Economic Effects Related to Water Adaptation Strategy in the Mediterranean Agriculture the Areas of Baalbeck–Hermel (Lebanon)

Dr. **Salem Darwich**

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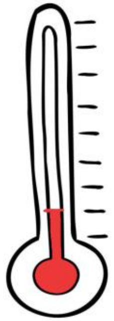
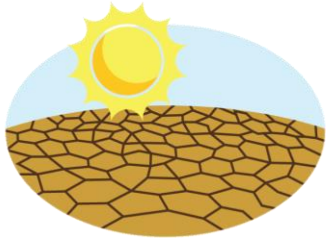
Introduction

Global Climate



Temperature increase

Rain decrease



Drought conditions
Degradation of soil

Meteorological conditions to have a good yield:

- **rainfall**
- **sunshine**

Introduction

Several constraints

Irrigated crops

Introduction

- ✓ Most important regions in Lebanon where farming systems play a strategic role
- ✓ Show relevant critical issues related to natural resources exploitation
- ✓ Characterized by irregular rainfall
- ✓ Long periods of drought

- ➢ Agricultural practices adopted by farmers, typically consume a huge amount of water, which leads to the overexploitation of water resources, reduction in the level of aquifers

.

- ➢ Recourse to irrigation from groundwater is proving to be impossible and climate change is further aggravating the situation.

Introduction

How to ensure a transition of farms in Baalbek Al Hermel towards sustainable agricultural practices, profitable, and less water consuming?

How to increase the resilience of farms in that region and reduce their vulnerability, in the short and long term, to the repercussions of climate change?

what are the difficulties and challenges that may hinder this process?

Introduction

Adaptive capacities of rural populations

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1. Understand the livelihoods of farmers

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2. Role of agriculture as a resilient livelihood for these populations

“The ability to reorganize and maintain the function and structure of systems, which are interconnected and span different spatial and temporal scales”

Purpose

- Understand how farmers in these areas currently perform in the face of limited water resources with little or no government support, to predict what could be the behavior of those farmers in case of a decrease in water availability in the future.

- Assess (using bioeconomic modeling) the resilience of farmers in the semi-arid **Baalbeck El Hermel** zone to climate change in a context of limited water resources.

Objectives

01 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",** considering the diversification of agricultural systems in this area.

02 Observe a clearer vision of the criteria selected in order to produce the exploitation typology and thus, better understand the context of the study area.

03 Analyze the resilience and adaptive capacity of agricultural systems in the governorate of Baalbeck El Hermel, taking into account the diversity of products for this area.

Chapter I

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

Material and Methods

Typology

Data collected and survey carried out

101 surveys for farmers were carried out at the level of crop production farms in 2019, randomly from different villages in the Baalbeck ELHermel region.

Considering Two main criteria:

Diversity of crops and **Climatic variability of the study area.**

Programs and software used

Quantitative typology of multivariate statistical analysis using the **Tanagra statistical software**, using principal component analysis (PCA).

Three criteria of classification:

Resource allocation, Production objectives, and **Intensification levels of production**

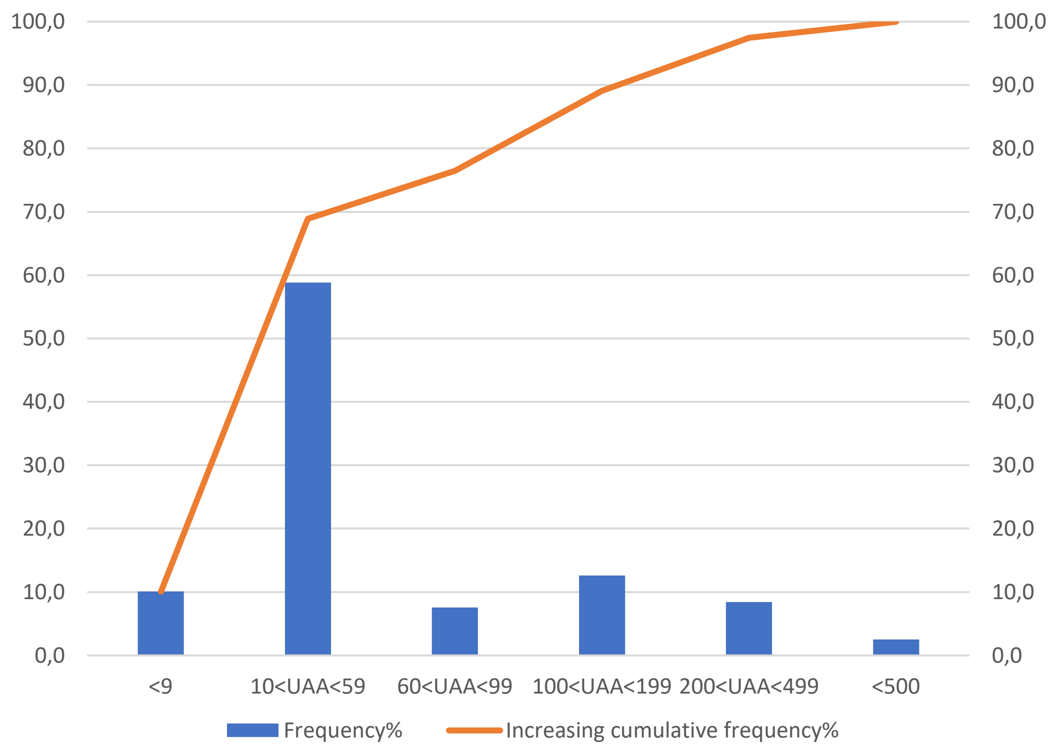
Analysis of types of farms at the agro-climatic level

After classifying farms according to their criteria at the farm level, we built a classification according to agro-climatic zones **based on the location of farms**.

SWOT analysis used to make strategic decisions rely on internal and external analysis

Result and Discussion

Preliminary analysis of survey results



The frequency of farms by UAA

- Baalbeck EL Hermel has different surface areas ranging from:

  4 dnm to 800 dnm with an average of 80 dnm.

- The surface area of farms varies as:
  1. **77% fewer than 100 dnm**
  2. **69% less than 60 dnm**
  3. **10% less than 10 dnm**
  4. **11% greater than 200 dnm**
  5. **3% greater than 500 dnm**

✓ Common in arid regions such as Tunisia (Elloumi, 2006) and Egypt (Radwan et al. ., 2011).

- Great variability in the income of the farmers:

  59 million LL/ha and 0.84 million LL/ha for others.

Result and Discussion

Determination of the main axes

The variables in this analysis

SAUUTIL: used agricultural area

PCEREAL: Percentage of cereals

PVEGTA: Percentage of plants

POLIV: percentage of Olives

PARBO: Percentage of arboriculture

QTEAUdn: Quantity of water per dn

ValPVM3: Plant production value per m3

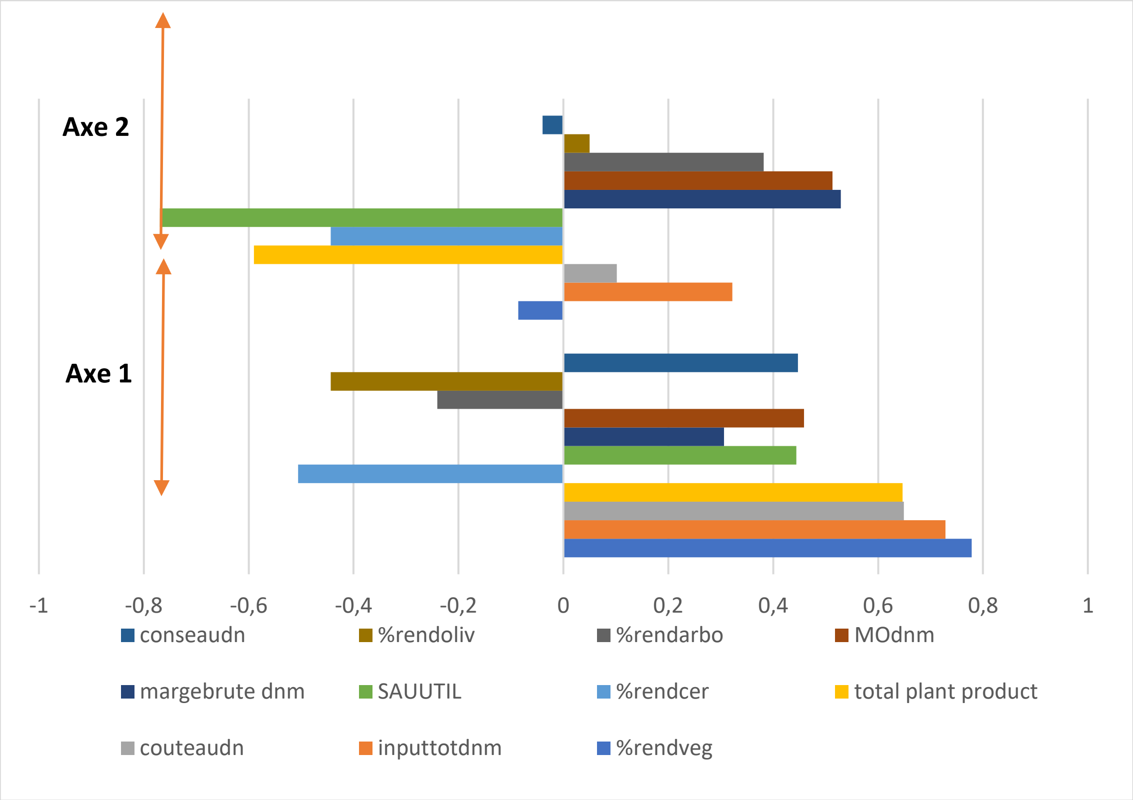
MBTVM3: Total plant gross margin per m3

The elements of the diagonal matrix of eigenvalues represent the variance of farms on the corresponding axis.

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 %

Result and Discussion

Typology of agricultural holdings



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

The results of the PCA and HAC explain **52.85% of the total variability,** represented by two axes of correlation:

- **Axis 1** (29.54%) is associated with vegetable production and the cost of inputs. This correlation confirms that the vegetable farms present on the market are those which use the most inputs.
- **Axis 2** (23.31%) is associated with the agricultural area used, the agricultural income per holding, and the gross margin.

Result and Discussion

Identification of typical farms

Five distinct typical farms were identified based on the statistical analysis of PCA and HAC:

1. **Large farms dominated by plants (LP).**
2. **Small intensive plant-dominated farms (SP).**
3. **Small farms with arboriculture dominance (SA)**
4. **Small farms with olive growing (SO).**
5. **Medium-sized diversified grain-dominated farms (MDC).**

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

Result and Discussion

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.

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

Chapter III

Evaluating and developing scenarios for resilient farms: the case of the Baalbek Al Hermel Region (Lebanon).

Material and Methods

Cognitive maps

Change factors and cognitive maps

Farmers were divided into 5 groups according to the type of their farms.

The cognitive maps are a participatory tool for obtaining semi-quantitative results (relative terms are used).

Resilience study

The resilience analysis is carried out in several stages: indicators were selected and then an evaluation grid was made for these indicators.

Evaluation grids and Resilience assessment

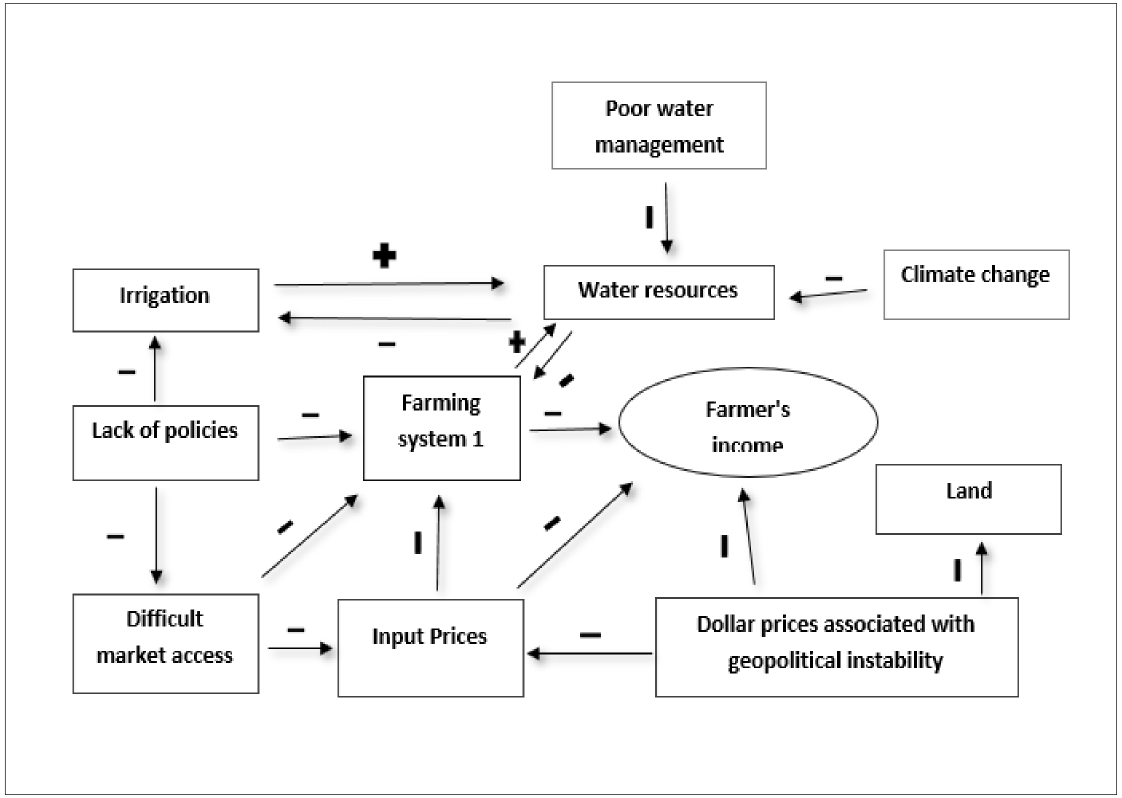
Compare the indicators reflecting the performance of current farms and those reflecting the performance of future farms.

Evaluation grids of resilience indicators, from the data collected in the database (questioners and interviews with farmers).

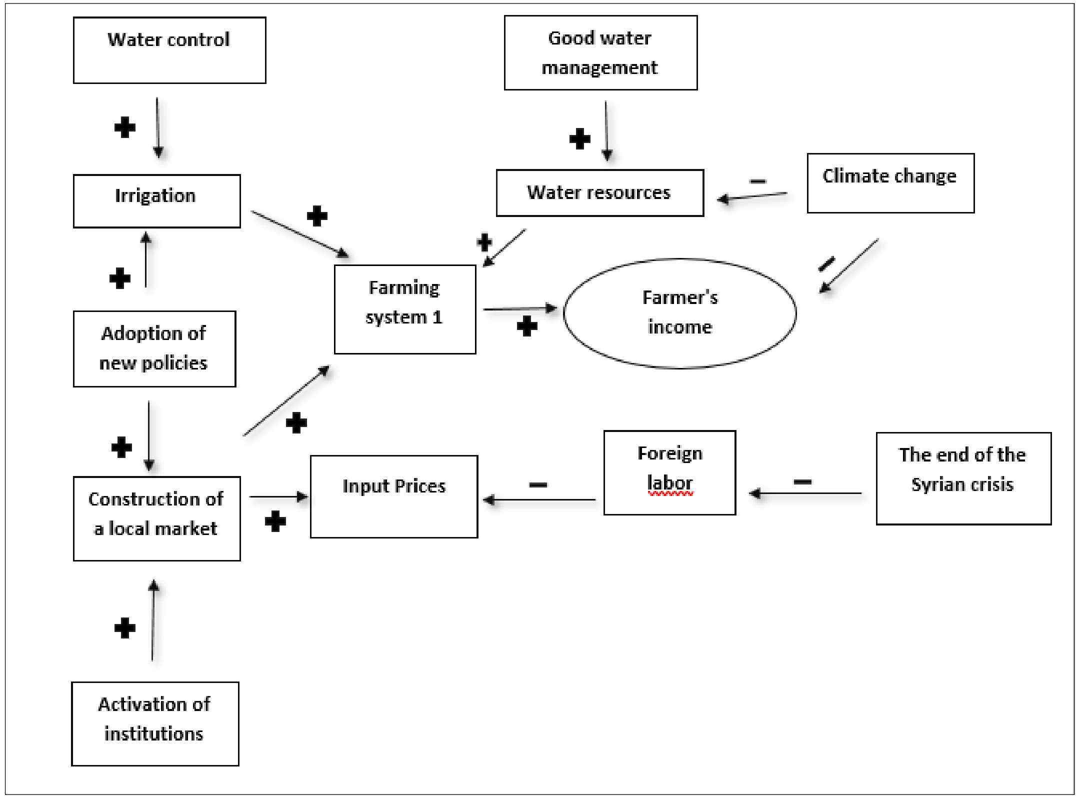
Result and Discussion

Identification of the characteristics Current situation and future situation for farms

1st type of farms: Large farms dominated by plants (LP)



Cognitive map of the future situation of the LP system

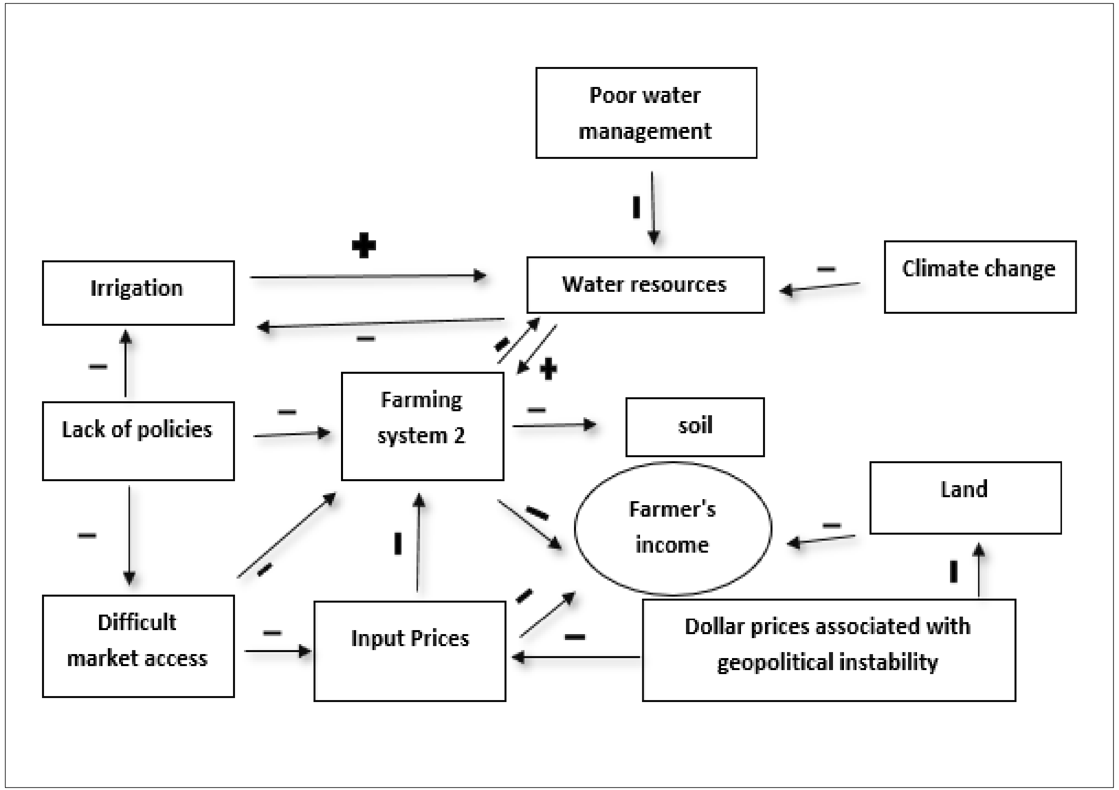


Cognitive map of the future situation of the LP system

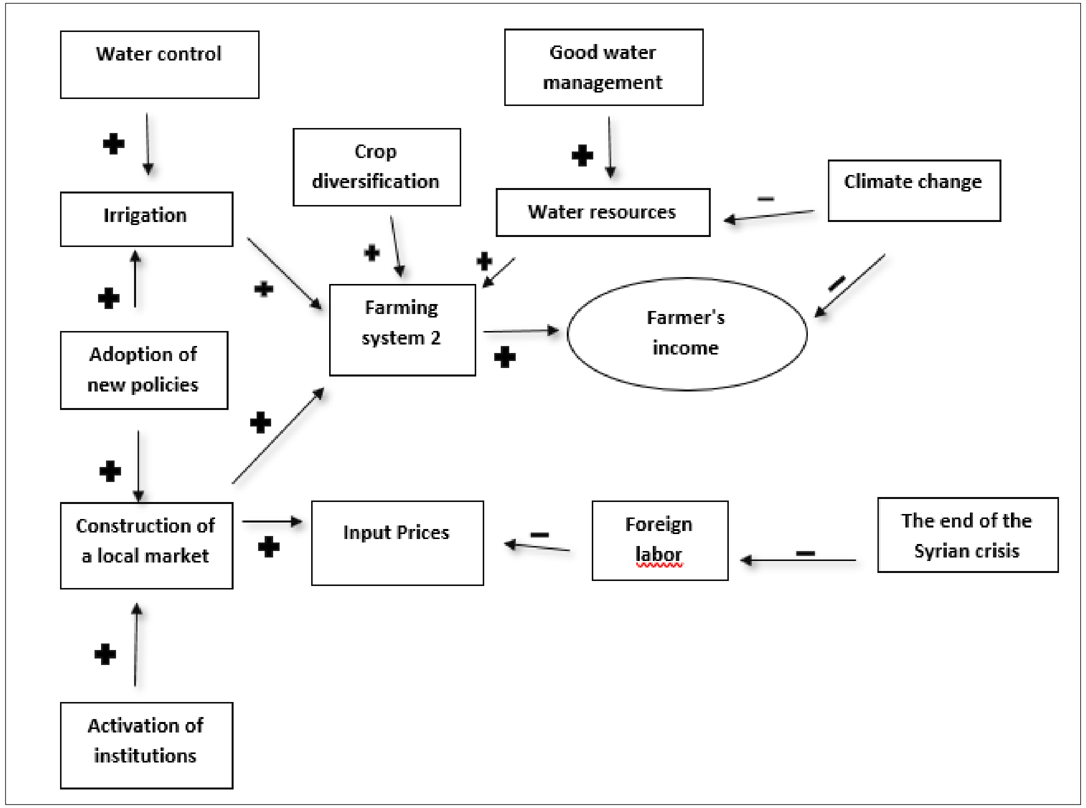
Result and Discussion

Identification of the characteristics Current situation and future situation for farms

2nd type of farms: Small intensive plant-dominated farms (SP)



Cognitive map SP system (current situation)

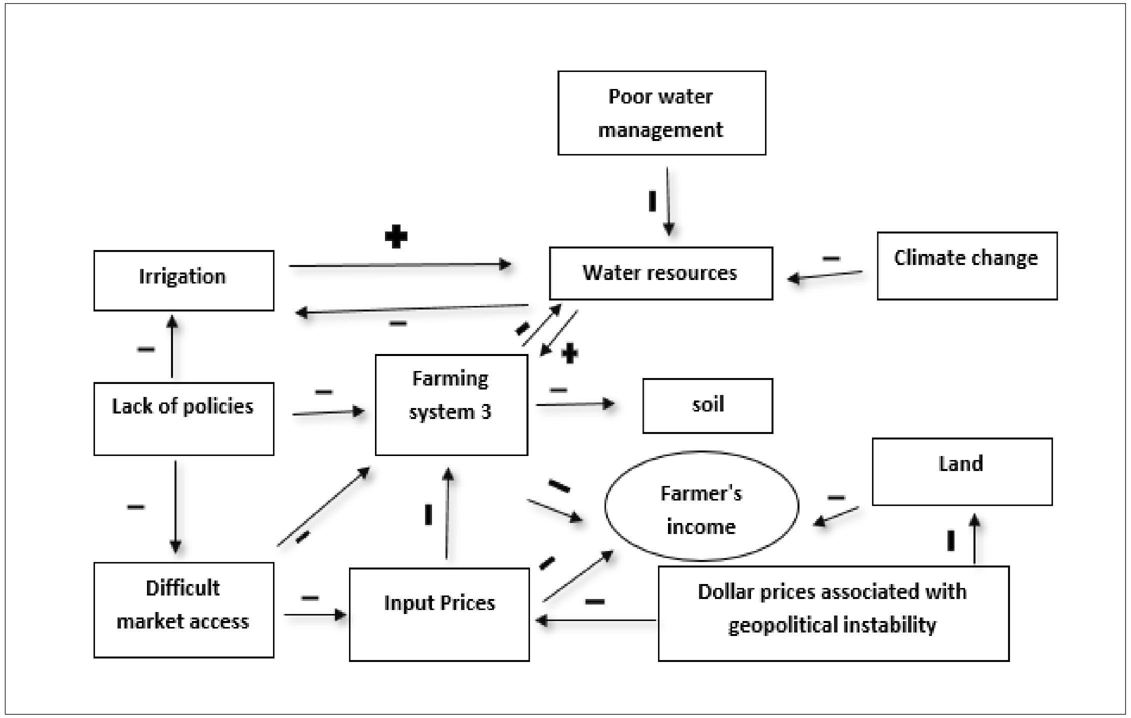


Cognitive map SP system (future situation)

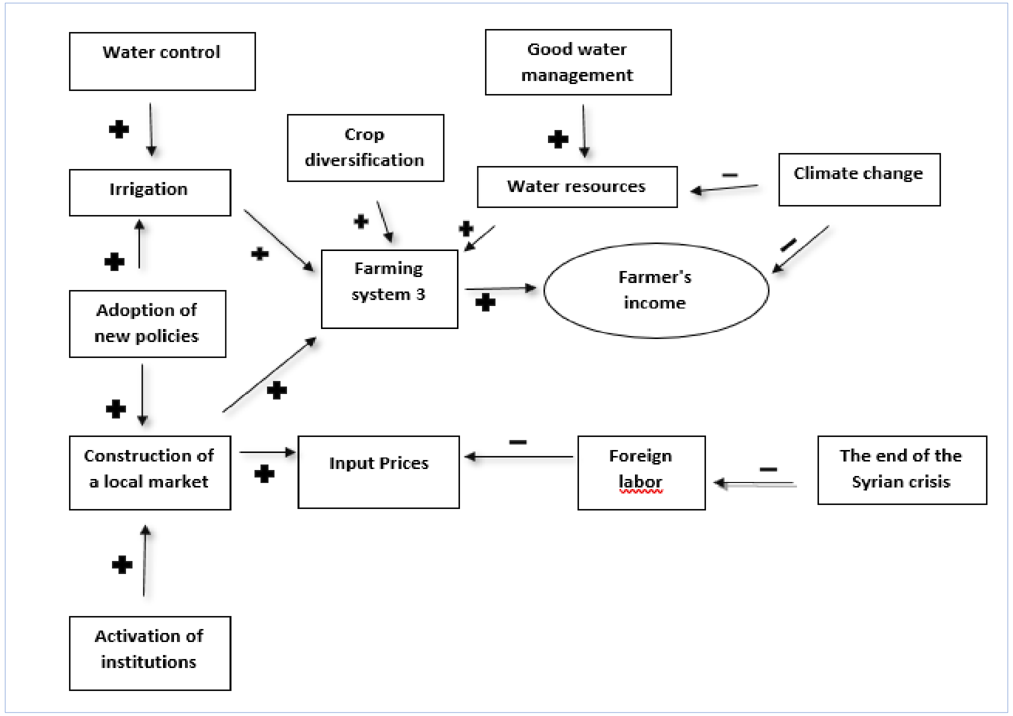
Result and Discussion

Identification of the characteristics Current situation and future situation for farms

3rd type of farms: Small farms with arboriculture dominance (SA)



Cognitive map SA system (current situation)



Cognitive map SA system (future situation)

Result and Discussion

Identification of the characteristics Current situation and future situation for farms

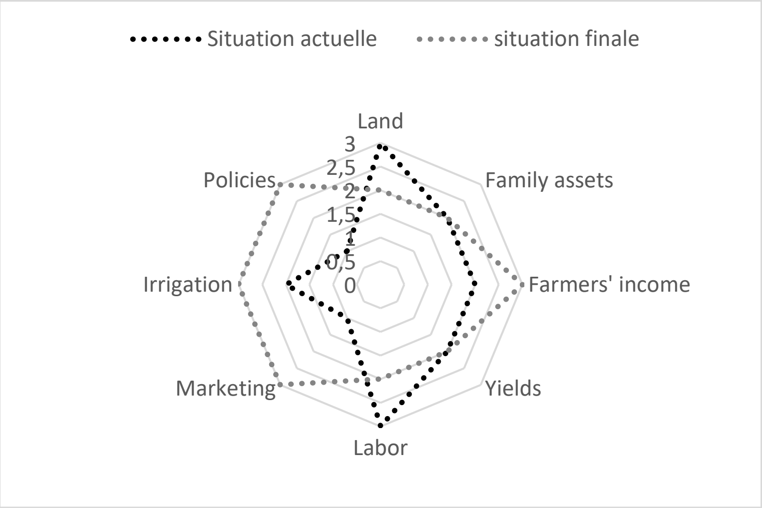
4th type of farms SO: *Small farms with olive growing (SO)*

Type 4 is specialized:

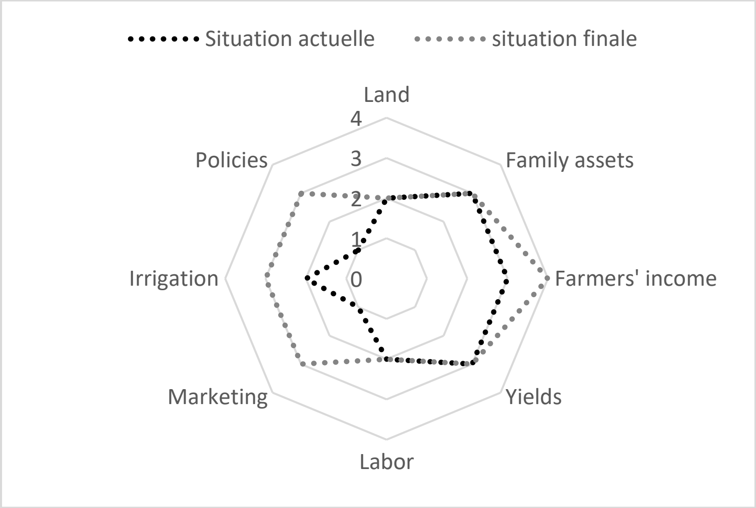
1. Cultivation of olive trees (45% of the total UAA)
2. Market gardening (42%)
3. Crops with very minimal area
4. Irrigated areas of farms represent 37% of the total area

Result and Discussion

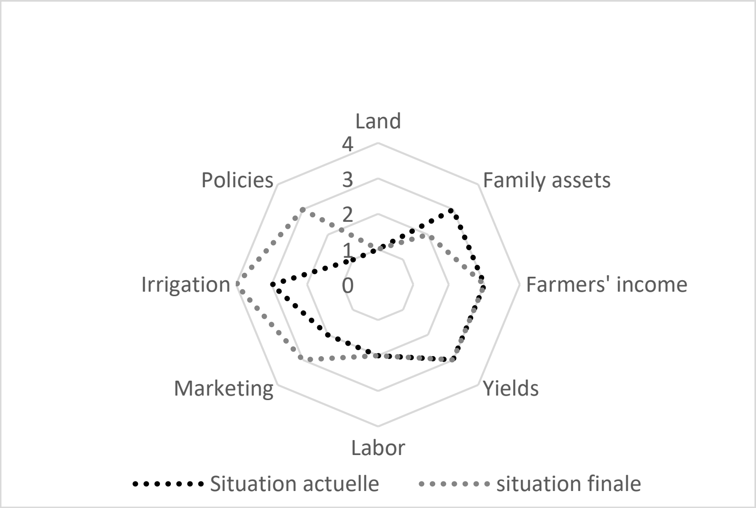
Future situation



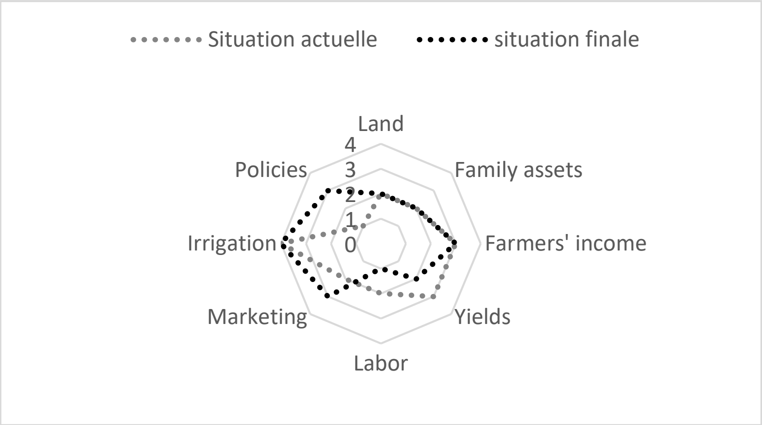
Current and future performance of type 1



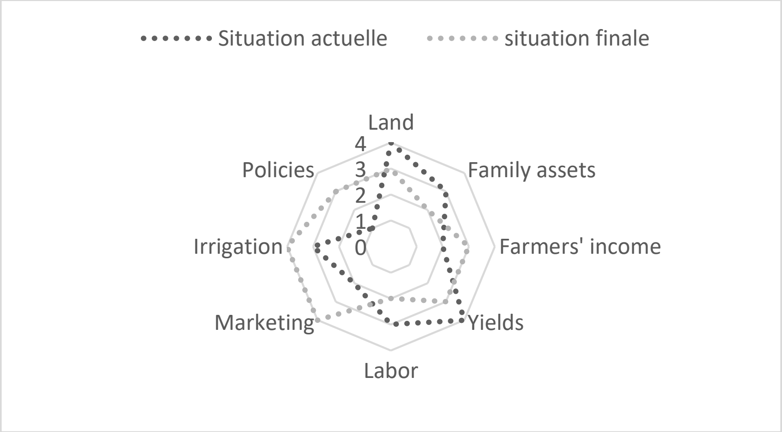
Current and future performance of type 2



Current and future performance of type 3



Current and future performance of type 5



Current and future performance of type 4

Chapter IV

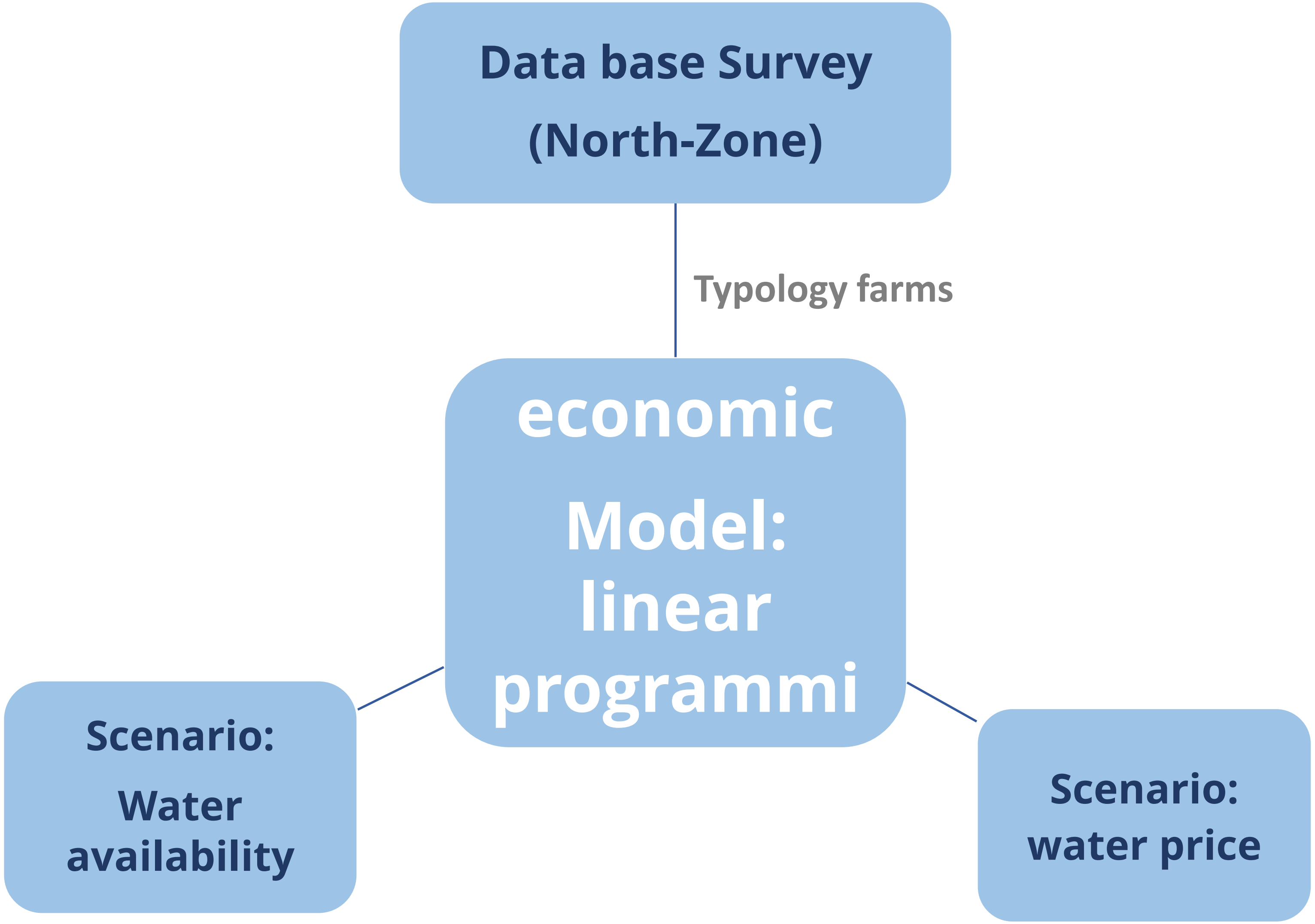
Assessment by bioeconomic modeling of the resilience of agricultural production systems in a semi-arid region: Case of Baalbeck El Hermel – Lebanon

Part I

Title: Assessment by bioeconomic modeling of the resilience of agricultural production systems in a semi-arid region: Case of Baalbeck El Hermel – Lebanon (Water availability)

Material and Methods

Part I & II



Result and Discussion

Scenario analysis

Water Availability

Farm Type	Crop	Observed area	Simulated surface	PAD%
SA farm	Apricot	20	20	0
	Peach	10	10	0
SO farm	Vine	10	10	0
	Olive	50	50	0
	Molokhia	10	10	0
SP farm	Peas	15	0	-
	Cabbage	20	27	25.93
	Bean	60	93	35.48

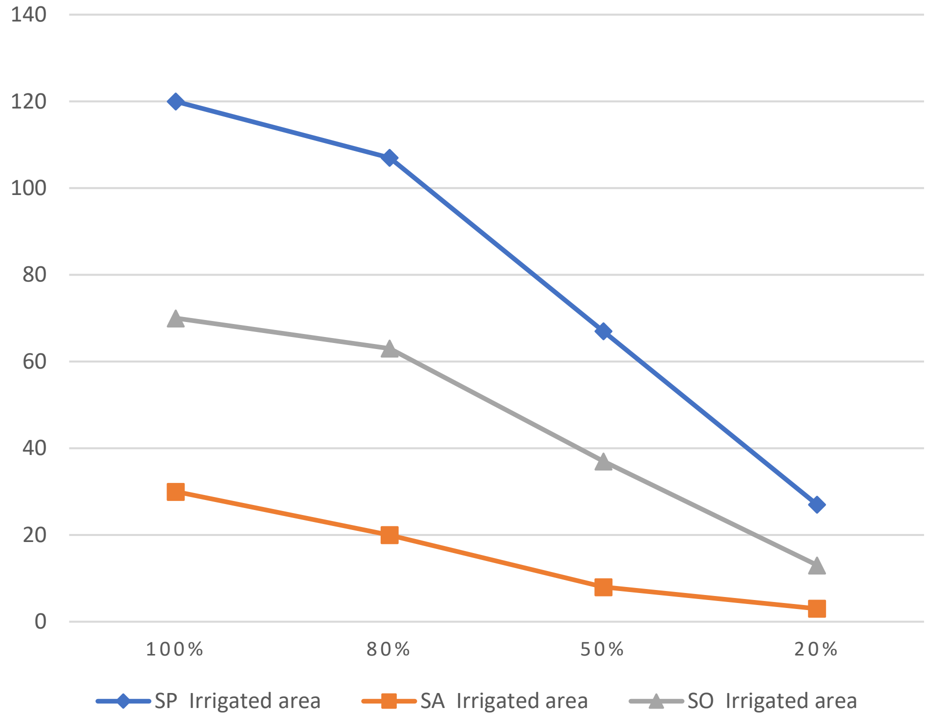
Result of the validation of the bioeconomic model for the 3 types of farms in the North zone

- ➢ Comparison of these two results for each farm showed that for each type of farm, the majority of crop areas do not exceed a relative error of more than 30%.
- ✓ The model reproduced the real (observed) situation for the different farming systems and for each crop reason, except for the SP farm which has a relative error equal to 35.48%. For this type of farm, the suitable crops are market gardens which are very risky: their yields and prices vary a lot.
- ✓ For the two other types, rotation is well simulated, and the error is 0% (since these are dominant perennial crops with a constant surface area).

Result and Discussion

Scenario analysis

Water Availability



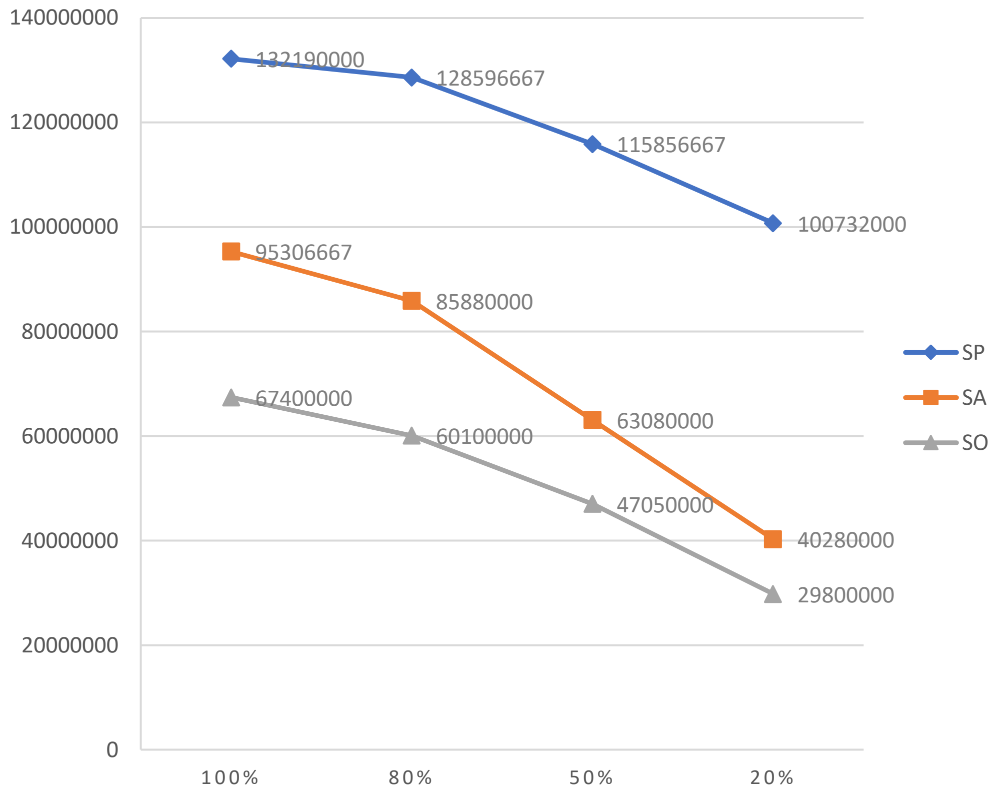
Variation of the irrigated agricultural area according to the availability of water between the base scenario and the scenario of water availability.

- Irrigated area of the three farms decreased to less than 22% of the total cultivated agricultural area for a water availability of 20%.
- The two SP and SO type farms showed almost the same behaviour in terms of reduction of the irrigated area with a gradual decrease of just 10% of the irrigated area (respectively from 120 to 107 dnm and from 70 to 67 dnm)
- when the availability in water decreases by 20% whereas for the PA type farm, the irrigated surface decreases by more than 30% (from 30 to 20 dnm) for the same degree of water availability.
- The lower the availability of water, the more the irrigated area decreases to 22% and 21% of the total cultivated area respectively for SP and SO farms, while it decreases to 11% for the SA type farm.

Result and Discussion

Scenario analysis

Water Availability



Analysis farming systems in terms of crop selection and management.

1. **For the farm dominated by market gardening (SP):**

Conservation of the rotation and of the cultivated agricultural area for all the water availability conditions.

2. **For the farm with fruit tree dominance (SA):**

Perennial crops are much more profitable in irrigated than in dry land.

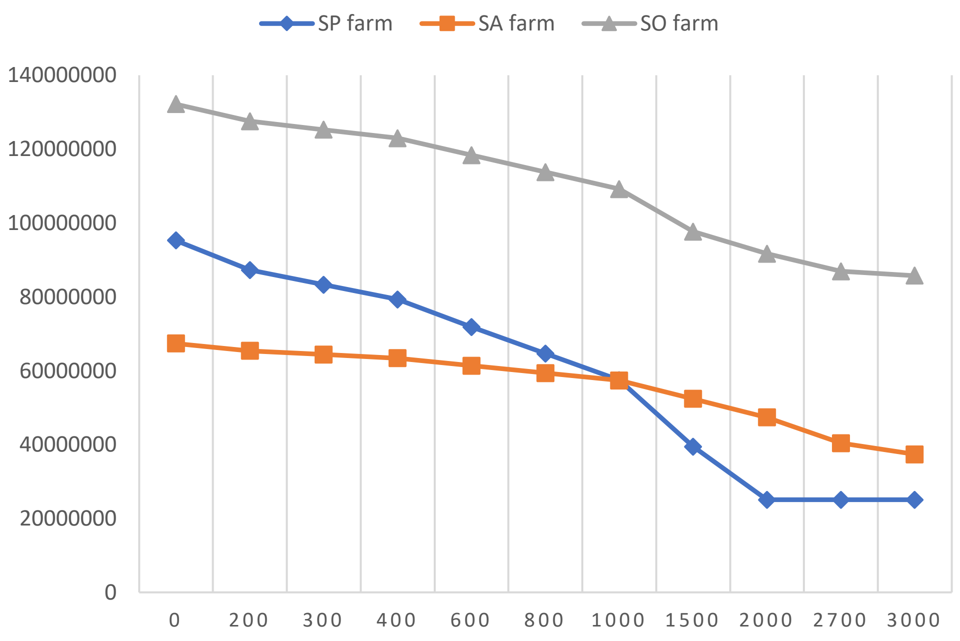
3. **For the SO type of farm:**

Most profitable crop completely irrigated (the vine) by reducing either the total area of his farm or by switching to the dry technique.

Result and Discussion

Scenario analysis

Water price



Variation of the gross margin according to the different water prices for the three types of farms.

Gross margin of this operation decreases with the increase in the price of water.

We note that:

1. Prices between 200 and 400 LL / m3, the gross margin decreases slightly from 95.3million Lebanese pounds to 79.5million (16%).

2. Price exceeds 1000 LL / m3 to reach 25.1 million Lebanese pounds for a water price of 3000 LL / m3 and the farmer loses more than 70% of the initial gross margin.

3. Water tariff of between 600 and 1000 LL / m3 forces the farmer to reduce his water consumption without his income decreasing remarkably but affects the efficiency of his rotation (switch to monoculture).

Result and Discussion

Resilience assessment of typical farms

Farm Type	Level of diversification	Production system	Resilience indicators	Resilience level	Adaptation
SP	Specialized	Market gardening	↘↘ gross margin ≃ UAA ↗ amount of work	Not resilient	× crop irrigation ↘ diversification
SA	Specialized	Arboriculture	↘↘↘ gross margin ≃ UAA ≃ amount of work	Not resilient	↘ irrigation of less profitable crops No flexibility: cost of replacing perennial crops is high
SO	Diversified	Olive trees + market gardening + arboriculture	↘ gross margin ↘BASK ↘ amount of work	Little resilient	× irrigation of olive crops (profitable in the dry) ↘ surface area of crops consuming water ↘ diversification ≃ fully irrigated profitable cultivation

Two levels of resilience in this study area:

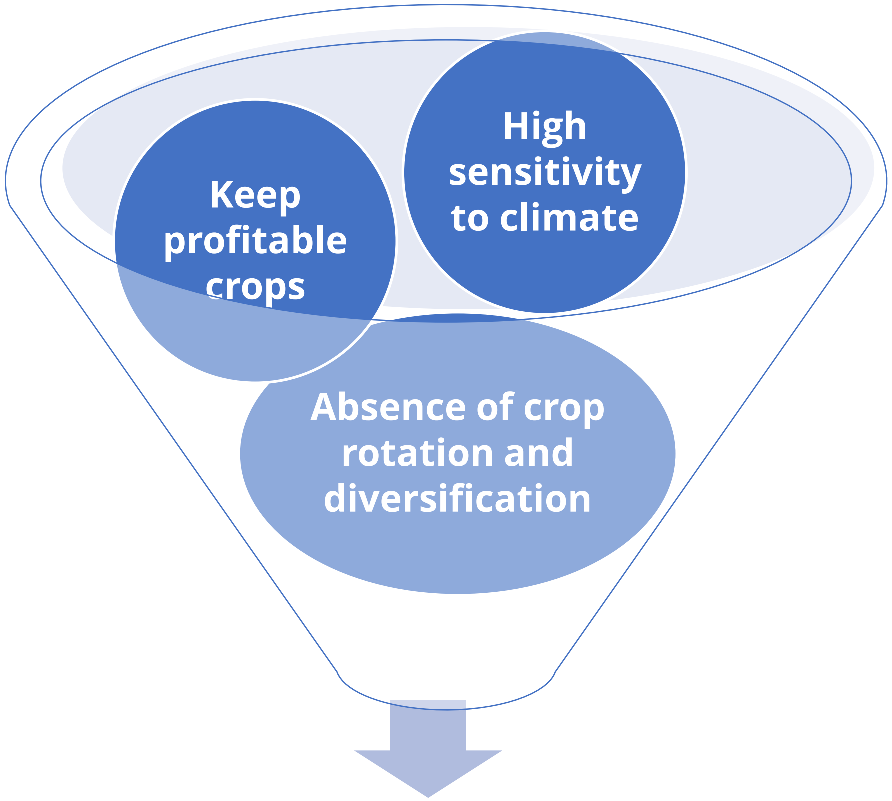
1. **Non-resilient farms:**

These are farms that adapt mainly irrigated crops and the water factor is a crucial factor in their agricultural work.

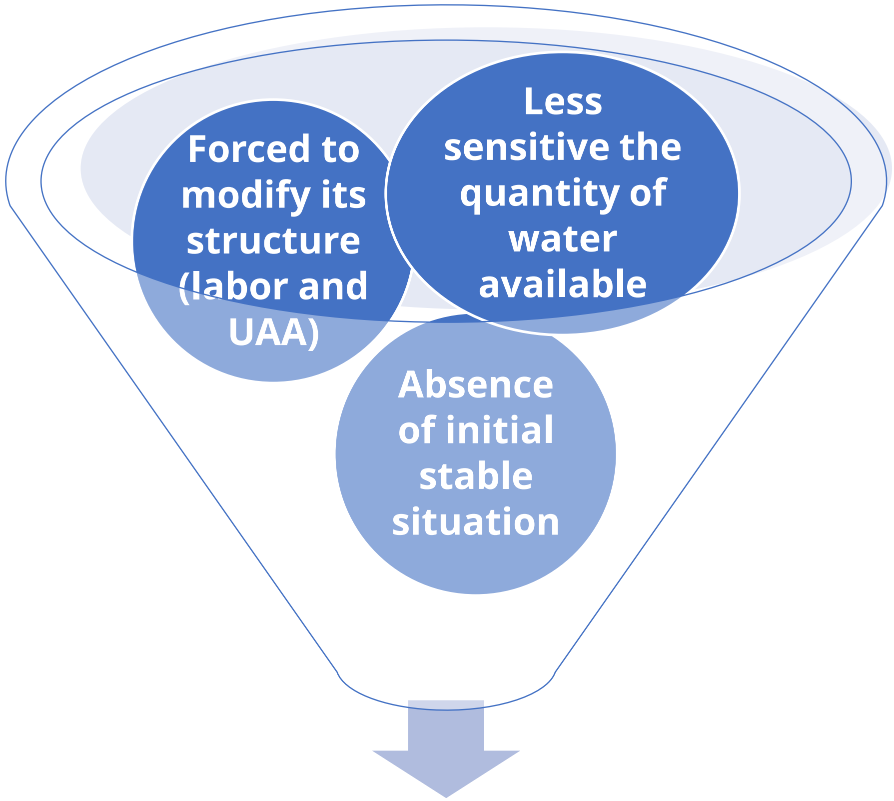
2. **Little resilient farms:**

It is considered "not very resilient" in terms of gross margin but "not resilient" in terms of cultivated agricultural area. In fact, the farmer has reduced his UAA to limit these losses by eliminating the crop consuming water.

Conclusion



“Non-resilient” farms (SP and SA)



Resilience is “little resilient” farms (SO)

Conclusion

Lebanon suffers from:

1. Lack of effective policies for the management of water resources, especially for vulnerable areas.
2. Lack of planning for the development of resilient agriculture in the face of the various risks that threaten it.

This study is important because it proposes a method allowing farmers to test their choices and their adaptation strategies under conditions of limited water before applying them in the future.

Recommendations

01 Address the improvement of the bioeconomic model by the combination of a biophysical model simulating the variability of crop yields and taking into account the risk on the market especially.

02 Analyze the resilience and adaptation capacities at the regional level by taking into account the capacity for the exchange of land and labor between farms at the regional level.

03 Improve the resilience analysis framework by dealing with more indicators in relation not only to the farmer's income but also to the other environmental and social resilience indicators.

Thank You!!

For Your Attention