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# Influence of land practices on the sustainability of irrigated farms in Tunisia: An analysis using the IDEA method

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**Abstract –** The aim of this study is to investigate the impact of indirect land tenure on irrigated farms sustainability in Tunisia. This analysis is based on the farm sustainability assessing method (IDEA-*Indicateurs de Durabilité des Exploitations Agricoles*= Farm Sustainability Indicators) adapted to the Tunisian context. It is based on the calculation of indicators scores for the three sustainability dimensions: agro-ecological, socio-territorial and economic.
Faced with land constraints, 40% of farmers sort to indirect land tenure through diverse a range of land contracts (rental and sharecropping). Our results showed that the lowest sustainability scores are found for indirect farming (31/100) and are related to the agro-ecological and socio-territorial dimensions. Conversely, these exploitations showed the highest score (72/100) for the economic dimension, much better than those obtained by landowners, with incomes reaching 3 times the Tunisian Guaranteed Agricultural Minimum Wage and an economic efficiency reaching 80%. Thus, access to land, through indirect tenure, leads, on the one hand, to improve the economic sustainability, but on the other hand, to low agro-ecological performances and negative externalities (soil degradation and overexploitation of resources). These findings reflect a degree of “conflicts” between both the economic and agro-ecological objectives. In fact, lessees seek to maximize their production in the short term and neglect the agro-ecological dimension, knowing that they will exploit these lands only for a few years. Conversely, landowners are more concerned with the agro-ecological dimension, as their lands and they are sure to keep them.

**Keywords:** sustainability, agro-ecological, economic, evaluation, land contracts.

## 1. Introduction

The concept of sustainable development appeared in the 1960s and was gradually adopted by international institutions (Food and Agriculture Organization-FAO, World Bank-WB, etc.). Many countries included it in their public policies and it has become an inevitable part of any discourse about the future (Barbosa et al. 2014). The most frequent definition of sustainable development is the one proposed in Brundtland Report:"*sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs*"(Brundtland1987).
Because of its production methods and the way it uses natural resources, agriculture is one of the most concerned sectors by sustainable development, particularly in developing countries (Adenle et al. 2018).Sustainable agriculture ought to maintain production capacity while preserving natural resources it depends and contributes to the sustainability of the territory that is part of: integration into the local economy, local supply services and job creation (Gafsi et al. 2006).
For farmers, land constitutes the main production factor. It is also a source of investment and wealth accumulation. Enhancing land governance, and ensuring secure land tenure and fair access to land, is a key issue for international donors to address in their development strategies (Lavigne-Delville et al. 2001; Amanor 2008). Land tenure can thus be one way to achieve sustainable development goals in developing countries by providing tenure security to poor people and creating country-wide land recordation systems (Reidsma et al. 2011).In some developing countries, land constraints (absence of property title, land fragmentation, small areas, landlessness, etc.) lead farmers to develop various strategies, particularly the indirect land tenure via contracts (rental and sharecropping) (Adamczewski et al. 2015; Gharbi 2019).However, these land tenure practices, particularly the informal or illegal ones, may have environmental and social impacts and threaten the sustainability of concerned territories and put them at great risk (Clover and Eriksen 2009).In many cases, land ownership status (owner, renter and sharecropper) significantly influences thus the sustainable growth of agriculture.
The prospect of sustainable development implies that the future of exploitations can no longer be assessed according to their technical and economic performances. It is necessary to forge sustainability indicators and

to develop suitable benchmarks (Marchand et al. 2014; Latruffe et al. 2016).It is therefore necessary to develop evaluation tools built on sustainability indicators and performance scores (Schindler et al. 2015), but also to focus more on calculating indicators than on their determinants (Pham and Smith 2013).These methods for assessing the farms sustainability should also allow farmers to identify levers to improve their farms' performance, and public authorities to broaden their technical advice and identify tools for addressing sustainability issues (Zahm et al. 2019).

Various methods, such as RISE (Häni et al. 2003) and MOTIFS (Meul et al. 2008), have been developed to study farms' sustainability, but mainly in developed countries and to a very lesser extent in developing countries (Fadul-Pacheco et al. 2013).Among these methods, IDEA (*Indicateurs de Durabilité des Exploitations Agricoles*/Farm Sustainability Indicators) enables to the description of the global performance of farms, taking into account the three dimensions of sustainability: agro-ecological, socio-territorial and economic. This method allows a thorough analysis of each sustainability aspect includes all dimensions of the farm and is compatible with different contexts (Zahm et al. 2008).

The present study aims to investigate the impact of farmers' land practices and land contracts on the farms' sustainability within an irrigated area in the northwest of Tunisia, using the IDEA method adapted to the Tunisian context.

## 2. Methodology

### 2.1. Study area

The study area is the irrigation scheme of Gaâfour, located in the Siliana governorate in the northwest of Tunisia (Fig.1) which is supplied with surface water from the Siliana dam.

It covers a total irrigable area of 1,728 ha including 1,261 ha (73%) of private lands belonged by 196 owners and 467 ha (27%) are public lands allocated by the State to smallholders and private companies. There are 59% of public lands are allocated for long periods (15 or 40 years) to 98 young farmers with a dual objective of creating jobs for unemployed young people in rural areas and rejuvenating the agricultural population (Gharbi et al. 2018).The individual plots sizes range from 2.5 to 3.5 ha.

Within the Gaâfour area, indirect land tenure is widespread. It is present on 56% of irrigable lands where 27% of them are public lands allocated to settlers and leased by their beneficiaries and 29% are private lands. Different contracts, rental or sharecropping, formal or informal (long term, or limited to one growing season) are signed with various actors (other private farmers, State settlers, and landless farmers).

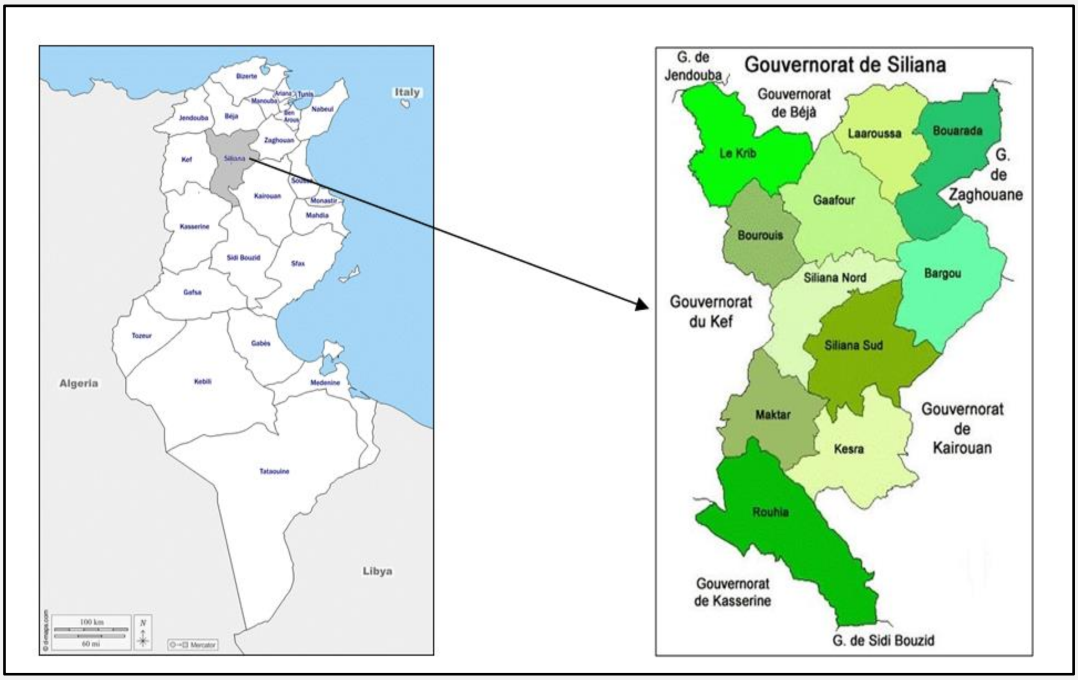


**Figure 1.** Location of Gaâfour area (Siliana-Tunisia)

### 2.2. Methods

Our methodological approach was first based on open exploratory interviews that were carried out with the regional agricultural administration staff and different categories of farmers (owners, State beneficiaries, tenants, and sharecroppers) to understanding the different ways of exploiting the irrigable lands within the perimeter. Before starting our systematic detailed surveys, the farmers were randomly interviewed in their fields and asked to describe their farm's background and current situation (total area, land tenure, land origin, crop rotation). They were also requested to explain how they manage land constraints and opportunities. At the end of this exploratory stage, a combination of the survey results as well as data provided by the agricultural administration, allowed to draw up the first classification of all the operators within the area (State beneficiaries and farmer owners) according to the land exploitation modes (land exploited by its recipient or owner, land given up for rent/ sharecropping, abandoned land).

Using this first classification, we selected our sample, for more detailed surveys. This sample was to ensure representativeness and allow the results to be generalized to all operators in the area. Therefore we proceeded according to the stratified sampling method, which consists in subdividing the parent population into homogeneous strata or classes (classification already carried out according to the land tenure status) and in choosing in each stratum several of farmers to be surveyed to reach, in the sample, the same proportions for each stratum, as in the target population. Our sample was selected, besides the type of land tenure (direct, indirect, and mixed), according to the cultivated total area and to the cropping system practiced.

In a second step, detailed qualitative and quantitative surveys were carried out among 35 State beneficiaries and 50 farmer-owners. Concerning the land given up for indirect use (rent/ sharecropping), the surveys were carried out both with the assignors (beneficiaries and owners) and the lessees (tenants and sharecroppers) of the land. Before the detailed surveys, a finer typology of holdings was carried out, for our sample, according to the land status of the plots (direct land tenure, indirect land tenure, mixed land tenure), both for State beneficiaries and for owners. The development of this typology will enableus, on the one hand, to analyze, for each type, the cropping and livestock systems and to explain the farmers' practices to meet their economic, social and productive goals. On the other hand, it will allow us to assess the farms' sustainability according to their land status. Indeed, detailed surveys were carried out for each identified type.

In a third step, a sustainability assessment was carried out for the different identified types of farms using the IDEA method, an innovative tool to assess sustainability (Zahm et al. 2008). The objective is to analyze the impact of farmers' practices, particularly renting and sharecropping, on the three dimensions of farms' sustainability. Sustainability indicators are often focused on the environmental dimension, while neglecting economic and social dimensions (Latruffe et al. 2016). However, the IDEA method qualifies the overall performance of farms in the three dimensions of sustainability: agro-ecological, socio-territorial and economic. It was therefore the most suitable to meet our objective. The main hypothesis of the IDEA method is that it is possible to quantify the performance of various components of an agricultural system by assigning them a numerical score, then to weigh and aggregate this information to obtain a score for each of the three dimensions (Zahm et al. 2008).

The IDEA method, developed in an European context, has been adapted to other contexts: e.g. Mexico (Salas-Reyes et al. 2015), Morocco (Baccar et al. 2019) and Lebanon (Ghadban et al. 2013).This method has also been adapted by ourselves to the Tunisian context and our study area. We have kept the same components for the three dimensions, but we made modifications for some indicators and their calculation. As examples:

- For the "Diversity" component of the agro-ecological dimension, we removed the "permanent meadow" criterion from the calculation of the "diversity of perennial crops" indicator (A2).
- For the "Space organization" component of the agro-ecological dimension and the "ecological regulation zone" indicator (A8), we capped the score at 6, and we adapted the calculation method to our study area. We also removed the indicator "contribution to environmental issues" (A9), as in our case there is no territorialized specification to assess this indicator.
- For the "products and land quality" component of the socio-territorial dimension, for the "quality approach" indicator (B1), there are no officially recognized standards or labels in the region (red label, organic farming, etc.). However, there are productions whose quality Tunisian consumers usually associate with their territorial origin. We capped the score at 6.
- For the "employment and services" component of the socio-territorial dimension and the "service, pluriactivity" indicator (B8), we removed the agro-tourism and educational farm criteria, as they are not relevant in our study area (Table 1).Finally, we used 41 indicators (grid adapted to our study area):17 for the agro-ecological dimension, 18 for the socio-territorial dimension and 6 for the economic dimension; they are composed of elementary items characterizing a practice and contributing to the final value of the indicator. The number of sustainability units allocated to each indicator ranges from zero (even if the sum of elementary

items is negative) and a maximum value that is specific to each indicator (even if the sum of its elementary items is higher) (Table 1).

The score of a farm, for each of the three sustainability dimensions, is the sum of the sustainability points obtained for the various indicators of the considered dimension. To calculate them, we used the farmers' information provided during our detailed surveys and some regional technical references (regional variety, organic waste management, etc.).The IDEA method does not combine the three dimensions' scores, but considers that the real level of a farm's sustainability corresponds to the lowest value among the three dimensions: this dimension is the one limiting sustainability and on which the farmer should focus his efforts (Zahm et al. 2008).

**Table 1.** Dimensions, components and indicators of the IDEA method

| Dimensions (3) | Components (10) | Indicators (42) | | Limits |
|---|---|---|---|---|
| Agro-ecological | Diversity | A1 | Diversity of annual crops | 0 to 14 |
| | | A2 | Diversity of perennial crops | 0 to 10 |
| | | A3 | Animal diversity | 0 to 14 |
| | | A4 | Conservation of genetic heritage | 0 to 6 |
| | Organization of space | A5 | Crop rotation | 0 to 8 |
| | | A6 | Dimension of fields | 0 to 6 |
| | | A7 | Management of organic waste | 0 to 5 |
| | | A8 | Ecological buffer zones | 0 to 6 |
| | | A9 | Improvement of the space | 0 to 5 |
| | | A10 | Stocking rate | 0 to 3 |
| | Farming practices | A11 | Fertilization | 0 to 8 |
| | | A12 | Manure management | 0 to 3 |
| | | A13 | Pesticides | 0 to 13 |
| | | A14 | Veterinary products | 0 to 3 |
| | | A15 | Soil protection | 0 to 5 |
| | | A16 | Water management | 0 to 4 |
| | | A17 | Energy dependency | 0 to 10 |
| | Total | | | /100 |
| Socio-territorial | Quality of products and the land | B1 | Quality process | 0 to 6 |
| | | B2 | Valorization of the building patrimony | 0 to 8 |
| | | B3 | Non-organic waste management | 0 to 5 |
| | | B4 | Access to the property | 0 to 5 |
| | | B5 | Social involvement | 0 to 6 |
| | Employment and services | B6 | Short trade value chains | 0 to 8 |
| | | B7 | Enhancement of local resources | 0 to 6 |
| | | B8 | Services and multiple activities | 0 to 5 |
| | | B9 | Contribution to employment | 0 to 6 |
| | | B10 | Collective work | 0 to 5 |
| | | B11 | Probable farm sustainability | 0 to 3 |
| | Ethics and human development | B12 | Dependence on commercial concentrates | 0 to 10 |
| | | B13 | Animal welfare | 0 to 3 |
| | | B14 | Training–education | 0 to 6 |
| | | B15 | Labor intensity | 0 to 7 |
| | | B16 | Quality of life | 0 to 6 |
| | | B17 | Isolation | 0 to 3 |
| | | B18 | Quality of buildings | 0 to 4 |
| | Total | | | /100 |
| Economic | Viability | C1 | Economic viability | 0 to 20 |
| | | C2 | Economic specialization rate | 0 to 10 |
| | Independence | C3 | Financial autonomy | 0 to 15 |
| | | C4 | Sensibility to government subsidies | 0 to 10 |
| | Transferability | C5 | Transferability | 0 to 20 |
| | Efficiency | C6 | The efficiency of the productive process | 0 to 25 |
| | Total | | | /100 |

## 3. Results and discussion

### 3.1. Land tenure and diversity of farms

The main types of farmers identified according to land tenure are presented in the table 2. Four types, for State beneficiaries (young farmers) and farmer-owners, are thus distinguished.

Lessees of plots rented out by owners or settlers (types $Y^3$ and $O^3$) can be other young farmers (type $Y^2$), other owners within the irrigation scheme (type $O^2$), owners with only rain-fed land, or landless farmers. These lessees use irrigated land through formal contracts (30% of owned land), or informal contracts (70% of owned land and 100% of public land as this is prohibited by law).

**Table 2.** Types of farmers according to their land tenure system

| Land tenure | Young farmers (State beneficiaries) Type | Number Total | Number Investigated (36%) | Owner farmers Type | Number Total | Number Investigated (26%) |
|---|---|---|---|---|---|---|
| **Owner farming** Farmers who only exploit their land (owned or allocated) | **Type $Y^1$** | 27 | 10 | **Type $O^1$** | 90 | 23 |
| **Farming both own land and other** Farmers who exploit their land and also rent other plots | **Type $Y^2$** | 23 | 8 | **Type $O^2$** | 35 | 9 |
| **Renting/Sharecropping** Owners and settlers who concede their land to other farmers under leasehold arrangements | **Type $Y^3$** | 20 Lessees | 9Lessees | **Type $O^3$** | 34 Lessees | 10 Lessees |
| **Unexploited land** Owners and settlers who do not crop their land | **Type $Y^4$** | 4 | 1 | **Type $O^4$** | 14 | 4 |

## 3.2. Sustainability of the different types of farms

### 3.2.1. Assessment of overall sustainability

The mean overall sustainability for all studied farms is low, only 36/100. This value matches the two lowest scoring dimensions, agro-ecological and socio-territorial, both with 36/100, while economic sustainability scores were higher, with an average of 54/100 (Table 3).The results related to type $Y^3$ concerning the lessees of the plots, i.e. the current farmers (even if illegal) and not the initial "young farmers" beneficiaries who are no longer exploiting them. Likewise, the results related to the type $O^3$ concerning the lessees effectively farming the plots and not the landowners, who are no longer farmers.

Large differences in sustainability scores between the different types of farmers can be observed, due to differences in farming strategies and techniques. These differences are also linked to the land tenure status of the plots (owner farmed or not).Thus, farmers who directly exploit their land, either allocated by the State or under private ownership, and who also rent other plots (types $Y^2$ and $O^2$) have the highest overall sustainability score, which corresponds to the agro-ecological dimension (Table 3). This overall score reaches 41% for farmers of type $Y^2$ and 47% for type $O^2$. These farmers have also good scores for the economic dimension, reaching 65% (Table 3).Indeed, renting land, combined with farming land under private ownership or long-term allocation by State, enables these farmers to reach the best sustainability situation.

Conversely, the lowest sustainability scores are found (except for abandoned farms) with types $Y^3$ and $O^3$, which are based on renting land by lessees who are, for our sample, either land owners farmers cultivating only irrigated plots or landless farmers. Therefore, these farmers do not have their base of irrigated land to ensure minimum sustainability. Their sustainability score does not exceed 31% of the maximum score. The scores relating to agro-ecological and socio-territorial dimensions are very low. They reach only respectively 31% and 34% of the maximum score for lessees of public lands (type $Y^3$), and 36% and 28% of the maximum score for lessees of private lands (type $O^3$).However, for the economic dimension, lessees of type $Y^3$ and $O^3$ have the highest scores; cumulating up to 75% of the maximum score (Table 3). Farmers with the lowest agro-ecological and socio-territorial sustainability are also those who, in contrast, have the best economic sustainability.

**Table 3.** Sustainability scores of the different types of farmers in Gaâfour

| Types of farmers | Overall sustainability | Sustainability dimensions Agro-ecological | Socio-territorial | Economic |
|---|---|---|---|---|
| **Type $Y^1$ (Owner farming)** | **34/100** | 38/100 | 36/100 | 34/100 |
| **Type $Y^2$ (Farming both own land and other)** | **41/100** | 41/100 | 44/100 | 54/100 |
| **Lands of $Y^3$ (Renting/Sharecropping)** | **31/100** | 31/100 | 34/100 | 72/100 |
| **Type $Y^4$ (Unexploited land)** | **0/100** | 0/100 | 0/100 | 0/100 |
| **Average for young farmers' lands** | **35/100** | **35/100** | **36/100** | **51/100** |
| **Type $O^1$ (Owner farming)** | **40/100** | 40/100 | 42/100 | 59/100 |
| **Type $O^2$ (Farming both own land and other)** | **47/100** | 47/100 | 51/100 | 65/100 |
| **Lands of $O^3$ (Renting/Sharecropping)** | **28/100** | 36/100 | 28/100 | 69/100 |
| **Type $O^4$ (Unexploited land)** | **0/100** | 0/100 | 0/100 | 0/100 |
| **Average for owners' lands** | **37/100** | **37/100** | **37/100** | **57/100** |
| **Average for the whole irrigated scheme** | **36/100** | **36/100** | **36/100** | **54/100** |

The analyses of the results by sustainability dimension are detailed in the following section.

### 3.2.2. Sustainability assessment by dimension

***Agro-ecological dimension***

The average score for the agro-ecological dimension shows that all studied farms in Gaâfour area, whatever the land tenure mode, are not sustainable for this dimension (Table3). This is particularly notice able for lands exploited through rental (types $Y^3$ and $O^3$) which have the lowest scores.

The farmers who limit their activity to their own lands in order to seek stability (types $Y^1$ and $O^1$), most of which exploit cereal farms (young farmers) or olive and almond trees (the owners), have a higher agro-ecological sustainability (38% for $Y^1$ and 40% for $O^1$) than the farmers following a logic of land extension and production diversification, particularly those renting land (types $Y^3$ and $O^3$) with 31% and 28% respectively (Table 3). As tenants do not have private land, they cannot afford to invest in agro-ecological techniques that are only worthwhile in a medium-term, whereas they may be expelled from their plots at the end of each growing season.

The fairly widespread low scores for agro-ecological sustainability have several origins.

First, for all farmers, whatever their land tenure status, this is linked to the poor diversification of annual crops which are limited to 2 or 3 species (common wheat, durum wheat, onion, potato, pepper, tomato), to the limited place of legumes in crop rotation (linked to the low place of livestock) and also to the low presence of perennial crops (olive and fruit trees cover only 19% of the irrigable surface). Both the indicators "diversity of annual crops" and "diversity of perennial crops" get low scores, ranging respectively between 3 and 8 (/14) and 1 and 6 (/10) (Table 4).

The more a production system promotes diversification and integration of agricultural and livestock activity, the higher its sustainability is (Dugué et al. 2014). Diversity limits risks related to economic fluctuations (selling price variance, variations in the level of State aid, etc.) and climatic conditions (drought, hail, etc.). Studying the Saïs plain (Morocco), Baccar et al. (2019) also showed that agro-ecological sustainability strongly depends on the diversification of activities.

**Table 4.** Indicators Scores of the agro-ecological dimension of sustainability

| | Scores of some indicators of the agro-ecological dimension of sustainability | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diversity of annual crops | | Diversity of perennial crops | | Animal diversity | | Crop rotation | | Fertilization | | Pesticides | | Water management | |
| | Score[1] | Max score[2] | Score | Max score | Score | Max score | Score | Max score | Score | Max score | Score | Max score | Score | Max score |
| **Type $Y^1$** | 3 | **14** | 2 | **10** | 1 | **14** | 3 | **8** | 4 | **8** | 8 | **13** | 3 | **4** |
| **Type $Y^2$** | 5 | **14** | 1 | **10** | 2 | **14** | 4 | **8** | 3 | **8** | 4 | **13** | 3 | **4** |
| **Type $Y^3$** | 5 | **14** | 1 | **10** | 1 | **14** | 2 | **8** | 2 | **8** | 2 | **13** | 4 | **4** |
| **Type $O^1$** | 3 | **14** | 5 | **10** | 3 | **14** | 2 | **8** | 4 | **8** | 4 | **13** | 3 | **4** |
| **Type $O^2$** | 8 | **14** | 6 | **10** | 2 | **14** | 5 | **8** | 2 | **8** | 3 | **13** | 4 | **4** |
| **Type $O^3$** | 8 | **14** | 0 | **10** | 0 | **14** | 4 | **8** | 2 | **8** | 2 | **13** | 4 | **4** |

Furthermore, the narrowness of the areas farmed (42% of farms have a surface of less than 3ha while only 10% have farms exceeding 10ha) does not enable farmers to diversify their production. Farmers who have small surface remain limited to two or three annual crop species, for our sample.

The low tree growing presence is linked to the insecure land tenure status for both State beneficiaries and tenants. For State-owned lands (types $Y^1$ and $Y^2$), few farmers are taking the risk of planting trees on land they do not own. Only 20% of "young farmers" plant trees. They are often the older ones, who consider themselves as owners of these lands, due to the duration of their occupancy, and thus ignore the uncertainty about their future and plant trees.

Paradoxically, this land uncertainty is also present among owners (types $O^1$and $O^2$), because of problems occurring between heirs over land division: as long as this is not settled (and it could take years, even decades), planting trees is too risky and would be an additional source of conflict. Therefore, land owners only plant trees when they have no conflicts with the other heirs, i.e. when the intra-family land distribution[3] has been made and when each heir has a "proof" for his inherited share. As tenure is unsecure, it prevents farmers from making heavy investments in planting trees. Therefore, only 40% of owners plant trees.

Land conflicts between heirs may also lead some owners to abandon their irrigable land, as it happened to some of the interviewed farmers (type $O^4$).Within the perimeter, 39ha are unexploited and abandoned by their owners. However, the situation of these lands is not so serious as for lands abandoned by young farmers (type $Y^4$) because of salinity (10ha) (Table 2): even if it covers more surface, the production capacity of plots not cropped because of inheritance problems is not altered, or even, on the contrary, may improve, since these lands left uncultivated will have a natural increase in fertility, thanks to a long fallow.

Secondly, the low score for this agro-ecological dimension also results from the lack of livestock farming (both on owned and rented farms). Even the few farmers (10% of the total) who live inside the irrigation scheme do not all breed livestock, owing to an increase in concentrated feed prices, but also due to security concerns (risk of cattle rustling). Hence, only 5% of the young farmers and 9% of the private farmers practice

[1]Average score accumulated by farms of each type.
[2]Maximum score defined by IDEA method.
[3]Intra-family land distribution of land property is done formally (i.e. with witnesses) between heirs but not officially registered, meaning that the same family property title is kept.

livestock breeding. As a result, the “animal diversity” indicator has a very low score and does not exceed 3/14 (Table4).
The absence of livestock and consequently of organic fertilizers penalizes the sustainability of farms, which are more vulnerable and more dependent on chemical fertilizers bought on the market. Indeed, regular maintenance of soil fertility is more problematic for farms without livestock, as they have no means to compensate for the mineralization of their soil organic matter.
For tenants’ farms (types $Y^3$ and $O^3$), the low score for the agro-ecological dimension is also linked to their agricultural practices. The logic of annual crops intensification for these farmers (rain-fed farmers and landless farmers) leads them to high use of fertilizers and pesticides.
The score assigned to the "fertilization" indicator is estimated, for tenants' farms (types $Y^3$ and $O^3$), at 2/13 on average, only 15% of the maximum score. Conversely, for farms combining owned and rented plots (types $Y^2$ and $O^2$),the score assigned to this indicator is also low, 3/13 on average (Table 4).Quantities of nitrogen supplied are high, ranging, on average, between 55 and 85 kg/ha, which reflects that most of the tenant farmers adopt practices representing pollution risks and threats to the ecosystem. These practices have a degrading effect on soil and land productivity in both the medium and long term. These farms are not sustainable and such practices can lead to land degradation.
Indeed, lessees seek short-term maximization of land and water productivity. They do not invest in caring for soil fertility. They focus on their economic objective and neglect the agro-ecological dimension, since they know that they can only exploit these lands for a few years or even one growing season. Conversely, farmer-owners are more concerned with the agro-ecological dimension as it is their land and they are fairly sure to keep it.
Unlike these pollution risk practices, the studied farms are also characterized by other practices more in line with sustainability. They use water-saving techniques, such as drip and spray irrigation, on over 60% of irrigated areas. This leads to the maximum score for this water management criterion for many farmers (Table 4). This practice depends on the water resources available in the dam as well as on the kind of crops grown (drip irrigation is used for vegetables and fruit trees, but not for forage and cereals irrigated with sprinklers).

***Socio-territorial dimension***
For all farms, the score relating to the socio-territorial dimension is low, 36/100 (Table3).This is linked weakness of farmers’ supervision, to the lack of training and the poor integration of farmers in territorial dynamics.
Within the area, only a few farmers have undergone training in the agricultural field, which subsequently influences the way they run their farms and leads to a lack of technical skills in irrigated farming. As a result, the “training” indicator has a low score; it does not exceed 2/6 (Table 5). For young farmers’ land abandoned because of salinity (type $Y^4$), this is partly the failure of these farmers and their neighbors to master irrigation techniques that have led to salt rising to the surface, thus handicapping their exploitation and reducing their sustainability.
The agricultural administration in charge of extension organizes only few training courses or informative days specifically tailored to small and mid-sized farmers’ requirements, which would enable them to improve their production techniques. Most of the farmers do not attend the training courses organized by the agricultural administration. They say, "*We are not interested in these training because they do not fit our own needs*". For their part, of the extension officers at the agricultural administration say that they do not have enough resources (up dated documents, sufficient means of transport) to organize more frequent training.
Farms’ sustainability results from relationships that farmers maintain with their environment. Indeed, social tie refers to the farmers’ integration in relationship networks with other farmers as with social actors. Within the perimeter, the "social involvement" indicator gets a low score, ranging from 0 to 3 (/6) (Table 5). Farmers’ social involvement is limited to some of them joining the Tunisian Union of Agriculture and Fisheries (27% of farmers investigated), the Tunisian Farmers Union (20%), or the local water user association.
Membership in the local water user association is not compulsory; it costs only 5 Tunisian dinars (TD) /year (1 € = 3.26 TD in 2022), but only 33% of farmers were members. This results from a large number of tenants (40% of farmers), many of whom exploit lands via informal and illegal contracts (renting State-owned land is forbidden).Yet only owners and State-owned land beneficiaries can become members. Furthermore, tenants, particularly informal ones, jeopardized the sustainability of the water user association, as they sometimes fail to pay their water charges. As owners, who have informally let their lands, refuse to take on these debts, this negatively impact the financial situation of the association, which is no longer able to pay for maintenance costs of the irrigation system.

In addition, we can note the lack of Mutual Agricultural Service Societies (professional organizations) and this reflects the weakness of associative dynamics among local actors. These societies could provide their members with various services such as purchasing inputs, processing and marketing farm products. In the 1990s, there was such a society, but it was dissolved following problems between members, due to insufficient trust between them. Farmers say that this failure discourages them from setting a new society. However, some farmers would like to create a society and consider that if farmers work in a collective way they can succeed: "*the best solution is to create a mutual society...through it we could make our voices heard and express our opinion!*.

**Table 5.** Indicators scores of the socio-territorial dimension of sustainability

| | **Scores of some indicators of the socio-territorial dimension of sustainability** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Social involvement** | | **Services, pluriactivity** | | **Contributionto employment** | | **Probable farm sustainability** | | **Training** | | **Intensity labor** | | **Quality of life** | |
| | **Score** | **Max score** | **Score** | **Max score** | **Score** | **Max score** | **Score** | **Max score** | **Score** | **Max score** | **Score** | **Max score** | **Score** | **Max score** |
| **Type $Y^1$** | 2 | **6** | 2 | **5** | 2 | **6** | 1 | **3** | 0 | **6** | 3 | **7** | 3 | **6** |
| **Type $Y^2$** | 2 | **6** | 2 | **5** | 4 | **6** | 2 | **3** | 2 | **6** | 5 | **7** | 3 | **6** |
| **Type $Y^3$** | 0 | **6** | 3 | **5** | 4 | **6** | 1 | **3** | 2 | **6** | 5 | **7** | 3 | **6** |
| **Type $O^1$** | 2 | **6** | 2 | **5** | 3 | **6** | 3 | **3** | 2 | **6** | 3 | **7** | 3 | **6** |
| **Type $O^2$** | 3 | **6** | 2 | **5** | 4 | **6** | 3 | **3** | 2 | **6** | 6 | **7** | 3 | **6** |
| **Type $O^3$** | 2 | **6** | 2 | **5** | 4 | **6** | 1 | **3** | 1 | **6** | 5 | **7** | 4 | **6** |

Sustainable agriculture generates employment and absorbs surplus labor. Within the irrigation scheme, tenants renting lands of types $Y^3$ and $O^3$ and $Y^2$ and $O^2$ farmers are the most involved in job creation. The score assigned to the "contribution to employment" indicator reaches67% of the maximum score (Table 5). The exploitation of several plots and the diversity of their activities lead farmers to employ permanent workers (transport of equipment, agricultural tasks, and surveillance) most of whom where young people from the area. Moreover, they employ seasonal workers (planting, weeding, and harvesting); 80% of the mare from the territory. Conversely, owner farms (types $Y^1$ and $O^1$), which produce only cereals and a few vegetable crops, do not contribute to creating jobs and their score does not exceed 40% of the maximum score (Table 5).

Moreover, while land contracts contribute to improving the farmers' economic situation (running several irrigated plots enables farmers to diversify their activities and increase their incomes), they also lead to increased land concentration. This benefits a small number of farmers who own the most financial means, and therefore leads to social marginalization for farmers with low levels of capital (financial and land). Some tenant's farmers crop a large number of plots, up to 6, with a total irrigated area of 45ha.

***Economic dimension***

Assessing farms' economic sustainability with the IDEA method goes beyond the analysis of their short- and medium-term economic viability, and extends to their economic independence, transferability and efficiency (Zahm et al. 2008).

Farmers who exploit only their land (types $Y^1$ and $O^1$) generate an average income ranging from one to two times the Guaranteed Agricultural Minimum Wage (called SMAG in French) in Tunisia (390 TD/month) (Table 6) which means a low to medium economic viability. This situation affects the attractiveness of the agricultural profession and the settlement in rural areas. Such is the case for some" young farmers" (45% of type $Y^3$) who left their farm after successive failures and rented their plots to other farmers.

**Table 1.** The economic viability of studied farms (compared to the Guaranteed Agricultural Minimum Wage – SMAG in French)

| **Farm income** / **Types of farms** | **<SMAG** | **1 to 2*SMAG** | **2,5 to 3* SMAG** | **>3*SMAG** |
|---|---|---|---|---|
| **Type$Y^1$ (Owner farming)** | **X** | **X** | | |
| **Type $Y^2$(Farming both own land and other plots)** | | **X** | **X** | |
| **Type $Y^3$ (Renting/Sharecropping)** | | | **X** | |
| **Type $O^1$ (Owner farming)** | | **X** | | |
| **Type $O^2$ (Farming both own land and other plots)** | | | **X** | |
| **Type $O^3$ (Renting/Sharecropping)** | | | **X** | **X** |

Farmers renting all (types $Y^3$ and $O^3$) or part (types $Y^2$ and $O^2$) of their farm have higher average incomes than those generated by farmers who only exploit their own land (types $Y^1$ and $O^1$), between 2.5 and 3 times the SMAG, and therefore show a good economic viability (Table 6). These results are related to the gross margins achieved and are proportional to the farm size. Thus, farmers with large areas devoted to high added value crops (vegetable crops, fruit trees) (types$Y^3$, $O^3$, $Y^2$ and $O^2$) obtain higher incomes than farmers whose cropping systems are only cereal based-systems (type $Y^1$), thereby improving their viability.

The "specialization rate" indicator constitutes a weak point, particularly for owner farms (types $Y^1$ and $O^1$). These farms are not diversified, due to the lack of surface area and financial means, and the main production concerning surface area (cereals or vegetable crops), generates from 50% to 80% of farms turnover. Therefore, the overall gross margin is highly dependent on a single crop, leading to farm fragility and threat to its viability in case of poor yields (sanitary or climatic accident) or a drop in market prices. Conversely, for tenants ($O^2$, $Y^2$, $O^3$ and $Y^3$ farms), the main production concerning surface area generates only 30% to 50% of the farm turnover. These diversified tenant farms are less dependent on a single crop and its hazards than the specialized owner farms $Y^1$ and $O^1$.
Credits from the National Agricultural Bank are the main source of financing for farmers in Tunisia. But our results show that most of the farmers, particularly State allotters, tenants and small owners, are fairly self-sufficient and financially independent from the State, since their land status (tenant, non-owner, lack of guarantees) does not enable them to have access to public bank credits. Therefore, these farmers are not very receptive to financial aid (premiums, subsidies, etc.). Their interest mainly concerns, on the one hand, short-term credits for cereal, fodder and potato crops, which are strategic crops for the State. On the other hand, it concerns equipment for irrigation water saving, for which State subsidies reach 60%.This highlights the lack of public aid, particularly for small owners and State allotters, there by worsening their capital shortage and impeding them from carrying out heavy investments (livestock, tree planting, etc.).
Tenant Farms, partly or fully rented, are more sustainable than ownership ones regarding the economic dimension, except for the "transferability" component. This component brings an additional dimension to sustainability analysis by assessing the existence of capital and its sustainability during foreseeable successions.
Several farmers, particularly State allotters and tenants, stated that it seems unlikely that they would continue to be farmers in the future. Indeed land exploitation, particularly through informal contracts, constitutes a very insecure form of access to land and threatens the sustainability of these farms, even if they are currently running well. Although tenant farms are often more economically viable (they generate more income than ownership farms), they are non-transferable and unsustainable due to insecure land tenure. Conversely, owners are almost certain that their farms will still exist within 10 years. They are not going to abandon their land, even those with other activities than agriculture. These farms are transferable; security of tenure and economic viability guarantee this transferability because heirs can then take them over, and thus it remains possible to maintain farmers throughout the territory. But it also implies some problems regarding land-sharing at the inheritance phase.

**Table 7.** Economic efficiency of farms studied

| **Efficiency** / **Types of farms** | **< 20%** | **20% to 40 %** | **40% to 60%** | **60% to 80%** | **> 80%** |
|---|---|---|---|---|---|
| **Type $Y^1$ (Owner farming)** | X | X | | | |
| **Type $Y^2$(Farming both own land and other plots)** | | | X | X | |
| **Type $Y^3$ (Renting/Sharecropping)** | | | | X | |
| **Type $O^1$ (Owner farming)** | | | X | | |
| **Type $O^2$ (Farming both own land and other plots)** | | | | X | |
| **Type $O^3$ (Renting/Sharecropping)** | | | | X | X |

The efficiency of the productive process measures the performance of the production system and techniques adopted by farmers to achieve profit (Zahm et al. 2008). There fore, this component provides an assessment of the farmer's ability to develop their resources in long term and to ensure their sustainability. Thus, landowner farmers (types $Y^1$ and $O^1$) have low average efficiency, between 20% and 40%. Conversely, tenant farmers (types$Y^3$ and $O^3$) show a good efficiency, between 60 and 80% (Table 7).
Various factors limiting the farm's sustainability are summarized in figure 2. Finally, to ensure the irrigated farms sustainability, a dialogue between the various institutions and the farmers in the scheme should be carried out based on these elements.

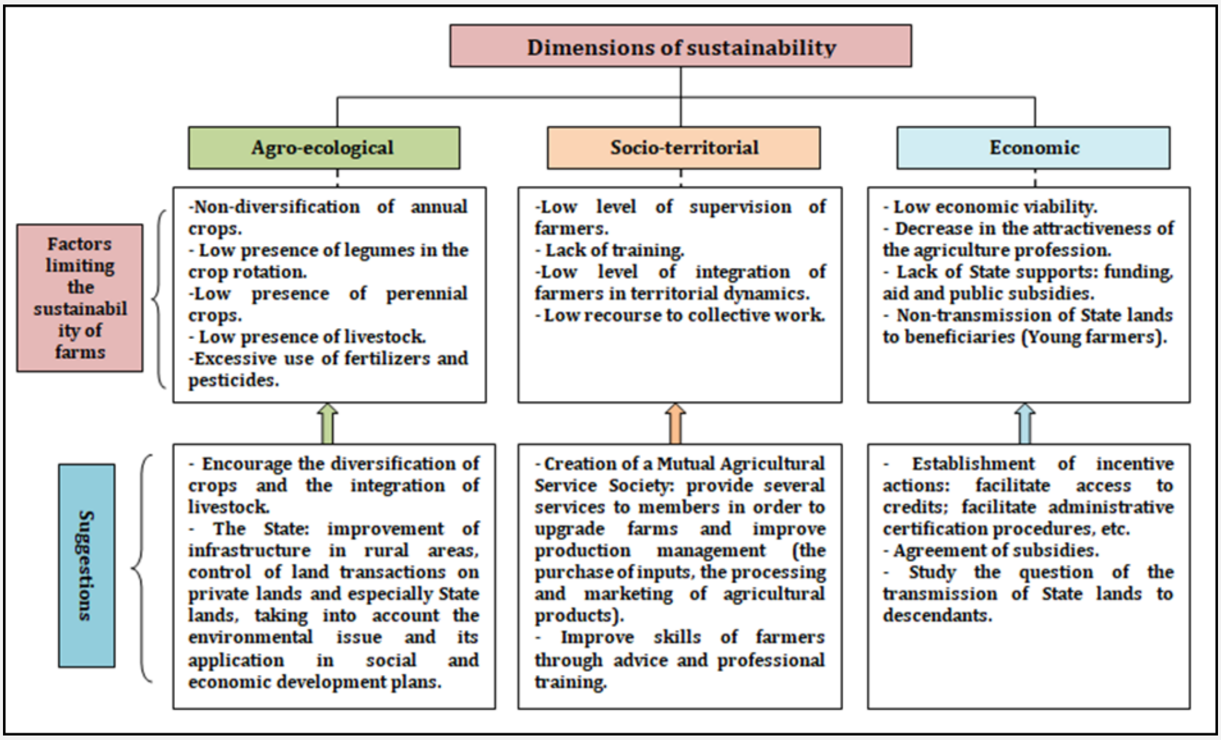


**Figure 2.** Factors limiting sustainability in Gaâfour scheme and suggestions for areas for improvement

## 4. Conclusion

Within the Gaâfour irrigated area, renting land allows tenant farmers to build up a larger farm to increase their production and their farm income. Informal "contracts" are quite common, both for private-owned plots and State plots (allocated to people who were once “young farmers” and are not entitled to sublease these plots).However, the development of informal settings has generated negative effects on the scheme sustainability, even if it has positive effects on the economy.

Our results show that the studied farms only obtain low overall sustainability scores, less than half of the highest score set by the IDEA method (100). The lowest sustainability scores are found on tenant farms and are related to agro-ecological and socio-territorial sustainability. Conversely, for the economic dimension, tenant farms show the highest scores, significantly higher than those of the other types, with incomes reaching 3 times the Guaranteed Agricultural Minimum Wage in Tunisia and an economic efficiency reaching 80%.

Thus, renting land leads, on the one hand, to improved economic sustainability, through good economic performances. However, on the other hand, it produces poor environmental performance, due to an insecure tenure system and unsustainable agricultural practices (high use of pesticides and fertilizers, absence of organic fertilization, absence of legumes, absence of perennial crops, and absence of livestock).Lessees, which have no tenure security, have strategies that prioritize short-term economic objectives and neglect the agro-ecological dimension. This is linked to specific constraints imposed by tenancy status, such as the need to make short-term returns on rentals with no guaranteed duration and the impossibility of planting trees on leased land.

This situation also shows that there is a divergence between the targeted objectives of the different territory actors (institutions and farmers, owners and tenants). Economic concerns are more important for farmers, especially for tenants, than the environmental and social ones; this is also the case elsewhere in Tunisia (Taghouti et al. 2017). There is, therefore, a significant degree of "conflict" between the economic and environmental objectives, since the maximization of profit leads to increased pollution and land exhaustion. This was also observed by Baccar et al. (2019) who studied practices of irrigating farmers in the Saïs plain (Morocco), and showed that economic and environmental dimensions of sustainability may vary in opposite directions.

To improve agro-ecological sustainability the State should encourage production diversification, livestock integration and environmentally agricultural practices. It should also create a framework that enables farmers to improve their production, particularly by enhancing rural infrastructure and considering the environmental issue in agricultural policy. In addition, agricultural policies, and particularly the allocation of State lands, should have positive consequences on farms’ sustainability. The State have also inheritance issues. In fact, even after the end of the contract, the old beneficiaries who have invested a lot of their time refuse to leave these plots (Gharbi et al. 2018).

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