pressure [ARABI, ROOSE 1989; AUBERT 1986; HABI, MORSLI 2011; HEUSCH 1986]. This degradation is reflected by the decline and depletion of resources, and also by the worsening of environmental problems. This situation implies that it is urgent to establish adaptation strategies and develop adequate and sustainable management techniques to remedy these problems.

Traditional societies have always been able to implement community-based management that adapts to local environmental and socio-economic conditions; they have contributed to the development and improvement of a rich heritage of water and soil management and conservation techniques, which have served as a support for the survival of a population which is often too large to be adequately supported by the available resources.

Due to the failure of modern water and soil conservation management strategies [ARABI *et al*. 2004; ROOSE 1995; 1997; TAABNI 1997], it has become necessary today to take into account, in the new strategies of water and soil fertility conservation management, all the old techniques along with the ancestral and traditional strategies and systems that had proven effective over time, and particularly those that farmers had adopted, adapted and mastered. A good understanding and a sound assessment of traditional strategies (techniques and know-how), which are unknown and still raise questions regarding their functioning, are essential due to their socio-economic role and their environmental importance. These strategies can inspire us to put in place new and more appropriate policies that are commensurate with current and future challenges (climate change and population growth). This know-how must be rethought and restyled in order to make it more efficient, more profitable and more sustainable.

In southern Mediterranean regions, particularly in Algeria, several traditional strategies have been developed. These strategies are certainly still operational in some regions of the Algerian territory but they often remain scattered and sometimes abandoned or ignored [MAZOUAR *et al*. 2008]. However, in some other areas such as the semi-arid mountainous area of Béni-Snous, these strategies have been used intensively for centuries, and have been maintained until now. In fact, they continue to be used up to now, and there is even renewed interest that justifies and encourages their investigation. The region of Béni-Snous offers a great diversity of conservatory water and soil management strategies and presents a form of adaptation of man to the strong physical constraints in the region. Indeed, the area of Béni-Snous constitutes a rich hydro-agricultural and cultural heritage from which inspiration should be drawn.

This work aims to contribute to the understanding and evaluation of this heritage. It is an attempt to explain its functioning, to highlight traditional knowledge and to preserve it for future generations, and to learn from these traditional strategies that constitute essential elements to promote better water and soil management techniques and to implement sustainable development programs.

MATERIALS AND METHODS

STUDY AREA

Nobody can deny the immeasurable role played by the traditional techniques (structures/systems) of water and soil management. Their scientific importance urges us today to undergo a deeper assessment of the know-how related to these systems. To this end, it was decided to choose the mountainous region of Béni-Snous. The choice of this area is justified by the rich heritage offered by its traditional hydro-agricultural system as well as by the technical knowledge that still employed by the traditional society of Béni-Snous.

The region of Béni-Snous, which is the area of this study, is a mountainous area, located in the Province (Wilaya) of Tlemcen, North-West of Algeria (Fig. 1). It is a rugged and hilly region, where 80% of its territory is mainly mountainous; it is characterized by poor soils, excessive erosion and limited water resources [PDAU 2008]. This area is primarily composed of carbonate soil, from the Jurassic period. The most important outcrops are Jurassic formations and karst limestones. This geographical zone is characterized by a very important hydrographic network, whose main river is Wadi El Khemis (Wadi El Khemis River), tributary of Wadi Tafna. The surface waters of the watershed are regulated by the dam of Béni Bahdel (56 hm^3). Hydro-geologically, the two large sets of calcareous-dolomitic formations, which lie in the most part of the area, indicate that Béni-Snous is a widely karstified zone. These formations make up the most important aquifers in that zone [SALHI, TRANDJI 2008]. The climate of the region is semi-arid, of Mediterranean type. The average annual rainfall is about 400 mm. This area is described as representative of the diversity of natural and socio-economic conditions; it provides a range of varied traditional techniques for water and soil conservation. The main activities of people in this area are, in order of importance, irrigated agriculture practiced on terraces on the mountain slopes and in the valleys of wadis (rivers), livestock and craft activities. The villages clinging to the mountainsides (Khemis, Beni Achir, Ouled Mousssa and other), are known for their olive trees and olive oil, their famous orchards and their beautiful cultivated terraces. Irrigation water comes from wadis (rivers) and water sources. The territory of Béni-Snous is characterized by its long tradition of irrigated agriculture with surface water.

METHODS

The methodological approach followed for the realization of this work is as follows:

- Identification, spatialization and classification of traditional water and soil conservation structures:
  - identification is based on field explorations and field surveys, and also on the examination of pre-established questionnaires;
  - spatialization of water and soil fertility conservation management structures (position and spatial distribution of traditional structures) is achieved through the use of MapInfo GIS software.
- Evaluation and analysis of traditional water and soil fertility conservation management structures. Assessment is based on the analysis of several parameters (adaptability of systems to the natural environment, adoption by farmers, cost-effectiveness, sustainability, reproducibility etc.). The collected data were subjected to a Multiple Correspondence Analysis (MCA). This statistical analysis is a method that is perfectly suited to processing surveys where the questions may have multiple answers and are of qualitative nature, which is our case.

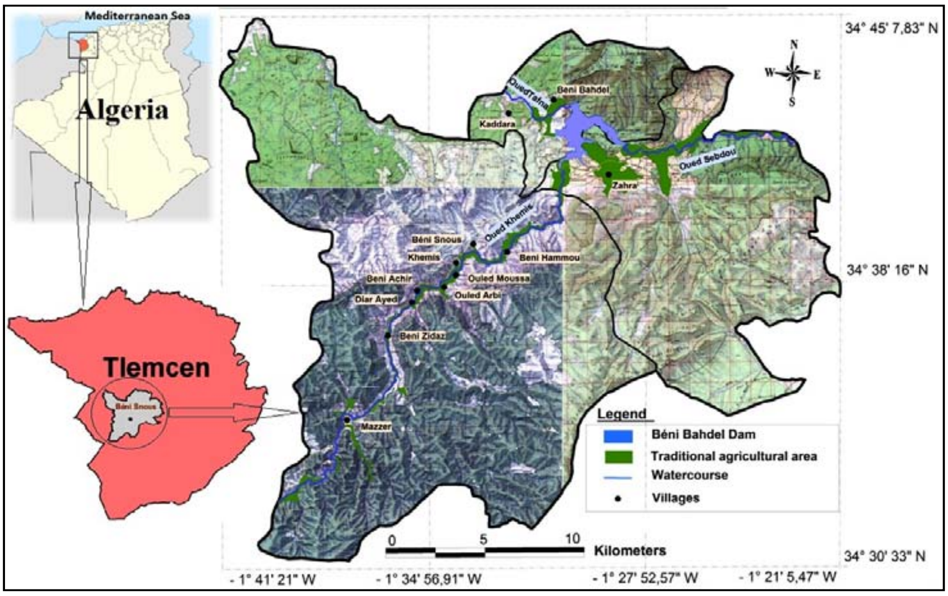

Fig. 1. Location of the study area (Beni Snous region); source: own elaboration

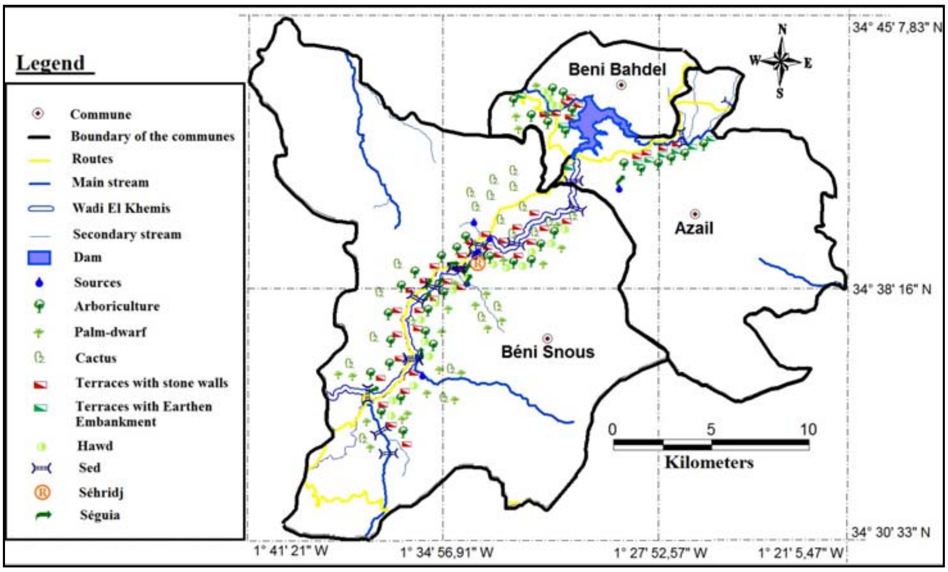

Fig. 2. Distribution of the different techniques identified at the study area level; source: own elaboration

RESULTS

IDENTIFICATION AND SPATIALIZATION OF TRADITIONAL WATER AND SOIL CONSERVATION MANAGEMENT STRUCTURES

The observations and surveys made on the field as well as the examination of the questionnaires allowed us to identify a very rich heritage of traditional water and soil fertility conservation management structures, namely the Seds, Séhridj, Séguias, terraces of irrigated agriculture with stone walls or embankments, and individual micro-basins reinforced with stones (*Hawd*). The terraces of vegetable crops are usually combined with other farming practices such as the traditional land use, manure use, ridge cultivation and board cultivation. The spatialization of these installations allowed us to have the map of their distribution in space (Fig. 2). This map shows the great variability and abundance of water and soil fertility conservation management structures in the region of Béni-Snous.

ANALYSIS OF STRUCTURES, USING THE MULTIPLE CORRESPONDENCE ANALYSIS (MCA)

The analysis of questionnaires made it possible to have a condensed data coding table (Fig. 3), comprising $I = 53$ observations (structures/systems) in rows and $J = 16$ qualitative variables (parameters) in columns. At the intersection of line i and column j is the category x_{ij} of the variable j which characterizes the observation i. The category represents one of the possible cases of a parameter.

The variables-observations data were subjected to a multiple correspondence analysis (MCA); this is a method that is very well suited to the treatment of surveys that involve qualitative questions which have multiple answers, which is the case of our study. This method

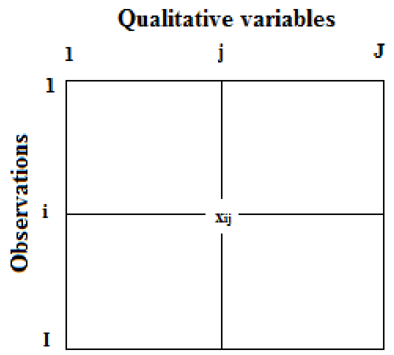

Fig. 3. Condensed data coding table; source: own elaboration

makes it possible to analyse the relationship that may exist between different qualitative variables [BACCINI 2010]. In order to have readable graphics, the observations (structures) have been replaced by the number of their classification in the condensed coding table (from 1 to 53); however, the qualitative variables (parameters) and their categories are represented by abbreviations. The parameters, which are 16 in number, are the type of structure (*Type*); objective with respect to water conservation (*Object.W*) and soil (*Object.S*), state of structures (*State*), slope (*Slp*) and altitude (*Alt*) of developed land, maintenance (*Maint*), frequency of maintenance of systems (*Freq.M*), cost of construction and maintenance of installations (*Ct*), age of structures (*Age*), adoption of structures by farmers (*Adopt*), reproducibility of the structures (*Reproduc*), acceptance of structures by the local population (*Accept*), human pressure (*Hum.P*), effectiveness of installations with respect to water and soil conservation (*Eff*); and soil texture (*S.T*).

The multiple correspondence analysis (MCA) provided an overview of the relationships (dependencies and non-dependencies) between a large number of qualitative variables (as opposed to univariate and bivariate statistics), and even more than that. It has helped to establish representation maps on which it is possible to observe visually the reconciliations between the categories of these variables and the observations.

The representative map of observations (Fig. 4) obtained by this method made it possible to distinguish two groups of systems along the horizontal axis. The first

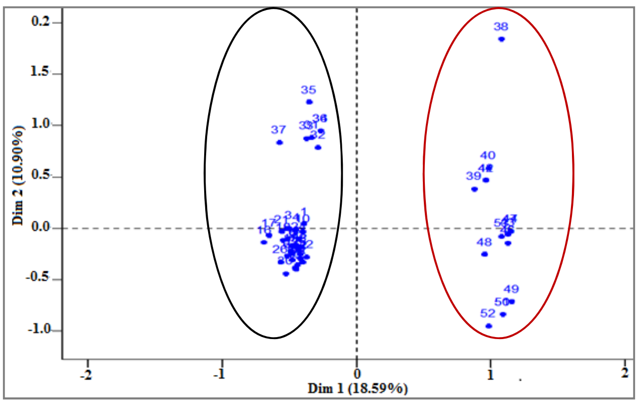

Fig. 4. Representation of observations (structures); source: own study

group, located on the left part of this axis, includes the structures from 1 to 37 (terraces with stone walls, terraces with earthen embankment and individual stone micro-basins (*Hawd*)) and the second group, located on the right, gathers the structures from 38 to 53 (*Seds, Séhridj* and *Séguias*).

To describe these two groups of structures, it was decided to focus on the study of the cloud of points representing the categories. In addition, in order to have a clearer representative map of categories, it was decided to retain only the categories of variables that have a good correlation ratio (R^2 > 0.45) with axis 1 (Fig. 5), and therefore only those which are highly dependent on each other.

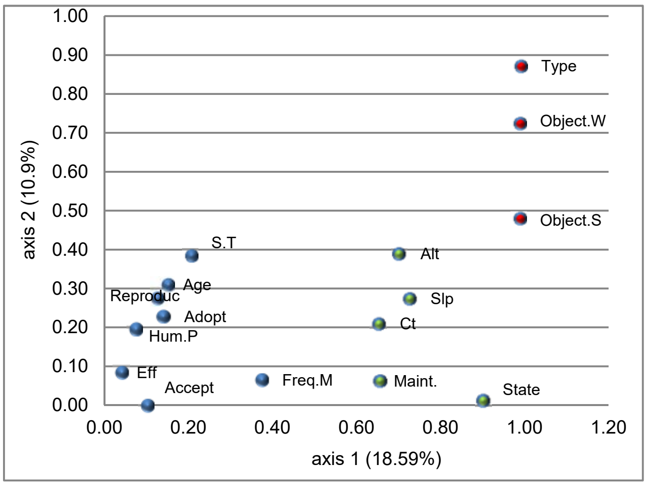

Fig. 5. Presentation of the variables according to their correlation ratio with axes 1 and 2; variables explanations as in Tab. 1; source: own study

Figure 5 shows that only the variables *Type*, *Object.W*, *Object.S*, *State*, *Slp*, *Alt*, *Maint* and *Ct* have a good correlation ratio (R^2) with the first axis, which can be explained by the high dependence between these variables, and therefore the strong link between their categories.

Figure 6 displays the representation of the categories of these variables which show a good correlation ratio. The abbreviations of these variables (with R^2 > 0.45) and their categories, with their meanings, are given in Table 1.

Moreover, the representation of categories (Fig. 6) highlights an opposition between two distinct groups of categories along axis 1. This opposition indicates that the first group of structures (observations) is characterized by the categories that are well associated and grouped on the negative side of axis 1 (*IES* and *RCS* for the variable "*Object.W*"; *SM* and *CS* for the variable "*Object.S*"; *CFV*, *LD* and *VMD* for the variable "*State*"; *Slp.2*, *Slp.3*, *Slp.4*, *Slp.5* for the variable "*Slp*"; *Alt.1*, *Alt.2*, *Alt .3*, *Alt.4*, *Alt.5* for the variable "*Alt*"; *Ct.l* for the variable "*Ct*"; Owner for the variable "*Maint*"). On the other hand, the 2nd group is characterized by the categories that are gathered on the positive side (*SWD* and *SWM*, *ISP*, *CF*, *Slp.1* and *Slp.V*, *Alt.V*, *Ct.insg* and *Ct.a* and *Touiza* of identical variables).

Table 1. Abbreviations and meanings of variables and categories

Parameter	Abbreviations of parameters	Categories	Abbreviations of categories
Type of technique	*Type*	– Hawd (individual stone micro-basins) – *Séhridj* (open air storage basin) – *Sed* (water diversion dyke) – *Séguia* for irrigation – terraces with stone walls – terraces with earthen embankment	*Hawd* *Séhr* *Sed* *Ség* *TSW* *TEE*
Water conservation objective	*Object.E*	– infiltration enhancement system – runoff capture system on slopes and valleys – system of water diversion – system of water mobilization	*IES* *RCS* *SWD* *SWM*
Soil conservation objective	*Object.S*	– improvement of soil productivity – capture of soils – slope modification	*ISP* *CS* *SM*
Current situation of techniques	*Situ.*	– currently functional – currently functional and valorised – little degraded – very much degraded	*C.F* *C.F.V* *L.D* *V.M.D*
Slope of developed land	*Slp.*	Slp.1 [0; 3[; Slp.2 [3; 6[; Slp.3 [6; 12.5[; Slp.4 [12.5; 25[; Slp.5 [25; 40]; Slp.V (varying slope)	*Slp.1; Slp.2; Slp.3;* *Slp.4; Slp.5; Slp.V*
Altitude of developed lands	*Alt.*	Alt.1 [500; 600[; Alt.2 [600; 700[; Alt.3 [700; 800[; Alt.4 [800; 900[; Alt.5 [900; 1600]; Alt.V (varying alt.)	*Alt.1; Alt.2; Alt3;* *Alt.4; Alt.5; Alt.V*
Who does the maintenance and how?	*Maint.*	– construction and maintenance is done by the owners and their families – construction and maintenance are collectively done by users (Touiza)	*Owner* *Touiza*
Cost of construction and maintenance	*Ct.*	– low cost – average cost – insignificant cost	*Ct.l* *Ct.a* *Ct.insg*

Source: own study.

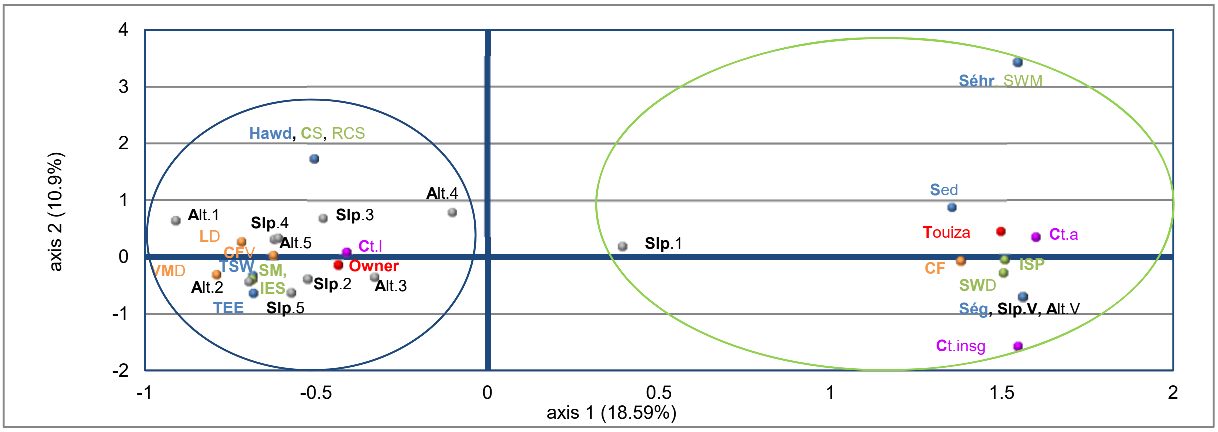

Fig. 6. Representation of categories; variables meanings as in Tab. 1; source: own study

DISCUSSION

RANKING OF ANALYZED TECHNIQUES ACCORDING TO THEIR OBJECTIVES

Based on the results obtained (Figs. 4 and 6), the rich heritage in traditional management systems and water and soil conservation structures, which were identified within the study area, can be classified into two groups, depending on their objectives. The first group includes the *Seds* for the catchment and diversion of watercourses (*Sed*), the *Séhridj* for the storage of spring waters (*Séhr*) and the traditional *Séguias* which are used for the distribution of water (*Ség*), and also for the mobilization and management of irrigation water from rivers and springs. In the field, these techniques are not applied separately, but in combination with each other, in order to make the most out of the available runoff water resources and thus promote agriculture and improve yields and incomes. The second group consists of irrigated terraces built with stones (*TEE*) or talus (*TSW*) and individual stone micro-basins (*Hawd*) whose objectives are water and soil conservation as well as management of irrigation and runoff waters.

- **Structures for the mobilization and management of spring water and watercourses**

The area of Béni-Snous offers a wide variety of strategies for the mobilization, diversion and management of waters from springs and streams (*Seds*, *Séhridj*, *Séguias*). The *Seds* system consists of an earthen dyke that is reinforced with stones and tree branches; it is most often built transversely to the watercourse. The shape of the dyke is not rectilinear but vaulted, so as to disperse the forces of water stored behind that dyke on the rocky banks of the watercourse. The objective of such a system is to diverse watercourses (*SWD*) towards terraced fields through a large network of *Séguias* (*Ség*). The other system of mobilization and management of water, which characterizes the region of Béni-Snous, consists of using the *Séhridj* (*Sehr*). The *Séhridj* is generally dug in a rocky terrain. This type of installations makes it possible to store water from springs during the night to be used during the day for irrigation. The objective of such a system is to better mobilize and manage the water from low-flow springs (*SWM*) and also to divide the collected water as equitably as possible between the beneficiaries. These two systems are combined with large networks of *Séguias* (*Séguia* are made of earth and/or stones or excavated into the rock (*Nokba*)) to allow the routing, partitioning and distribution of water to each farm, as well as the evacuation of excess irrigation or runoff water. All these systems help to better manage the accessible but very limited water resources (wadis and low-flow water sources) and to improve the production of terraced lands (*ISP*). These hydro-agricultural systems, very typical and specific to this region, have had a very positive environmental and socio-economic impact on the region of Beni Snous. These types of systems can be found even in the hyper-arid areas where farmers have developed small dams (made of local materials) and *Séguia*s for the distribution and delivery of water to gardens [REMINI *et al*. 2012].

- **Systems for the management and conservation of water and soil**

The sector of Beni Snous, which is characterized by a rough terrain, has favoured the appearance of structures for water and soil management and conservation. These structures, well established in the environment and well adapted to the conditions of the area, allowed transforming the region deeply at various levels. Different types of systems exist; the most used are terraces and individual basins made of stones. Setting up terraces (*TSW*, *TEE*) consists in modifying the slope of mountains (*SM*) and thus providing flat surfaces on steep hillsides; this should facilitate tilling and irrigation while limiting soil erosion. Cultivation terraces play an effective role in the retention of sediments and the enhancement of water infiltration (*IES*) and consequently in the improvement in crop yields [JORDA, PROVANSAL 1990]. In the minds of farmers of the mountainous region of Béni-Snous, terraces are much more a means of valorising these mountain slopes for survival than a way to limit erosion, even if these two aspects are closely linked. These terrace systems are directly associated with the habitat. Indeed, the best terraces are usually closer to homes. The main objective of individual stone micro-basins (*Hawd*) is to collect runoff waters on slopes and in valleys (*RCS*) as well as the capture of soils rich in organic matter from the upstream area. These micro-basins are built even in the rocky zones; this allows for the rehabilitation of degraded areas.

SUSTAINABILITY AND CURRENT STATUS OF TRADITIONAL STRATEGIES FOR WATER AND SOIL FERTILITY CONSERVATION MANAGEMENT

Cultured terraces and basins were introduced a long time ago in the mountainous zones of Béni-Snous. Investigations showed that these structures are very ancient, since more than 64% of the terraces and basins surveyed are over 100 years old. There are terraces dating back more than 5 centuries. These structures were developed a very long time ago [DESTAING 1907]. The first traces of these systems are very old and some of them may go back to more than 7000 years ago [ROOSE 1995]. These installations are the fruits of the ancestral knowledge and know-how of all civilizations that had encountered problems of land degradation, lack of water and arable land. MAJDOUB *et al*. [2012] indicated that terraces have been developed in order to benefit from the least amount of water and to preserve soil fertility.

The assessment of the current state of these facilities has shown that, despite their age and lack of maintenance, 78% of these structures are still functional and operational. This can be explained by the strong link between the *CFV* category of the *State* variable and the categories *TSW*, *TEE* and *Hawd* of the *Type* variable (Fig. 6). The degraded samples (*LD* and *VMD*) are generally found on abandoned sites. Their abandonment is not due to their inefficiency but rather to the changes in the socio-economic conditions, which were aggravated by periods of persistent drought and security conditions during colonization that forced landowners to abandon their lands. These sites found themselves under strong pressure from animals. This explains even more the causes of degradation of these installations.

Water mobilization and management techniques are also very traditional practices in this semi-arid zone. According to the population of Béni-Snous, these systems (*Seds, Séhridj, Séguias*) have been used for centuries in this area. Figure 6 shows that they are all characterized by the category *CF* (currently functional).

ADAPTABILITY OF TRADITIONAL STRUCTURES FOR WATER AND SOIL CONSERVATION TO THE NATURAL AND SOCIAL CONDITIONS OF THE REGION OF BÉNI-SNOUS

Terraces and individual stone micro-basins (*Hawd*) were built on all types of slopes and at various altitudes (Fig. 6). The categories of the slope variable (*Slp*) are grouped around the category *TSW*, which means that it is possible to find this type of terrace on all types of slopes. Generally, the steeper the slope, the width of the terraces is reduced. It is widely known that *Hawds* are generally found on rocky sites and steep slopes where it is not possible to install terraces. Thus, all sloping space can be worked and made more profitable.

The results obtained indicate that the terraces with stone walls are very compatible with the local physical environment and the very difficult natural conditions of the region of Béni-Snous (very uneven and rocky terrain with steep slopes and skeletal soils). It is also noted that a very good harmony exists between these very rugged environments and this type of installations.

These cultivated terraces, which require considerable efforts, are created under the pressure of necessity and also for growing profitable crops such as the olive tree, and even more so for irrigated crops that require horizontal surfaces [DESPOIS 1961]. In the region of Béni-Snous, narrow terraces are used mainly for olive trees which are cultivated for the production of olive oil, which represents the label of that region, and fruit trees as well. However, on the larger terraces, intensive and intermediate farming is practiced. There is a tendency to associate arboriculture with market garden crops in order to make better use of the limited available land and also to make the most out of available water resources. According to MOREL [2008], the terraces were once intended to make land more profitable and also to control the action of water. These installations can be adapted to all natural, social and economic conditions; they can also be installed in all areas where it is necessary to arrange the slopes and where the living conditions of the rural population are of paramount importance. Cultivated terraces are found all over the world [DESPOIS 1956].

On the other hand, individual stone micro-basins (*Hawd*) are particularly intended for olive growing; their dimensions (diameter and depth) depend on the slope of the mountain and the availability of soil. Water and soil conservation structures have been developed to address the problem of scarcity of land and water resources; they are developed in such a way as to take maximum advantage of runoff waters [ABDELLI 2012; BOUFAROUA 2004] and also to valorize rainwater harvesting. Moreover, these individual micro-basins allow the trapping of sediments, which are very rich in organic matter and come from upstream under the effect of runoff; it also helps to reduce the risk of erosion. BERGAOUI *et al.* [2008] indicated that in Tunisia, individual micro-basins constitute an excellent means for water retention, since they increase the soil moisture content by about 50%; they also help to increase nutrient intake, particularly, phosphorus and potassium, by 20%.

Regarding the second group of structures, the *Seds* represent the main irrigation system for farmers on both banks of Wadi El Khemis. All along this watercourse (30 km), 13 *Seds* have been identified (Fig. 7).

These *Seds* enable to irrigate about 60% of agricultural land on both banks of the valley of Wadi El Khemis. The mobilization and valorization of runoff water, by means of these structures, have a very positive impact on the environmental and socio-economic conditions [HABI, MORSLI 2013].

The principle of these systems is to divert water by gravity through a network of *Séguias* in order to irrigate the lands downstream. The performance of these systems is conditioned by the difference in altitude. The area of Béni-Snous, characterized by its highly variable and very uneven relief, favoured the existence of these types of structures. These structures, which are well established in the environment and well adapted to the conditions of the area, have made it possible to profoundly transform the surroundings and improve the life of the local population by mobilizing this rare and vital natural resource. Such systems are found in semi-arid areas, such as the mountainous region of Béni-Snous and other arid areas (Ksour Mountains). The easy adaptation of the inhabitants to the difficult living conditions was at the origin of the application of these techniques [LAOUINA 2010].

ADOPTION AND REPRODUCIBILITY OF WATER AND SOIL CONSERVATION STRUCTURES

Field surveys indicate a trend toward the rehabilitation of demeaned systems, which demonstrates the importance, effectiveness and adoption of these water and soil conservation structures by the local population. The maintenance, supervision and protection of the developed lots are ensured by the owners, and this explains the link between the category *Owner* and these systems. Field surveys have also shown trends towards the reproducibility of these structures, which further corroborates their importance.

The adoption by the local population of water mobilization and management systems goes back several generations because these systems are managed and protected by ancestral regulations based on the interests of the rights holders and owners of the irrigated land. Figure 6 shows that these systems are characterized by the category of *Touiza*, which means that the *Seds*, *Séhridj* and *Séguias* are restored and maintained periodically by a collective operation, called Touiza, where the beneficiaries from the mobilized and derived waters meet whenever this is necessary in order to perform a restoration or maintenance work. Only farmers who have participated in the realization of the system can benefit from the collected or derived water for the irrigation of their lands.

COST AND EFFECTIVENESS OF TRADITIONAL WATER AND SOIL CONSERVATION STRUCTURES

The Mediterranean area is well known for being subject to very high erosive risks [HUDSON 1992]. In Algeria, 45% of fertile land has been damaged by erosion; in fact, the average annual specific erosion varies between 2,000 and 4,000 $t \cdot 10^{-2} \cdot ha^{-1}$ [DEMMAK 1982; MEGHRAOUI *et al.* 2017], which ranks Algeria among the most erodible countries in the world [TOUAIBIA 2010]. Western Algeria, where our study area is located, remains the most affected area [BENDERRADJI *et al.* 2006] and the major erosions are much more related to exceptional runoffs where the maximum runoff coefficient (*Kr*max%) exceeds 0.3 (30%) and can reach the value 0.8 (80%) on bare and compact soil [MORSLI *et al.* 2012]. Soil erosion by water has a lasting impact on soil productivity. This type of erosion is an important economical issue strongly deteriorating environment and requiring remedial actions [RYBICKI 2017].

On the mountains of Béni-Snous, where the environment is very conducive to erosion, the results show that the water and soil conservation structures are beneficial and effective. In fact, lands fitted out in terraces and individual micro-basins are very slightly affected by water erosion; in 60% of cases, very good efficiency is observed with regard to erosion and soil fertility improvement. It is also noted that the organic matter content is relatively high in the fitted out zones. The best results were obtained on wide irrigated terraces which are intended for vegetable crops and are generally delimited by olive trees or fruit trees. Although abandoned, terraced slopes have remained relatively stable compared to unterraced land. Terraces continue to act as barriers to erosion.

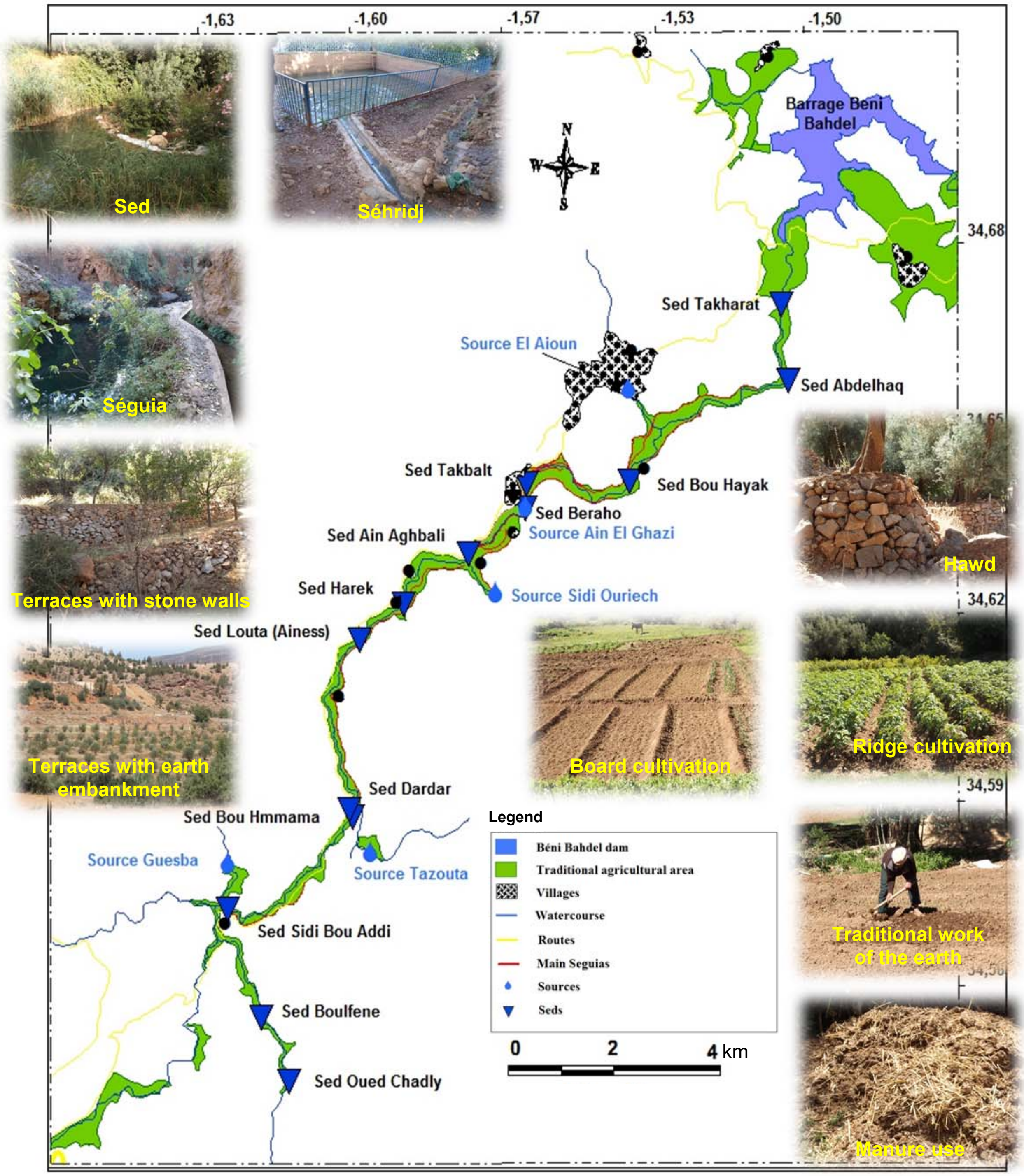

Fig. 7. Traditional agricultural perimeters (irrigated) of Wadi El Khemis (Beni Snous Region) and photos of the traditional techniques; source: own study

These terraces are generally associated with other cultural practices (tilled soil, ridges, organic manure etc). These combined systems very remarkably increase the efficiency of water and soil conservation structures. According to the work of MORSLI *et al.* [2006], these simple cultural practices have shown great effectiveness in water conservation and erosion control. Stone-reinforced basins, in the region of Béni-Snous, have been maintained for centuries; they have increased olive production even on rocky sites.

In addition to their effectiveness in preventing water erosion and improving yields and incomes, landscaping techniques can be realized with relatively little money and is financially within the reach of farmers (*Ct.l*). Building materials are available *in-situ* and the work is done by the owners (*Owner*) and their families (women, sons and friends) – Figure 6. The cost of realization is assessed rather in number of working days. For example, in a day, a farmer can achieve 5 meters of terraces approximately. An individual stone micro-basins (Fig. 7) requires about a day's work. The costs for building these structures are quite low and can be amortized in a short time. The cost-to-efficiency ratio is very interesting. These traditional installations are more efficient and less demanding in terms of work and cost than the flat benches that used to be very popular in Algeria and have rarely proven effective. The large, often very expensive, structures that were built under the DRS in Algeria for 40 years, without any collaboration with farmers, have proved their low sustainability and often their low efficiency and effectiveness [HAMOUDI *et al.* 2008].

Figure 6 shows that the categories (*Séhr*) and (*Ség*) are associated with categories (*Ct.a*) and (*Ct.insg*), which means that most of these techniques are characterized by medium to negligible costs. Indeed, the realization costs of a *Séhridj* (*Séhr*) are just average, but as it is realized by Touiza (collective mutual aid for certain important works), the costs are shared between the beneficiaries and the part of each of them becomes quite low in cost and time of realization. In addition, the construction materials of the *Séhridj* are available *in situ*. The *Séguias*, which are used for diversion and distribution of irrigation water, are dug in the ground, or in the rock in the worst cases, and the total costs of realization, which are quantified rather in time and force of work than in money, are low. The category (*Ct.insg*) characterizes the *Séguias* for irrigation which are dug in their fields by the farmers themselves. These *Séguias* do not require much time or physical efforts to achieve them.

On the other hand, the *Seds* also have a low realization price (*Ct.l*); they do not require heavy equipment and machinery, and the materials used are found locally. Regarding human resources, construction works are also carried out by *Touiza* or *Jmaâ* (mutual aid for some social works), since the beneficiaries of these structures work and build them together. These *Seds* require some maintenance, especially after floods.

Thus, in mountainous cultivated areas, sustainable management of land and water resources requires not only large physical structures, but also sustainable, community-based and above all efficient and cheap agricultural practices and techniques. The combination of appropriate techniques helps to minimize the risk of water erosion, to better manage the available water resources and also to increase production and income.

ORGANIZATIONAL ASPECTS AND COMMUNITY WATER MANAGEMENT

The region of Béni-Snous is one of the main agricultural regions where traditional agricultural plots are located. The ingenuity in developing traditional irrigation systems is mainly due to the high technical and organizational level existing within the local community. The entire hydro-agricultural system, which runs from the *Sed*, for the wadi water diversion to the terraces on the sides of the mountains (flattened and bordered by low ridges), via the *Séguias*, seems to be designed in a very ingenious way.

The success of traditional irrigation systems is mainly due to the good community organization which has also been a key factor in promoting social cohesion. The organizational system of exploitation and collective management of water resources (sharing, preservation, maintenance etc.), developed by local communities, has helped to maintain this heritage for centuries. Ancestral gravity irrigation systems are traditionally associated with complex forms of social organization in terms of water rights and uses [EL ABBASSI 2000; GRANDGUILLAUME 1973; HOUIMLI 2008; REMINI, ACHOUR 2008; ROOSE *et al.* 2010]. The implementation of this participatory management of water resources is essential for water security [GHOLAMREZAI, SEPAHVAND 2017; KUNTIYAWICHAI *et al.* 2017].

The traditional management of water that is mobilized, derived and conveyed by these systems in the region of Béni-Snous obeys some customary laws of water distribution called "Rights to water". Every farmer has the right to benefit from land and water. These same laws continue to serve as a basis for the organization of maintenance and upkeep operations. The *Seds* and *Séhridj*, with their immense networks of *Séguias*, are the oldest irrigation systems in this region and the most symbolic of this community; these systems alone can irrigate 70% of the total area of the Valley of Wadi El Khemis, located on the territory of Béni Snous (Fig. 7). Analysis of the operation and management of the irrigation system shows that these communities have been able to take advantage of the existing hydraulic potential in an efficient and fair way. This irrigation system provides equitably a certain amount of water per unit area to every agricultural plot. As for the distribution of irrigation water, each farmer is attributed a certain quantity according to a well-defined timetable. Water is distributed according to a double logic; the first one is temporal (day/night) and the other is spatial (upstream–downstream/downstream–upstream). This logic is supposed to guarantee equal access to water. This operation is repeated over and over again. Each plot is irrigated every 10 days, which keeps the soil moisture at a continuously high level for optimal crop growth. The method of sharing irrigation water in the region of Béni-Snous is based on time management. Water is distributed according to the seasons and the position of the land to be irrigated (the agricultural plots located upstream do not have priority over those situated downstream). In addition, night irrigation is equitably shared among all farmers. Generally, the volume of water allocated to each farmer is set according to the surface area of the land to be irrigated. It is important to note that the amount of water allocated to each plot was calculated a long time ago and has remained unchanged. Despite the absence of a supervisor to oversee the water distribution system, no conflict between farmers has ever been recorded so far. When a problem, sometimes due to the random contributions of the wadi and the insufficient quantities of water, arises, it is solved by the *Djamaa* or religious body (a group of wise religious individuals). In the region of Béni-Snous, there are two modes of water sharing; the first one is the time-related distribution, where all the water that is available in the *Séguias* is put at the disposal of the right holders during a certain period of time (amount of water per unit of time) and the second one is the volume-related distribution where each farmer receives continuously the part of water volume he deserves. This amount of water is estimated before the distribution operation; it is measured by means of a wood stick (number of fingers) placed upright in the storage tank (*Séhridj*) which is filled during the night. The water collected through the *Séguias* is stored in a basin before being redistributed among the surrounding lands to be irrigated. This system of night water storage is intended for the farthest plots to avoid day evaporation of water throughout the *Séguias* and to ensure sufficient flow for irrigation.

The spatial analysis of the system reflects a certain lineage organization of the society of Béni-Snous. Almost every perimeter has its own small village and irrigation network. Each village with its irrigation network is a territorial unit where the rules of collective management of resources are decided and applied; minor conflicts are managed and solved by respectful religious people from the village.

The traditional irrigation system in Béni-Snous is still in place and is maintained as long as water resources are available. The maintenance of the system is guaranteed by the beneficiaries themselves. It is easy to note the attachment of community members to the land and particularly to the sustainability of a community organization that is founded on solidarity, discipline and mutual respect. However, this system that has lasted a long time begins to suffer from a number of problems. The most salient of these are water pollution in wadis (the acute problem of water sanitization) and the demographic haemorrhage. Migratory movements to cities have been numerous and permanent since the beginning of the 20th century, and even before [SARI 1977]. This migration may have been the result of the more general process of economic diversification in the region; it is also probably due to the evolution of mentalities in the region.

CONCLUSIONS

The present work enabled us to identify and highlight a heritage rich in traditional water and soil fertility conservation management techniques that have shown a great adaptation to the very difficult socio-economic and natural conditions that characterize this semi-arid region. In general, these techniques relate either to hillside development, or to the mobilization and management of water. These rich traditional techniques for water and soil conservation testify to the very high level of the farmers' awareness in the region of Béni-Snous due to the scarcity of water and soil resources and also to the risks to which these farmers were exposed. It also testifies to the rich knowledge and know-how of the rural population which has been able to withstand the different crises that have rocked the region for a long time. Assessment of the current situation indicates that water mobilization and management structures are all still functional to date because they are important; their maintenance is always provided periodically by the population of the region through Touiza. It is estimated that 78% of the structures on hillsides are still functional and regularly valorised.

Regarding efficiency and profitability, these systems have shown good cost-to-effectiveness and cost-to-efficiency ratios. In fact, the structures for the management and conservation of water and soil (*TSW*, *TEE*, *Hawd*) still play the roles for which they were initially built (modification of the slope, improvement of water infiltration, capture of soil and runoffs); they have proven their effectiveness in preventing different forms of erosion, and have also had a very positive impact on water control and conservation of physical environments under difficult conditions. These traditional techniques combined with other typical cultural practical methods have helped to restore and improve the productivity of low potential land. In addition, water mobilization and management techniques, which are founded on very ancestral and community-based laws, have made it possible to exploit water resources in an efficient and fair way and also to expand and intensify agriculture on land with high constraints. Unfortunately, these resources are becoming increasingly scarce due to the recent climate changes.

The area of Béni-Snous offers a wide variety of water and soil conservatory management strategies; it presents a form of adaptation of man to strong physical constraints and thus constitutes a rich hydro-agricultural and cultural heritage from which one can draw inspiration. The results obtained clearly indicate that these techniques for water and soil management, which have proven their effectiveness over time, and especially those adopted by farmers, can be improved and adapted to current and future natural and socio-economic conditions; they can be introduced in a new participatory approach for water and soil conservation. These techniques can be used as complementary or alternative options to limit the risks and reduce the impacts of climate change.

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Ocena technik gospodarowania wodą w rolnictwie i wiedzy wdrażanej przez tradycyjne społeczności: przykład regionu Béni-Snous w mieście Tlemcen w Algierii

STRESZCZENIE

Społeczności wiejskie były w przeszłości zdolne wdrażać pewne formy zespołowego zarządzania przestrzenią, wodą i ziemią, które zwiększały zdolność przeżycia populacji z reguły zbyt licznej w stosunku do dostępnych zasobów. W górskim regionie Béni-Snous funkcjonują rozliczne strategie zarządzania ochroną wody i żyzności gleb. Region ten jest przykładem adaptacji człowieka do znacznych ograniczeń fizycznych i dlatego stanowi rolnicze i kulturowe dziedzictwo, które, niestety, nie doczekało się zainteresowania, na jakie zasługuje, i którym człowiek może się inspirować. Pomysłowość tradycyjnych systemów, które mają długą historię, skłania do analizowania i badania tych systemów, w szczególności w ich aspekcie technicznym i organizacyjnym. Badania prezentowane w niniejszej pracy były prowadzone w takim właśnie kontekście. Niniejsza praca miała na celu ocenę tradycyjnych systemów gospodarowania wodą i żyznością gleb, które spotyka się w górach Béni-Snous o półsuchym klimacie. Badane systemy reprezentują pewną kreatywność, rozumianą w sensie praktycznym, organizacyjnym i socjalnym. Ocena stanu gospodarki wodą i glebami oraz technicznych rozwiązań ochronnych wykazała, że 78% spośród tych rozwiązań funkcjonuje nadal i jest waloryzowane. Biorąc pod uwagę ich znaczenie, należy uznać, że wszystkie rozwiązania techniczne są nadal funkcjonalne, a stosunek kosztów do efektywności ich funkcjonowania jest dobry.

Słowa kluczowe: *Béni-Snous, efektywność kosztów, gospodarka gminna, ocena technik gospodarowania wodą w rolnictwie, zarządzanie ochroną wody i gleby*