Evaluation of Construction Parameters of Traditional Water Harvesting Technique (Jessour) by PCA analysis in the Southeast of Tunisia

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Abstract

Soil and water conservation issue is one of the most important environmental challenges for climate change and land degradation processes in arid and semi-arid regions of the century. Many water-harvesting techniques have been developed so far to face these challenges. In this technique, the components of constructions directly affect the water runoff and water quantity and indirectly affect the soil loss amounts by water erosion.

In this study, we tried to find out that the most important constructional parameters of the jessour which is a traditional water harvesting technique known from the Roman occupation for soil and water conservation attempts in the arid regions. This study was performed in the micro-watershed of El-Jouabit in Matmata mountains in the southeast of Tunisia Totally, 620 Jesr and 9 construction parameters were evaluated, such as; length of the terrace of the Jesr (m); width of the terrace of the Jesr (m); height of retention (m); height of the tabia (m); length of the tabia (m); capacity of retention (m^3); surface of retention (m^2); surface of the impluvium (m^2) and number of planted trees). As a result, 4 parameters were found as the most important to ensure the best performance of this technique which is the height of retention, the capacity of retention, the surface of retention and surface of the surface of the impluvium.

Keywords: Watershed management, Soil and water conservation, Water harvesting techniques, Southeastern Tunisia, Jessour

1. Introduction

Tunisia, located on the southern shore of the Mediterranean, remains an arid to semi-arid climate, characterized by limited and fragile natural resources, subjected to an intense exploitation with a pronounced water deficit. On the other hand, physical, geomorphological, hydro climatic and socioeconomic conditions affecting Tunisian lands are particularly favorable to their degradation [1]. And regionally as arid and semi-arid ecosystems are very sensitive to environmental changes and highly tend to degradation due to environmental impacts [2]. However, rehabilitation of such areas by tree plantation positively affects the soil properties and decrease soil erosion in a short period [3].Southeast of Tunisia marked by an arid Mediterranean climate, with a mean annual rainfall ranges between 100-200 mm. Rainfalls in this area are torrential and stormy which promotes water erosion [4]. These areas are largely conditioned by the different modalities of the access and the use of water, depending on the geomorphology and the adopted techniques.

The current situation of water resources and their uses in the Tunisian Southeast present some risks that are common to many regions of the Mediterranean basin, limited water resources [5] are widely used to meet the growing needs, a sever climate conditions that reinforce pressures around limited water

resources [6]. Which, required the implementation of techniques for mobilization, valorization of runoff water and reduce soil erosion caused by water [7].

Many constructions in the field have been developed by traditional and modern techniques to prevent and managing natural disaster such as erosion, flooding and avalanches [8]. In southern Tunisia, the well-known and used many water harvesting techniques as; ***Jessour***, ***Tabia, Mgoud, citerns*** [9]. The Jessour implemented in mountainous regions to decrease the risk of flooding during exceptional rainfall events by decreasing the velocity and the amount of runoff water, and the eroded soils coming from the upstream deposit in the terraces of the Jessour increasing then the soil fertility and the capacity of soil water storage.

In this study, in order to ensure the best performance, the jessour should be constructed according to the dimensions and the received amount of water to do so, some data are needed like daily rainfall data, topography, soil infiltration rate. However, due to the limitation of data, we are just assessing the components of the construction of the ***jessour*** by taking measurements in the field and then we performed a PCA analysis to see the proportion between the different parameters.

2. Materials and methods

2.1. Study area

The region of El-Jouabit belongs to the delegation of Mareth, in the southeast of the governorate of Gabes. It is bounded; in the north by Beni Zelten, in the south by Zmerten, in the west by Techin and in the East by Tounine. The study focuses on the watershed of El Jouabit, which the surface is about 305 ha, with 620 Jesr. Located between 32 S 602895.36 m E, 3706171.84 m N and 32 S605014.12 m E, 3708572.12 m N (figure 1).

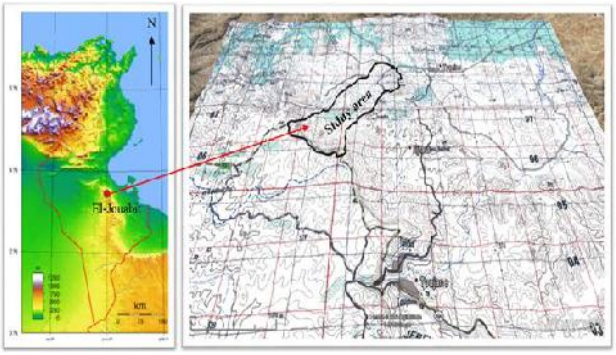


Figure 1: Location of study area

2.1.1. Geology and geomorphology of the study area

The micro watershed of El Jouabit is located in the upper part of Wadi Segui watershed, it is a mountainous area made up of the alternation of hard rock benches (limestone, dolomitic limestone and dolostone) and soft rock (marly limestone and gypsum marl). These secondary age formations have a steep slope to the front-facing East and a flip side with a gentle slope westward form the cuesta. In addition, because of the actual climate, the region of El Jouabit has been subjected to significant gully erosion forming the badlands from eroded silt and alluvial deposits in the downstream due to enhanced water erosion resulting from the weakness of the vegetation cover and the heavy rain (Figure 2).

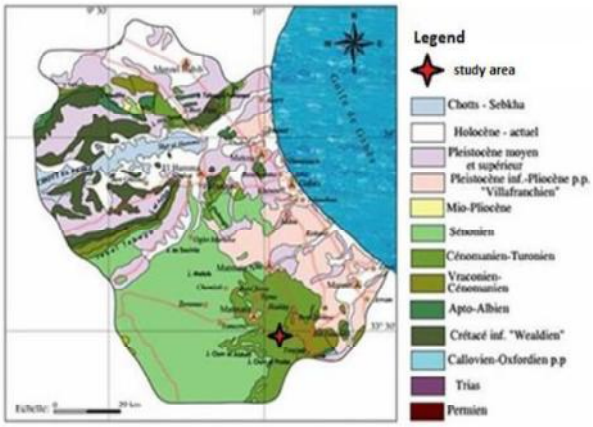


Figure 2. Geological strcuture of study area (from the map 1/500000) [10]



Figure 3. soil profile in the upstream of study area (Moussa, 2007)

2.1.2. Climatic condition

There is an erratic rainfall annual, seasonal or daily, which is the most significant feature of the arid climate. Annual precipitation varies from 130.2 mm to 190 mm. This region is classified to arid regions according [11]. The rainfall in this region has been characterized by a stormy and violent appearance with an intensity that exceeds the 100mm / h for 5 minutes and resulting devastating floods [5]. The average wind speed is 11km/h. This speed can lift the fine silty particles and deposit them far away. It is observed that there are 28 days of sirocco throughout the year in this region which causing a marked increase in air temperature.

2.1.3. Soil

The relief is highly affected by water and wind erosion. The land formed by limestone and marl which are covered by a thick layer of silt, clay and sand, of alluvial and aeolian origin and become thinner going to the south. A soil profile realized in 2007 by Moussa shows the characteristics of the soil in the study area (figure 3).

This profile is located in a small gulley between Wadi Toujan and Wadi Tounine on a non-tilled terrace, the soil occupation consists essentially of palm and olive trees. It is characterized by a dry horizon, slightly compacted with the presence of roots and calcareous nodules. The texture is sandy-loamy and the fragmentary structure is sub-angular polyhedral.

2.1.4. Surface water

Surface waters are mainly related to rainfall and inflows of the wadis during floods. The exploitation of these waters has been insured by water harvesting techniques such as the jessour. The amount of water coming from the scarce rainfall is about 30 million m^3/year, which 15 million m^3 come from the mountains of Matmata, but only 0.9 million m^3 are retained by the new dam of Matmata [12].

3. Methodology

In this paper, we focused on the study of the proportion between the different construction components of the Jessour. To assess the relationship

between the different components we have been performed a Principal Component Analysis (PCA), and we have chosen to study the following parameters:

- Longj: length of the terrace of the Jesr (m);
- Largj: width of the terrace of the Jesr (m);
- Hrj: height of retention (m);
- HT: height of the tabia (m);
- LongtT: length of the tabia (m);
- Cr: capacity of retention (m^3);
- Sr: surface of retention (m^2);
- Sup_imp: surface of the impluvium (m^2);
- Nb_esp: number of trees in the terrace of the Jessr.

The capacity of retention (holding capacity), the surface of retention and the surface of the catchment area have been calculated later using computing tools such as ArcView Gis 3.2 and Microsoft Excel program.

Jessour: the jessour are recognized as an ancient method for collecting runoff water water from the long slope, which allowing the use of stored water for the planting of trees (olive, peach, almond etc.) and the practice of annual crop (wheat, barley etc.). This system is generally based on the building of earthen dykes called tabia (figure 4), which across the valley floor to trap runoff water and erosion products basically silt from the upstream. However, these dykes are built more frequently with soil from the bottom of the valley, and they armed in the downstream by a wall of dry stone to make it more powerful and we talk here about "Sirra". Torrential rain in the mountainous areas causes an important volume of loose of materials such as silt and sand extracted from the slope by runoff and consequently across the time accumulated behind the tabia to form the "kliss". In fact, to protect the dykes from destruction two types of spillway are constructed to evacuate excess water to the next units located on the downstream, the lateral spillway located in the end of dyke called "Menfess" whereas the "Masraf" is the central spillway which is much more difficult to construct, since their building requires a lot of investments in labor and materials. Every jesr has an impluvium or catchment area for which is considered as a watershed and it's naturally delimited by the water parting line between the different units [13], [14],[15],[16], [17].



Figure 4. components of the Jessr construction

3.1. Principal Component Analysis (PCA)

The statistical analysis was performed with STATBOX 6.5, using the Principal Component Analysis (PCA). We have applied the PCA to interpret the relationship between the different parameters of the jessour in the sub-catchment, this analysis helps to define the typical jessour that has

acceptable dimensions and can be resistant to the overflow even during exceptional rainfall events.. This method is applied to the quantitative data sets of at least two variables. It comes to a multifactorial data analysis method its purpose is to summarize the data set. Firstly, it provides simple tools and a clear representation of processed information, to bring out the raw data possible to links between the variables (in terms of the correlation).

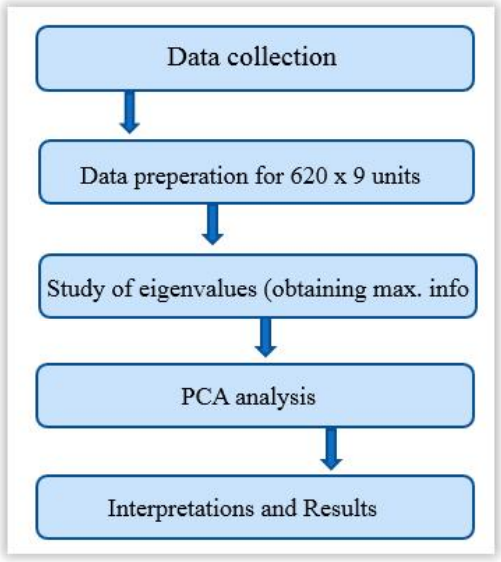


Figure 5. Data processing diagram

then it provides informations about the nature, strength and relevance of these links, to facilitate their interpretation and find out which are the dominant trends in the data set, and finally, it may effectively reduce the number of dimensions studied (and thus simplify the analysis), by seeking to express as accurately as possible the original data set detected through relationships between variables (figure 5).

4. Results and discussion

4.1 . Data preparation

As a first step, the nature of the data has been determined, they nature must be quantitative and it was performed after a sorting flat (medium and standard deviation (STDEV)). The table 1 determines the nature of each parameter (necessary to apply quantitative PCA) and calculates the mean and standard deviation for each one to facilitate the data processing. The parameter "mean" describing jessour is summarized in Table 1, it is noted that for the variables « Longj », « Largj », « Hrj », « HT » and « LongT », the standard deviation is below the average, reflecting a low dispersion, while for the rest of the parameters, the standard deviation is greater than the average that reflect a significant dispersion.

Table 1.Determination of the average and the standard deviation of data

	Wording	Mean	Standard deviation
Longj	Terrace length	32,36	23,13
Largj	Terrace width	17,21	13,32
HrJ	Height of retention of the Jess	0,24	0,23
HT	Height of the tabia	0,95	0,51
LongT	Length of the tabia	29,19	23,42
Cr	Retention capacity	229,16	538,76
Sr	Surface of retention	771,55	1182,59
Nb_esp	Number of species	4,61	4,96
Sup_imp	Surface of impluvium	0,49	0,76

3.2 study of the eigenvalue

We have chosen to study the factors: F1, F2 and F3 in order to obtain the maximum information with the conservation of the minimum of factors (table 2). However, it is very important to note that the first 3 axes show almost 80% of the information.

Table 2. eigenvalue table

	F1	F2	F3
% variance	53,88	13,38	10,23
% cumulated	53,88	67,27	77,50

- **Representation of the variables carried by the axis 1: 2 on the correlation circle (Figure 7)**

We note that the variables carried by the F1 axis and the variables carried by the F2 axis form an angle indicating the absence of a linear correlation. The studied variables are almost close to the correlation circle (figure 7). The Plan 1: 2 shows the influence of the surface of retention (Sr) and the surface of the catchment area (Sup_imp) on the height of retention (Hrj) from where there is a small correlation between them. While there is a strong correlation between the height of retention (Hrj), the capacity of retention (Cr) and the height of the tabia (HT). Moreover, it was observed that the group 2 and 3 of variables are strongly related to each other.

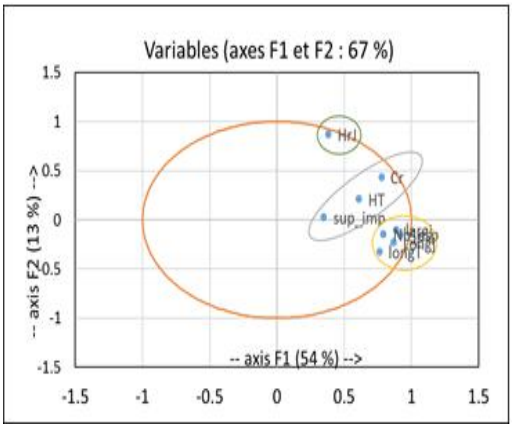


Figure 7. variables (axes F1 and F2)

- **Representation of variables and individuals carried by the axis 1: 2 (Figure 8)**

This plan (fig. 6) allows measuring the influence of the surface of retention (Sr) on the height of retention (Hr.).

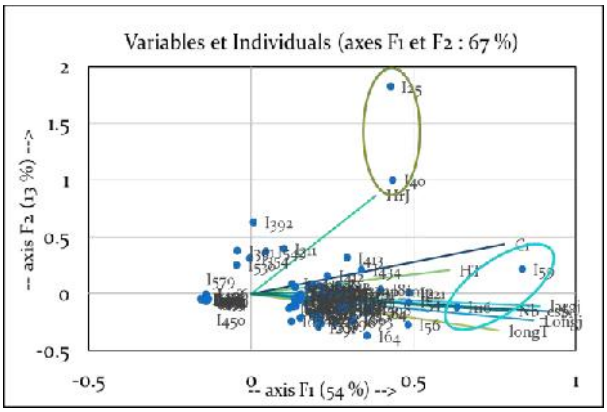


Figure 8. Representation of the variables and individuals on the axes F1 and F2

This plan shows two groups of units, the first group where the height of retention is important but the surface of retention is low. The second, where the height of retention is low but the surface of retention is important.

- **Representation of variables and individuals carried by the axis 1: 3 (Figure 9)**

This axis allows measuring the influence of the surface of the catchment area (Sup_imp) on the height of retention (Hr.). The F1 axis is represented by the units 116 and 59, and the axis F3 induced by the variable surface of the catchment area (Sup_imp) is strongly contributed by the units 137, 151 and 15. This plan shows two groups of units, the first group, where the surface of the catchment area is important but the height of retention is low. The second one, where the surface of the catchment area is low but the height of retention is important.

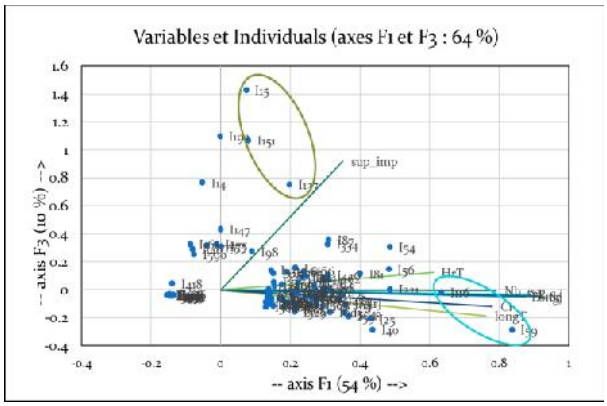


Figure 9. Representation of individuals carried on the axes F1 and F3

5. conclusion

By using the PCA test, we were able to lead a detailed study concerning the problematic of the influence of the surface of Jesr and the surface of its catchment area on the height of retention. It was observed that there is a weak relationship between the surface of the Jesr, the surface of its catchment area and the height of retention indicating that there is a significant disproportion between these three factors. While in some cases, the surface of Jesr or the surface of the catchment area is important while the height retention is very low. Meanwhile, the surface of retention and the surface of the catchment area have an indirect effect on the height of retention. In addition, for the units 25 and 40 (figure 10), it is noted that the height of retention is more significant compared to the surface of retention and the surface of the catchment area where with a small area of the latter two there is a very important height of retention. Moreover, it is noted that the capacity of retention is almost similar for both units, which ensure the relationship between the three parameters. We conclude that only 2 typical jessour in the sub-catchment El Jouabit, which characterized as follows (Table 3).

Table 3. Typical Jessour

N° Jesr	X	Y	Z	L (m)	l (m)	Hr (m)	HT (m)	longT (m)	spillway	Cr (m²)	Sr (m²)	S (m²)
25	603034	3706825	336	43	34	4	5	33	masraf	5848	1462	15787
40	603260	3707058	340	56	53	2	3	52	Consolidated manfis	5936	2968	6630

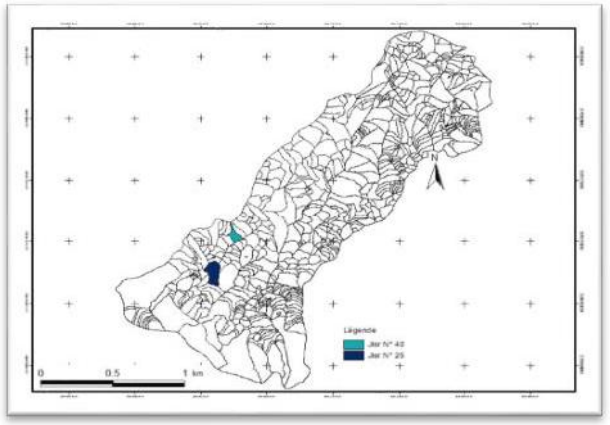


Figure 10. localisation of the typical jessour in the sub-catchment El-Jouabit

Acknowledgments

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References

[1] Achouri. M.1995. La Conservation des eaux et du sol en Tunisie : bilan et perspectives. Direction de Conservation des Eaux et du Sol. Ministère de l'Agriculture. p : 35-47.

[2] Hacisalihoğlu S. 2010. Variations Of Measured And Simulated Soil-Loss Amounts In A Semiarid Area In Turkey, ENVIRONMENTAL MONITORING AND ASSESSMENT, vol.165, pp.255-262.

[3] Hacisalihoglu, S., Kezik, U. 2017. Plantation Effects of Anatolian Black Pine on Soil Erosion in Semi-arid Region, Asia Minor, The International Forestry and Environment Symposium on "Climate Change and Tree Migration", Trabzon-Turkey, 7 November 2017.

[4] Gasmi, I., Karbout, N., Moussa, M. 2016. The impact of the dimensions of the jessour on the destruction of the small hydraulic units (jessour) in the mounts of Matmata. Journal of Research in Environmental and Earth Sciences, 04 (2016).

[5] Moussa. M. 2007. Gestion des ressources naturelles en milieu aride Tunisien : contribution à l'étude de la dynamique du milieu dans le bassin versant de l'oued Ségui-Mareth (sud Tunisien). Thèse de Doctorat, université d'Almeria, Espagne.

[6] Romagny. B. Guillaume. H. Ben ouezdou. H. and Palluault. S. 2004. Ressources en eau, usages et concurrences dans la jeffara Tunisienne. Série usages, appropriation, gestion des écosystèmes. Document de recherche N°1.

[7] Gasmi, I., Moussa, M., Lamourou, H. 2014. Soil and water conservation in southeastern Tunisia. Gestion des ressources et applications biotechnologiques en Aridoculture et culture saharienne : perspective pour un développement durable des zones arides » 17-19/12/2013

[8] USDA, 2008. Urban Soil Erosion and Sediment Control. Conservation Practices for Protecting and Enhancing Soil and Water Resources. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_034363.pdf (accessed in 15 January 2018).

[9] Schiettecatte, M., Ouessar, M., Gabriels, D., Tanghe, S., Heirman, S., Abdelli, F. 2005. Impact of water harvesting techniques on soil and water conservation: a case study on a micro catchment in southeastern Tunisia. Journal of Arid Environments 61 (2005) 297–313.

[10] Chahbani. B. 1990. Contribution à l'étude de la destruction des jessour dans le sud Tunisien. Revue des régions arides. P : 137-172.

[11] Walter, H., Harnickell, E. and Mueller-Dombois, D. (1975) Climate-diagram maps of the individual continents and the ecological climatic regions of the earth. Berlin: Springer-Verlag. 36p. with 9 maps.

[12] SEP. 1994. Atlas de gouvernorat de Gabes.

[13] Boufaroua. M. Yemna. K. 2002. Techniques traditionnelles de conservation de l'eau et des sols dans les zones arides et semi-arides de la Tunisie.

[14] Boufaroua. M. El Mourid. M. Ben Khalifa. W. 2001. Techniques de Conservation des Eaux et des Sols dans les zones arides et semi-arides de la Tunisie.

[15] Chahbani. B. 1990. Contribution à l'étude de la destruction des jessour dans le sud Tunisien. Revue des régions arides. P : 137-172.

[16] Gasmi, I**.,** Moussa, M., Karbout, N. 2017. The influence of the different components of jessour on the overflow phenomenon in the microwatershed of El-jouabit, Mareth. Revue de Regions Arides n°41, num special-Journée Scientifiques de la Mejerda 2016 Esier Medjez El Bab

[17] Gasmi, I., Moussa, M., Rejeb, H. 2014. The jessour: wise traditional technique for water and soil conservation in southeastern Tunisia (the case of micro-watershed El-Jouabit, Mareth, Gabes). Research Journal of Social Science and Management. Volume 04, number 04, august 2014.

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