THE INTERNATIONAL JOURNAL OF HUMANITIES & SOCIAL STUDIES

The Impact of a Rainwater Harvesting Project on Farming System: Case Study of Oued Soukra Watershed – Tunisia

Mohamed Amir Bouzaida
Laboratory of Economy and Rural Societies, Institute of Arid lands, Médenine, Tunisia
Dalel Ouerchefani
Laboratory of Eremology and combating Desertification, Institute of Arid lands, Médenine, Tunisia
Refka Rahali
Laboratory of Economy and Rural Societies, Institute of Arid lands, Médenine, Tunisia

Abstract: *Since the last decades natural regions of Southern Tunisia are being faced to a severe degradation of water and soil resources. This phenomenon is in continuous progress due to the importance of irrational human activities coupled with the extreme climatic conditions. To deal with this situation, Tunisian government has implemented a national plan for soil and water conservation consisting in technical, agronomical and legislative actions for soil and water management. This paper presents the impact of the management of Oued Soukra watershed on Land use in the framework of this strategy. Many techniques have been used to assess land use change and its effect on farmers' income and life level: Remote sensing and Geographic information system for map generation, questionnaire and literature review for socio-economical evaluation of agrarian reforms. This study shows that cereal and fruit trees area has increased respectively by 130% and 69% whereas an important regression was noted for rangelands 36%. Moreover clear diversifications of cropping systems (new fruit trees including pistachio, vegetable crops) have been noticed. These results haves been retrieved from maps and confirmed by onsite survey done with local farmers.*

Keywords: *Tunisia, water and soil conservation, land use, remote sensing, cropping system.*

1. Introduction

Despite severe climatic conditions, agriculture remains the major and sometimes the unique source of income in southern Tunisia. In these rural regions, this income is very uncertain and vulnerable because it is conditioned by the availability of water resources (Sghaier et al., 2000). In El Hamma region, ground water is the most important natural resource that is widely used in agricultural production. Water is captured by tube wells at shallow and deep depth from respectively local phreatic acquifer and fossil Continental Intercalaire acquifer. Surface water resources are very limited because of the aridity of the climate and uneven distribution of rainfall in space and in time, resulting in devastating floods in some areas whiles some others face chronic drought.

In arid regions direct rainfall is insufficient to develop and expand agricultural activities. Implementing rainwater harvesting systems have become the only option for sustainable agriculture. WHS is defined as a method for inducing, collecting, storing and conserving local surface runoff for in arid and semi-arid regions (Boers and Ben-Asher, 1982). The use of such techniques is known to be very old. The principle is the following: Rainwater Harvesting concentrates rainfall by allowing and encouraging it to run off catchment's surfaces in a controlled way and then storing the harvested water for subsequent use. Water may be stored in a number of ways: small dams, cisterns, shallow aquifers, or in the soil profile. It is then made available to a target crop, shrub, tree or domestic purposes (MA, 2009).

In this regard, and due to the increasing demands and irregular supply of water, an extensive national strategy for soil and water conservation have been implemented in this area in 1990 (MA, 1998). This strategy aims to insure a better use of available rainwater resources and to protect agricultural plots from devastating rainfall episodes causing soil and water erosion. It plans also to maintain groundwater resources availability and to preserve fossil aquifer from overexploitation as it is a non renewable resource (Achouri, 1995).

In this framework and since almost 25 years, large amounts of time and effort have been invested in the conception and the implementation of water harvesting systems (WHS) for a better valorization of surface water resources (Ministry of Environment, 1998).

Hence, today, there is an urgent need to have an accurate, reliable, timely data on various aspects of the impact of these WHS on the agricultural activity in the region, mainly on land use. While Geographical information system (GIS) has been found to be an effective tool for delineating the major WHS implemented in the region, remote sensing technology provides synoptic, repetitive coverage of useful information on Land Use/ Land Cover layers (LU/LC). This evaluation task would represent an efficient tool for decision makers for planning future management in this region.

2. Study Area

The watershed of Oued Soukra is located in southeastern Tunisia; it covers an area of 99 km^2 (figure 1). It is situated in the sector of Bouattouche belonging to the delegation of El Hamma in the governorate of Gabès. This region is located at about 40 km to the Northwest of Gabes and about 25 km to the North of El Hamma. It is located, also at 7 km of Northern Chott el Fejij, where is the final outlet of Oued Soukra. . It is worth noting that Oued Soukra, starts from the mountains Estah and Hadifa to the West and those of El Bhair in North. The study zone belongs to the arid climate delimitation and the annual rainfall is about 125 mm. Natural Steppic and adapted vegetation is the most represented in this sector (Le Houérou, 1969)

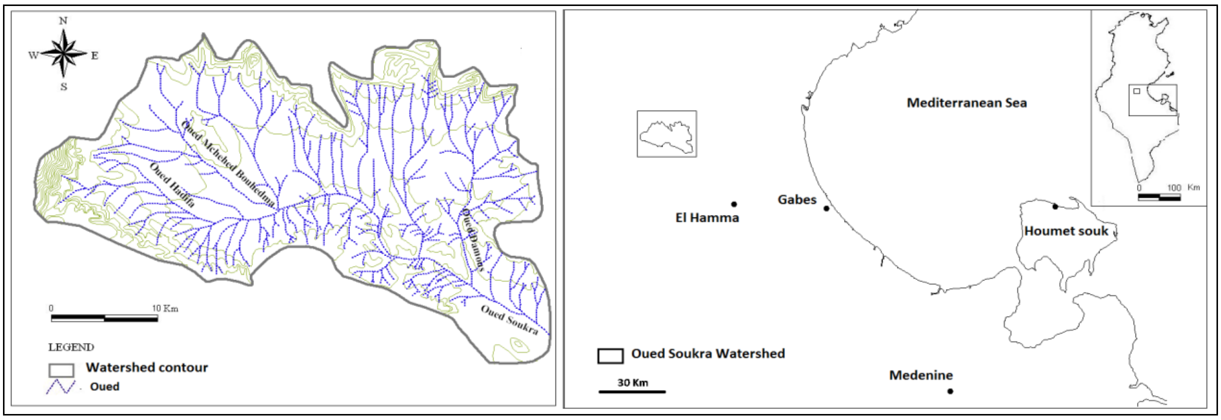

Figure 1: Study area : Oued Soukra watershed

3. Methodological Approach

In light of the foreseen objectives of the present work, an adapted methodological approach have been established to set up appropriate tools for collection and analysis of data in order to assess the impact of the project of conservation of soil and water resources on land use in Soukra watershed. This work is based on the following main methodological elements:

3.1. In-Depth Literature Review

This review is concerning all the documents of program reports and rural development projects, such as the Integrated and Rural Development Program (PDRI), the Regional Development Program (PRD), the National Solidarity Program, the Natural Resources Management Program. As well as water and soils Conservation national strategy's policies documents.

3.2. Survey and interview

To assess the impact of soil and water harvesting project in Soukra watershed, the approach was also based on a survey questionnaire to provide a detailed economic and social vision of farmers about the possible integrated effects of the project on agricultural activities.

The acquisition of information necessary for assessing the impact of the project was carried out in the study area by questioning 62 farmers, who could have benefited from the project. The data was collected with the aim of having quantitative and qualitative information about ancient and current situation of farmers plots (land use, crops, production, etc.) before and after the project, It was necessary to involve all beneficiaries and various stakeholders (farmers, regional decision makers, chief of district, researchers, etc.):

It must be stressed that some of the information could already be extracted from the project reports and the scientific literature available. To better assess the impact of the project, the investigation has focused on two reference years: 2004 i.e. before the project implementation and a more recent year (after the project): 2013.

3.3. Thematic Mapping

The techniques of remote sensing and Geographical Information Systems (GIS) have been used since the early nineties to map natural phenomena and territorial dynamics. These techniques which are in continuous progress provide a tool for decision support in sustainable ecosystem management and particularly for soil and water harvesting. In the context of this present study, thematic mapping had the following main objectives:

- Physical characterization of the watershed of Oued Soukra;
- Evaluation of the land use change before and after the implementation of the project.

<u>3.3.1. Data used</u>

Three GeoEye scenes were downloaded directly from Google Earth. These images captured in March 2004, 2009 and 2013 were georeferenced to be spatially and temporally comparable. These images are 1440 * 791 pixels and have a spatial resolution of 1 meter.

In addition to spatial data, a set of field observation was conducted over a fifteen station. These observations, describing the ground truth, were made using a field sheet established beforehand. For each station, data on the location, physical characteristics of the environment, etc. was retrieved from existing maps (topographic: the sheet of El Hamma scaled 1/100 000). These data were used during the two phases of this work: review of existing thematic maps and validation of produced maps.

3.3.2. Specific data processing

Some preprocessing operations were necessary to make the cartographic and satellite data usable, digital, and overlayed in the same geographic reference. Photo interpretation on the screen was undertaken for mapping soil and WHS (tabias, dams ...) as well as land use for the corresponding three dates. This mapping is based on differences in color and shape of the corresponding pixels. Prior knowledge of the identified different Land use classes was essential to later on recognize their aerial correspondences.

The mapping approach has allowed us to develop two kind of maps: a basic mapping for those variables that do not change in time (slope map, digital terrain model, so on) and dynamic mapping to study the evolution of land use through multi-temporal approach (2004, 2009 and 2013)

4. Results and Discussion

4.1. Land use change in Soukra watershed

In order to highlight the evolution of the agricultural landscape, the existing and past land use was mapped using very high spatial resolution imagery. Changes in land use and crop distributions for the years 2004, 2009 and 2013 are shown in figure 3. According to this figure cereal and fruit trees area has increased at the expense of rangelands. This trend has began with the implementation of the project, as shown in the map of land use for the year 2009, through the planting of a large number of olive and other fruit trees. The extension of the area occupied by cereals is clearly observed during the year 2013 land-use map. Also, several plots previously neglected have been cultivated with crops, benefiting from conservative techniques undertaken by the project. The graphical representation of land use in 2013 and its comparison with 2004 (figure 2), shows a remarkable increase of fruit trees (130%) and cereals (62%) area. A clear regression of rangeland (36%) is also noticed. These results haves been confirmed by the onsite questionnaire done with local farmers.

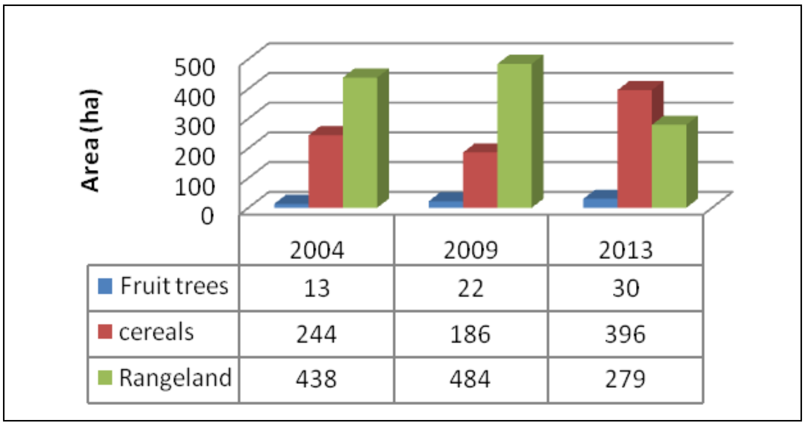

Figure 2: Land use change during the period 2004-2013.

The area of main cereal speculation have increased with a rate of 12.9% for wheat and 9.8% for barley (table 1), confirming the evolutionary trend illustrated by land use change mapping between 2004 and 2013 (table 1). Surveyed farmers argue that this dynamic is due on the one hand, to the effects of the water and soil conservation practices, including the improvement of water collection by the WHS and other hand, the development farming practices (tillage, fertilization, phytosanitary treatment, cereal/legume rotation, etc.), and, thanks to the extension and awareness of farmers within the project.

Fruit trees area increase in a slow and progressive manner within runoff mobilized by the flow diversion structures put in place by the project (table 2). However, this increase is also due to the introduction of new orchards of olive and fruit trees including pistachio. It represents currently 4.5 % of the total area, compared with 2004 when it represented only 1.8%.

The project promoted the planting of 50 ha of fruit trees; However due to lack of funding, the total area cultivated was 27 ha which is only 54% of the area planned to be managed. The following table shows the current distribution of the main species according to age, level of the spreading of Oued Soukra perimeter as reported by farmers:

	Wheat		**Barley**		**Total**
	Ha	%	Ha	%	Ha
2004	31	33	61	67	92
2012	35	35	67	65	102

Table 1: Area of wheat and barley in 2004 and 2012

Figure3: Land use maps of Soukra watershed in 2004, 2009 and 2013

According to the results of the field investigation, there are 430 olive trees, 150 almonds, 75 figs 180 pistachios cultivated in the framework of the project. These young plantations came into production, despite weather conditions and strong winds from the Southeast and Northwest. Furthermore, the project encouraged farmers for choosing not only conventional species which are the most suitable for the climatic conditions of the region and consequently the most cultivated by the majority of them(olive, almond and fig trees), but also further speculation such as pistachio. Technically, fruit trees plantations behind tabias enable the improvement of soil structure and therefore its resistance to water erosion, but also the increase in production and therefore, the improvement of the agricultural income of farmers.

Species	Young plantation	Mature plantation	Total
-Olive trees	430	420	850
-Almond trees	150	350	500
-Fig trees	75	120	195
-Pistachio trees	180	0	180

Table 2: Area occupied by fruit trees

The decrease of the sylvo-pastoral area related with the extension of the cereal and arboreal area is remarkable: (from 438 Ha in 2004 to 279 Ha). Although this change in land use is beneficial for farmer's life level, it has many adverse effects on natural resources. Indeed, the current pastoral area undergoes a pressure and a growing overgrazing and therefore, the destruction of vegetation cover is more than imminent. To resolve this problem, the majority of farmers use fodder obtained by cereal. Indeed, after harvesting season, the seeded area may constitute an excellent rangeland in summer. In this sense, in addition to the production of seeds, cereal farming provides interesting products for livestock. According to estimates made by the CRDA, straw production is evaluated to 80 T/year corresponding to 20000 Fodder Units in 2013. This had as a consequence of relieving the pressure on the rangelands.

It should be noted that legume plantations do not constitute a regular speculation and therefore a very less represented class in land-use maps due to its episodic cycler depending on rainfall. Taking advantage of the first autumn rains, farmers plant vegetables, including the pea, lentils, bean and chickpea, mainly for home consumption. Operators argue that after the implementation of the WHS, this speculation can reach 40 Ha, for a rainy year, compared to a negligible area, and even zero previously. This trend is given by the table 3.

	Area of legume plantations								Total
	Peas		Lentil		Bean		Chickpea		
	(Ha)	%	(Ha)	%	(Ha)	%	(Ha)	%	(Ha)
2004	8	67	2	17	1	8	1	8	12
2012	19	48	13	33	5	12	3	7	40

Table 3 : Evolution of legume plantations by species before and after the project

The pea is now the most cultivated species, occupying 67% of the vegetable area in 2004 and about half in 2012. The area of this speculation has increased between 2004 and 2012 with a rate of 137%. For a rainy year, an important part is intended for local marketing. Other crops have also benefited from WHS undertaken within the project. Indeed the area occupied by the lentil has increased from 2 ha in 2004 to 13 Ha in 2013. The same trend is noticed for beans and chickpea.

To meet their food needs and in order to have a source of extra income, the farmers surveyed, reported that the implementation of WHS in the watershed encouraged them to diversify their cropping systems (new fruit trees speculation including pistachio, vegetable crops). The agricultural component of the integrated management of the study area therefore shows a clear improvement of the production.

4.2. Agricultural plots distribution and fragmentation

As already noticed in the land use change maps, the number of cultivable plots has increased approximately with about 32% more agricultural plots in 2013 compared with 2004 (figure 4). This strong demand in production is not only for home consumption but also for sale. Data relating to this evolution is presented in the following table. These data were retrieved from the questionnaire of 62 farmers on site.

The percentages of plots with an area less than 6 ha are the most dominant representing respectively 74% and 80% of the total area in 2004 and 2013. This is a real proof of the phenomenon of land fragmentation becoming more and more apparent in the study area, as shown in figure 4.

Looking to the table 4, it is also shown that the number of plots has increased in 2013 with more than30 plots in total. The fragmentation is due to three main reasons en direct relation with the project:

- the first one is social: the farmer's enthusiasm regarding the project success by creating new plots
- economic: the new created plots are therefore smaller because they are easier to manage
- agronomic: the diversification of crop system.

Year		Plots area (ha)					Total
		0-3	3-6	6-10	10-15	>15	
2004	Number	56	21	16	9	2	104
	%	54	20	15	9	2	
2013	Number	78	32	19	7	1	137
	%	57	23	14	5	1	

Table 4: Evolution of plots number according to their area before and after the project

This fragmentation makes agricultural activities relatively difficult (mechanical working of the soil, harvest and transportation of products, etc.). Moreover, the fragmentation process presents an obstacle to the modernization of agriculture and a major handicap to competitiveness, a problem of profitability, and even viability for these plots.

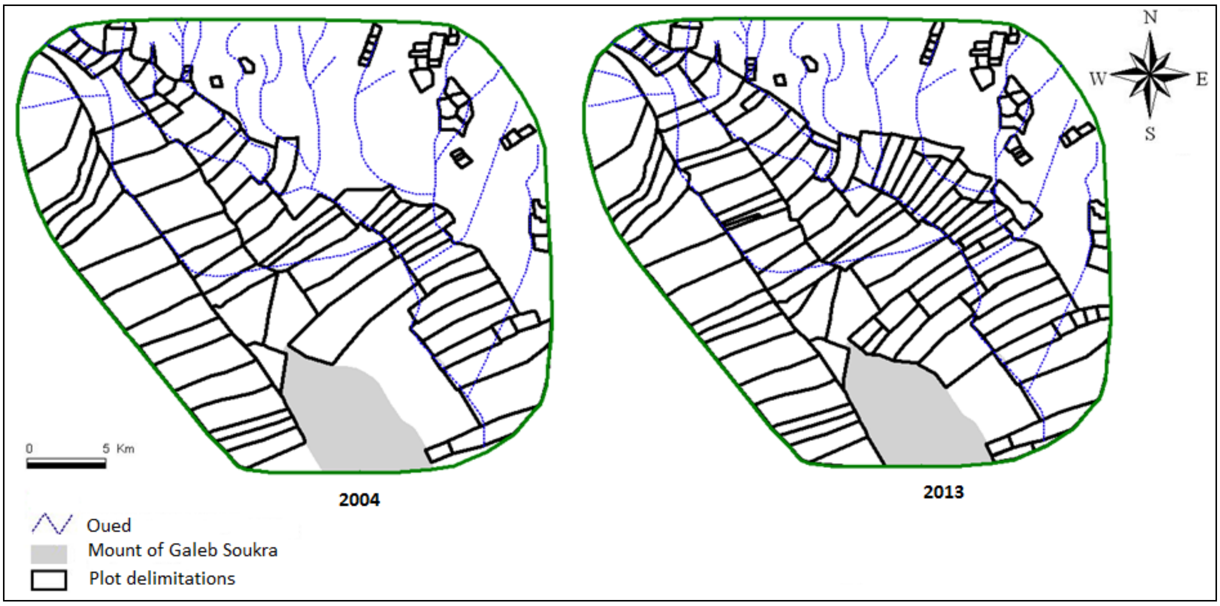

Figure 4: Plot delineation before (2004) and after the project (2013)

5. Conclusion

This study was performed in the framework of a project for harvesting rainwater in an arid region of Tunisia using geo-information technologies, basically remote sensing and GIS. Thus, an important change in land use was shown during and mainly after the project. This change is underlined by a considerable increase of cereals and common fruit trees area like olive and almond trees and the emergence of new profitable other species. Whereas an important decrease have been noticed for rangelands. This positive trend after the project is also shown by the increase of plots number: this is the best indicator of farmer's interest and therefore the project success. This kind of projects could be an interesting alternative for maintaining agricultural activities in extreme natural conditions.

6. References

1. Achouri M. 1995. La conservation des eaux et du sol en Tunisie : bilan et perspectives. In: Zekri S. (ed.), Agriculture, durabilité et environnement. Zaragoza CIHEAM, p. 35-47 (Cahiers Options Méditerranéennes; n.9).
2. Boers, T.M. , Ben-Asher, J. 1982. A review of rainwater harvesting. Agric. Water Management 5: 145-158.
3. Le Houérou, H.N. 1969. La végétation de la Tunisie steppique avec référence en Algérie et au Maroc. Ann. INRAT Tunis, 42 (5) : 624 p. + annexes et carte au 1/500 000 en couleurs.
4. Ministère de l'Environnement et de l'Aménagement du Territoire.1997. Atlas du gouvernorat de Gabès. Rapport de première phase (Bilan, Diagnostic, Problématique).
5. Ministère de l'Environnement et de l'Aménagement du Territoire. 1997. Projet de Gestion des Ressources Naturelles. Rapport d'exécution, volume II, Annexes Techniques. Projet. TUN-5736.
6. Ministère de l'Environnement et de l'Aménagement du Territoire. 1998. Programme d'Action National de lutte contre la désertification (PAN/LCD). Tunis p. 34.
7. Ministère de l'Agriculture / Direction de CES. 1998. Rapport générale : Planification des aménagements de conservation des eaux et du sol dans le gouvernorat de Gabès.
8. Ministère de l'Agriculture. 2009. Etude d'aménagement de 3 zones d'épandages dans le Gouvernorat de Gabès : Phase 3 Avant-Projet Détaillé Définitif (A.P.D / D) « Zone d'épandage d'Oued Soukra, délégation d'El Hamma », Juillet 2009, page 31.
9. Ouessar M. 2007. Hydrological impacts of rainwater harvesting in wadi Oum Zessar watershed (Southern Tunisia). Ph.D. thesis, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium, 154 pp.
10. Sghaier.M, Picouet.M, Auclair.L. 2000. Observatoires des relations populations-Environnement en milieu rural Tunisien : Pour une gestion durable des ressources naturelles DYPEN II, Rapport scientifique Tome II, juin 2000, page12-34.
11. WAHIA 2002. Water Harvesting in Mediterranean zones: an impact assessment and economic evaluation. Proceeding from EU WAHIA Project Final seminar in Lanzarote. Jan de Graff and Mohamed Ouessar edition (Final Report).