Technium Sustainability

Technium Sustainability
Vol. 5, pp 8-28 (2024)
ISSN: 2810-2991
www.techniumscience.com

Typology of agricultural holdings: a starting point for understanding the performance of irrigated systems in Baalbek Al Hermel Lebanon

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Abstract

The Mediterranean region is one of the most vulnerable regions to climate change (CC) which raises important problems for Mediterranean agriculture. In fact, climate disruption creates some uncertainty in the decision-making of farmers in the management of their farms. This understanding can help researchers to better orient agricultural research on adaptation at the farm level and can help policy makers to develop adaptation policies. The semi-arid region of Baalbeck El Hermel is increasingly threatened by climate change. The agricultural systems constituting the main source of household subsistence in this zone show a significant vulnerability to these disturbances, especially about the limit in water resources. In this research we propose a framework to represent agricultural activities using typologies of farms and production units aggregated at a regional scale. We used empirical data from a local case study of the five most representative farming systems in the Baalbek-Hermel Governorate. Analysis of the results showed several behaviors and several levels of resilience of these farms:1-farms specializing in market gardening or perennial crops are very sensitive to drought conditions and are not resilient in the face of water limit conditions;2-the diversified farm with olive tree dominance is less sensitive and more resilient.

Key words: Baalbek Al Hermel, typology, climate change

Introduction

The climate on our earth has always undergone changes, but due to human activities, these changes are becoming more pronounced, and evolving more rapidly than before. This is the phenomenon that scientists and politicians are referring to when discussing the topic of climate change. Before, climatic

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Vol. 5, pp 8-28 (2024)
ISSN: 2810-2991
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changes were mainly due to natural phenomena, but since the beginning of the industrial revolution in the 18th century, Man contributes more and more to these by releasing enormous quantities of greenhouse gases in our atmosphere or by burning fossil fuels such as petroleum to generate electricity or by clearing forests to produce crops as an example. At the same time, these emissions further increase the natural greenhouse effect, thus leading to increasingly intense global warming. (OCDE 2016)

Climate change is a large-scale scourge, as no country can escape its repercussions at various levels, whether developed or developing. To face it, there have been the adoption of many policies at the international level, such as the Kyoto Protocol, which was signed on December 11, 1997 and of which 37 countries were committed to reduce their emissions of gas. greenhouse effect of at least 5% over two periods (2008-2012) and (2013-2020) and for which the objective for the first period has been reached, such that the 37 countries involved have reduced their emissions by more than 20%. There was also, recently, the signing of the Paris Agreement which constitutes the first universal agreement bringing together all nations around a single cause which is the fight against climate change and adaptation to its consequences, the main objective of this agreement is that the global average temperature does not increase above 2 degrees Celsius compared to pre-industrial levels.

According to the 5th report of the Intergovernmental Panel on Climate Change, several scenarios between 2016 and 2035 show an increase in the average temperature of the earth between 0.3C and 0.7C (IPCC, 2014), This increase has impacts at different levels, such as rising sea level, weather conditions become more and more unpredictable, phenomena like droughts, floods increase even more. This upheaval in the climate also has impacts on crops, on the water supply, as well as on various organisms as well as it can also have impacts on infrastructure. The combination of all these impacts gives rise to new impacts at three levels: social, economic, and political.

The agricultural sector, which is a key sector for many countries, especially developing countries, is affected by climate change, which leads to a decrease in crop yields, given that it is highly dependent on the climate and conditioned by specific meteorological conditions of rainfall and sunshine to have a good yield. On the other hand, it contributes to the emission of greenhouse gases, such that, on its own, it concentrates 13.5% of emissions (IPCC, 2014). But despite this, the agricultural sector has a great capacity for adaptation and mitigation, with a good cost-effectiveness ratio, mainly from carbon sequestration thus decreasing carbon sequestration in the atmosphere.

The agricultural sector in Lebanon in general, and in the Baalbek-Al Hermel region particularly, is largely made up of small farms, which face several constraints, and consequently, are exposed to dangers and shocks.

The Baalbek-Al Hermel region is characterized by irregular rainfall with periods of drought. In addition, climate change further aggravating the situation, however, the recourse to irrigation from groundwater is proving to be impossible.

What is more, certain agricultural practices adopted by farmers consume water such as vegetables, which leads to the overexploitation of water resources, and therefore, the reduction in the level of aquifers.

Reflection around this situation prompts us to ask the following question:

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ISSN: 2810-2991
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How to increase the resilience of farms and reduce their vulnerability, in the short and long term, of the Baalbek-Al Hermel region to the repercussions of climate change by reducing their dependence on water resources?

In this research, the use of diagnostic analysis in relation to irrigation water management helps structure the analysis of problems and the identification of potential solutions related to water management (Dorian et al., 1999). It is within this framework that this first stage of the research action takes place, the aim of which is to take stock of the current situation of water management at the level of an irrigated field in Baalbek Hermel.

Materials and methods

The variations in climatic factors in Lebanon such as temperature, precipitation, and relative humidity, will have impacts on water resources which constitute the main element of life. The decrease in precipitation and the rise in temperatures, with the increase in drought and the decrease in relative humidity would have impacts on agriculture in the Bekaa Valley and would encourage farmers to irrigate by using artesian wells. Therefore, the climatic change would have negative effects on the groundwater level and would increase the risk of its pollution.

The Bekaa Valley, lying on the East of the Lebanon Range, is a very fertile High Land about 16 km wide and 129 km long, representing 42% of Lebanon's area, gently sloping from North to South from an altitude of 900 to 1,100 m. It is divided into three main zones: North Bekaa composed of Baalbek and Hermel, Central Bekaa which has Zahle as its Governorate and West Bekaa.

The Baalbek-Hermel governorate illustrated in Figure 1 is located between the two mountain ranges (Mount-Lebanon and Anti-Lebanon), more precisely in the north of the Bekaa Valley. It occupies 25% of the total area of Lebanon (2640 km2) and is composed of two districts, Baalbek and Hermel. The altitude in this governorate varies from 1100 m to 600m which run along from Baalbek to the northern border of Syria, with a length and a width of 60km and 13 km respectively. Moreover, Baalbek-Hermel represents 64% of the total area of the valley. Despite the fact that Baalbek district is composed of a large part of lowlands, 94.6% of the Baalbek-Hermel regions are highlands.

Figure 1 Case study area Baalbek-Hermel (Bekaa, Lebanon)

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ISSN: 2810-2991
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Although this governorate has a significant agricultural activity, it faces a certain number of constraints (Darwish. 2004), of which we can enumerate among others: small population, low income, and the large size of families.

Baalbek-Hermel has 2 types of climate which depend on the geographical location: a continental climate in Baalbek district with a good amount of precipitation which varies from 600 mm to 800 mm per year, and a semi-arid climate in Hermel district with precipitation not exceeding 200 mm. Besides, the temperatures know a great variability between the warm season and the winter, such as it reaches 40°C in the dry period and below 0°C in the cold period. This variability generates agricultural problems especially for flowering fruit trees and some early crops. Moreover, spring frosts cause farmers to switch to illicit cultivation which is less demanding (Darwich, 2004). In sum, Baalbek-Hermel is the most desert area of Lebanon where the rainfall is around 400 mm/y (MoA, 2003).

The nature of the soil in the Baalbek region is not the same; it varies according to the geographical location (Darwish, 2004). For example, in the center and south of Baalbek, the soils are of the colluvial type with a depth of about 2-3m, therefore they are poor in organic matter. However, in the North of Baalbek and in a large part of Hermel, the soils are of the limestone type, they are not very deep, and not very clayey, which poses a problem for irrigation as well as for mechanization. Nevertheless, next to the Orontes and its effluents, the soil type is mainly alluvial.

The Baalbek-Hermel region is characterized by low rainfall which is irregular, and which occurs between November and March, therefore irrigation from groundwater is essential (Darwish. 2004). Additionally, there are two river basins that stretch throughout the Bekaa Valley, that are the Orontes in North Bekaa and Litani in Central and South Bekaa. These two basins have the same source which is north of Bekaa however, they do not flow in the same direction. The Litani, with a length of 160 km, flows towards the south, while the Orontes flows north towards Syria. The Orontes constitutes the most important source of Lebanon with a flow which varies from 7 to 16 m^3/ s (Darwich. 2004).

Typology

Data collected and survey carried out:

This work is based on a sample of 101 surveys carried out at the level of crop production farms in Baalbeck El Hermel in 2019. These farms were chosen at random from different villages in the Baalbeck ELHermel region, taking into account two main criteria: the diversity of crops and the climatic variability of the study area.

The questionnaire addresses several main issues which are:

- Characteristics of the farmer (age, status, origin, pluriactivity, level of education, etc.)
- Characteristics of the farm (location, total UAA, UAA by type of crop, date of installation, mode of acquisition, etc.)
- Labor (family labor, cost of permanent labor, cost of seasonal labor, origin of labor)

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- Structure of the agricultural area and type of crop (name of the crop, yield per crop, quantity of irrigation, estimated cost of irrigation, source of irrigation, method of irrigation, total production cost, income by type of culture, marketing channels, etc.)
- Agricultural machinery and equipment (number of tractors, generators, pumps, PVC, private wells, etc.)
- Investment and non-agricultural external resources (value of the external income of the farmer and other members of the family, etc.)
- Analysis of climate change and perspectives.

The data obtained from the questionnaire allowed us to calculate the production costs and the gross margin resulting from agricultural activity for each farmer. The main variables derived from this questionnaire are:

- The cultivated agricultural area (dnm): the total area per farm, the area per type of crop (cereals, market gardening, olives and fruit trees).
- Yield per crop (Kg / dnm): the yield of each crop in kilograms per denomination from which we calculated the average yield per type of crop per denom.
- The total income of the farmer (LL): from the yields by type of crop we calculated the total income of the farm in Lebanese pounds
- Total labor cost per farm (LL): the permanent and seasonal labor cost for each farm from which we calculated the total labor cost per name for each farm.
- The amount of irrigation water applied per crop (m3 / dnm): from the amount of water consumed by each crop in one season, we were able to calculate the average total water consumption for each farm.
- The cost of irrigation per crop (LL / dnm): from the cost of irrigation per crop we were able to calculate the average cost of irrigation of the farm per dnom in a season.

Note that the cost of irrigation does not represent the cost of the cubic meter of water per name since farmers pay either a cost per year which varies according to the region (nearly 75,000 LL per year) or irrigation charges (pumps, fuels) especially for those who irrigate by wells and canals.

Concerning the characterization of cropping systems, the analysis of the samples showed a dominance of market gardening crops which cover more than half of the total cultivated agricultural surface followed by cereals, arboriculture and olive trees. The identification of the dominant crops was not possible in terms of area since the questionnaire did not include the question concerning the cultivated area per crop. So we were just able to identify the different varieties of crops present for each type of crop and the typology was built according to the types of crop.

Programs and software used:

Typology is a method of analyzing the diversity and complexity of agricultural systems. It is a method used in development research projects to take into account the heterogeneity of agricultural systems in a region. It is carried out by classifying groups of agricultural holdings according to homogeneous criteria. This allows us to obtain typical farms that answer the question of agricultural development research following a specific objective (Chenoune, 2014).

There are several typology methods which are: The "step by step" comparison of farms (Landais, 1998), the “expert opinion” typology (Landais, 1998), the participatory classification (Kebede, 2009), and the multivariate analysis (Chenoune et al., 2016). In this work, we will follow a quantitative typology of multivariate statistical analysis using the Tanagra statistical software.

A principal component analysis (PCA) was used to draw up the typology of farms by identifying classes of farmers according to trend axes. PCA is an essentially descriptive statistical method that allows the maximum amount of information contained in a data table to be represented in graphical form (Philippeau, 1986). It makes it possible to see more clearly the link between the characteristic variables of the holdings and to observe their distributions.

The diversity of farms in the Baalbek Al Hermel region makes studying this area complicated; however, a typology makes it easier to understand. A typology of a farm represents the diversity of systems which are based on the distinction between a set of types of farms on the basis of a certain number of criteria which are defined according to the objective of this typology. It makes it possible to represent a reality which is complex. In other words, the development of a typology of farms aims to bring together in the same group, a set of farms who have almost the same characteristics, and thus reduce their diversity in order to represent them as easily as possible.

According to AGRESTE (2013), the development of a typology of farms aims to:

- Have a grid in order to better understand the different agricultural systems;
- Define the most important characteristics of the different farming systems;
- Locate as well as quantify agricultural production;
- Concoct tools for study and decision support.

In the case of our study, the development of the agricultural typology in the three Lebanese villages, Bouday, Hermel and Saarin will allow us to group the farms that have the same characteristics in the same system. Thus, to meet the objective of this study, which is to propose strategies for adapting farms in the Baalbek-Hermel region to climate change as well as their dependence on water resources in order to increase their resilience and reduce their vulnerability.

To develop this typology, three criteria of classification are proposed:

- the resource allocation:

The resource allocation by the 3 villages includes a wide range of resources, but in our study we will investigate two resources that we consider more important since they are the most likely to influence the decisions of production and productivity of the farm; they are the production potential and the financial resources. The production potential in an arid zone is associated with the level of access to natural biophysical resources, for example: land and water. Concerning the financial resources of the farmers, we can estimate them for example by the capacity of the farmer to buy and use the different production factors in order to improve the productivity of his farm (labor, fertilizer ...), and the level of total agricultural income.

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Vol. 5, pp 8-28 (2024)
ISSN: 2810-2991
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- the production objectives:

These criteria include several factors, of which we can cite among others: the choice of cultivation (crops versus livestock); the choice within the plant and animal systems, and the orientation of agricultural production (if it is oriented to be sold on the market and thus generate income, or it is oriented to meet the needs of farmers); and the share of each crop in agricultural income.

- the intensification levels of production

The two criteria mentioned above can have an impact on the decisions of the farmers concerning the types as well as the quantities of the factors of production, which can either be respectful of the environment (fertilizers, labor ... .) or the reverse (the non-respect of the doses of chemical fertilizers, irrigation water ...). We can summarize the variables that we can use in order to bring together the farms which are somewhat similar in point view of these in the same system in the following table:

Table 1 Factors of production

<table>
<tr><td rowspan="2">Criteria taking into account the resource allocation</td><td>Production potential</td><td>-Agricultural land (ha)
- Irrigated area per farm
-The share of each crop in UAA
-Topography (plain / mountain)</td></tr>
<tr><td>Availability of financial resources</td><td>-Gross margin per farm on crops
- Non-operating income</td></tr>
<tr><td colspan="2">Criteria taking into account the production objectives</td><td>-Size of the active family population
-Time spent on the farm
-Production of each crop / ha
-Production (breeding)</td></tr>
<tr><td colspan="2">Criteria taking into account the intensification levels of production</td><td>-Total amount of irrigation water per farm (m3 / ha / crop)
- Irrigation source
- Irrigation mode
-Cost of fertilizers (LL / ha)
-Cost of seeds (LL / ha)
-Cost of pesticides (LL / ha)
-Cost of water (LL / ha)
-Labor cost (LL / ha)
-Cost of seasonal and permanent labor (LL / ha)
-Cost of inputs into the plant system
-Cost of inputs into the animal system</td></tr>
</table>

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Vol. 5, pp 8-28 (2024)
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Analysis of types of farms at the agro-climatic level:

After classifying farms according to their criteria at farm level, we built a classification according to agro-climatic zones based on the location of farms. This analysis will allow us to characterize the agricultural production of each agro-climatic zone, to identify the diversification of these zones and to identify the homogeneous production systems present in the different zones. The grouping of farms according to the climate criterion is important in a semi-arid zone where the main factor that impacts the performance of farmers is the amount of rain on its territory (Verner et al., 2018).

SWOT analysis

The SWOT matrix is a universal decision support tool, developed since the 1960s (Schendel, 1994). At the level of a SWOT analysis, strengths, weaknesses, opportunities, and threats are to be identified. The purpose of this analysis is to rely on internal and external analysis to make strategic decisions. This will therefore make it possible to counter threats and seize opportunities, while starting from improving the internal functioning of the system. Indeed, through the SWOT matrix, strategies of attack, adjustment, defense, and survival will be identified

Results

Preliminary analysis of survey results:

The farms surveyed in the Baalbeck EL Hermel area have different surface areas ranging from 4 dnm to 800 dnm with an average of 80 dnm. The frequency analysis shows that the majority of farms have a surface area of less than 100 dnm (77%) with 69% less than 60 dnm and 10% less than 10 dnm (figure 2). In addition, just 11% of farmers own surface farms greater than 200 dnm with only 3% greater than 500 dnm, which is common in arid regions such as Tunisia (Elloumi, 2006) and Egypt (Radwan et al. ., 2011).

In addition, one notices a great variability in the income of the farmers which is 59 million LL / ha for some farmers and 0.84 million LL / ha for others.

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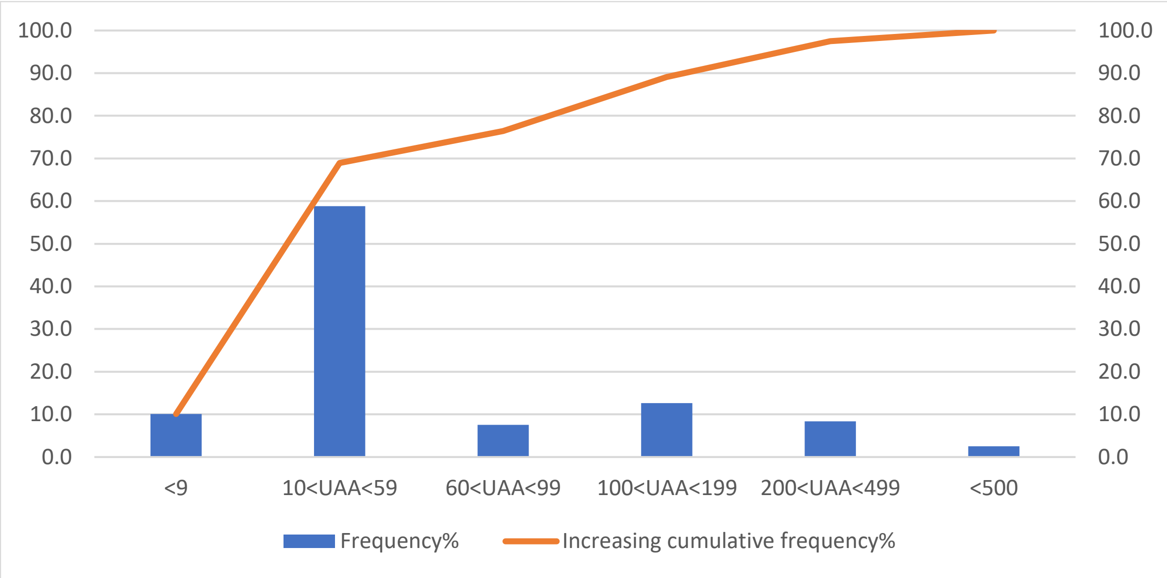

Figure 2 The frequency of farms by UAA

Typology of agricultural holdings

The statistical analysis of farms based on the two techniques PCA and HAC on the Tanagra software allowed us to classify the farms surveyed into 5 types of agricultural systems having the same characteristics and respecting the variables chosen in Methodology-I-2. To measure the association, two correlation axes were chosen using the Kaiser criterion which implies the choice of axes whose "Eigen Values" are greater than 1 and which explain a "good proportion" of the total variation. This means that the sum of the inertia (variation) explained by each of the axes must represent a significant part of the total inertia. The results of the PCA and HAC revealed that the distribution of categories of agricultural households according to the selected criteria (called discriminant variables) represented by two axes of correlation, explain 46.72% of the total variability. Axis 1 (28.98%) is associated with vegetable production and the cost of inputs. This correlation confirms that the vegetable farms present on the

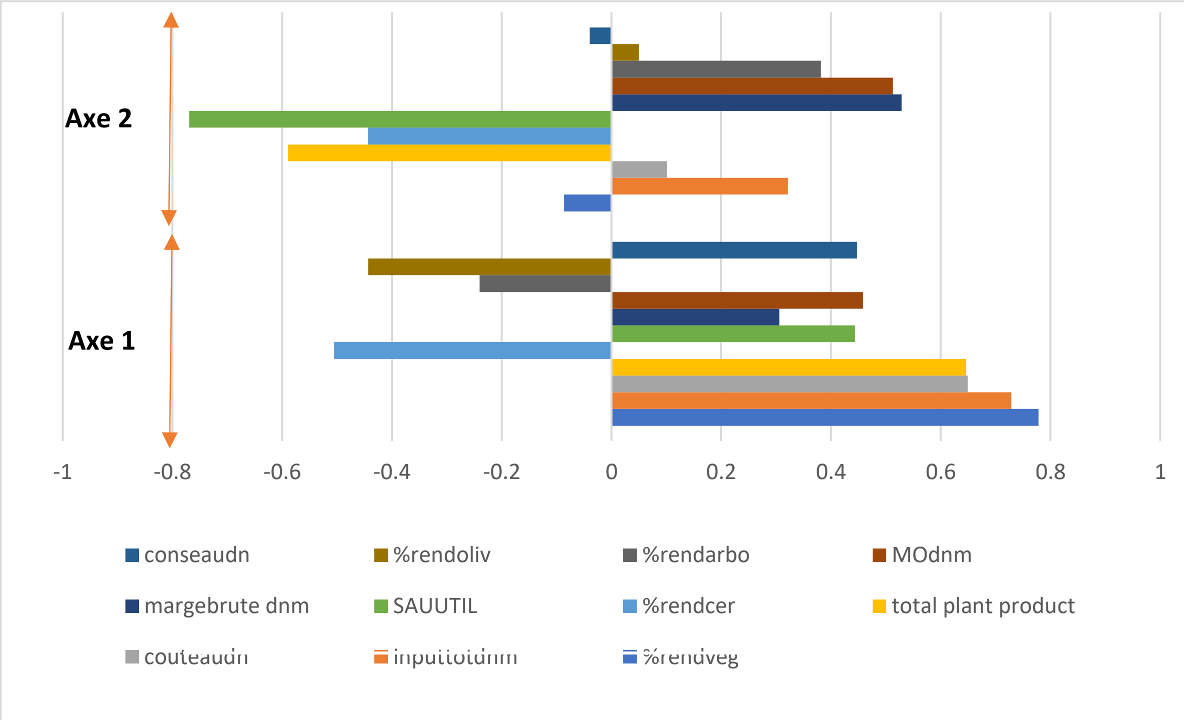

Figure 3 The two correlation axes linked to the tested variables (correlation scatter plot)

market are those which use the most inputs. Axis 2 (17.74%) is associated with the agricultural area used, the agricultural income per holding and the gross margin (Figure 3)

Typology of farms

The variables in this analysis are:

SAUUTIL used agricultural area
PCEREAL Percentage of cereals
PVEGTA Percentage of plants
POLIV percentage of Olives
PARBO Percentage of arboriculture
QTEAU dn Quantity of water per dn
ValPVM3 Plant production value per m3
MBTVM3 Total plant gross margin per m3

Determination of the main axes

The eight inter-correlated quantitative variables are transformed into eight new uncorrelated quantitative variables (principal components or principal axes). The main axes are defined by the matrix of the eigenvectors of the matrix of the correlations of the initial variables. The elements of the matrix of the eigenvectors are the coordinates of the initial variables on the principal axes (table 2). This matrix makes it possible to represent the initial variables on 1, 2 or 3 axes or even more.

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ISSN: 2810-2991
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Table 2 Matrix of the eigenvectors: (coordinates of the initial variables on the first five main axes).

Variable	Axe1	Axe2	Axe3	Axe4	Axe5
ValPVM3	0.95377	0.09837	0.18548	0.14113	-0.05246
MBTVM3	0.93591	0.13042	0.19999	0.14746	-0.01487
PCEREAL	-0.54757	0.12529	0.66762	0.29901	0.31143
PVEGETA	0.41936	-0.86101	0.04108	-0.15456	0.08008
QTEAUDn	-0.18006	-0.66653	-0.56466	-0.04441	-0.00030
POLIV	0.00658	0.52601	0.01699	-0.80941	-0.22095
PARBO	0.00369	0.49752	-0.66645	0.51118	-0.21145
SAUUTIL	-0.26378	-0.33543	0.43622	0.18433	-0.76990
Var. Expl.	2.36335	1.86470	1.47537	1.10735	0.79266

The elements of the diagonal matrix of eigenvalues represent the variance of farms on the corresponding axis, as shown in Table 3

Table 3 Variance of the initial variables on the main axes.

Axis	Variance	Difference	Proportion (%)
1	2.363353	0.498650	29.54 %
2	1.864703	0.389332	23.31 %
3	1.475372	0.368022	18.44 %
4	1.107349	0.314693	13.84 %
5	0.792657	0.409239	9.91 %

Examination of this table shows that the farm variance is 2.363 on the first axis (this is the maximum variance), and is 1.8647 on the second. The share of all initial information visible on the main plane is in the order of 50%.

The software provides a hierarchical classification tree for farms. To choose a cut from this tree into classes, we study the progression of interclass inertia for different cuts. By examining the results of the software concerning the progression of inter-class inertia, we notice that the values of the latter before and after iterations are the same starting from the division of the hierarchical tree into 5 classes.

Identification of typical farms

Five distinct typical farms were identified based on the statistical analysis of ACP and HAC. These farms are distributed homogeneously, having the same characteristics, and respecting the variables chosen in establishing the typology. The types of farms obtained are as follows:

A. ***Large farms dominated by plants (LP):***

These farms represent 8.4% of the sample and they are the farms with the highest surface area with an average surface area of 417 dnm. Market gardening is the dominant crop with 75% of the cultivated area and a 96% share of the total yield. The remaining area (25%) is cultivated with cereals and generates only 4% of the total income of the farmer. These farms consume the highest amount of water per hectare (on average 499 m3 / dnm). This result is in line with previous studies carried out on the same region (Khansa et al., 2017) which show that plant farms are irrigated excessively. This group has high production costs of an average of 681,000 Lebanese pounds per denom and the highest water cost of nearly 100,000 LL per denom.

Small intensive plant-dominated farms (SP):

Small, intensive plant-dominated farms represent the largest group in the sample (37%) and are generally small in size with an average of 37 dnm. The main crop for this type is market gardening which represents 91% of the total area with a share of 96% of the total yield. The quantity of water consumed per hectare is significant but lower than the previous group (464 m3 / dnm on average). Labor and production costs of this type are the highest compared to other types, respectively 408,000 and 729,000 LL per denom. This group represents the highest gross margin averaging LL 1,670,000 per denom.

Small farms with arboriculture dominance (SA):

This group represents 14.3% of the sample and are small farms with an average surface area of 29 dnm. The main crops of these farms are fruit trees which represent 97% of the total area and 98% of the farmer's income. Water consumption for irrigation for this group is high (411 m3 per denom) but with moderate consumption of labor and input (on average 212,000 and 371,000 LL per denom respectively). The gross margin of this group is an average of LL 803,000 per denom.

Small farms with olive growing (SO):

These farms with an average surface area of 40 dnm represent 10.1% of our sample. The dominant crop for this group is the olive tree which represents 81% of the total area and contributes 89% of the total average income. Other crops (market gardens, arboriculture) represent a very low share in this group. Water consumption for irrigation by these farms is the lowest at 282 m3 per dnm. This result is expected

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Vol. 5, pp 8-28 (2024)
ISSN: 2810-2991
www.techniumscience.com

since olive crops are crops that consume little water (rain-fed crops) and are resistant to drought. The consumption of input and labor is relatively low, with respective values of 236,000 and 110,000 LL per denom. This type generates a gross margin of LL 734,000 per denom.

Medium-sized diversified grain-dominated farms (MDC):

Diversified farms represent 30.3% of our sample. These farms have an average surface area of 76 dnm and are characterized by the presence of several types of crops, mainly cereals and market gardens (respectively represent 61% and 30% of the total cultivated area and respectively contribute 37% and 59% of total income). The production and labor costs for this type are the lowest (respectively 100,000 and 160,000 LL per denom). Its gross margin is also relatively low compared to other types of operations of LL 354,000 per denom.

Table 4 below represents the average characteristics of the five groups of typical farms according to the variables chosen.

Table 4 Average structural characteristics of the 5 types of farms

Criteria	Variables	LP	SP	SA	SO	MDC
Number of farms		10	44	17	12	36
Environmental potential	Cultivated area (dnm)	417	37	30	40	75
Availability of financial resources	Gross margin (LL / dnm)	648,000	1,270,000	803,000	734,000	354,000
Production goal (Contribution of each crop to yield)	Cereal production in%	4	0	0	1	37
	Market garden production in%	96	96	0	5	1
	Arboriculture production in%	0	3	98	5	59
	Olive tree production in%	0	1	2	89	3
Factors of production intensification	Water consumed (m3 / dnm)	499	464	412	282	382
	Production cost (LL / dnm)	661,000	729,000	371,000	236,000	160,000
	Labor cost (LL / dnm)	208,000	408,000	212000	110,000	100,000
	Water cost (LL / dnm)	99,000	83,000	70,000	27,000	25,000

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Vol. 5, pp 8-28 (2024)
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Identification of the characteristics of agro-climatic zones

The aggregation of the five types of farms according to their location in the 3 agro-climatic zones allowed us to identify the dominant agricultural systems for each zone.

For the North zone, characterized by the lowest rainfall, only three types of agricultural systems are identified, namely SP (15 farms), SA (6 farms) and SO (6 farms). It is above all small-scale farms which produce the majority of plants and fruits (fruit trees and olive trees). In this zone there are almost no cereal crops. This is expected since they are rain-fed crops that depend on the amount of rain and require large areas to produce enough. Crop rotation for these farms is almost absent and they adapt the same cropping systems every year. Most of these systems are irrigated by artesian wells and the rest by canals from water sources.

For the Center zone, the results of the typology showed that 4 different agricultural systems are present. These systems are LP (7 farms), SP (17 farms), SO (4 farms) and MDG (34 farms). The presence of these farms in the center of the plain offers them the opportunity to cultivate large areas. They are irrigated from the Yammouneh Lake. Moreover, the majority of diversified grain-dominated farms are present in this zone. This type is characterized by the lowest gross margin and the lowest intensification factors.

For the South zone, the results of the typology showed the presence of the five types of exploitation. The dominant types according to our sample are SP (12 farms) and SA (11 farms). The majority of these farms are irrigated by wells. The presence of various production orientations in this zone can be explained by the significant contribution of rainfall, the wealth of water resources and the availability of large agricultural areas.

The characteristics of these subgroups are shown in Table 5 below.

Table 5 Average structural characteristics of sub-groups distributed by agro-climatic zone

	Type	NB	UAA	UAA cereals	Vegetable UAA	UAA Olives	UAA arboriculture	Water consumption	Irrigation source
North	SP	15	30.2	0	26.8	2	1.4	375	Well
	SA	6	27.3	0	0	5	22.3	348	
	SO	6	67.5	16.7	3.3	40	7.5	264	
Center	LP	7	353.4	50	303	0	0	513	Lake
	SP	17	32.5	0	32.5	0	0	577	
	SO	4	15.8	0	0	13.3	2.5	350	
	MDC	34	68.5	41.8	21.9	2.4	2.5	393	
South	LP	3	566.7	283.3	283.3	0	0	467	Well
	SP	12	50.3	4.2	43.2	0	2.9	415	
	SA	11	31.1	0	0	0	31.1	446	

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	SO	2	8	0	0	8	0	200	
	MDC	2	200	150	50	0	0	189	

Table 6 SWOT analysis of the different operating systems

	LP	**SP**	**SA**	**SO**	**MDC**
Strengths	-Use of a lower irrigation dose within the group compared to the average dose for all farms. -The farmers have non-farm income; they are pluriactive so as not to depend only on their productions. -The farms are close to the market, which would facilitate the sale of their production. -Diversification of cultures -Good yield of cereals, vegetable crops and tobacco compared to the average	-Use of a lower irrigation dose within the group compared to the average dose for all farms. -Adoption of drip irrigation, which is a water-saving method. -Diversification of cultivations. -The farms are, on average, close to the market, which would facilitate the sale of their production. -Good yield of vegetable crops, tobacco and fruit trees compared to the average yield of all farms. -Gross margin	-Use of a lower irrigation dose within the group compared to the average dose for all farms. -Adoption of drip as the method of irrigation, which is a water-saving method. -Diversification of cultivations. - Good	-Diversification of production systems. -Diversification in the plant production system. -Diversification in the animal production system. -The farmers have non-farm income; they are pluriactive so as not to depend only on their productions.	-Diversification of production systems. -Diversification in the plant production system. -Diversification in the animal production system. -Use of a lower irrigation dose within the group compared to the average dose for all farms. -access to the market is almost similar to the average distance of all the farms which makes the marketing of productions less difficult -The costs of inputs in the plant and animal system are low compared to the average costs. -Good yield for the productions of the two

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	yield of all farms.	/ ha is higher than the average margin of all farms, which shows good management of the farm. -The farms have non-farm income, they are pluriactive so as not to depend only on their productions.	yield of fruit trees. -The costs of inputs into the plant system are low compared to the average costs.		systems (animal and vegetable).
Weaknesses	-The costs of all the inputs in the plant system are higher than the average costs of all the farms, while the gross margin / ha is low compared to the general average. -No diversification of production systems. -The source of water used in an important way is the wells, which could have a negative	-The source of water used in an important way is the wells, which could have a negative impact on the groundwater. -No agricultural monitoring. -Absence of agricultural aid.	-Very small farm size compared to the general average size of all farms. -No diversification of production systems. -The only source of water used is wells, which	-No agricultural monitoring. -Absence of agricultural aid. -Access to the market that is far from the average for all farms which could make it difficult to market their productions. -Very small farm size compared to the general average size of all farms.	-No agricultural monitoring. -Absence of agricultural aid. -Very small farm size compared to the general average size of all farms.

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	impact on the groundwater. -The costs of labor, whether seasonal or permanent, are very high compared to average costs. -no agricultural monitoring. -No agricultural aid.		could have a negative impact on ground water. -The gross margin / ha as well as the non-operating income are lower. -Access to the market far from the average for all farms which could make it difficult to market their productions. -No agricultural monitoring. -Absence of		

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			agricultural aid.		
Opportunities	- Large farms could be an attraction for investments. -Export of agricultural products	-Export of agricultural products	-Export of agricultural products	-Export of agricultural products	-Export of agricultural products
Threats	-The negative impacts of climate change on this type of exploitation. -The overexploitation of water resources, especially groundwater. -High input costs in the face of a low gross margin / ha could subsequently lead to a financial crisis for this type of farm. - Very large farms could cause difficulties in their management.	-The negative impacts of climate change on this type exploitation. -The overexploitation of water resources, especially groundwater.	-The negative impacts of climate change on this type of exploitation. -The overexploitation of water resources, especially groundwater. - Importance of fruit trees in terms of UAA compared to other crops,	-The negative impacts of climate change on this type of exploitation -The irrigation dose is greater than the average dose for all farms.	-The negative impacts of climate change on this type of exploitation. -The source of water used is the lake, which can cause disease if it is contaminated.

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			which could create a crisis for operators of this system in the event of low production.		

Discussion and Conclusion

The future of agricultural systems in the Mediterranean area is threatened by several external factors. The scarcity of water resources and the climate changes affecting this area are according to several authors the most threatening factors, especially in semi-arid regions. These authors predict a significant decrease in water availability caused by rising average temperatures and variability in precipitation in the future. These conditions will influence the productivity of agricultural systems in these areas and lead to uncertainty about the performance and future of existing farms. However, it is an area characterized by its diversification in terms of production systems distributed in a different way depending on the climatic context of the area.

In this context, the objective of our study is to develop a framework for assessing the resilience and the capacity to adapt to climate change of agricultural systems in the semi-arid region of Baalbeck El Hermel, taking into account the diversification of agricultural systems in this area.

To meet this objective, we have developed a methodology based on characterization of the diversity of agricultural systems in this territory by carrying out a quantitative typology according to precise variables,

According to the typology produced Our work has brought out several results concerning the heterogeneity of the agricultural systems studied at the level of the governorate of Baalbeck El Hermel, the farms in the studied area present a diversity of agricultural production systems. The analysis of the diversity at the level of agro-climatic zones showed a low diversity of agricultural practices at the level of the North zone. Such a result is expected for an area receiving the least amount of precipitation and characterized by the highest average temperatures. We also found that despite the dominance of small agricultural areas, agricultural practices are diverse and several types of crops are present in Baalbeck El Hermel.

The "not very resilient" farm has the capacity to maintain a slight decrease in its gross margin even if the quantities of water available are very low. That is, even for years of drought, this farm has the capacity to keep a good income. Nevertheless, this type is forced to modify its structure (labor and UAA) to maintain the gross margin and consequently does not keep its initial situation stable. It is the most diversified type of farm in the northern area on the one hand and in the Baalbeck El Hermel area on the other. For this type of farm, the diversification of agricultural practices and the adaptation of crops resistant to drought (olive trees) obviously guaranteed farmers a more remarkable income than for other farms. These results are similar to those of studies conducted with agricultural systems to prove the importance of diversification in the resilience of agriculture (Aspar, 2019; Lefeuvre, 2018; Souissi et al., 2017).

"Non-resilient" farms are farms unable to maintain their net gross margin under conditions of limited water resources. These are specialized farms producing either arboriculture or vegetable crops. In this group, the significant drop in gross margin is mainly due to the decrease in yields of arboriculture and market gardens unable to maintain their productivity in the absence of irrigation (water stress). These crops, despite their high profitability, are very risky crops and require high amounts of water. The farmer is forced to change his rotation (limit crops by choosing the most profitable in conditions of water stress) and limit his production because of dry techniques since for perennial crops it will be very expensive to replace them.

In addition, the collective scientific expertises of INRA (2006) propose, under such water-limiting conditions, the adaptation of alternative crop strategies that are less tolerant to drought, ensuring the sustainability of farms and an improvement in their resilience. In this regard, it will be relevant to adapt strategies to strengthen the investment capacity of these farms before the implementation of a water tariff. It is a question of proposing and developing support strategies for the farmers of the zone. Support can be in the form of policies offering premiums and subsidies on behalf of the government for the most vulnerable farmers, especially that the crops present in the North are not subsidized crops (like tobacco and grains in Lebanon). So, this agricultural aid can help them invest in crops that are more resistant to drought.

In conclusion, these research results would help to design adaptation strategies for farming systems that are based on understanding farmers' and related impacts. This understanding can provide a solid foundation for the development of climate scenarios based on what farmers consider where appropriate. The results would also be beneficial for developing strategies that depend on the context as well as on the significance for farmers and, therefore, are probably more effective and sustainable.

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