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Impact of water and soil conservation works on farmers' income in Oued Sbaihia watershed, Tunisia

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Abstract: *In a semi-arid Tunisian context where landscape degradation by soil erosion has increased considerably, a comparative economic study of farmers' income over a timeline situation: before and with soil and water conservation amenities installation is necessary. We aim to analyze the socio-economic impact of these amenities in Oued Sbaihia watershed at the north east of Tunisia. The results show that these developments have important roles from an environmental and economic point of view. Indeed, they reduced the erosion of agricultural land and improving its productivity through maintaining soil fertility and increasing water reserves by correcting ravines and building manual benches and hill lake. Also, the integration of olive tree cultivation, has improved both the sustainability of land and the profitability of farmers. In addition, the expansion of fodder crops, especially the cultivation of Sulla, has improved the feed rations of the herds; which helped improve the quality and number of livestock and increased the selling price of livestock.*

Key-words: *Erosion, soil conservation, economic impact, Zaghouan, Tunisia.*

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I. Introduction

Due to its geographical location in the Mediterranean region, its rugged terrain, its fine soils and poor organic matter and its vegetation cover increasingly reduced, Tunisia is among the mediterranean countries most threatened by water erosion especially semi-arid areas. The aggressiveness of the climate generates significant losses in soil and runoff water pouring into the seas. On the other hand, the demographic increase and the economic expansion of the country make that the soil resource and even more the water resource become more and more scarce requiring a particular management.

This is why the Department of Water and Soil Conservation of the Ministry of Agriculture has defined since 1992 a national strategy aiming at collecting runoff water from small watersheds and rising development projects for medium and small hydropower and for land protection against erosion by better mastering farming methods, installing benches and cords with stones and sylvo-pastoral expansion.

However, it is necessary to assess the impact of the various anti-erosion facilities on the beneficiary population of these developments. For this, a calculation of farmers' incomes was made and this to compare two different states in two different periods: before installation of the facilities in a first place, then after installation of the facilities in a second place. Income calculations have focused on olive, wheat, pea and livestock crops.

The purpose of this analysis is to show the type and importance of the relationships between the stakeholder and his natural environment. Thus, this work was based on collecting data about: the study area (its location, its characteristics, its potential, its strengths and weaknesses) and the population (its activities, its location, its relations with its natural environment and its reactions towards the development facilities).

II. Methodological framework

1- Study zone

The watershed of Oued Sbaihia is administratively attached to the governorate of Zaghouan (Figures 1 and 2). It is located at 80 km from the capital Tunis and it is characterized by a semi-arid climatic. The population of the Oued Sbaihia watershed is 1,500 inhabitants divided into 206 families. The dwellings are scattered over the watershed. The total catchment area of Oued Sbaihia watershed is 6500ha, divided into useful agricultural area (53.6%) forest (25.5%), rangelands (14.4%) and uncultivated land (6.5%) (CRDA Zaghouan, 2003).

Figure 1 . Governorate of Zaghouan- Tunisia

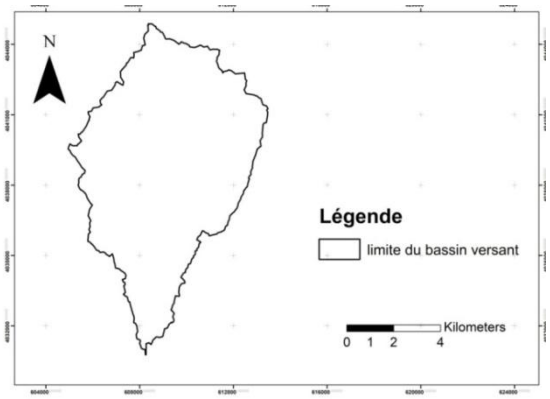

Figure 2. Delimitation of Oued Sbaihia watershed

The total plowing area in Oued Sbaihia watershed is 3610 ha, olive growing occupies the first place with an annual area of around 1500 ha or 41% of the UAA. The annual crops in the watershed of Oued Sbaihia mainly durum wheat, soft wheat, barley, oats, and legumes (bean, peas ...). The rotation practiced by the farmers of the basin is of biennial type: wheat / barley, wheat / legumes or wheat / fodder (CRDA Zaghouan, 2012)

In Oued Sbaihia watershed, the livestock population is mainly formed by: 1350 sheeps, 400 cattle, 1200 goats. (CRDA Zaghouan, 2012). There are two drilling intended for drinking water and 15 surface wells. There are 5 hill lakes, but only one well (called Oued Sbaihia 1 lake) is exploited by farmers, the others are clogged. **(**FAO, 2007). Water and soil conservation arrangements were made within Oued Sbaihia watershed in 2001.

The purpose of installed conservation structures is to develop the watershed and to protect agricultural land from the expansion of flooding scourge. The study area has a fairly pronounced relief with a remarkable density of ravines. The watershed of Oued Sbaihia was not developed enough and requires treatment and management. The main developments in our watershed are: mechanical benches, manual benches, the lake hill, gabion works, individual bowls, mechanical benches consolidated by acacia, plantation of Aleppo pine and plantation of Eucalyptus and Sulla meadows.

2- Inquiry methods

To meet the study's objectives, which consist mainly in identifying and analyzing the economic impacts of water and soil conservation (WSC) work, we had to undertake interviews with offices' human resources and carry out field surveys using questionnaires close to farmers. In our work, the survey was conducted among 30 farmers, that is to say 20% of all farmers and 56% of farmers whose land developed with WSC work. The purpose of this questionnaire is to collect all the data relating to the structures of agricultural holdings, production systems, existing WSC facilities, and facilities proposed by farmers from his point of view. This questionnaire allowed us to classify agricultural holdings according to a well-defined typology taking into account several variables on the one hand and to estimate the impact of WSC developments on the other hand.

The analysis of the surveys was done using Excel software. The processing of data collected by the survey was conducted in two stages: the calculations of some variables (average, standard deviation, yield, variable and fixed costs, income, revenue, etc.) and sorting flat to characterize farms. Note that all the conversion calculation were carried out to obtain monetary value converted into current currency in order to be able to make a well-founded comparison between the two periods: before installation of WSC (in 2001) and with WSC (in 2017).

III. Results

1- The current state of facilities

According visits on the field and statements of surveyed farmers, most of the facilities are in bad condition including mechanical bench which has dangerously exacerbated the phenomenon of erosion. This is why farmers use individual basins and manual benches to conserve their plots and improve the yield of their crops, especially the cultivation of the olive tree. It is to be noted that the CRDA Zaghouan is mainly involved in the construction manual benches and individual bowls since these facilities are less expensive and have an effect remarkable fight against erosion.

Most of the surveyed farmers claim that the effects of erosion consist mainly in damaging the infrastructure, cutting up the soil, which accentuates the phenomenon of fragmentation. Most of the farmers declare that the erosion control interventions on their farms are insufficient, and that the costs of conservation operations are very high. In addition, even simple anti-erosion developments require a very large workforce; other actions require huge financial means which is not within the reach of farmers in this area.

2- Features of the farmlands

The survey assessment has shown that agriculture in this watershed is to date of the traditional type. It is marked by a production system based on annual crops (cereals, fodder and legumes) and extensive livestock farming which feeds mainly on rangelands, crop residues and self-produced hay. Survey analyzes and observations bring out the following results. The population of Oued Sbaihia watershed practices agriculture based on cereal crops and grain legumes generally cultivated in intercropping with the olive trees. This type of culture plays a triple role: human food (self-consumption), the supply of farm cash from the sale of part of the production and enrichment of the soil with organic matter.

The general characterization of Oued Sbaihia watershed brought out certain physical, agricultural, social and economic aspects characterizing the population, namely: the preponderance of small and medium-sized farms, the production system is traditional, the production units are generally of reduced size and marked by a relatively high degree of land fragmentation, very rugged terrain and marl soil which is very vulnerable to water erosion. According to farmlands features, we developed a classification of the holdings according to total useful agricultural area (UAA) and the average size farm in the same class. Table 1 summarizes the number of farmers, the useful, average and total areas by class.

Table 1. Characteristics of farms by classes

Classes	Num. of farmers	Total area	% of total area	Farmlands average size	Total UAA
Class 1 : 0-5	18	57	34%	3 .16	44.5
Class 2 : 6-15	12	110	66%	9.16	84
Total/Average	30	167	100%	5.56	128.5

(Our Survey, 2018)

Examination of Table 1 shows that the average size of the farm belonging to the 0 to 5 ha classis is 3.16 ha and that of the second class (6 to 15) ha is 9.16 ha. About 18 farmers of have farms size less than the average, this justifies the problem of fragmentation of farms in this area. This problem is an obstacle to the installation of WSC facilities on small farms.

3- Impact of WSC facilities on family income

3-1- Impact of WSC work on olive cultivation

The results obtained by the economic analysis of the income showed the positive impact of the WSC installations on the olive tree income which results in an increase in average annual income which goes from 836.6DT before the WSC installations to 2180DT with the WSC development.

From figures 3 and 4 we see that for farms with areas ranging from 1 to 5 ha, the annual income average from olive cultivation increased from 652.2DT to 1869.4DT and for the farms of the second class (6 to 15 ha), the average annual income increased from 1101.6DT to 3289.16DT.

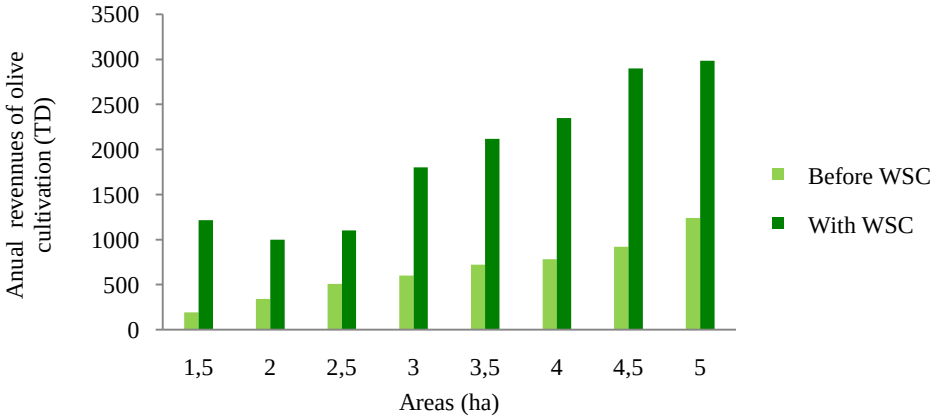

Figure 3. Annual income of the olive tree before and with WSC amenities (Class 0 to 5 ha)

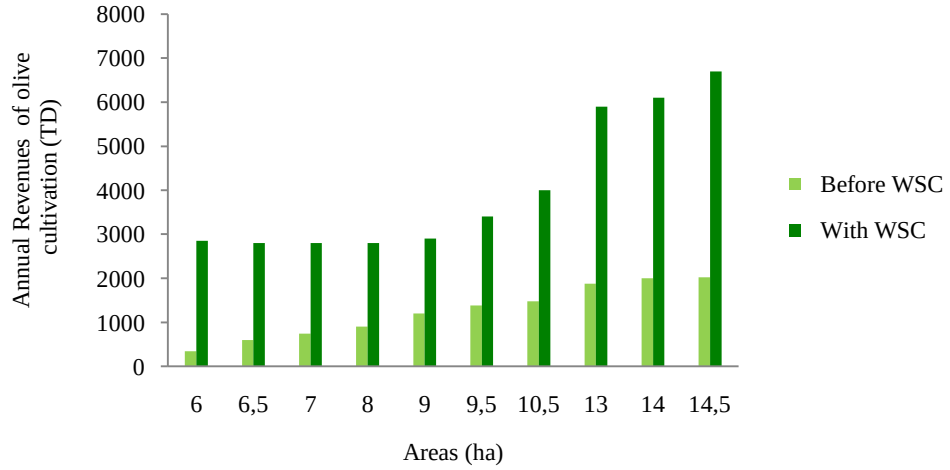

Figure 4. Annual income of the olive tree before and with WSC amenities (Class 6 to 15 ha)

In fact, the average yield of the olive trees increased from 15 quintals / ha to 25 quintals / ha. This increase is due to some factors such as the developments carried out on the plots, especially the basins, the manual benches and the correction of the ravines which reduces erosion and therefore preserves soil fertility.

Moreover, we note the effect of irrigation and the increase in density of tree plantation per ha (increase from 100 feet / ha to 150 feet / ha in new fields, especially those planted and irrigated during dry periods). Also there is another favorable factor which is the encouragement of the Government to plant the olive tree by providing farmers with significant subsidies in addition to the intervention of several development projects especially around the hill lake 'Oued Sbaihia 1: for example the FAO project in 2001, 2013 and 2015, and the FIDA project in 2007.

Thus, it can be said that the objectives of the conservation strategies have been achieved. We have managed to develop and mobilize runoff, encourage farmers to welcome young olive plantations, provide additional irrigation, improve livestock watering and expand olive plantations.

Following these incentives, the area planted by the olive tree is estimated at 800ha in 2014. In fact, the FAO project -in 2008- made available to farmers 75,000 olive seedlings with motor pump units and irrigation equipment (tanks, pipes, etc.) (CES Zaghouan, 2016).

3-2- Impacts of WSC work on wheat cultivation

The results from income calculations showed that the average annual income increased from 386TND to 782TND following the introduction of anti-erosion works for wheat. This increase in income is prevalent especially for farms in the second layer (figure 6). Indeed, the annual income average has improved from 629.1 TND 1275 TND; but for smaller farms income average annual increased from 213.8 DT to 487.5 DT (figure 5).

This difference is explained on the one hand by the increase in the cultivated areas of wheat for farmers who have large-sized farms and on the other hand by the fact that benches are installed mainly on the farms of larger size.

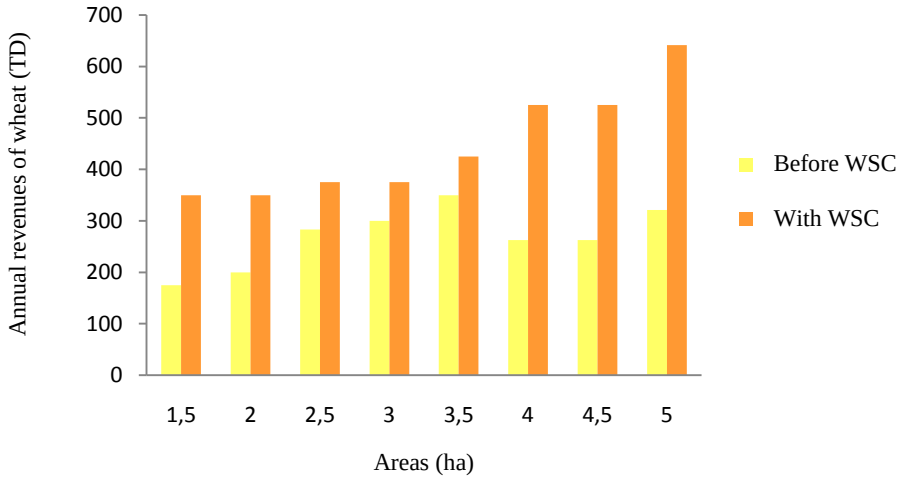

Figure 5. Annual income from wheat cultivation before and with WSC development (class 0 to 5 ha)

The increase in annual income of wheat cultivation for both classes of farms is explained mainly by the increase of the yield rising up from 8 quintals per hectare to 10 quintals per hectare. This is due to the capacity of the benches to hold the soil (which has favored the stability of the soil) and to the mobilization of the water runoff which is translated into the increase in vegetative development indicated by better tillering and a higher height.

It is also due to the increase in the selling price of wheat. Operating costs have not increased much, especially since the cereals are grown extensively, especially on small farms (low use of fertilizers and low degree of mechanization of farming operations).

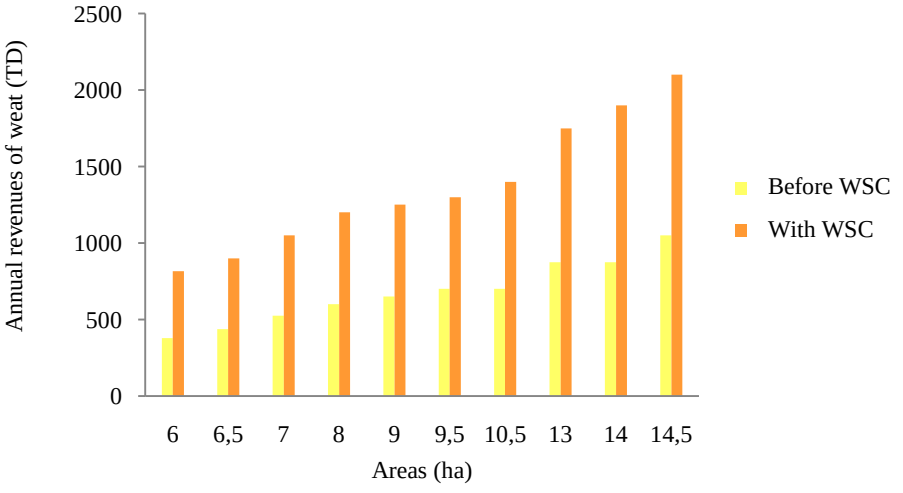

Figure 6. Annual income from wheat before and with WSC class adjustments (6 to 15 ha)

3-3- Impacts of WSC work green peas cultivation

Figure 7 shows the average annual income of green peas cultivation at the two timeline situations for the first class.

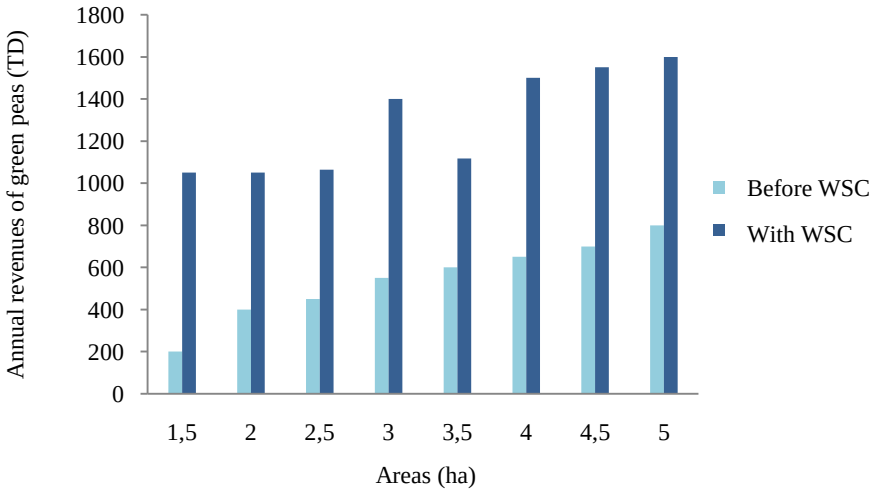

Figure 7. Annual income of the green peas before and with WSC developments (Class: 0 to 5ha)

Calculations show that the average annual income of green peas crops augmented from 793.3TND to 1540TND following the introduction of anti-erosion works. In fact, this augment in income is prevalent especially in farms of the second class (figure 8) where the annual income amplified from 1233TND to 2104 TND since the cultivated areas are most important but for farms of small size income amplified from 643TND to 1,634TND (figure 7).

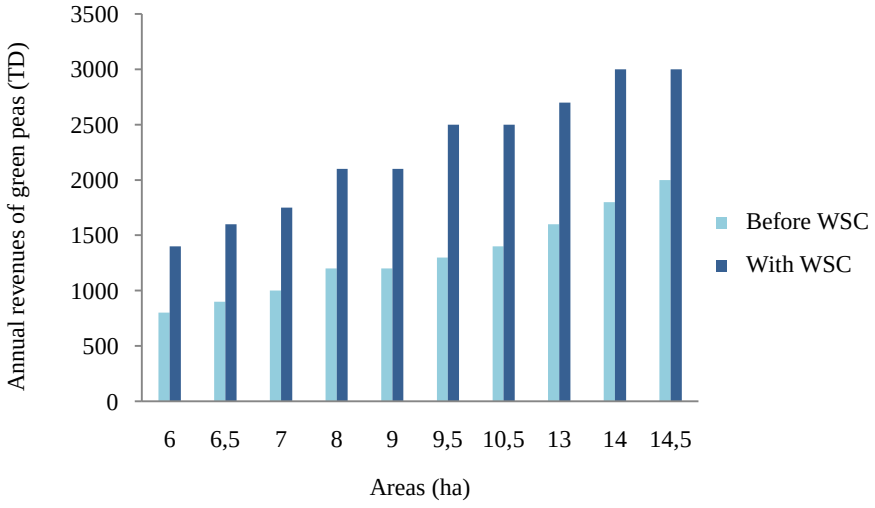

Figure 8. Annual income of the green peas before and with WSC developments (Class6 to 15 ha)

The revenue increase is explained by the role of WSC developments in conserving soil fertility and mobilizing runoff which positively influences the performance of green peas cultivation growing from 2 tones to 3 tones /ha.

3-4- Impact of WSC work on the total cultivated production

Note that figure 9 shows that the annual income of farmlands is due mainly to olive cultivation. This is noticed after the introduction of WSC management. In fact, average annual income of olive growing has risen sharply to 2180 TND. This raise is explained by the planted acreage expansion in olive for soil consolidation purpose.

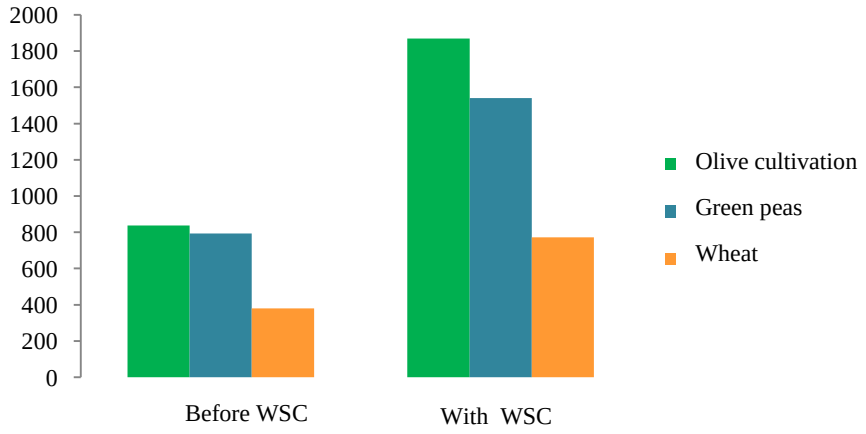

Figure 9. Annual income of the three cultures before and with WSC developments

Table 2 summarizes the results obtained for the three crops according to the two classes, before and with the improvements.

Table 2. Income generated from crop production before and with WSC facilities

	Income before WSC facilities (TND)			Income with WSC facilities (TND)		
Class (ha)	Olivier	Corn	Pea	Olivier	Corn	Pea
0 to 5	652.2	213.8	643055	1869.4	437.5	1634.8
5 to 16	1101.6	629.1	1233	32869.16	1275	2104
Total / Average	836.6	380	793.3	2180	772.5	1540

(Our survey, 2018)

The increase in yield per hectare can be explained by the increase in the number of plants per hectare for the fields carried out after management and the irrigation of olive trees during the dry periods of the year thanks to water irrigation from the lake.

It should be noted that the increase in revenue generated by each production or crop is due not only to the increase in yields but to the selling price, in particular for green peas and olives for oil extraction type, the selling price of which reached 1.5dt / Kg of olive. We remind that the calculations were made and compared taking into account the conversion to the current price.

3-5- Impact of WSC facilities on livestock numbers

Livestock in the Oued Sbaihia watershed focuses mainly on goats and sheep depending on the size of the farm and/or on its position with forest routes. Cattle present a form of secondary farming compared to that of sheep and goats in terms of numbers (table 3) because farmers cannot bear the high costs of cattle breeding.

Table 3. Headcount before and with WSC facilities

	Number before WSC facilites	Number with WSC facilities
Cattle	42	38
sheep	315	406
goats	154	178
Total	511	622

(Our survey, 2018)

We note that the number of sheep and goats livestock has evolved after the introduction of WSC facilities and pastoral improvement, which has enhanced herd management.

Table 4 shows that farms in the first class provide farmers with lower incomes, this is due to the small size of the farm and the absence of self-produced fodder resources. In fact, the larger the size of the farm, the greater is the number of head of cattle and therefore the higher is the income.

Table 4. Annual income derived from livestock before and with WSC facilities

	Income before WSC facilities (TND)			Income with WSC facilities (TND)		
Classes (ha)	Cattle	Sheep	Goats	Cattle	Sheep	Goats
0 to 5	255.5	1926	966.4	200	2155	1089.4
6 to 15	314.28	1602.85	977.85	285.14	2234.28	1321.42
Total/Average	280	1575	847	246.6	1970	979

(Our survey, 2018)

In any case, the increase in annual income after the installation of WSC facilities is explained by the pastoral improvement effect which allows farmers to recover almost uncultivated land and to have another source of food for their livestock.

For most of farms, the quantities of livestock by-products (bovine, goat and sheep milk, wool, manure and skin) are too limited to be marketed; thus they are intended for self-consumption (milk) or for internal use (wool, manure).

3-6- Impact of WSC on cultivated and livestock productions

In what follows we will put forward the calculated total farm income from crop and animal productions. Table 31 shows the total agricultural income per farm. Note that total farm income is the addition of income from crop production and income of animal production.

Table 5. Total farm income before and with WSC amenities

Class (ha)	Income of farm before WSC facilities (TND)	Income of farm with WSC facilities (TND)
0 to 5	1962.5	3928.77
6 to15	2389.037	4360.58
Total/Average	2243.7	3661

(Our survey, 2018)

From Table 33, it should be noted that the total agricultural income per farm for the two classes increased considerably. This increase of income proves the positive impact of WSC installations on the increase in yields and the extension of planted areas as well as the increase in livestock number.

IV. Discussion

According to field visits of Oued Sbaihia watershed, it has been noted that certain facilities such as the unconsolidated benches and the hill lakes are in poor condition, so they require urgent maintenance.

After having shown the positive impact of WSC amenities on the social and economic setting which consists above all in improving farmers' incomes, it will be necessary to think that this development is sustainable, that is to say that farmers must participate in anti-erosion practices and their maintenance and recognize the role of these facilities in the development and improvement of their income and that the success of these actions is conditioned by their attitudes. Therefore, in the future, farmers must rely on their own strengths and means.

Accordingly, farmers should be aware that conservation and maintenance of these facilities can strengthen and increase the lifespan of these works and compensate for their losses and ensure the conservation and improvement of natural resources in parallel with socio-economic development.

The solutions that we can propose relate to the maintenance of hill lakes and mechanical benches and the carrying out of studies on the water potential of the area for a possible creation of surface wells, dams and hill lakes. In addition, the consolidation of benches by plantations must take into account the needs of farmers by considering their proposals in the choice of species during biological treatment.

Besides, the development of beekeeping should be considered with a view to rehabilitating natural honey resources and the development of crops of honey interest (Sulla, Sunflower, acacias, cacti, eucalyptus). Support must also be given to the creation of an agricultural development group of farmers' association, given the role of community life in the participatory process which integrates specialists, technicians and farmers to create sustainable technical and socioeconomic development.

V. Conclusion

Water erosion is a natural phenomenon which can worsen under the combined action of specific climatic and anthropogenic conditions. Concerning the anti-erosion actions in the watershed, the comparison of the two timeline situations -before and with adjustments- allowed us to detect a positive impact of these actions, felt mainly at the level of the total annual agricultural income. This increase is mainly brought by olive growing given the increase in its yield and the extension of the areas planted with olive trees, considered a conservation strategy. We mention additionally an upgrading of farmers' incomes by creating jobs through the various actions carried out in the intervention area, notably the construction of the hill lake. However, intervention for the maintenance and consolidation of existing facilities remains an important necessity since more than 70% of the total area of the Oued Sbaihia watershed is exposed to moderate and very high erosion and that several anti-erosion facilities are in bad condition especially as the benches are unconsolidated and the hill lakes are clogged. To ensure the protection and rational exploitation of natural resources, it is necessary to take into consideration the role of rural communities in the management of collective projects: spirit of participation and responsibility.

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