**Dynamiques environnementales**
Journal international de géosciences et de l'environnement

**48 | 2021**
**DE Varia**

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*Comprendre la sécheresse comme un phénomène physique vécu par les agriculteurs : une nécessité pour la gestion de l'adaptation et le développement rural durable. Le cas de la Beqaa centrale au Liban*

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**Electronic version**
URL: https://journals.openedition.org/dynenviron/5909
ISSN: 2534-4358

**Publisher**
Presses universitaires de Bordeaux

**Printed version**
Date of publication: 5 June 2021
Number of pages: 45-63
ISSN: 1968-469X

**Electronic reference**
Tarek Nasser, Laurent Touchart, Ghaleb Faour and Christine Romero, "Understanding drought as a physical phenomenon experienced by farmers: a necessity for adaptation management and sustainable rural development. The case of the Central Beqaa in Lebanon", *Dynamiques environnementales* [Online], 48 | 2021, Online since 01 June 2022, connection on 09 December 2022. URL: http://journals.openedition.org/dynenviron/5909

# Understanding drought as a physical phenomenon experienced by farmers: a necessity for adaptation management and sustainable rural development. The case of the Central Beqaa in Lebanon

*Comprendre la sécheresse comme un phénomène physique vécu par les agriculteurs : une nécessité pour la gestion de l'adaptation et le développement rural durable. Le cas de la Beqaa centrale au Liban*

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## Introduction

1 The relationship between agriculture and a natural environment is an essential starting point for defining drought from a farming perspective. Indeed, drought, as a climatic hazard, is one of the components of the natural environment that becomes a risk by disrupting the balance between the needs of a society and the potential resources provided by a given environment (Charre, 1977). This image, which is ingrained in the minds of the population, makes drought in the Beqaa so interesting to follow, define and identify.

2 Thus, farmers may perceive drought differently. It depends on the farmer's physical environment, the type and degree of involvement in their farming activities and the level of impact on their financial well-being (Ashraf and Routray, 2013).

3 Long-term drought risk management is totally absent in Lebanon. Traditionally, an ad hoc strategy for emergency relief measures is applied in the short term to manage climate risks such as drought. Lebanon has failed to manage drought risks for two major reasons:

- There is no centralized, guiding national strategy for drought management. At a broader level, the dysfunction of the government and the country's eternal political paralysis make it difficult to put in place local development strategies to mitigate drought risks (Blanc, 2006; Ghiotti and Riachi, 2013).
- The lack of a drought monitoring mechanism. Monitoring systems act as sources of information to trigger action. The meteorological network is relatively recent and has begun to be rebuilt since the end of the civil war (1975 - 1990), so the data available is limited.

4 In the Beqaa plain, due to its semi-arid and arid climate, especially towards the north, the majority of agricultural areas are strongly linked to groundwater resources during the summer period (Bennafla, 2006; el Hage Hassan, Charbel and Touchart, 2018; Nasser, Faour and Touchart, 2020). Due to the lack of sustainable local development, these resources would be threatened in the event of a probable climate change or a human factor allowing a possible evolution of water stress in the region.

5 Droughts have a disproportionate impact on Lebanon's poorest communities, where agricultural activity is considered the main means of subsistence (Bennafla, 2013). This is particularly true in the poorest governorates such as the Beqaa region, where agriculture is one of the main sources of income and employment (Bennafla, 2006). What does drought mean in a semi-arid or arid agricultural region? Does it originate from the management of an already limited resource to be shared among the farmers of the region? It is therefore necessary to look at the farming practices used by farmers on the one hand and rainfall inputs on the other.

6 In this sense and in order to develop a strategy for adapting to a possible scarcity of water resources, it is necessary to know about drought. Therefore, it is important to have adapted tools and means to provide a database. Several means already exist to measure the level of drought in vegetation to characterize a given environment. These are indicators based on climate data provided by meteorological stations such as precipitation, evaporation and temperature indices. Other indicators are based on satellite data such as NDVI, VHI and NDWI (Bannari *et al.*, 1995; Duchemin *et al.*, 2008; Cook *et al.*, 2016; Nasser, Faour and Touchart, 2020).

7 Despite the importance of these indicators in monitoring climatic hazards, these data remain an indirect witness and can be distorted by anthropogenic factors such as unsuitable crops or irrational exploitation of groundwater.

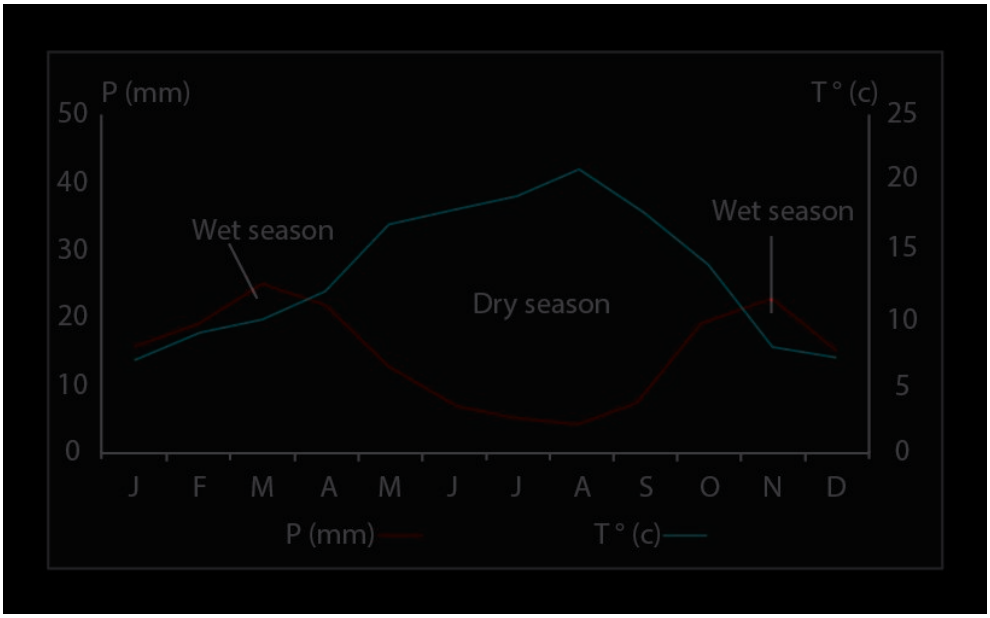
8 Integrating fieldwork can be relevant to understanding drought and its impacts from a farmer's perspective. This work offers a real knowledge of the drought situation in the local context of the study area we have chosen: What is drought for farmers? What are the perceived impacts? What are the farming practices adapted to avoid a drought situation? We faced with elements identified by farmers, based on their experiences, which would help to understand the place of drought episodes in the agricultural system of the Beqaa. Field observation provides another avenue for research on drought identification. However, this phenomenon can be defined differently within the same area. Wondering about the origin of this phenomenon and its definition from a farmer's point of view can help us to better understand this problem. We decided to

identify human and physical elements and to cross them at the level of the perimeter of the study region. We were interested in the relationship between the farmer and the drought because of the close link that exists between the two. The objective of this study is to identify drought by the main economic actors of the Central Beqaa, the farmers. Drought knowledge on current agricultural systems could be used to establish adaptation strategies for sustainable local development. Integrating the field can be relevant to understanding drought and its impacts from a farmer's perspective. This article begins with a presentation of the methodology applied and its implementation in the field. It then discusses the social aspects of drought, the pressures on the resource that lead to a decrease in the availability of the water reserve.

## The study area: an agricultural territory in the Beqaa plain

9 The Beqaa Plain is traditionally a dry area and periods of drought are not a new phenomenon for farmers. Every year it is dry for six or seven months, from the end of the rainy season in March until the commencement of the following year's rainy season in November. The most important period for rainfall (rain and snow) is between November and February (figure 1). It is during this period that the water tables are recharged for use in irrigation during the dry season. The volumetric change in rainfall during this period can have a serious negative impact on agricultural activity in the Beqaa Plain.

**Figure 1 - Umbro-thermal diagram. Realization: T. Nasser, 2021. Source: Rainfall data from 1960 – 2017, Rayak's station.**




10 The study area chosen for this study is bounded by the Beqaa Plain (figure 2). This figure determine the location of the different crops grown in the region. The types of crops planted in the region are varied and divided into four groups: open ground crops, vines, fruit trees and intensive crops. The semi-arid climate of the Beqaa valley and its position in relation to the two mountain ranges the prevailing atmospheric

circulations, characterized by cold winters (figure 3), and very dry summers influenced by the arid climate coming from the Syrian desert.

Figure 2 - Land cover of the study area in the Beqaa center, Source: IKONOS Satellite. Realized by T. NASSER, 2020.

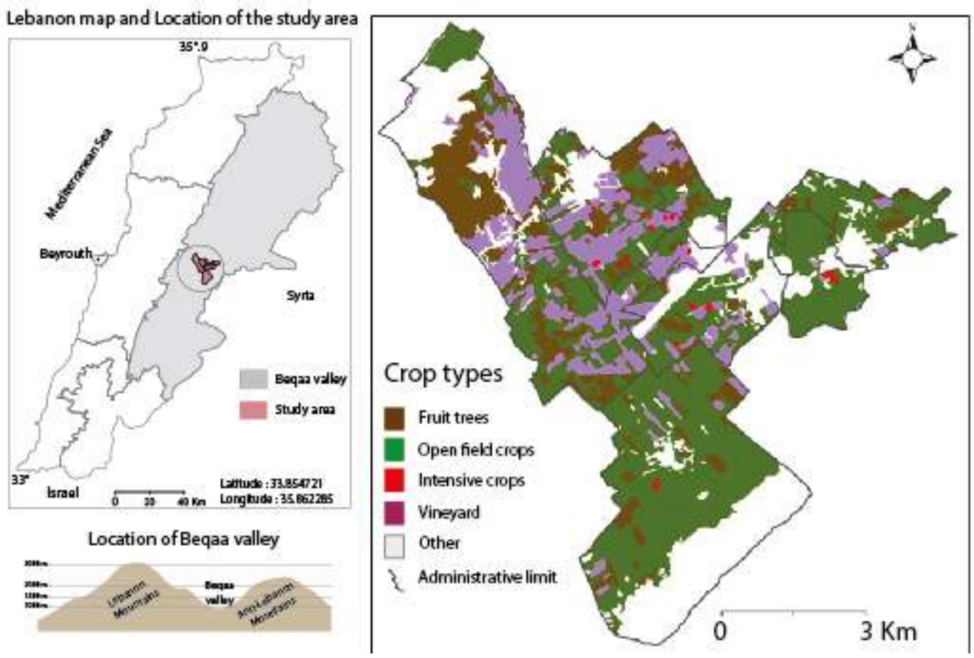



Figure 3 - Mount-Lebanon and Anti-Lebanon, water tanks. Source: MODIS, 2016.


11 The agricultural model of the Beqaa, based heavily on irrigation, gave priority to the massive use of wells, without worrying about water supply during the summer period.

(Nasser, Faour and Touchart, 2020) This overexploitation of water resources, supported by insufficient recharge due to the rainfall deficit, could weaken the region's economic system, which is essentially based on agriculture (Karam and Sarraf, 2010; Nasser, Faour and Touchart, 2020). The number of farms in Beqaa center is large in comparison with other areas of the Beqaa Plain. This can be explained, on the one hand, by the passage within the region of the Litani River, an important source for irrigation, and, on the other hand, the lake of Oronte that feeds the Assi River (figure 4).

12 Our study area represents different permanent agricultural sectors (Table1). To make this table, data from figure 1 was computed using the geographical information System of ArcGIS software. Field crops, dominated by potato cultivation, occupy 59.4% of the region's agricultural area, or about 2,546 hectares. The vineyard constitutes 20% or 873 hectares, fruit trees 18% or 777 hectares and intensive crops constitute only 2% and are cultivated under plastic greenhouses. Most of these cultures are characterized by a high consumption of water to have a stable production (Shaban *et al.*, 2019).

Figure 4 - Circulation of the Oronte and Litani rivers. Realization: T. Nasser, 2022.

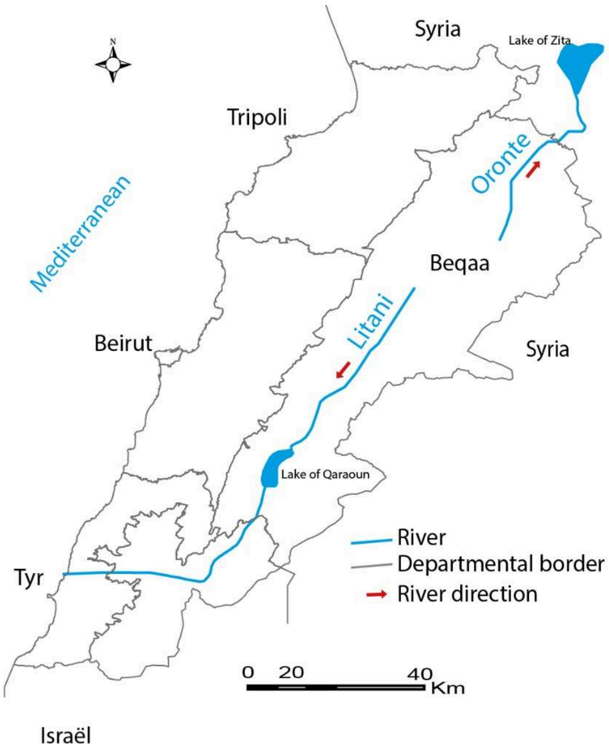



Table 1 - Types of crop land use in the study area. Calculation of GIS data using IKONOS satellite images. Realized by T. Nasser - CEDETE, 2019.

| Landcover | Open field crop | Vineyard | Fruit trees | Intensive crops |
|---|---|---|---|---|
| Surface (ha) | 2546.8 | 873.1 | 777.4 | 89.9 |
| Surface (%) | 59.4% | 20.4% | 18.1% | 2.1% |

## Drought analyzed under its social aspect: a survey methodology

13 In a previous study, we reviewed drought using remote sensing techniques (Nasser, Faour and Touchart, 2020). However, in this research, a qualitative approach, through semi-directive surveys among farmers, was used to obtain a broader picture of the drought situation in the region and to identify the most common impacts and adaptation strategies. Indeed, this type of interview effectively enabled us to collect the precise data expected and more original information, spontaneously delivered in the course of the conversation.

14 We used the qualitative approach to assess the phenomenon of drought in the study area. The qualitative approach, through semi-structured surveys, was used to obtain a larger picture of the situation of the region in the face of drought and to identify the most common impacts and coping strategies adopted by farmers.

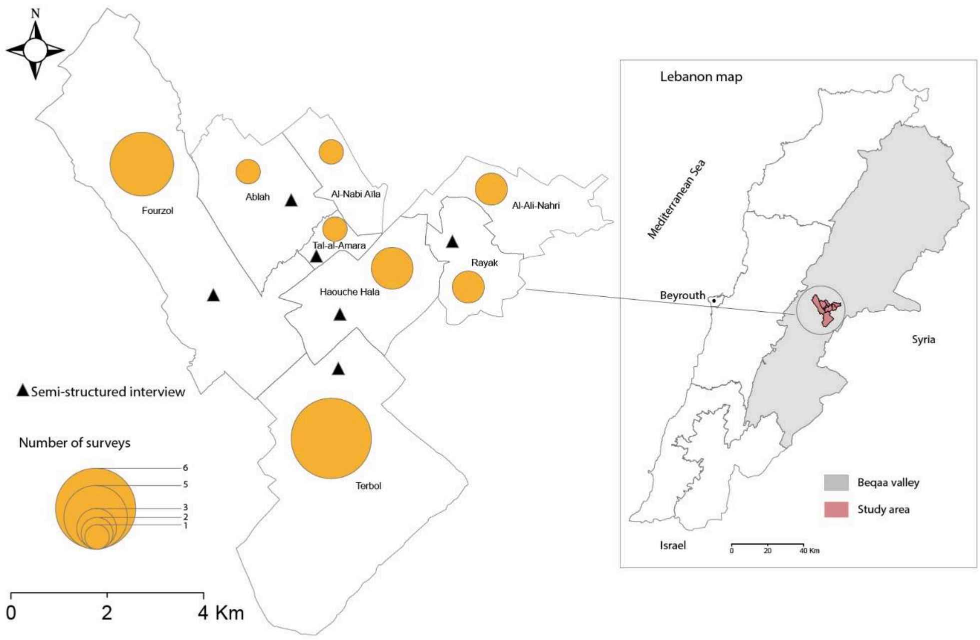
15 A review of each interview was conducted to select similar information. This selection of information permitted a clustering of data and interactions that may appear. Transcription, by using Transcriber software, of the interviews was an important step in our study, allowing for clarification of the information collected.

16 The interviews took place in twelve different locations in the central Beqaa. We conducted two field visits in 2018 and 2019. These interviews have been realized during the agricultural season between mid-March and mid-May (figure 5).

17 In 2018, there were 7 farmers who agreed to complete a semi-directive survey. These interviews were conducted during the agricultural season between the months of March and May. In 2019, we conducted 57 questionnaires in order to collect quantitative data concerning the impacts of the drought on agricultural activity in the region. The majority of the interviews were carried in the farmers' field.

18 Our interviews were often spent with two generations of farmers answering questions together (father-mother and son). Interviewing an older person allowed us to go further back in time and to mobilize as much temporal memory as possible about the evolution of drought perception in the region. We then checked if there was a link between the perceived and lived elements (interviews) and measurable elements such as rainfall data. A quantitative analysis was done from the questionnaire data to generate descriptive statistical data on the impacts of drought. The aim is to extract information that describes the phenomenon of drought and to estimate the impacts of dry spells on farmers' activities.

Figure 5 - Location of farmers surveyed. Source: Fieldwork, 2018-2019. Production and design: T. Nasser, 2020




19 Due to the lack of agricultural census data by region or city, we had set a main objective to ensure that the study was representative. This objective was to meet relatively similar profiles in terms of geographical location (similar climatic, topographical and physical conditions). We considered that this allowed us to conduct an analysis consistent with the territorial characteristics of the study area. The aim of our interviews was not representativeness but the knowledge of the panel of profiles (practices, representations, opinions) in relation to the theme of understanding the drought phenomenon.

20 The interview grid consisted of three parts:

- A general presentation of the interviewed farmer: surname, first name, age, field address and number of dependents.
- The description and evolution of its activity: this part goes into the details of the varieties cultivated, the variation of the agricultural surface used, the type of irrigation used, and the evolution of the irrigation method.
- Experience and the link to dry spells: this is about how farmers define drought and how they deal with it. In addition, a question was asked about the years of droughts that have marked them. This question helps to sketch out analyses on the conduct of their farming activity.

21 We note that half of the farmers surveyed are between 40 and 55 years of age. The average family structure of the surveyed farmer is six people. This is relatively higher than the average family size resident in Beirut, which is four (Verdeil, Faour and Hamze, 2016).

Table 2 - Age of farmers. Source: Field surveys, 2018-2019.

| Age range | Percentage (%) |
|---|---|
| >25 | 6 |

| | |
|---|---|
| 25-40 | 18 |
| 40-55 | 51 |
| 55-70 | 32 |
| < 70 | 3 |

22 The purpose of the interview with these farmers, from different ages, was to examine more closely the direct impacts of the dry spells. These farmers interviewed, in their local languages, about the perception of drought observed on their agricultural activities.

## Drought: what phenomenon and what perception?

23 According to the interviews conducted, various answers emerged from our open-ended question: "How is drought perceived in your region?

24 Farmers also used the terms: it is not new, regular; it is normal, dangerous, recent, worrisome, not regular, occasional...

25 Following the processing of the interviews, these terms were classified into two categories: "usual drought" and "exceptional drought". The so-called "usual" drought is generally considered not dangerous for the crops in place according to the farmers interviewed. They have put in place permanent adaptation strategies during these periods: water storage during the rainy period, additional water inputs for high consumption crops. For this reason, we note that this type of drought does not constitute a remarkable climatic event for these farmers.

26 On the other hand, exceptional drought refers to a period accompanied by a significant rainfall deficit and too high temperature. This type of drought was perceived by one-third of respondents. In these cases, farmers were prompted to increase irrigation hours. For those without adequate equipment, it was through novice systems, such as hoses connected to plastic basins pulled by a tractor and sometimes an animal that they coped.

27 For this reason, we evaluated the second type of drought with farmers. According to them, this has worsened the situation of agriculture in the region especially in the spring period, which is essential for the start of the agricultural season. The evolution of the snow cover, on the two mountain ranges (Anti-Lebanon and Mount Lebanon), was strongly mentioned by these farmers. They observed that the area and duration of the snow have decreased during the last years, as well as the rate and duration of precipitation, which are crucial elements for the farmers in Beqaa. We noted that the majority of respondents reported a decrease in rainfall and only 25% reported irregularity. This shows that a large proportion of farmers have suffered from the changes in rainfall.

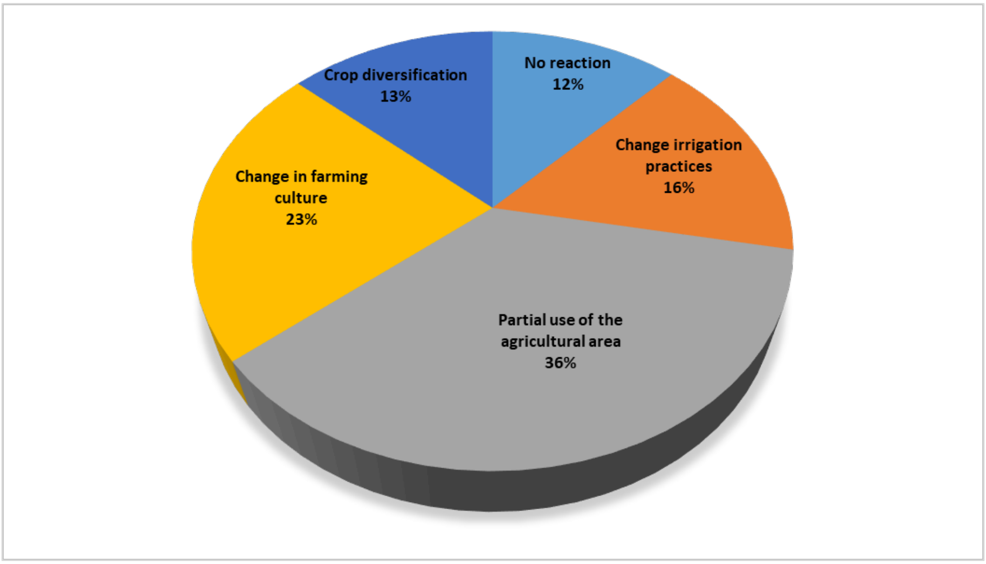
28 On the other hand, less than 10% of the farmers interviewed think that the water shortage is due to management (field survey). This group of farmers believes that agricultural wells are heavily used during the dry season, especially with the appearance of dry periods, which puts a great pressure on the groundwater resource.

Thus, they consider that the massive and chaotic implantation of wells is an important factor in the drying up of the water source and the variation of the stockage water level.

29 Concerning crop production, loss was the main impact that was mentioned by the farmers. Half of the farmers reported reduced harvests due to low rainfall and increased crop diseases and pests (aphids, leafhoppers, cochylis, etc...). Most farmers in the region have faced similar situations several times in recent years. We noted that the legumes production, especially potatoes, showed a significant loss of yield and sometimes it has exceeded 50% always according to these farmers.

30 However, we observed during our surveys that losses varied greatly from one farmer to another. This can be explained by the farming practices used by each farmer such as irrigation methods, crop sowing, agricultural practices and water storage strategies (figure 6).

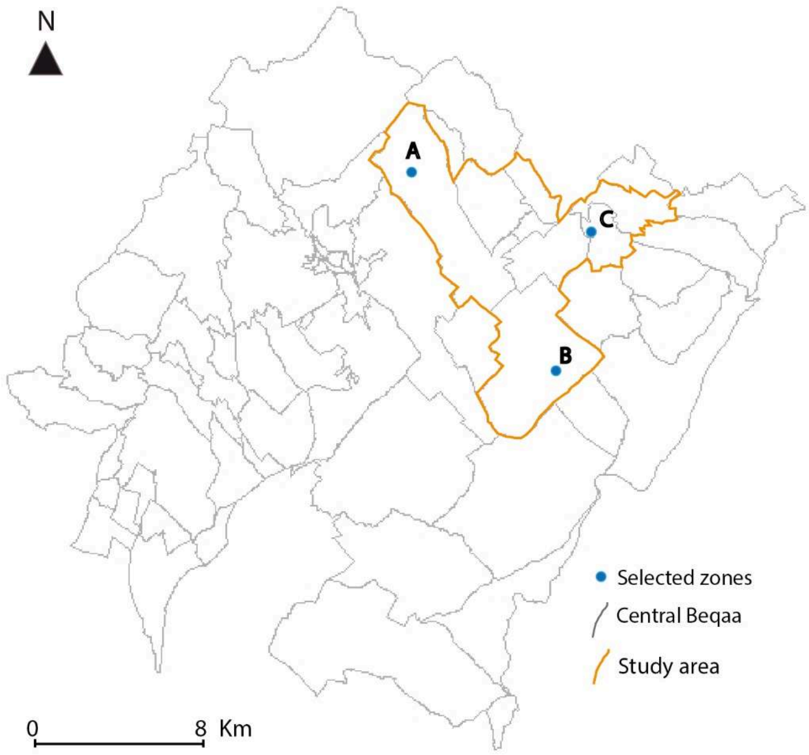
Figure 6 - Measures adopted by farmers because of the drought. Source: Field surveys, 2018-2019. Realization: T. Nasser, 2019.




31 To highlight the role of agricultural practices on drought intensity, we selected three farmers in our study region, using almost the same field size to make a spatial comparison of the health status of agricultural crops (figure 7). Potato crops occupy the agricultural surface used by these farmers.

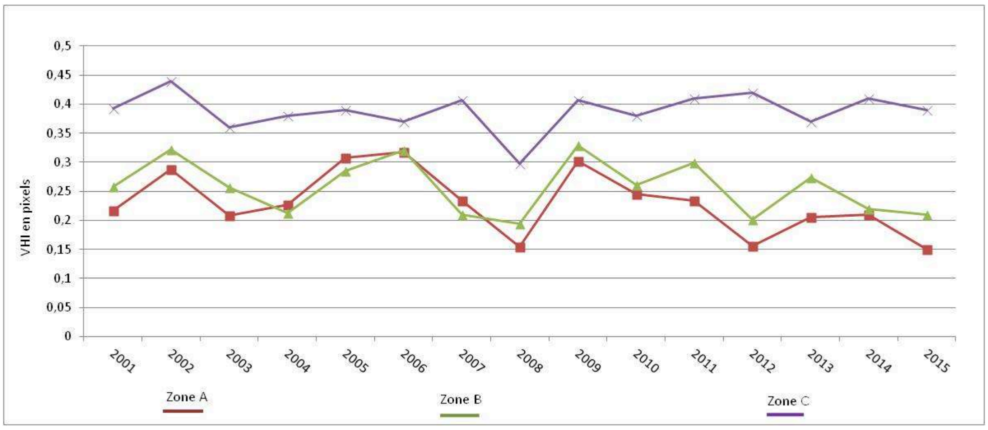
32 Farmers A and B have almost the same profile. Both have a medium level of education and they apply the same agricultural practice in their fields. They have both non-metered agricultural wells. The irrigation system is based on the use of sprinkler. The first farmer irrigate 8 to 10 hours daily during the growth season. The second one irrigate 6 hours per day. While the third farmer (C) has different criteria. Education wise, he has a higher level than the two previous farmers. He has an agricultural well on his land with a counter and a pressure regulator. He has also an underground basin and an artificial pond to collect rainwater.

Figure 7 – The three cases studied to compare the relationship between agricultural practices and drought. Source: Field surveys, 2018-2019 Realization: T. Nasser, 2019.




33 To make such spatial comparison between three farmers, the Vegetation Health Index, issued from MODIS-TERRA[1] satellite, was calculated, using ArcGis software, from the available data series from the period 2001-2015 (figure 8). As a reminder, The VHI is a one of the first attempts to monitor and identify drought-related agricultural impacts using remotely sensed data (Kogan, 2001). According to the formula of Kogan, a VHI value lower than 0.2 indicates a strong drought. The value between 0.2 and 0.4 refers to weak drought. The value above 0.4 considered a normal condition.

Figure 8 - Average variation of VHI values observed over the period 2001-2015 for the selected plots in the Central Beqaa region.




34 The value of VHI in the three agricultural plots do not show the same evolution over the period studied. Plots A and B show a variable VHI from year to year. It indicates mostly light drought in intensity. The years 2008 and 2015 show periods heavily

impacted by drought with a VHI value that is less than 0.2. There is also a decreasing trend in VHI starting in 2010. Thus, water use in plots A and B is excessive than in plot C. This may have caused the wells to dry out more quickly and increase the intensity of the drought.

35 We find that plot C is less impacted by drought because the VHI shows a few variable of values and mustly stability during the study period. We also note that 2008 was an exceptional year with drought for farmers. Despite the high intensity of the drought during this period, farmer C was less affected than the other two. This may be due to different farming practices than the other two plots. Thus, optimal water use and management helped to combat the deficit periods.

## The need for a planning strategy for sustainable local development in the Beqaa plain

36 In our study region, the exceptional drought experienced over the last decade has become an event as a risk for farmers especially for those who have not made an adaptation of agricultural practices (Farmers A and B). Thus, cumulative drought cycles with a lack of winter recharge require water management at the farm level.

37 The analysis of recent droughts by our surveys shows that farmers in the region have started to put in place immediate solutions to cope with present and future risks (figure 5). The evolution of constraints to farmers is dependent on the magnitude of these episodes (level of rainfall deficits and its duration).

38 Some of the farmers interviewed (field vegetable and potato growers) made the choice to invest in irrigation equipment (electric pumps, sprinklers, drip irrigation), construction of underground ponds or to install artificial ponds (like farmer C). The aim of these type of farmers was to build up their own water reserves to be able to persist in the face of exceptional dry periods. Thus, this type of farmer is convinced that the frequency of such episodes will increase over time. For this reason, securing the crops becomes a necessity for these farmers who have farming as their main income.

39 In our case, we selected the major problem identified by farmers: water shortage or water deficit during the dry period.

40 The main objective is to save water by developing potential agricultural management tools:

41 ***Irrigation:*** efficient irrigation management is essential for a more sustainable development of agricultural wells. We present in table 3 two irrigation management methods: annual and weekly.

**Table 3** - Irrigation management conducted for several years. Realization: T. NASSER, 2018.

| Annual | Weekly |
|---|---|
| -Adapt the choice of irrigation to economic and hydric constraints<br>- Adjust the projected watering schedule and equipment usage plan | - Irrigation management during an agricultural season according to current events<br>- Irrigation equipment management and control |

| | |
|---|---|
| Farmers take into account the climate of previous years | Farmers take into account the current observed climate |

42 Managing the ratio (Soil Evaporation/Transpiration): Decreasing the ES/T ratio can be achieved by mulching or by choosing a variety characterized by rapid soil cover. This technique makes it possible to conserve the water reserve and improve the yield of the existing crop (Debaeke and Aboudrare, 2004; Passioura, 2006).

43 ***Adjust the date of the crop cycle:*** This adjustment can be made according to climate or groundwater availability.

44 Depending on the climate: in our case, the Mediterranean climate, early sowing with the onset of rains (mid-autumn in Lebanon) could increase the potential yield due to the large water stock available in the groundwater (Turner, 2004). This method has been shown to be successful for legumes characterized by an indeterminate flowering period (Turner, Wright and Siddique, 2001). For example, this method was applied in Syria for faba beans, where production was higher than with supplementary or supplemental irrigation. Another example is Israel, which has a climate close to that of Lebanon. Sorghum with sowings in mid-March (versus mid-April) gave better yields with reduced water consumption (Blum, 2011). In fact, the amount of water consumed, in the case of early sowing, is less during the first phases of the cycle when the leaf index is lower and the development of the root system is slower. This allows a prolonged maintenance of the leaf surface.

45 The only risk of this method comes from diseases and late frost (often during the night in Beqaa) which can affect the return of cereals.

46 ***Depending on groundwater availability:*** Crops in our region are often planted in the spring (April-May) when evaporation is moderate. However, the vegetative growth phases fall in periods when the risk of water deficit is higher (late May - June). For this, farmers speak of irrigation difficulties due to the depletion of agricultural wells. Irrigation at the end of the agricultural season sometimes encounters problems, especially in years when the winter recharge of the soil reserve is low. In order to overcome the drying up of wells, an adjustment of the crop cycle to the available water resource can be made. This involves sowing crops in the autumn or winter instead of spring. This change in seeding time eliminates the need for supplemental irrigation at the end of the crop season for crops such as wheat, barley and peas. Thus, this method has been applied in southern Spain and Morocco (Gimeno, Fernandez-Martinez and Fereres, 1989; Boujghagh, 1990). This method requires the selection of cold-tolerant species, weeding and nitrogen fertilization.

## Conclusion

47 The objective of this study was to identify the impact of drought on farmers' activity, in order to assess the difficulties encountered in coping with this phenomenon.

48 The analysis of the surveys made it possible to distinguish between two types of agricultural drought: the usual drought and the occasional drought. The usual drought is considered 'normal' or 'non-hazardous' in traditionally dry regions, such as the Beqaa plain, because existing agricultural practices are adapted to cope with this type

of drought. Thus, this drought is not a remarkable event for farmers because they apply supplementary irrigation to complete a crop cycle and maintain their yield, as is the case in the Beqaa Plain. On the other hand, the occasional drought corresponds to an exceeded threshold in which the agricultural system is unsuitable. This event often occurs after a winter period with a deficit in rainfall, a period of groundwater recharge, causing a phreatic drought (Lambert, 1996). At this time, unsuitable irrigation can lead to the drying up of agricultural wells

49 In the light of the results obtained, we can therefore say that agriculture's heavy dependence on irrigation in the Beqaa, subject to the amount of water available, could become more vulnerable to what farmers define as "occasional drought". We are therefore in the presence of a drought that has a direct impact on agricultural practices. Farmers are then more confronted with this phenomenon, which affects them in their short- and medium-term farm management. They should therefore reorient their agricultural practices to face the risk of drought: implementation of water-saving techniques either by changing irrigation equipment or by changing crops. This is why, the implementation of an agricultural development strategy in which water resources would be better distributed during the year is also a solution to the adaptation of agriculture to the risk of increasing drought intensity.

50 There is, however, a limitation in our study regarding the location of investigations. Indeed, our field of study only forms a local or even micro-local scale. It could therefore be extended and developed on a regional scale in order to form a large set of social and economic data, and to better understand the stakes of water management at the territorial level.

51 Finally, the context of sustainable development and more particularly agriculture leads to prospective reflections to be taken into account in order to mitigate the impacts of future droughts. Indeed, our study is based on retrospective data. A more advanced agronomic approach, taking into account the phenological stages of crops, would improve the realism of drought. Farmers could be integrated into a program to monitor the frequency and intensity of drought using adapted agricultural practices, which are addressed in this study. This brings an additional and more applied dimension to this work. The interpretation of the results of this program could be used as an aid to decision-making. This monitoring program will also allow testing the impact of different types of crops on water reserves and drought intensity in the context of sustainable agriculture.

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## NOTES

**1.** Moderate Resolution Imaging Spectroradiometer: satellite-based sensor used for earth and climate measurements.

## ABSTRACTS

The relationship between agriculture and its natural environment is an important starting point for defining drought from an agricultural perspective. Indeed, farmers may perceive drought, as a climatic risk, differently. This could depend on the physical environment of the farmer, the

type and degree of involvement in his agricultural activities as well as the level of impact on his financial well-being (Ashraf and Routray, 2013).
In Lebanon and particularly in the Beqaa plain, the majority of agricultural areas are strongly related to groundwater resources during the summer period. Due to the lack of sustainable local development, these resources would be threatened in the case of a probable climate change or a human factor allowing a possible evolution of water stress in the region.
Questioning the origin of this phenomenon and its definition from the farmer's point of view can help us to better understand this problem. The objective of this study is therefore to identify the drought by crossing the human and physical elements in the perimeter of the study area.

La relation entre l'agriculture et son environnement naturel est un point de départ important pour définir la sécheresse d'un point de vue agricole. En effet, la sécheresse, en tant que risque climatique, peut être perçue différemment par les agriculteurs. Cela pourrait dépendre de l'environnement physique de l'agriculteur, du type et du degré d'implication dans ses activités agricoles ainsi que du niveau d'impact sur son bien-être financier (Ashraf et Routray, 2013).
Au Liban et particulièrement dans la plaine de la Beqaa, la majorité des zones agricoles sont fortement liées aux ressources en eau souterraine pendant la période estivale. En raison de l'absence de développement local durable, ces ressources seraient menacées dans le cas d'un probable changement climatique ou d'un facteur humain permettant une possible évolution du stress hydrique dans la région.
S'interroger sur l'origine de ce phénomène et sa définition du point de vue de l'agriculteur peut nous aider à mieux comprendre ce problème. L'objectif de cette étude est donc d'identifier la sécheresse en croisant les éléments humains et physiques dans le périmètre de la zone d'étude.

## INDEX

**Keywords:** Drought, adaptation, climate change, sustainable agriculture
**Mots-clés:** Sécheresse, adaptation, changement climatique, agriculture durable

## AUTHORS

### TAREK NASSER

CEDETE - Centre d'Etudes pour le Développement des Territoires et l'Environnement

### LAURENT TOUCHART

CEDETE - Centre d'Etudes pour le Développement des Territoires et l'Environnement

### GHALEB FAOUR

CNT/CNRS LIBAN - Centre National de Télédétection

### CHRISTINE ROMERO

CEDETE - Centre d'Etudes pour le Développement des Territoires et l'Environnement