Climate Change Adaptation Measures and Their Determinants:

A case of farm-level in Rachaya Bekaa, Lebanon

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Abstract

Climate change is increasing the detrimental effects on agricultural productivity. Effective adaptation measures are crucial to cope with climate change impacts to reduce farmers' vulnerability and build resilience. Therefore, this study conducted surveys in the Bekaa Valley of the Rachaya district to identify the most common measures farmers use to adapt to climate change, the factors influencing their adaptation, and their perception of climate change. Crop diversification, efficient water irrigation systems, and change in planting dates are the most used adaptation measures among 185 farmers. The multivariate probit model results showed that age and crop pest attack significantly influence the adoption of crop diversification, whereas training, crop pest attacks, floods, access to climate information, and social capital significantly influence the adaptation measure of efficient water irrigation systems. Change in planting dates was affected negatively by access to credits and schooling years; however, access to climate information and social capital were positively influenced. Our findings show that farmers adopt measures that are not aligned with the increase of precipitation levels, have a weak educational background, minimal youth participation, and face credit constraints. On the other hand, receiving climate-related information and participating in social groups significantly impacts the adaptation measures chosen. Therefore, the implications for policymakers will be implementing climate change learning centers, agricultural and credit policies, establishing agricultural schools and tailored programs, and forming social clubs. These will enhance the agricultural sector and adaptation to climate change.

Keywords: Climate change, adaptation measures, Lebanon, Multivariate Probit Model, farmer, and agriculture.

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Abbreviations

MVP: Multivariate Probit Model

IPCC: Intergovernmental Panel on Climate Change

NGO: Non-governmental Organization

USAID: U.S. Agency for International Development

LARI: Lebanese Agricultural Research Institute

1.Introduction

Climate change is currently affecting almost all regions around the world, making it one of the most critical challenges facing humanity today. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), extreme weather events like droughts, floods, storms, and cold and heat waves will become more frequent and severe in the next few years. There are several threats associated with the occurrence of these extreme events. Looking at it from an agricultural perspective, Foguesatto et al. (2020) and Khanal et al. (2018b) showed that it will lead to high economic losses, increase farmers' vulnerability, and endanger food security for many people, especially in developing countries. Although a significant effort was seen in implementing mitigation policies and strategies to reduce the negative impact of climate change, Dessai et al. (2005) argued that mitigation alone is not sufficient, and the European Commission (2021) emphasized the need to employ adaptation. Therefore, the focus of this study will be on the adaptation measures at the Lebanese farm level.

Adaptation, as defined by IPCC, is "the process of adjustment to actual or expected climate and its effects" (IPCC, 2014: Chp 14). Several studies in the literature have shown that adaptation sustains production, enhances agricultural yield, increases farmer's income and welfare, reduces vulnerability, and builds resilience (Mottaleb et al.,2017; Ahmad et al., 2020; Schonhart et al., 2016; Hernandez et al., 2018; Vizinho, 2021). However, it was pointed out that the socioeconomic conditions (e.g., age, gender, household size, education, and farm size), local institutions (e.g., social capital), farmers' perception, and environmental factors (e.g., droughts, floods, and crop pest attacks) play a crucial role in influencing the decision to adopt climate change measures (Arbuckle et al., 2015; Atube et al., 2021; Below et al., 2012; Mwinkom et al., 2021; Marie et al., 2020). Moreover, Tesfahunegn et al. (2016) and Islam et al. (2020) argue that identifying the determinants of local climate change adaptation is absolutely crucial since it assists in ensuring policy interventions relevant to local climate issues. Therefore, this paper aims first to determine the adaptation measures adopted by farmers and second to assess the factors that influence farmers' adaptation measures.

While a significant body of research exists to assess the factors that influence farmers' adaptation measures globally, this does not include Lebanon. The adaptation topic in Lebanon is under-researched and limited to two studies we found. Mahfoud and Gerard (2021) studied the local adaptive capacity among apple grower farmers in the mountains, while Dirani et al. (2021) examined the small family farmers' perceptions and attitudes towards climate change and identified the adaptation measures in central Bekaa. Although both studies determined the adaptation measures used among farmers, they did not assess the factors influencing farmers' adaptation measures. Moreover, the geographic area that Mahfoud and Gerard targeted was the mountains, and for Dirani, it was Central Bekaa. Therefore, we could say that our paper will get different results than the abovementioned papers since we will be taking Rachaya as our study area. Alternatively, most studies that are found investigate the factors that influence farmers' adaptation decisions and not the type of adaptation measures taken by the farmers (e.g., Zamasiya et al., 2017; Arunrat et al., 2017; Le Dang et al., 2019). The latter studies are hypothetical and assume either adaptation or no adaptation option disregarding the effect of specific adaptation measures taken. In other words, their findings only account for the farmers' decision to adopt, not their adaptation measures.

Moreover, few studies have taken farmers' adaptation measures as their dependent variable; however, they only considered a single adaptation measure (e.g., Seo & Mendelsohn, 2008;

Asmare et al., 2017). Nevertheless, farmers usually adopt more than one measure to reduce climate-related risks. Therefore, the latter studies do not give the complete information needed, leading to an incomplete understanding of the farmers' adaptation decisions. Furthermore, other studies base their studies on a national and household level instead of farm level (see Alam et al., 2016; Bryan et al., 2009; Tiwari et al., 2014). However, Adger et al. (2005) mentioned that adaptation actions take place within hierarchical structures such that the levels interact with each other. Nevertheless, for these actions to take place, we need to start from the bottom of the hierarchical diagram to reach the top. Hence, it is essential to examine the adaptation measures at the farm level.

On that note, the contribution of this paper is first filling the gap that is present in the Lebanese adaptation literature, which allows policymakers to formulate appropriate policies by integrating sensitive factors for implementing and enforcing climate change adaptation measures in agriculture that can increase resilience, as well as for future research. In addition, taking the three most adopted adaptation measures among Lebanese farmers and assessing the socioeconomic and environmental factors that affect the adaptation measures taken by farmers using the multivariate probit econometric model provides more accurate estimates between each adaptation measure chosen and the explanatory variables. Also, we will be contributing to the international literature by taking the type of farmers' adaptation measures as our dependent variable instead of farmers' decisions to adopt adaptation measures or not to adopt (as has been done in most of the existing studies). Our approach gives more precise information on what factors influence specific adaptation measures, which allow governments to directly target the constraints and the significant factors and implement the right policy for every measure. The following sections of the paper have been arranged as follows: section 2: background, section 3: literature review, followed by sections 4 and 5 of a conceptual framework and method and data. Section 6 portrays results and discussion, which is followed by section 7 of conclusion and policy implication.

2.Background

Located in the eastern basin of the Mediterranean Sea, Lebanon is a small country with a land area of 10,452 square kilometers and a population of 6,8 million. The country has a coastline of 225 km and a mostly mountainous landscape. Lebanese people enjoy a Mediterranean climate characterized by dry and hot summers and cool and rainy winters. The annual mean temperature and precipitation are 16°C and 638.42 mm (Climate Change Knowledge Portal, n.d). Precipitation is distributed widely across the country; therefore, five distinct agro-climatic zones are observed along the coastal strip, in the low and middle altitudes of Mount Lebanon, as well as in western, central, and northern Bekaa (IUCN, 2013). In consequence, this allows for an agricultural production that is highly diverse, resulting in high productivity, higher profitability, and comparative advantage (Jeanmougin, 2017). According to the Chamber of Commerce Industry and Agriculture trade report (2020), Lebanon exports vegetables and fruit preparations and fruits and citruses to neighboring countries like Saudi Arabia, Qatar, and Turkey. The agriculture trade is mainly dominated by the country's most important crops, such as potatoes, tomatoes, apples, grapes, cereals, and olives (IDAL, 2020).

Although Lebanon has geographical and climate advantages over its neighboring countries, its complicated history, and unstable political and economic events affected different sectors of the economy, especially the agricultural one. It is worth mentioning that Lebanon went under the French mandate and got its independence in 1943. After receiving independence, and more precisely under the mandate of General Fouad Chéhab, Lebanese agriculture showed an impressive growth of 48% of the Gross National Agricultural Product (GNAP) in 4 years between 1962 and 1966 (Saade, 2021). However, the agricultural institutions were destroyed, and the export market structures collapsed after the outbreak of the civil war from 1975 to 1990 (ibid). The '90s were marked by the reconstruction of the country and an ultra-liberal economy, favoring the service and tourism sector and putting aside the industrial and agricultural sectors. The latter's effect has been affirmed by the International Labor Organization Statistics (ILOSTAT) database, which shows that the percentage of the total employment in agriculture decreased from 43.675 % in 1991 to 26.692% in 2019 (World Bank Group, n.d.).

Agriculture in Lebanon continues to be agonizing not only because of government neglect but also because climate change is exacerbating the problem. While climate change is an essential topic today, its impacts have been present in Lebanon since the 1950s, where the temperature has been linearly increasing by 0.7 °C till 2000 (Climate Change Knowledge Portal, n.d). An explanation for the temperature rise comes from the findings of an International Union for Conservation of Nature (IUCN, 2013) report, which mentions that in 2000 Lebanon's total emissions reached 18.5 million tons, showing a 2.77% annual rise since 1994. Furthermore, precipitation has fallen by 12 percent in Lebanon since the 1980s (Shaban, 2009). The changing precipitation patterns and increased temperatures lead to lower crop yields, weed and pest proliferation, and an elevated drought risk (Niles & Mueller, 2016; World Bank, 2015). According to Bergaoui et al. (2015), the intensity of drought events in Lebanon has significantly increased in recent years due to climate change, and 2001, 2008, and 2014 were considered to be three of the most significant drought years. Additionally, climate projections for 2040 indicate an increase in temperature in the summer of 1°C along the coast and up to 2°C in mountainous regions, as well as an increase in temperature from 3 to 5°C by 2090 (MoE/UNDP/GEF 2011). Moreover, climate models have also projected that global warming will likely affect Lebanon's precipitation and snowpack and shorten the snow season (Karmalkar et al., 2010; MoEW, 2010). In a study by Fayad et al. (2017), altered snow dynamics will impact Lebanon's major surface and groundwater basins, resulting in altered water availability patterns.

In short, all of these environmental and political factors place pressure on the Lebanese farmer leaving him/her in a vulnerable position and without protection. Moreover, agricultural budget allocations have never exceeded 1 percent of the annual national budget (FAO, 2021). As a result, agricultural services in Lebanon have been limited in terms of funding, staffing, and skill levels, thereby limiting farmers' ability to operate. Therefore, UNFCCC (2006) emphasized that adaptation is inevitable in light of climate change. According to Smit & Skinner (2002) and Adger et al. (2007), adaptation in agriculture is evolutionary. It is influenced by several forces such as climate, economic, social, and political forces that are difficult to segregate, and most practices serve multiple purposes and are highly intertwined (ibid). On that note, the literature review will elaborate more on the climate change adaptation measures and the socioeconomic and environmental factors that affect farmers' adaptation.

3.Literature Review

3.1 Climate change adaptation measures

According to Akinnagbe and Irohibe (2014), adaptation can have three objectives: reducing exposure to damage risks, coping mechanisms for unforeseen damage, and taking advantage of new opportunities. In order to achieve the adaptation objective, an effective measure should be developed and implemented to mitigate climate change impacts on agriculture. As reported by Bradshaw et al. (2004) and Kandlinkar and Risbey (2000), adaptation measures can occur either at a farm level (micro-level) or at a national level (macro-level). On the farm level, adaptation is based on decisions made by farmers in response to changes in climate, economy, and other factors on a short-run basis; at the national level, adaptation focuses on national policies and decisions which are based on a long-term view of climate, market and other factors (ibid). However, we will be focusing our attention on farm-level adaptation measures in this paper, as it is crucial to deliver information that can be used to formulate policies to improve adaptation to manage the aforementioned climate-related risks.

The most common and important adaptation measures used globally on a farm level are crop diversification, adjusting the degree and timing of fertilizers, applying soil conservation techniques, changes in planting dates, increasing and decreasing plantation size, using different crop varieties, water efficient irrigation system, and growing crop tolerant varieties (Bradshaw et al., 2004; Nhemachena & Hassan, 2007; Molua, 2002). According to Lin (2011), diversifying crop types can be a safe and cost-effective measure to improve the resilience of agricultural systems and reduce risks in the face of climate change. Diversification of crops also improves food security and allows farmers to sell surplus products at markets, obtaining additional income for household needs (Khanam et al., 2018). Additionally, crop diversification may also present the best route for improving crop yields through disease and pest control, increasing soil fertility, and enhancing the efficiency of local agroecological systems (Malaiarasan et al., 2021).

Utilizing soil conservation techniques has been found to provide farmers with a firewall against the destruction caused by drought, reduce crop loss risks, increase water use efficiency, and preserve soil quality (Aryal et al., 2020). In addition, Hunt et al. (2019) demonstrate that changes in planting dates and, more precisely, earlier planting dates usually result in higher yields. Affirming the latter, in India, wheat and rice planting dates were shifted 15 days earlier than the usual practice, minimizing yield losses by more than 4% (Jalota et al., 2013).

Besides reducing the negative impacts of climate change on agricultural systems, the use of crop varieties helps to ensure stable agricultural production, enhance biodiversity and ecosystem, reduce crop failure, and leads to diversified agricultural production (EEA, 2019). In addition to improving crop varieties, fertilizers were also developed to increase crop yields (Magen, 2008). Despite this, excessive chemical fertilizers can cause soil hardening and lower soil organic matter, ultimately leading to depletion of soil productivity (Wang et al., 2019). Utilizing an irrigation system that can dissolve nutrients for uniform distribution could be one way to reduce excessive chemical fertilizer usage and manage limited water supplies and increase crop profitability (IFC, 2014; Enciso et al., 2015). According to the International Finance Corporation (2014), the key benefits and impacts of irrigation systems are increased crop quality and yield, higher incomes, sustainability, and decreased input use. Moreover, in recent years, crop types and varieties that are tolerant to drought and high temperatures have steadily shifted, as well as those adapted explicitly to harsh climatic conditions (FAO, 2011). Tesfaye et al.

(2017) found that maize varieties with drought and heat tolerance could counteract the negative impacts of hotter and drier conditions in Eastern and Southern Africa and South Asia, increasing food security. In Zimbabwe, farmers that planted drought tolerant maize varieties have earned an additional USD 240 per hectare (Lunduka et al., 2017).

Despite that, one of the main challenges of adapting to climate change is that they are highly localized, and their implementation can vary depending on the geographical area and agricultural settings (Tesfaye & Nayak, 2022; Ali & Erenstein, 2017). Based on the geographical area and agricultural settings, farmers use different adaptation measures within the same country. For example, in Lebanon, smallholder farmers in central Bekaa applied mixed cropping, soil conservation techniques, crop rotation, and increased chemical fertilizers usage as their adaptation practices (Dirani et al., 2021). On the other hand, Mahfoud and Gerard (2021) results show that the adaptation measures used the most in four different zones in the mountain area of Lebanon from apple grower farmers' behalf were crop diversification, water efficient irrigation system, rainwater harvesting, and reducing planting size. Moreover, Farajalla (n.d) mentioned that in the Kfardebian district, which follows the Mount Lebanon governorate, the adaptation measures used are changing the irrigation system, changing planting species, changing the planting time, and buying water. As such, it is apparent that farmers employ various measures even within the same country and even within the same geographic area. Hence, to understand why farmers adopt different adaptation measures, we will evaluate their socioeconomic and environmental factors. Moreover, for policymakers to design and promote successful adaptation policies in the agricultural sector and to precisely understand farmers' adaptation measures, we need to consider farmers' perceptions of climate change. Foguesatto et al. (2020) mentioned that the decision to adopt and what to adopt lies within the farmer. However, their decision is dependent on how well they perceive climate change (ibid). Additionally, Maddison (2006) argued that for farmers to implement effective adaptation measures, they must first acknowledge that the climate has changed. Therefore, we dedicated a section in our survey regarding farmers' perceptions to assess if they are perceiving the changes in climate.

There are many shapes and forms of adaptation, depending on the specific context of a community, country, or region (UNFCCC, n.d.). The literature discussed above shows that different adaptation measures are implemented to cope with different climatic changes and risks. Therefore, and based on the adaptation measures type that was addressed in Dirani et al. (2021), Mahfoud and Gerard (2021), and Farajalla (n.d), we combined several measures from these studies and addressed them to the farmers in the Rachaya district to evaluate what type of adaptation measures do they implement on their farms. These measures include crop diversification, water efficient irrigation system, change in planting dates, crop rotation, growing crop tolerant varieties, growing different varieties on the same plot, increased use of chemical fertilizers, off-farm activities, rainwater harvesting, reduction of planting size, applying soil conservation techniques, and others.

3.2 Socioeconomics and Environmental Factors

One of the prerequisites for understanding climate change adaptation measures is identifying the factors that might impact farmers' adaptation decisions (Vo et al., 2021). Deressa et al. (2009) state that the choice of climate change adaptation methods or farmers' reactions is strongly influenced by a host of socioeconomic and environmental factors. Also, Reidsma et al. (2010) mentioned that regional socioeconomic factors influence agricultural adaptation. By knowing these socioeconomic and environmental factors, policymakers can implement appropriate interventions and formulate a policy to protect farmers from climate change impacts.

When adapting to climate change, education can be a powerful tool (IPCC, 2014). Education allows farmers to receive and better understand climate information and how to deal with it, and the higher the educational level, the higher the chances of farmers' understanding (Maddison, 2006). Moreover, Zamasiya et al. (2017) contend that farmers' beliefs and perceptions about climate change can be improved through education, leading to better behavior and more intent for adaptation.

Gender[1] is one of the most influential variables affecting farmers' decision-making for adoption (Bayard et al., 2007). Gender-based vulnerability and consequent adaptation and adaptive capacity to climate change are becoming increasingly recognized, especially in developing countries (UNDP, 2012). Women and men may choose different climate change adaptation strategies because they hold different levels of education, assets, and other resources, Bayard et al. (2007) state. Over and above that, marital status is considered an essential factor in a farmer's adaptation strategy. Two studies in Nigeria and Ghana proved that marital status has a negative significance level on farmer adaptation (Ogunpaimo & Dipeolu, 2019; Denkyirah et al., 2017). In Ethiopia, marital status positively affected early and late planting adaptation measures and had a negative effect on all other adaptation measures (Marie et al., 2020). Hence, this variable depends on the type of adaptation.

The farmer's age has a positive influence on perceptions, attitudes, and practices regarding climate change adaptation (Burton, 2014), and it is also highly correlated with the farmer's experience (Genius et al., 2006). Thus, older farmers are likely to know more about climatic patterns, how they impact farming, and the measures they may take to minimize climate change impacts. Farmer's experience over the years grants them to know more about climate patterns and how this will impact their farms and contribute to the way they acknowledge risks. Older farmers are generally considered more risk-averse than their counterparts, which explains why they are more prone to adjust to climate change (Zamsiya et al., 2017). In this sense, age and experience positively affect farmers' intentions toward adopting climate change adaptation.

The number of households in a case study done in Ethiopia (Feleke et al., 2016), Nigeria (Adeagboa et al., 2021), and Thailand (Arunrat et al., 2017) showed to influence farmer's decisions for climate change adaptation. Furthermore, it was found that larger households adopt new technology more frequently than smaller households (De Souza Filho et al., 1999; Abdulai et al., 2008). Climate change adaptation is influenced by the size of the farm and land ownership, which increases the likelihood of adapting (Arunrat et al., 2017). The extension of the size and ownership of farms allows farmers to be more flexible in their adaptation strategies since they have more capital, a larger farm area, and the freedom to practice new farming methods (Arunrrat et al., 2017). Moreover, farmers can be encouraged to invest in equipment and resources by the availability of land ownership (Kokoye et al., 2013). Another valid reason why farmers are motivated to adapt to climate change is that they will be handing over their farms and land to the next generation (Arunrat et al., 2017)

Lack of credit accessibility significantly inhibits agriculture investment in adapting to climate change (Ojo & Baiyegunhi, 2020a), as well as the absence of climate information that poses significant economic and environmental threats (Karner et al., 2019). Ojo et al. (2021) mentioned that to minimize the risk associated with climate change's impact on agriculture,

[1] The gender variable was omitted later due to the absence of women's participation in the survey.

providing farmers with an accessible financial solution is critical. Moreover, it was found that access to information positively influences behavioral intentions and leads to an efficient and sustainable adaptation to climate change (Zamasiya et al., 2017; Carr & Onzere, 2018; Carr et al., 2020). On top of that, Arunrat et al. (2017) argued that through training and social capital engagements, farmers could share their experiences and information, which improves their confidence in adopting new technologies, including securing credit, to be able to invest more in adaptation strategies (Arunrat et al., 2017). Similarly, Wang et al. (2015) outlined that social capital could represent a social network where information and assistance are exchanged, allowing more options for adaptation. Nevertheless, climate shocks that the farmers experience also influence adaptation.

Furthermore, climate shocks such as floods, droughts, and pest attacks cause farmers to face more significant risks. For example, in sub-Saharan Africa, maize farmers have lost half of their harvest due to frequent drought events (CIMMYT, 2013b). In Nepal, floods caused agricultural losses of 70 million USD (National Planning Commission, 2017). In Brazil, Oliveira et al. (2014) mentioned that the mean annual loss of the total crop production caused by pests was estimated to be 7.7%, and the economic losses were 17.7 billion USD. Therefore, Fisher et al. (2015) reported that farmers who previously were exposed to climatic risks had greater adoption than farmers who did not. The latter is confirmed by the findings of Ngo (2016) and Tefsaye and Nayak (2022), who showed that farmers that experienced droughts, floods, and crop pest attacks implemented adaptation measures.

Based on what is known at this point from the literature above, area-specific studies are important as effects of socioeconomic, institutional, and environmental factors on adaptation might differ across localities (Marie et al., 2020). Moreover, every factor has its own influence over farmers' decisions to adopt. Nevertheless, aligned with the paper's objective, we will be taking all the factors mentioned above and assessing their influence on the type of adaptation measures most used by the Lebanese farmer in Rachaya. In section 5.4, we will be elaborating more on the economic reasoning and other information regarding these factors.

4. Conceptual Framework

Our approach in conceptualizing climate change adaptation measures will be influenced by the utility maximization framework from Nhemachena & Hassan (2007), where farmers adopt adaptation options that increase their utility. Farmer's utility is assessed as a function of estimated costs and benefits in implementing adaptation measures, as well as their preferences that are influenced by a host of factors. The benefit of choosing a strategy is that more productivity can be achieved, and that climate change impacts and risks are reduced implicitly (Ojo and Baiyegunhi, 2020a). Therefore, farmers' utility is maximized when they select a measure in which the net benefit of it is more than the benefits realized without adoption. On that note, the farmer's utility function is shown below following the method of Norton and Hazel (1986):

$$\mathrm{U}x = \mathrm{H}x - \beta\theta x \qquad (1)$$

Where Ux is the utility anticipated from adaptation strategy X, Hx is the non-stochastic term, θx is the error term representing variation in utilities, and β is the coefficient obstructs the risk aversion of each farmer, that would affect the degree of variation in the utility θx. The Farmer will choose the option based on the difference between the costs and benefits of the adaptation measures. If the net benefits of adoption measure X is higher than the net benefits of adoption measure Z then the farmer will choose X. The latter is illustrated in the equation below.

$$\mathrm{E}\ (Ux) - \mathrm{C}x > \mathrm{E}\ (Uz) - \mathrm{C}z \qquad (2)$$

Where E (Ux) is the estimated utility of adopting measure X and Cx is the associated costs, while the second term is the estimated utility of adopting measure Z and its related costs Cz.

5. Method and Data

5.1 Econometric model

Farmers select bundles of adaptation strategies based on the potential to maximize their expected utility so that the decision-making process inherently involves multiple variables. To estimate the impact of exogenous variables on adopting adaptation measures, an econometric model where the error terms of each strategy can be correlated freely, must be applied. Therefore, in this study, a multivariate probit model (MVP) will be used to analyze the data. MVP is a classic model used to study interactions among multiple entities (Ashford & Sowden, 1970) and allows for the correlation between unobserved factors to be simultaneously estimated as well as the effect of explanatory variables on the alternatives. In addition, it is helpful to utilize such a model to analyze categorical choice-dependent variables (Tarekegn et al., 2017). The MVP model implemented in this study was inspired by Tesfaye & Nayak (2022), Mulwa et al. (2017), and Ojo et al. (2021). It is worth mentioning that previous papers addressing the determinants of farmer's adaptation measures used different methodologies like multinomial logit (Asfaw et al., 2019; Kom et al., 2020), binary logit (Amare et al., 2018; Funk et al., 2020), binary probit (Maina et al., 2020), multiple regression analysis (Khanal & Wilson, 2019). Nevertheless, the effect of the explanatory variables on the outcome variables was neither overestimated nor underestimated in all of those papers (for detailed assessment, see Adego & Woldie, 2021). The MVP model is defined as follows:

$$\widehat{Yi} = \beta i\, X \;+\; \varepsilon i \quad i = 1,2,3 \qquad (3)$$

$$Yi = \begin{cases} 1, & if\ \hat{Y}i > 0 \\ 0, & \text{Otherwise} \end{cases} \qquad (4)$$

Where X is a vector of explanatory variables, βi a parameter to be estimated, εi random error terms, i represent crop diversification, water efficient irrigation systems, and change in planting dates. Yi is the binary dependent variable that depends on the decision of the farmer if they adopt or not one of the measures mentioned.

5.2 Descriptive data analysis

In this study, descriptive statistics will be used to summarize and present the socioeconomic data along with other independent variables using frequency, percentages, graphs, and tables. Among all adaptation measures, the difference between adopters and non-adopters was examined using t tests and Chi-square tests for the socioeconomic and environmental variables. The purpose of using these tests is primarily to determine whether the difference is statistically significant or not. For the analysis, R-Studio was used.

5.3 Dependent variable

The dominant forms of adaptation strategies the farmers used to mitigate against climate change in Rachaya included crop diversification, water efficient irrigation system, and change in planting dates. In line with our findings, Ndamani & Watanabe (2017), Hadgu et al. (2015), and Seid et al. (2016) also found that crop diversification, changes in planting dates, and the irrigation system were the most used adaptation measures in Ghana and Ethiopia. Thus, the dependent variable in this study is a dummy variable taking the variable of “1” if farmers have adopted crop diversification or/and water efficient irrigation system or/and change in planting dates; otherwise, it will take the value of “0” if they did not adopt.

5.4 Independent variable

The independent variables in this study are divided into two categories, dummy and continuous variables. As already mentioned in the literature review, this paper will focus on the socioeconomic and environmental factors that influence the farmers' adaptation measures. The continuous variables are age, farm experience, farm size, education, and household size. The variables farm experience and education function similarly. They respectively indicate that farmers with more years of education and experience can understand the importance and the advantage of adopting. Furthermore, age was demonstrated to be correlated with farm experience (Genius et al., 2006), showing that the older the farmer, the more experienced they are. Also, the size of the farm and the household play a role in farmers' adaptation, assuming that a bigger farm size allows farmers to adopt more frequently because the cost of production will be reduced, and farmers will gain more profits. Moreover, large household size can have its cons and pros for farmers since household members can be taken as farm labor, allowing farmers to avoid paying salaries and lower their farm costs. On the other hand, having a larger household size means farmers need to work more to secure their family needs.

The second category is a dummy variable. Each of the following variables is a dummy variable: gender, marital status, land ownership, access to credit, access to climate information, perception, social capital, attending training, experience of droughts, floods, and crop pest diseases. If the respondents answer "Yes," it will be coded as the value "1, "and if their answers are "No," then it will take the value of "0". Gender is a baffling variable since previous studies showed that it significantly influences different types of adaptation measures (Jin et al., 2021; Tesfaye & Nayak, 2022), while Azadi et al. (2019) findings contradict the latter. Due to the volatility in the results, we will be assessing the results of our paper to which studies it relates. Moreover, married farmers consider their family's survival in cases of uncertainty and adopt new practices (Danso-Abbeam et al., 2014) to lower their risks. Also, land ownership is an important variable to consider since farmers that own the land will be more interested in keeping their farms in good condition and inheriting it to future generations, thus supposing they will adopt. Access to credits and information were taken in other studies as barriers to adaptation (Roncoli et al., 2002; Bryan et al., 2009; Gbetibouo, 2009) which allows us to understand how critical these variables are. Access to credits and information can allow farmers to implement a better plan for their farms, reduce the risks of climate shocks, and increase their crop yield. Social capital and attending training work in a similar way, where farmers who participate in agricultural groups and attend training are exposed to information and experiences, suspecting that farmers will make better decisions regarding climate change adaptation. It is worth mentioning that our concept of social capital is based on what Aldrich (2012) claimed to be regarding social groups being a proxy of social capital. In addition, farmers who experienced climate shocks on their farms or who perceive that the climate is changing will be more concerned than farmers that did not, and we believe they will be adopting to avoid losses.

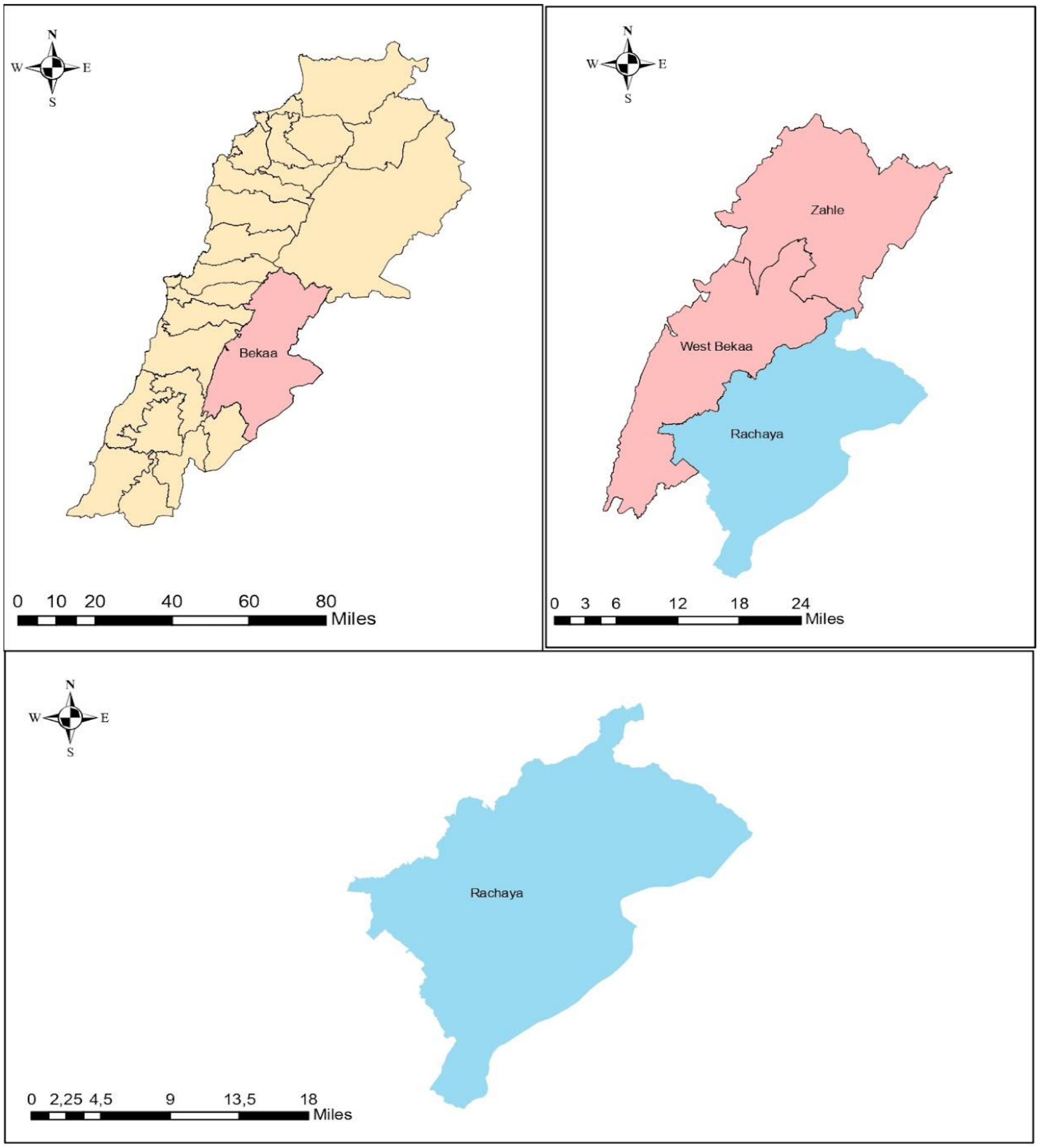
5.5 Farmers' Perception Evaluation

Adaptation measures are less effective without understanding farmers' perceptions about climate change (Regasa & Akirso, 2019). Therefore, farmer's perceptions concerning changes in temperature and precipitation will be evaluated using a categorical variable with three categories: "increasing, decreasing, no change. "If the farmer feels that the temperature degree and precipitation levels have been increasing, then their response will be added as "increasing," and if they feel it is decreasing, then it will be added as "decreasing." Alternatively, if a farmer does not feel any changes concerning the temperature degree and precipitation level are still the same, it will be added as "no change." Our choice of the latter category was inspired by Mahfoud and Gerard (2021) and Arunrat et al. (2017), who used the same category while examining farmers' perceptions. Moreover, this category allows us to match farmers' perceptions and historical climatological data and trends in the Bekaa Valley. In section 2, we discussed the changes, threats, and projections of Lebanon's climate, which is why precipitation and temperature were regarded as the two climate change variables. The time frame that will be taken is ten years to make it easier for farmers to remember the changes that happened.

5.6 Description of the study area

The study was conducted within the Bekaa Valley governorate, which includes three districts: Zahle, West Bekaa, and Rachaya. It is situated between the mountains of Lebanon to the west and Anti-mountains to the east with a latitude of N 33° 50' and longitude of E 36° 0'. There are two morphological units associated with the district: the eastern slopes of Mount Lebanon and the eastern planes of the valley. There are 880 to 1,000 meters of elevation in the district. According to the World Bank (2015), the Bekaa Valley has the highest concentration of agricultural lands, with 42 percent of the total cultivated area. It also provides the highest percentage of essential crop types, such as cereals, fruits, and vegetables (MoA, 2010). Furthermore, the duration between January and April is known to be the peak of the rainy seasons, where 75% of the rainfall occurs, and the average temperature is from 9°C in the winter to 27°C in the summer (Verner et al., 2013). In addition, the highest number of Syrian refugees is located in the region of Bekaa (Machayekhi et al., 2017).

Figure 1. Map of the study area.



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5.7 Method of data collection

An enumerator collected the data from 185 farmers in the study area via a structured questionnaire survey from March to April 2022 (see Appendix B). Face-to-face interviews were conducted, and the respondents' responses were uploaded directly into Qualtrics Software, where they were automatically sorted and formatted into a downloadable database. Following a pre-test, the questionnaire was revised and developed to eliminate poorly understood questions and divided into four parts: a) farmer's adaptation measures, b) socio-economic characteristics, c) perception regarding temperature and precipitation, and d) exposure to climate shocks. These structured questionnaires were prepared in English and then translated into the local dialect of Arabic spoken in Lebanon. The interviews were done in the Rachaya district to assure the homogeneity of the climate conditions, the economy is based on agriculture, and the absence of agricultural policy (Caiserman et al., 2019). On the other hand, the participants were selected using the snowball sampling method. The chosen enumerator was initially from Rachaya and had a tremendous personal connection with farmers from this area. The latter helped in collecting the data since participants motivated each other to participate. Moreover, primary data constituted the bulk of the study, while secondary data complemented primary data. After collecting the data, R-studio was used to implement the econometric model and analyze the data.

5.8 Descriptive statistics

In this study, the sample is 100%, male respondents. Unexpectedly, the enumerator could not reach Lebanese female farmers since their participation depended on their husbands' consent, and it was hard to find women in the field in general. This goes along with the findings of FOA (2012) that state that women face challenges in the agricultural sector like legal, cultural, and socioeconomic constraints. Furthermore, women are encouraged to work from home in sectors like food processing and embroidery after receiving training from many NGOs (GIZ, 2019), which may also explain why it was hard finding female farmers. On that note, the "Gender "variable was omitted from the MVP model since there was no variation in this variable. From table 1, we can find that the mean age of farmers is 46.74, where 85% of them are married with an average household size of 4.10. On average, farmers have 4.10 years of schooling compared to their farming experience, which shows to be 19.43 years. In addition, the average farm size is about 104.327 dunum (10.4327 ha), and about 61% of farmers own their land. On the other hand, approximately 84% of farmers do not have access to credits, only 29% attended training, and 46% participated in social capital.

Additionally, farmers were asked if they had ever suffered from flood, drought, or pest attacks on their farms. The survey results show that 74% of Rachaya's farmers have experienced drought events, in line with a map of drought hazards developed by USAID that illustrates the most frequent and severe drought events. The drought hazard map showed that Rachaya is one of the areas affected highly compared to other areas in the Bekaa Valley. Moreover, most climate shocks experienced by farmers are related to pest attacks on crops accounting for 83%, and floods account for 32%, which is a minor shock experienced. On access to climate change information, about 89% of the farmers have confirmed receiving information from the internet (72%), TV/Radio (58%), fellow farmers (45%), NGOs (18%), government institutions (7%), and other sources (6%).

Table 1. Descriptive statistics of variables used in the survey

Variables	Description	Mean	S.D
Dependent Variables			
Crop Diversification	Dummy=1 if farmer implemented crop diversification as an adaptation measure, 0 otherwise	0.70	N/A

Variables	Description	Mean	S.D
Water efficient irrigation system	Dummy=1 if farmer implemented water efficient irrigation system as an adaptation measure, 0 otherwise	0.48	N/A
Changing planting dates	Dummy=1 if farmer implemented changing planting dates as an adaptation measure, 0 otherwise	0.54	N/A
Independent Variables			
Gender	Dummy=1 if men and 0 if women.	1	N/A
Age	Age of farmer in years	46.74	13.35
Marital Status	Dummy=1 if married and 0 if single or widow	0.85	N/A
Schooling	Year of schooling of farmer	4.10	5.74
Household size	Number of the family members in the household	5.04	1.61
Farm size	Size in Dunum (1 Dunum = 0.1 hectare)	104.32	279.20
Farm experience	Farmer experience in years	19.43	12.38

Variables	Description	Mean	S.D
Land ownership	Ownership of the land (Yes = 1, No = 0)	0.61	N/A
Access to credits	Access to credits (Yes = 1, No = 0)	0.16	N/A
Access to climate information	Access to climate information (Yes = 1, No = 0)	0.89	N/A
Social capital	Participation in social groups (Yes = 1, No = 0)	0.46	N/A
Trainings	Attending trainings (Yes = 1, No = 0)	0.29	N/A
Droughts	Experienced droughts on farms (Yes = 1, No = 0)	0.74	N/A
Floods	Experienced floods on farms (Yes = 1, No = 0)	0.32	N/A
Crop pest disease	Experienced crop pest disease on farms (Yes = 1, No = 0)	0.83	N/A

6. Results and Discussion

6.1 Farmers' perception regarding climate change

Farmer perceptions about changes in precipitation and temperature over the past ten years were asked. According to our data, 58%, 25%, and 17% of the respondents perceived that the precipitation level had decreased, increased, and no change, respectively. Regarding trends in temperature over the previous ten years, about 67%, 23%, and 10% of respondents thought there had been an increase, a decrease, and no change, respectively. The results show that most farmers noticed a decrease in precipitation and an increase in temperatures, respectively. We will take climate data provided by NASA POWER (2021) to confirm farmers' perceptions and compare the data with farmers' answers. Figure 2. illustrates a significant increase in the mean annual temperature between 1981 and 2020 according to the linear trend line. On the other hand, the trend line for the annual precipitation (mm) shows a slight increase with a significant fluctuation from one year to another (Figure 3.). As a result, farmers' perceptions of temperature changes match climatological records but not precipitation levels.

Figure 2. Average annual temperatures (°C) of the Bekaa Valley (at 2 m) from NASA POWER data (1981–2020)

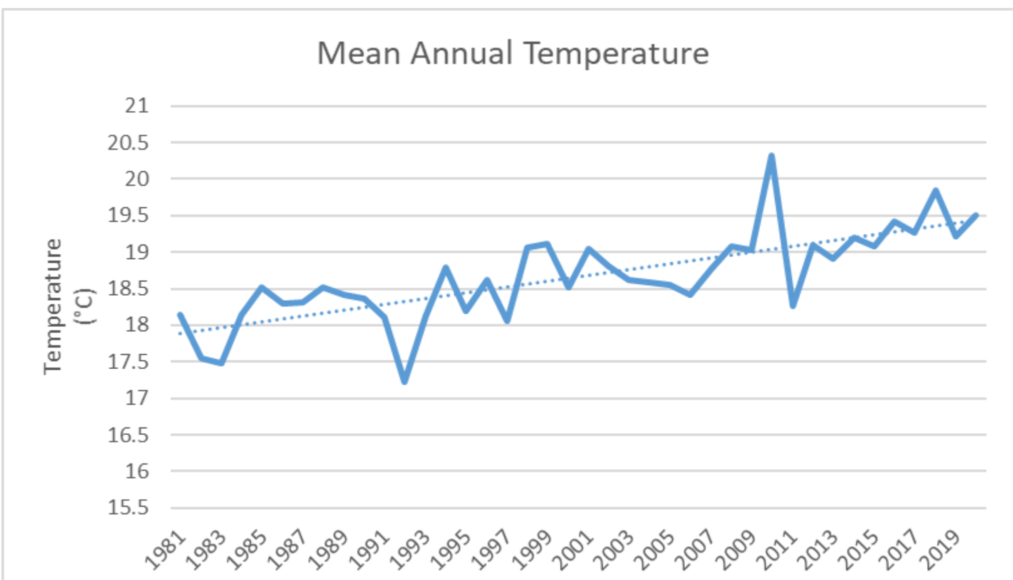
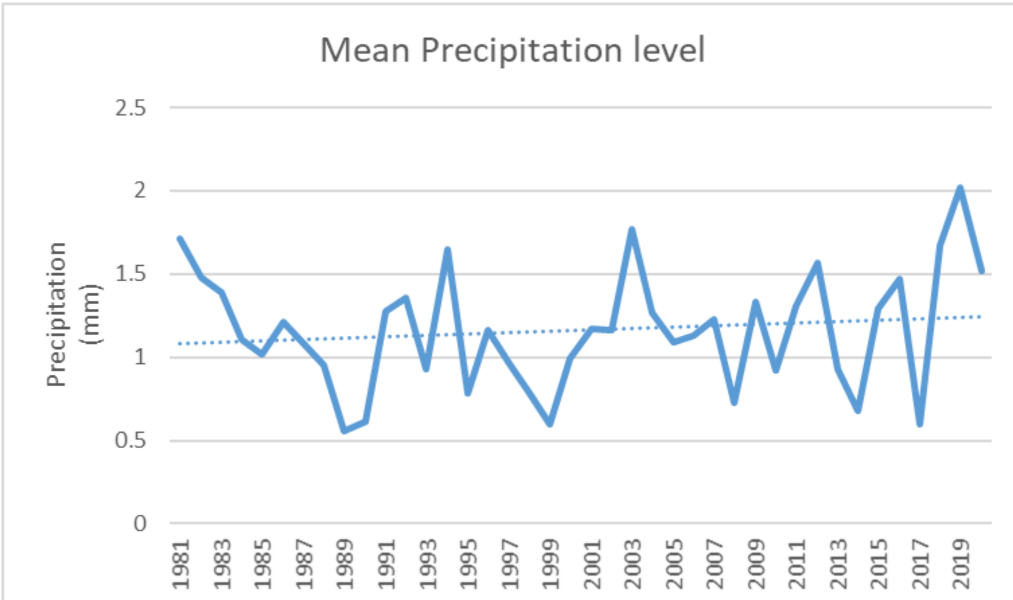


Figure 3. Average annual precipitation (mm) of the Bekaa Valley from NASA POWER data (1981-2020)



According to Foguesatto et al. (2020), farmers' perception can be affected by the fact that farmers have a negative expectation of utility and/or a particular event considered striking. Also, Foguesatto et al. (2020) show that divergences between farmers' perception and the decrease in precipitation level may be in relation to an increase in droughts' frequency and severity. Meze-Hausken (2004) proves that farmers who have suffered production losses due to droughts may perceive lower rainfall as a change even when no change has actually occurred. Thus, our survey results confirm the findings of the abovementioned studies, showing that 74% of farmers have confirmed that they experienced drought on their lands, and this may explain why farmers' perceptions regarding precipitation levels did not align with the climatological data. In addition, 2014 was one of the most significant drought years that Lebanon experienced (Bergaoui et al., 2015); hence, it is highly possible that farmers consider it a memorable event and are still stuck in the back of their heads. Nevertheless, 32% of farmers have also experienced floods which can confirm that precipitation levels increased.

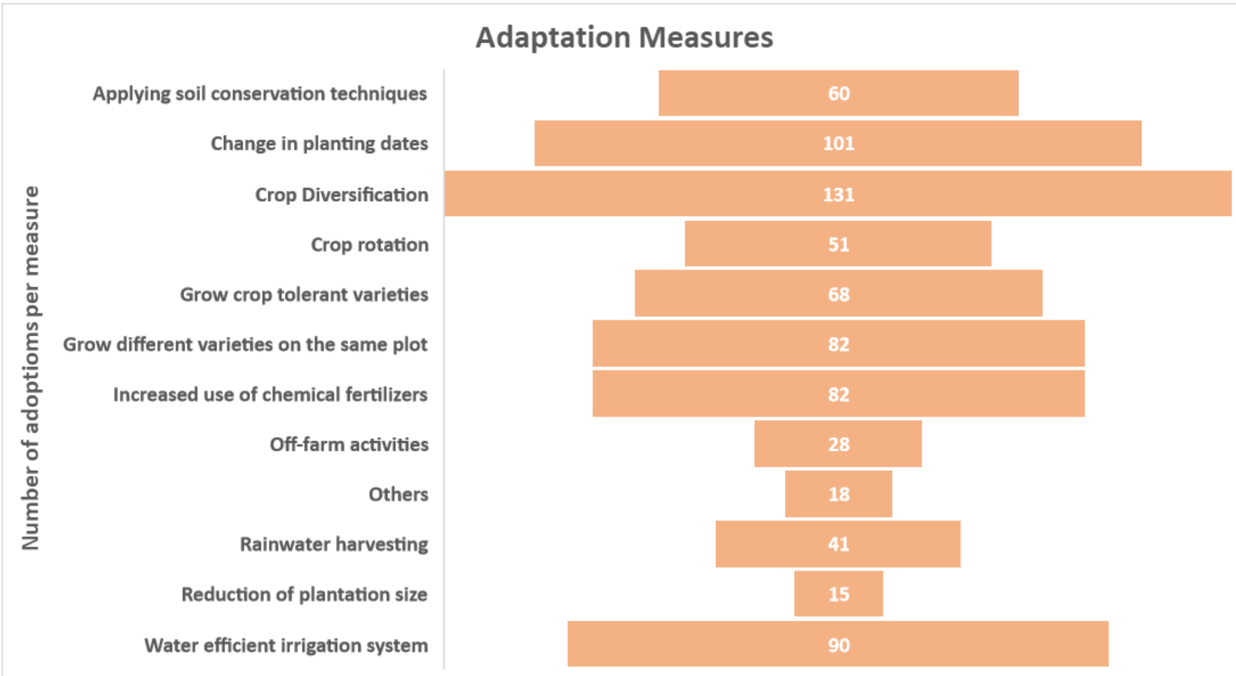
6.2 Climate change adaptation practices

The main question of the survey was whether farmers adopt climate change adaptation and, if yes, what are the adaptation measures. Figure 4 reveals that farmers have adopted various adaptation measures to reduce the impacts of climate change and restrain future climate change patterns, which was in line with the adaptation measures reported in the climate change adaptation literature (Mesfin & Beleke, 2018; Bedeke et al., 2019; Marie et al., 2020). In most cases, more than one climate change adaptation measure has been adopted since a single measure is not adequate to minimize the effects of climate change and variability. Crop diversification, water efficient irrigation system, and change in planting dates were the top three adaptation measures used in our study area (Figure 4).

Farmers diversify their crops to protect them from rainfall variability since different crops respond differently to different climate events (Orindi & Eriksen, 2005; Adger et al., 2003). In Mali, the irregular rainfall pattern and high temperatures prompted farmers to change their planting dates (Diallo et al., 2020). By checking Figure 2 and 3., it is visible that the Bekaa valley has been witnessing variation in the amount of precipitation and a clear increase in temperature trend over the years, which explains why 70% and 55% of farmers adopted crop diversification and change in planting dates. Deressa et al. (2011) and Thornton and Herrero (2014) have found that farmers are more likely to adopt measures like crop diversification, mixed cropping, changing planting dates, and planting resistant crops because they are more affordable than other measures. The latter can be aligned with our results since the agricultural sector in Lebanon has been lacking policies and development plans where farmers have been hardly receiving any subsidy or financial support (Caiserman et al., 2019). In addition, the staggering rise in fuel prices, fertilizer costs, continuing conflict in the region, and devaluation of local currencies are driving conservation agriculture like crop diversification into the spotlight as a way to help poor farmers (Bashour et al., 2016). Therefore, farmers will go after the adaptation measure that increases their utility with the least cost.

To adapt to climate change, farmers must first identify how the climate has changed and then identify beneficial adaptations that can be implemented (Maddison, 2006). Farmers in Rachaya have perceived a decrease in precipitation level, and part of the adaptation measures implemented is based on farmers' perception. Despite poor matching between farmers' perception of precipitation and climatological data, 48% of farmers used efficient water irrigation systems, a widely used method in response to inadequate precipitation (Woldemariam, 2017). Also, Deresa et al. (2009) confirmed that a decrease in precipitation level significantly increases the likelihood of adopting changes in planting dates and irrigation systems as adaptation measures. Furthermore, Tesfaye and Nayak (2022) found that farmers who have experienced droughts and floods are likely to adopt water irrigation as a climate change adaptation measure. The latter can be the reason behind why farmers in Rachaya have adopted a water irrigation system since the majority have experienced droughts and some experienced floods. On the other hand, reduction in planting size, off-farm activities, rainwater harvesting, and other measures were among the least measures used. Given our results, we can confirm that the adaptation measures used in this paper differ in frequency from those of Dirani et al. (2021), Mahfoud and Gerard (2021), and Farajalla (n.d) mentioned.

Figure 4. Adaptation measures frequency



An analysis of the paired samples t-test and Chi-square test were utilized to determine the characteristics differences between adopters and non-adopters. Also, we used both tests since the independent variables are divided into continuous and dummy variables. The results showed significant characteristics differences in all adaptation measures between these groups; however, since we are only focusing on the most used adaptation measures, crop diversification, water efficient irrigation system, and change in planting dates, we will only show and discuss their results. Nevertheless, the t-test and Chi-square test were also implemented on the other adaptation measures and showed significant results (see Appendix A).

As shown in Tables 2 and 3, there is a significant difference between adopters and non-adopters regarding household characteristics, climate shock experience, access to information, and farm characteristics. For example, farmers who adopt any of the three adaptation measures show to have lower schooling years than non-adopters, and this can be in relation to age since it also shows that non-adopters are younger than adopting farmers. Among younger and more educated farmers, none of the three adaptation measures were adopted, which is likely because they are more inclined to follow new technological innovations instead of old traditional methods (Chi & Yamada, 2002; Abdullah & Abu Samah, 2013). Although we did not define clear technological measures in our survey, we assume that the option of ¨ Others¨ (check Appendix A) includes technological options since it shows a significant difference between age, schooling years, and access to credits. Moreover, in interviews with young rural people from around the world, it was evident that "youth pick up new technologies related to farming more easily and that young farmers are keen on increasing their production through improved and modern technologies" (MIJARC/IFAD/FAO 2012). Also, this can be attributed to the fact that young people in the rural areas of Lebanon are moving out of agriculture to look for other employment opportunities. Furthermore, farmers who have experienced more crop pest attacks, floods, and social capital adopted adaptation measures, unlike non-adopters. For example, in Nepal and Bangladesh, farmers affected by flooding implemented adaptation measures on their farms more than others who were not affected (Khanal et al., 2018a).

Based on the t-test and chi-square results, we can conclude significant differences between the independent variables in the three different adaptation measures with significance levels varying from 1,5% to 10%. After determining the differences between adopters and non-adopters, it is possible to determine how socioeconomic and environmental factors impact farmers' adaptation measures.

Table 2. T-test results

	Crop Diversification			Water Efficient Irrigation System			Change in Planting Date		
	Mean		P-Value	Mean		P-Value	Mean		P-Value
Continus Variables	*Adopters*	*Non-Adopters*		*Adopters*	*Non-Adopters*		*Adopters*	*Non-Adopters*	
Household size	5.24	4.57	0.0098***	5.11	4.98	0.6095	5	5.1	0.654
Age	49.1	41.01	0.00014***	48.53	45.05	0.07639*	47.16	46.23	0.6385
Farm size	127.18	48.87	0.08281*	125.07	84.66	0.3265	120.25	85.17	0.3964
Schooling	3.24	6.18	0.00139***	2.76	5.36	0.0018***	2.54	5.97	0.000037***

Table 3. Chi-Square test results

	Crop Diversification		Water Efficient Irrigation System		Change in Planting Date	
Dummy Variables	Chi-Square	P-value	Chi-Square	P-value	Chi-Square	P-value
Land Ownership	0.525	0.468	0.3671	0.544	0	1
Access to Credit	0.211	0.645	0.4233	0.515	6.615	0.01*
Trainings	0.068	0.793	10.955	0.00093***	0.43002	0.512
Social Capital	3.3	0.0692*	16.235	0.000055***	9.7538	0.00179***
Climate info	1.922	0.165	11.729	0.000615***	20.063	0.00000749***
Floods	9.1585	0.0024***	21.81	0.000003***	12.794	0.000347***
Drought	11.36	0.00074***	7.72	0.0054***	1.1839	0.276
Crop Pest Attack	22.76	0.0000018***	15.331	0.00009***	18.345	0.0000184***

6.3 Econometric model results

The present study uses the multivariate probit model (MVP) to analyze climate change adaptation measures. A Pearson Correlation test has been done between all adaptation measures and independent variables to see if there is any correlation and relationship between them. The correlation matrix (see Table 4 and 5) results in Excel shows that there is a relation and moderate correlation between farmers adopting soil conservation techniques, change in planting dates, crop diversification, grow different varieties on the same plot, increase use of chemical fertilizers, off-farm activities, and water efficient irrigation system; change in planting dates, crop diversification, grow different varieties on the same plot, and water efficient irrigation system; crop diversification, crop rotation, grow different varieties on the same plot, and water efficient irrigation system; grow crop tolerant varieties and rainwater harvesting; increase use of chemical fertilizers and off-farm activities; off-farm activities and water efficient irrigation system. Given this, a multivariate probit regression model is appropriate for this particular study, as the adaptation measures are mutually dependent. Regarding the independent variables, the marital status variable was highly correlated with age, farming experience, and household size. Also, age and farm experience showed a high positive correlation (0.70), where a decision to remove the correlated variable was taken to reduce the problem of multicollinearity. Based on the log-likelihood coefficient, we omitted marital status and farm experience to fit the model better.

Table 4. Correlation matrix of all adaptation measures where *X1* is applying soil conservation techniques, *X2* change in planting dates, *X3* crop diversification, *X4* crop rotation, *X5* grow crop tolerant varieties, *X6* grow different varieties on the same plot, *X7* increased use of chemical fertilizers, *X8* off-farm activities, *X9* others, *X10* rainwater harvesting, *X11* reduction of plantation size, *X12* water efficient irrigation systems.

	X1	*X2*	*X3*	*X4*	*X5*	*X6*	*X7*	*X8*	*X9*	*X10*	*X11*	*X12*
X1	1											
X2	0.330	1										
X3	0.310	0.322	1									
X4	0.190	0.247	0.290	1								
X5	-0.070	0.132	0.194	0.157	1							
X6	0.380	0.464	0.334	0.277	0.042	1						
X7	0.350	0.224	0.286	0.156	-0.229	0.277	1					
X8	0.350	0.203	0.205	0.178	-0.197	0.230	0.382	1				
X9	0.006	-0.067	-0.030	0.002	0.090	0.001	-0.073	-0.139	1			
X10	0.019	-0.036	0.171	0.108	0.376	-0.136	-0.188	-0.044	0.132	1		
X11	-0.030	0.112	0.016	0.038	-0.021	-0.026	0.014	0.096	0.036	0.271	1	
X12	0.380	0.431	0.363	0.247	0.155	0.285	0.177	0.313	-0.064	0.080	0.0278	1

Table 5. Correlation matrix for all independent variables where *S1* is land ownership, *S2* access to credits, *S3* trainings, *S4* social capital, *S5* climate information, *S6* floods, *S7* droughts, *S8* crop pest attacks, *S9* marital status, *S10* farming experience, *S11* schooling years, *S12* household size, *S13* age, *S14* farm size.

	S1	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*	*S9*	*S10*	*S11*	*S12*	*S13*	*S14*
S1	1.00													
S2	0.17	1.00												
S3	0.15	0.21	1.00											
S4	0.00	0.19	0.33	1.00										
S5	-0.07	0.05	0.07	0.01	1.00									
S6	-0.21	-0.14	0.12	0.11	0.16	1.00								
S7	0.07	-0.04	-0.02	0.09	0.03	0.31	1.00							
S8	0.01	-0.20	0.01	0.17	0.02	0.25	0.28	1.00						
S9	0.07	0.01	0.00	0.11	0.15	-0.01	-0.01	0.05	1.00					
S10	0.28	0.13	0.23	0.15	-0.14	-0.10	0.02	0.08	0.41	1.00				
S11	0.03	0.37	0.15	0.09	-0.06	-0.17	-0.18	-0.32	-0.04	0.10	1.00			
S12	0.17	0.09	0.14	0.03	-0.08	0.00	0.02	0.00	0.33	0.32	-0.04	1.00		
S13	0.20	0.08	0.13	0.12	-0.01	-0.05	0.04	0.06	0.65	0.70	0.03	0.39	1.00	
S14	0.00	0.11	0.07	0.04	0.07	0.22	0.14	0.11	0.05	0.11	-0.10	-0.01	0.05	1.00

The multivariate probit model results are presented in Table 6. Climate change adaptation measures are significantly influenced by some of the demographic factors, institutional factors, and climate shocks and information. Results from the MVP model show that age significantly and positively influences the adoption of crop diversification. The high correlation between farm experience and age indicates that the age of a farmer represents their farming experience. The latter is supported by the findings of Maddison (2006), Zamasiya et al. (2017), and Ishaya and Abaje (2008), who stated that the age of farmers is often associated with their level of experience, which plays a significant role in their willingness to adopt a particular adaptation measure. Therefore, as the age of the farmers increases, their farming experience will also increase. As a result, they will become more capable of foreseeing the weather and assessing technology in order to plant different crops to reduce the effect of climate change. Derese et al. (2009), Tazeze et al. (2012), and Sarker et al. (2013) results have shown a positive relationship between farmers' age and the adoption of climate change adaptation measures as well.

Unexpectedly, the model output shows that schooling years significantly and negatively influence change in planting dates. Although our results contradict the findings of Khanal et al. (2018a), Zamasiya et al. (2017), Below et al. (2012), and Tiwari et al. (2014), that confirms that education positively influences the adaptation decision, nevertheless, they did not mention what type of adaptation measure was adopted. Therefore, the findings of these papers are different from ours since they aim to assess determinants that influence farmers' adaptation decisions disregarding what type of adaptation they are adopting. Additionally, our findings that schooling years have a negative influence may reflect that the key to adopting appropriate farming practices lies in being far more educated. Also, it can be because more educated farmers are looking for better off-farm opportunities that can secure them better income.

Access to credits negatively and significantly affects change in planting dates as a climate change adaptation measure. Again, our findings contradict the results of other papers that confirm the positive correlation between access to credits and adopting climate change adaptation measures (Ojo et al., 2021; Bryan et al., 2009). Nevertheless, we have mentioned that changing planting dates is a cost-effective method that does not require much capital, which allows Lebanese farmers to implement it in the absence of domestic agricultural policies and financial support. Hence, it is believed that receiving credits/cash flows will allow farmers to invest in more costly and better-rewarding measures, which could also reduce the negative impact of climate change, and this is why farmers will opt out of adopting change in planting dates. Furthermore, Simtowe and Zeller (2006) argued that credit availability eases liquidity constraints, allowing farmers to increase their technological adaptation and observe better adaptation measures. As an example, farmers with financial resources can purchase new crop varieties, irrigation technologies, and other essential inputs needed to alter their practices in accordance with forecasted and prevailing climatic conditions (Nhemachena & Hassan, 2007).

Training has been shown to have a significant and positive influence on water irrigation systems at a $p<5\%$ probability level. It was found in Ethiopia that training develops awareness and acknowledgment of the irrigation system benefits (Dawit et al., 2020). Also, Bekaa Valley has been the focus of research by many international organizations, local institutions, and universities. The latter organizes a wide range of training targeting climate change in general and water efficient irrigation systems specifically. For example, jointly with LARI, the World Bank has done training and workshops on impacts and possible response options to climate changes in agriculture (Verner et al., 2013). On the other side, FAO-ICARDA (2019) initiated training to inform participants about the new irrigation techniques that they can use to enhance agricultural productivity. In addition, the United Nations Economic and Social Commission for Western Asia (UNESCWA) and the Arab Centre for the Studies of Arid Lands and Dry Zones (ACSAD) jointly organized a training workshop on aqua crops for irrigation water management, intending to enhance national capacity in irrigation water management (UNESCWA, 2019). Therefore, implementing these training and other numerous training should have raised awareness of the importance of taking measures to adapt to climate change in the agricultural sector. Our results are similar to a study done in Tunisia that also concluded that training positively and significantly affects efficient water irrigation systems (Frija et al., 2009; Dhehibi et al., 2007).

As was expected, climate shocks significantly influence farmers' adaptation measures. Crop pest attack has shown to have a significant and positive effect on water efficient irrigation systems and crop diversification at less than a 10% significance level. In contrast, floods only positively and significantly influence water efficient irrigation systems. Considering that crop diversification has been used to cope with pest attacks and diseases (Oleke et al., 2012), it is not surprising that pests contribute to the adaptation of crop diversification. In addition, crop pest attacks and diseases are more likely to develop when soil is wet due to flooding or over-irrigation (Irmak & Rathje, 2008). Therefore, we can infer that crop pests and diseases are one of the indirect consequences of flooding, which puts more risk and pressure on the farmer dealing with the immediate direct impacts of floods as well. Some examples of the direct impacts of flooding are the destruction of crops, soil erosion, damage to agricultural infrastructure and machinery, and increased nutrient losses (Das, 2005; Nuñez, 2005; Clarke & Rendell, 2007). We assume, therefore, that rather than purchasing pesticides that will be paid for in dollars to solve the problem of crop pest attacks and taking another adaptation measure to reduce the flood risk, the Lebanese farmer will opt in to use an efficient water irrigation system that targets both problems at once. Furthermore, having the Lebanese currency devalued against the US dollar makes the situation for Lebanese farmers worse since most agricultural inputs are imported (Chehaita & Ibrahim, 2015), which will raise the cost of production. Hence it is more evident now why crop pest attacks and floods influence the adoption of an efficient water irrigation system. Tesfaye and Nayak (2022) results are similar to what we found regarding the influence of crop pest attacks on crop diversification and water efficient irrigation systems being influenced by both floods and crop pest attacks.

Access to climate change information positively and significantly influences the use of efficient water irrigation systems and changes in planting dates at significance levels less than 10% and 1%. The latter indicates the importance of making climate-related information accessible to farmers. Despite not specifying what type of information the farmers receive, the survey specified the information source. Mostly, farmers did receive their climate-related information from informal sources like TV/radio, the internet, and fellow farmers, where we can conclude that they increase the likelihood of adapting to climate change adaptation measures. Moreover, Belay et al. (2017) findings agree with our findings in that they endorse that receiving climate-related information (more precisely, weather information) allows farmers to make an informed decision on changes in planting dates and increase water use efficiency.

Social capital was another variable that influenced efficient water irrigation systems and changes in planting dates. According to Frankenberger et al. (2013), social groups enable farmers to build social trust and rely on information shared by their peers. Additionally, when farmers work in groups, they are more likely to follow the example of their fellow farmers, which will motivate them to adopt new strategies, especially if they see the positive impacts the strategies have on their peers. Therefore, we can assume that farmers who participated in social groups are the ones who received climate-related information from their fellow farmers and adopted the same measures, which are efficient water irrigation systems and changes in planting dates. Miao et al. (2015), Yameogo et al. (2018), and Wang et al. (2021) affirm our results of having a positive and significant influence of social capital on efficient water irrigation systems and changes in planting dates.

Table 6. Multivariate probit model results (N = 185)

Explanatory Variables	Crop diversification			Water efficient irrigation system			Change in planting dates		
	Coef	*S.E*	*P-Value*	*Coef*	*S.E*	*P-Value*	*Coef*	*S.E*	*P-Value*
Age	0.02603	0.0109	0.01786***	0.01352	0.01276	0.28950	0.004387	0.0109	0.6893
Household Size	0.01131	0.1001	0.25886	-0.009652	0.1150	0.93311	-0.03443	0.1019	0.73553
Schooling	-0.02946	0.02496	0.23780	-0.05082	0.03295	0.12297	-0.05295	0.02185	0.01538***
Farm size	0.00247	0.00309	0.42447	-0.000338	0.000975	0.7289	-0.000018	0.00083	0.98243
Access to credit	-0.04984	0.5036	0.92117	-0.2955	0.4700	0.5294	-0.8023	0.4349	0.06509*
Trainings	-0.5042	0.3955	0.20234	0.7653	0.3506	0.02906**	0.004103	0.3055	0.98928
Droughts	0.4438	0.3399	0.19164	0.2171	0.3687	0.55593	-0.3053	0.3397	0.36883
Crop pest attack	0.7876	0.4205	0.06109*	0.8381	0.4544	0.0651*	0.7084	0.4820	0.1416
Floods	0.2503	0.4796	0.60170	0.8657	0.3751	0.02101**	0.5385	0.4017	0.1801
Climate information	0.5371	0.4840	0.26712	1.622	0.9690	0.09418*	2.272	0.7311	0.00188***
Social Capital	0.3299	0.3335	0.32250	0.7672	0.3568	0.03155**	0.9776	0.3823	0.01055***
Land Ownership	0.1515	0.3411	0.65691	0.4446	0.4088	0.2768	0.3072	0.4349	0.48001
Constant	-2.776	0.8535	0.0011***	-3.817	1.638	0.0197***	-2.788	1.057	0.00838***
Log-Likelihood	-249.61								

Significance level: '***' 1%, '**' 5%, '*' 10%

6.4 Limitations

Climate change adaptation measures are not a new phenomenon that the Lebanese farmer got to know recently; instead, they have been adopting measures that Dirani et al. (2021) and Mahfoud and Gerard (2021) already discussed. Nevertheless, achieving the paper's aim comes with some limitations and weaknesses that should be considered. In the first place, the relatively small size of our sample (185 farmers) and our respondents being 100% male make generalizing the results difficult. Furthermore, the time constraints limited the survey duration to one month, which prevented the enumerator from reaching a more significant number of respondents. Additionally, the fact that no women took part in our study allows us to state that we have failed to hinder the gender bias prevalent in the Arab world. Despite this, we fully acknowledge and agree that women contribute significantly to developing countries' agricultural sector and rural economics. Nonetheless, in future research, it might be possible to target only women farmers within the same study area to provide more precise and clear recommendations and overviews regarding gender-specific climate change adaptation measures and determinants.

Due to Lebanon's location facing the Mediterranean Sea and its varied topography, the country is characterized by a wide range of climates, even within zones only a few kilometers apart (Telesca et al., 2019). Nevertheless, we restricted our study only to the Bekaa Valley and, in particular, to the Rachaya district, which means that our findings can not apply to other districts or regions. Despite this limitation, the study's conclusions are not invalidated; instead, it encourages further studies to cover the entire region and Lebanon. Moreover, choosing a MVP to study several dependent variables at once is a reliable and efficient tool. Nevertheless, using the R-Studio package to analyze MVP estimates was one of our major limitations. Implementing the MVP function on R-Studio was significantly time inefficient, inflexible, and very constrained. Henningsen (2021) confirms our experience with R and also added that the MVP function is still an experimental function. Therefore, we assume using the STATA program is better since several papers (e.g., Ojo et al., 2021; Tesfaye & Nayak, 2022) used it with their MVP and did not mention any limitations.

7. Conclusion and policy implications

Determining the factors influencing farmers' climate adaptation measures is crucial since it will help determine policy interventions and enhance the agricultural sector. Although this topic has been addressed significantly worldwide, this was not the case for Lebanon. Therefore, this study aims to determine the adaptation measures used among farmers and assess the factors that influence their adaptation measures using a multivariate probit model. Moreover, this study contributed to filling the literature gap found in Lebanon that allows policymakers to implement policies to enhance the agriculture sector and reduce farmers' vulnerability. In addition, we added to the existing literature by focusing on adaptation measures rather than farmers' adaptation decisions.

With 185 farmers as the sample size, we found that crop diversification, changes in planting dates, and efficient irrigation systems are three of the most adopted adaptation measures to cope with climate change. Results from the study showed that the majority of the farmers could not realize that the precipitation level had increased over the past ten years, and they adopted adaptation measures based on their perception. Thus, farmers are adopting measures that are not aligned with the occurring changes, which results in inefficiency and losses. Also, the average schooling years of farmers were four years, which resembles weak educational background and knowledge among farmers, which may contribute to the inaccurate perception and incorrect analysis of the climate information they have been receiving. Thus, the government should implement climate change learning centers to promote co-learning among farmers, expose them to different adaptation measures in relation to climate change, and enhance their understanding and acknowledgment of analyzing climate information.

Another finding worth highlighting was that only 7% of our respondents are under the age of 25, and the mean age is around 47 years. It is evident that the participation of the youth in farming was very minimal, and the majority of the farmers were elderly. Our findings are similar to the Chehaita and Ibrahim (2015) findings, showing that the majority of farmers in Lebanon are seniors, with 22.5% over 65 years old and only 1.6% under 25. The reason behind this is that the agricultural sector is less interesting and appealing to younger generations which Whitfield (2015) and Dirani et al. (2021) also agree on. Additionally, the national economy model focuses heavily on the finance and services sector, as well as real estate (Daher, 2022), which creates a social perception of favoring certain professions over others, whereas farming does not fall into that category. This might lead to a lower rate of agricultural labor productivity, the agricultural workforce to shrink, food insecurity would emerge, self-sufficiency would decline, and farmlands converted into non-farm activities. Hence, the government's first step should be to re-examine the economic model and to better develop the agricultural sector through implementing agricultural policies that encourage young generations to incorporate more in the sector. For example, they can establish a national agricultural college/school and tailor education content towards agriculture with special programs. They can also facilitate the start-up of new farmers by providing income support, input subsidies, and funding plans such as loans and grants, which mitigate the risk associated with farming.

As a result of our multivariate probit model and descriptive statistics, we conclude that access to credit is one constraint that hinders the adoption of advanced and better technological adaptation measures. Accordingly, we recommend that the government intensify efforts to develop credit policies that provide access to credits like loans with flexible repayment arrangements and low-interest rates. The result of this policy implication is to build resilience and encourage farmers to invest in new adaptation measures that enhance sustainability, increase crop yield, farmer's income, and welfare. The study also revealed that receiving climate-related information and social capital significantly impacts the adaptation measures chosen. This highlights the need to strengthen social capital in the study area as well as in the region, which can be achieved in collaboration between government organizations and NGOs by forming social clubs with farmers from different areas to share their experiences and information. Additionally, through these social clubs, experienced agents can offer farmers better climate information, production techniques, and sustainable practices to help them continue to adapt to climate change in the future successfully. Consideration of these recommendations can strengthen and sustain the agricultural sector, increase food availability, contribute to a more secure food supply regionally, and reduce the dependency on imported food. Individually, these recommendations can assist farmers in maintaining their income and welfare, ensuring continuity and sustainability of their farms, and decreasing their vulnerability to climate change.

8. References

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10. Appendix

Appendix A: T-test and Chi-Square test link below.

https://docs.google.com/spreadsheets/d/1-HZMBY
OYDeQ8xMMDE_XXYKMWuTxapHXx2c6xRlcMz4/edit?usp=sharing

Appendix B: Survey questions. Link below.

https://docs.google.com/document/d/13oRVCAvSp1kZwY_OsvSilue_lc3O5OaZbEp5pAXDNoU/edit?usp=sharing

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