The Jessour: Wise traditional technique for water and soil conservation in southeastern Tunisia (the case of micro-watershed El-Jouabit, Mareth, Gabes)

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Abstract
The agricultural production in arid zones, basically based on rainfed farming, which depend to conserve scarce water resources by many techniques of water harvesting, such as the technique of “Jessour”. However, several attempts were held to exploit the excess of runoff for rainfed farming and reduce water erosion in the mountainous regions, and the technique of “Jessour” is the best way for the conservation and the management of water and soil resources. Despite its important role, this technique known by a fragile structure, which can easily destroy in case of overflow, and consequently representing a real danger threat the small villages located in the downstream. In this paper, “Winjesr”, was used to simulate the impact of the overflow caused by the excess of runoff behind the dykes and the destruction of the Elementary Hydraulic Unit (Jesr). 620 jesr were studied with the use of data from the parameters of jessours such as: cultivated area (length, width), dyke (height, length, and spillway). Generally, the disproportion between the surface of retention and the surface of impluvium (catchment area), always causes the overflow and subsequently, the destruction of the dykes during exceptional events, even if they are maintained very well. Three quarters of jessour are destroyed at 50mm of runoff water. Moreover, the units located in the upstream are the most threatened (steep slope and a small surface of impluvium).

Key words: Tunisia, arid, jessour, conservation, winjesr, runoff, destruction.

Introduction
Southeast of Tunisia characterized by rainfall despite its scarcity possesses a torrential character, which threatens by their high erosive activity the agricultural soil (Gasmi et al, 2013). However, this area is basically marked by a complex hydrological system, based on a strong complementarity between surface water and ground water which forms the essential part of the available resources. Also, this complementarity reinforced by the public strategies of water and soil conservation (Romagny et al, 2006).

In fact, the current situation of water resources and their use in the southeastern part of Tunisia shows many issues, which are common in many regions of the Mediterranean. Moreover, limited, uncertain and random water resources (Moussa, 2007) are widely used to cover the growth in needs (Romagny et al, 2004), which required the implementation of several techniques to mobilize and valorize the runoff water.

Despite the existence of many techniques, some of them modern and others traditional have been used to valorize the runoff water, the most important and usable technique in Matmata Mountain is the traditional technique called “Jessour” and it is used basically to harvest and store water and erosion products behind their dykes.

Consequently, during exceptional rainfall events, the small hydraulic unit (jesr) knows several damages (Bonvallot, 1979) due to its fragile structure, which makes it necessary to study the status of these units and the assessment of their sensitivity to overflow and destruction.

Generalities about jessours
Jessour are recognized as an ancient method for collecting runoff water from the long slopes, which allowing the use of stored water for the planting of trees (olive, peach, almond…) and the practice of annual crops (wheat, barley …), chiefly in Matmata Mountains (Hilali, 2011 & Gasmi, 2013). This
system is generally based on the building of earthen dams or dykes called tabia, which across the valley floors to trap runoff water and erosion products basically silt from the summit. 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 stones 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 (Boufaroua, 2002, Boufaroua et al, 2001 &chehbani 1990).

![Fig.1. Lateral spillway](image1)

![Fig.2. Central spillway](image2)

![Fig.3. components of jessours (Gasmi, 2013)](image3)

**Materials and methods**

**Studied area:**
The study was conducted from October 2011 till May 2012, in the micro watershed El-Jouabit which belongs to the delegation of Mareth in the southeast of the province of Gabes, Tunisia (33°29’, 33°30’ North latitude, and 10°10’, 10°07’ East longitude). The studied area covers a surface of 304.7719 ha (3047719 m²) with 620 jesr. The micro watershed is located at the upstream of the watershed of wadi sagui. This area is predominately arid with fresh winter and warm summer, wind frequently violent from the eastern sector in the summer and from the western to the southeastern sector in winter with the average of 28 days of sirocco per annum. The rainfall is irregular in time and space, and the most important part concentrated in the winter. Moreover, the stormy character of rainfall has contributed to severe and frequent floods, which have been accelerated the degradation of the soil in this area (Mtimet and Escadafal, 1982, Moussa, 2007).
Methodology
This paper focuses on the simulation of the sensitivity of jessours to destruction in different depths of runoff water. To study the risk caused by the overflow, the following parameters have been elected on all units of the micro watershed of El-Jouabit to accomplish the desired goal:
- Height of retention (m): the difference of height between the dyke and the cultivated area;
- Holding area (m²): surface of cultivated area covered by water when the “jesr” is full;
- Surface of impluvium (m²): the area of the micro watershed having as outlet the holding area, and this surface will spread due to the existence of small rills called “Hammala”;
- Capacity of retention (m³): the maximum amount of water that the jesr may retain, it depends on the height of retention, the holding area and the cultivated area of the jesr.

The calculation of the capacity of retention can only be done for the non destructed jessour, while the destroyed units have a capacity of retention null. In addition, the capacity of retention, the holding area and the surface of impluvium have been calculated using some computing tools as Microsoft Excel, and for the cartography, we have been used satellite images from Google Earth with a definite scale. Besides, these images allow being located in the field and clearly identified the jessour by marking the traced of “Tabia” and assigned it a number directly on the map. After that, we have been reported the traced of every dyke and marking the pouring direction and the outline of impluvium for each unit as well on the same map.

Model of treatment
The algorithm has been developed with visual basic. It has the possibility to store and manage the parameters of all studied units. Currently, the jessour forms a kind of branched system of a large number of units.

Outgoing volume = incoming volume – stored volume
This equation provides an opportunity to verify the existence of a possible overflow which will be probably the main cause of destruction (Moussa, 2007).

A recurrence relation has been constructed for the application of the model:
\[ \text{Dev}(n) = \sum \text{Dev}(n-1) - \text{Cr}(n) + \text{Simp}(n)h; \]
if \( \sum \text{Dev}(n-1) > \text{Cr}(n) + \text{Simp}(n)h \)
\[ = 0; \]
if \( \sum \text{Dev}(n-1) < \text{Cr}(n) + \text{Simp}(n)h \)
\[ \text{Dev}(0) = \text{Simp}(0)h - \text{Cr}(0); \]
if \( \text{Simp}(0)h > \text{Cr}(0) \)
\[ = 0; \]
if \( \text{Simp}(0)h < \text{Cr}(0) \)

Where:
Dev (n): overflow of the unit of rank n
Dev (n-1): overflow of a unit n-1, spill of the unit of rank n
Cr (n): capacity of retention of the unit n
Simp (n): surface of the catchment area of the unit n
h : depth of runoff

The software ArcView 3.2 has been used to elaborate the different maps of the simulation of the sensitivity of each unit to destruction in different depths of runoff water.

Results and discussion
**Variation of the number of overflowing units compared to the depth of runoff**
Fig. 2 depicts the variation of the number of overflowed units in different depths of runoff water. In fact, in the beginning, there is a slight increase in the number of overflowed units, and then it becomes rapid so such there was an increase in the volume of the runoff water. Therefore, the number of units which overflowing in low depths of runoff is less significant, whence the overflowed units in this level were located on the steep slopes where there is an important runoff and this is explained by the high sensitivity of some jessour which have a small size (height of retention, holding area) and this jessour was characterized by their poor design (disproportion between surface of retention and surface of impluvium), so they are more susceptible to overflow. On the other hand, the bigger units are more resilient to significant volumes of runoff water from which a slight increase of the depth of runoff does not possess a significant effect on the number of overflowing units.

![Graph showing the variation of the number of overflowed units](image)

**Overflowed volume in the micro watershed**
Fig. 3 shows that there was a slight increase of overflowing volume, which accounts for this variation of the number of overflowing units, which thus affect the received volume by the units located on the downstream. In addition, the increase is made more significant for high values of runoff which exceeds 20mm. Furthermore, when the units located on the upstream are overflowed; the other units located in the downstream receive an amount of excess water that varies roughly in a linear manner with the different depths of runoff water.
Volume of water stocked into the micro watershed

Fig. 4 shows the variation of volume of water stocked in the holding area of non-destroyed jessour at different depths of runoff. For the values of runoff water below the 20mm, the shape of the curve says that the volume of water spilled after the overflow of the first units is negligible since it has no impact on the total stored volume. On the other hand, the variation of the curve shape for the values of runoff more than 20mm is the result of the overflow of bigger units that no longer retains water, which explains the decrease of the stock level. Indeed, the increase of stock level due to the overflow and the destruction of jessour on the upstream which increasing the volume of water stored in the rest of units.

Simulation of the sensitivity of jessours to destruction in different depths of runoff water

After the collection and the treatment of different data, the software “winjesr” has been used to simulate the volume of spilled water from the destroyed units as well as stocked volume of each intact unit. After all, the maps of the jessour that destroys at every 2mm of runoff water have been elaborated using the software ArcView 3.2. Furthermore, these maps give an idea about the number of overflowing units and their distribution throughout the micro watershed. The simulation was performed every 2mm of depth of runoff up to a maximum value of 50mm as showed in the table 1.

<table>
<thead>
<tr>
<th>Depth of runoff (mm)</th>
<th>Number of overflowing units</th>
<th>Number of non-flowing units</th>
<th>total volume of overflown water (m³)</th>
<th>Total volume of stocked water (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>41</td>
<td>529</td>
<td>1014</td>
<td>5177</td>
</tr>
<tr>
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<td>12</td>
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<td>14724</td>
<td>24033</td>
</tr>
</tbody>
</table>
The fig.5 shows the distribution of overflowing units in the micro watershed at respectively 20, 30, 40 and 50 mm of depth of runoff. For 2 mm of depth of runoff, there are 252 overflowing units (i.e. 40.64% of the total number of jessour), basically located on the upstream, zones with high altitude, the center and the downstream of the micro watershed but with a low percentage, the stored volume of water is 31208 m$^3$ while the total of spilled volume is 32819 m$^3$, we are noted that the stored volume is very close to spilled volume in this level. At 30 mm of runoff, it exists 312 overflowing units (i.e. 50.32%) it means almost 50% of jessour in the micro watershed are overflowed in this level, this units can be found all over the study area but the most important density located on the upstream; the volume of evacuated water is 64279 m$^3$ and stored volume of 38004 m$^3$. Finally, for 50 mm of runoff, we noted that almost 65% of jessour were overflowed, or the overflow was affected practically the three-quarters of units in the study area; the total volume of stored water is 39358 m$^3$ while the evacuated volume by the overflowing jessour is 144011 m$^3$. 

![Image](image_url)
Conclusion
The jessour in the Mount of Matmata basically marked by their hydro-morphological role, but it is insufficiently accomplished since the jessour suffer from various problems. However, this technique has been reported to have a fragile structure, which can be easily destroyed in case of excess of runoff water retained behind the dykes, representing therefore, a real danger to the small villages on the downstream. Thus, the overflow in the micro watershed is studied based on some parameters such as height of retention, holding area, etc. …. And the collected data have been analyzed to get a clear idea about the state of jessour and their sensitivities to destruction. Besides, the analyses of data with the algorithm “winjesr” show that the units located on the upstream are the most sensitive to destruction and in turn leads to the destruction of the units located in the center and downstream. In general, the main cause of this issue is the high disproportion between the surfaces of the holding area and catchment area, which cause always an imbalance between the volume of overflowing water and the capacity of retention.

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