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# Documents de travail

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Document de Travail n° 2023 – 36

*Octobre 2023*



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# Climate change perception, impact and adaptation: Implications for crop insurance

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**Abstract**

Weather-related events represent a main threat for French farmers, and their frequency and intensity are expected to increase due to climate change. In this context, we analyse the link between climate change perception, expected impact of climate change, and potential adaptation strategies that can be implemented to face climate change. For that purpose, we analysed the results of a survey conducted in 2021 on 288 French farmers. On the basis of these data, we created two indexes: a climate change perception index and an index of concern towards the expected impact of climate change. We first present some interesting correlations between adaptation strategies and hazards. We then identify some determinants of climate change perception and the expected impacts of climate change. Finally, we highlight two adaptation paths favoured by farmers. Depending on the characteristics of their farms and their perception of exposure today, some will favour farming adaptation, while others will favour the diversification of their income. We then discuss these results in terms of the existing crop insurance scheme in France.

**Keywords :** Climate change, Perception, Crop insurance, Adaptation, France.

**JEL Classification :** G22: Insurance, Insurance Companies, Actuarial Studies; Q54: Climate, Natural Disasters and Their Management, Global Warming

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# 1 Introduction

European agriculture is exposed to various weather-related events that threaten food production and the provision of environmental services. Indeed, climate change impacts agriculture through two major vectors, temperature and precipitation. Higher temperatures affect yields and favour pest invasion, whereas changes in precipitation regimes increase the likelihood of short-term crop failures and long-term production decline (Nelson et al., 2009). In addition, climate change has an impact on the frequency and intensity of weather-related events. Brás et al. (2021) have shown that crop losses tripled between 1961 and 2015 in Europe due to the severity of drought and heat waves.

In order to face these increasing risks, farmers may implement adaptation strategies. Among them, the adoption of a crop insurance contract is important since it has been identified by the COP23 as a major tool to adapt to climate change (Drieux et al., 2019). Crop insurance contracts are available in most European countries (Meuwissen et al., 2018). In France, a multi-peril crop insurance (MPCI) contract is available.[1] It offers coverage against 15 hazards (drought, hail, storm, etc.). The contract is unique and available for all farmers independently of location and crop. The insurance premium is subsidized up to 70% through the Common Agricultural Policy (CAP).[2] Currently, only around 30% of the French agricultural area is insured.

In a context of increasing risks due to climate change, this low level of insurance adoption is cause for concern. However, the implementation of adaptation strategies is expected to increase due to climate change, as is the demand for crop insurance. Consequently, in this paper, we analyse the role of climate change perception and its impact on adaptation decisions with an emphasis on crop insurance as one of the available adaptation tools. More precisely, we question whether or not the existing MPCI contract in France is still relevant in a context of climate change. Indeed, if farmers do not correctly perceive the risks and their expected impacts, then their behaviours in terms of adaptation strategies may not be adapted, leading to huge economic consequences. We also take a look at the link between insurance and the other adaptation strategies.

The literature on farmers' perceptions of climate change and the strategies they use to adapt to it is an emerging subject that draws on behavioural economics methods, in particular. Recently, Ricart et al. (2023) published a comprehensive review on the literature focused on climate change awareness, its perceived impacts and what farmers do to adapt to it. Using a sample of 465 articles published between 2010 and 2020, they conducted a specific analysis on 108 of

[1] The MRC policy (*Assurance MultiRisque Climatique sur récoltes*) available since 2005.
[2] The French insurance scheme is defined in greater detail in Koenig and Brunette (2023).

them. They highlight the emergence of the subject since the vast majority of articles from the last decade were published in the last 3 years. Economics journals are relatively under-represented in terms of publications. The journals with the greatest number of articles published on the subject are those dealing with climate change and sustainable development. The case studies are very diverse, dealing as much with farmers' perceptions of climate change in developed countries (particularly the USA) as in developing countries (sub-Saharan Africa and South-East Asia). On the other hand, with the exception of Germany, European countries are poorly represented in the corpus. The question of adopting crop insurance as one of the main adaptation measures was addressed by Jin et al. (2015), Mase et al. (2017) and Akinbile et al. (2018) for China, the United States and Nigeria respectively. Moreover, Woods et al. (2017) carried out a survey in which Danish farmers were questioned about their concerns and beliefs regarding climate change, the expected effects and their planned adaptation strategy. The authors found, among other adaptation strategies, that the more the farmers believed in climate change and the more they worried about its impacts, the greater their chances of taking out more or better insurance policies was. In the same vein, Schattman et al. (2016) studied climate change perception and forecasting from the point of view of farmers in Vermont. They interviewed farmers about the ecological and economic risks presented by climate change. They highlighted the importance of the psychological impact on climate change forecasting and anxiety. It appears that farmers are more likely to implement a risk adaptation strategy than a mitigation strategy in terms of the respective effect of both on their farm. Regarding the literature concerning the adaptation of French farmers to climate change, we can mention, in particular, Gouache et al. (2012) and Lungarska and Chakir (2018). The first one addresses the notion of adapting crop phenology in agronomic terms and, in particular, the importance of studying genetic variations that are resistant to heat shock for future choices of cultivated varieties. The second one deals with greenhouse gas abatement curves and highlights the positive interactions between mitigation and adaptation practices. They also show that, depending on the climate scenarios, there will be a change in land use, with a reduction in forest area in favour of an increase in agricultural land, which could be limited by the introduction of a carbon tax.

In this article, the objective is to analyse the link between climate change perception, the expected impact of climate change, and potential adaptation strategies that can be implemented by French farmers. For that purpose, we analysed the results of a survey conducted in 2021 on 288 French farmers. We collected information about their perception of climate change, its expected impact and their adaptation strategies. We also asked them questions about the characteristics of the farms and the farmers. We created two indexes: a climate change perception index and an index of concern towards the expected impact of climate change. We first present some interesting correlations between adaptation strategies, indicating that they are substitutes two-by-two. Concerning correlations between hazards, we show that storm is the hazard whose frequency is the least correlated with the frequency of another hazard. We then identify some determinants of climate change perception (having received an insurance compensation in the past, education level, farm exposure and having recently suffered from a loss due to a weather-related event) and the expected impact of climate change (having received an insurance compensation in the past, farm exposure and type of agricultural activity). Finally, we show that the perception of climate change only has a significant and negative impact on the diversification of crops as a potential adaptation strategy, whereas the expected impact of climate change never impacts the adaptation strategy. We discuss these results with regard to the existing crop insurance scheme in France.

The rest of the paper is organised as follows. Section 2 presents the materials and methods used. Section 3 indicates the results, which are then discussed in Section 4. Finally, Section 5 provides a conclusion.

# 2 Materials and methods

## 2.1 Data

We used survey data taken from a questionnaire answered by 288 French farmers in 2021. The survey was composed of 57 questions and is fully described in Koenig and Brunette (2023). The survey was carried out online and distributed via the French Chambers of Agriculture. Before going further and presenting the three variables of interest for our analysis and describing the sample in terms of the characteristics of the farm and the farmers, we demonstrate that the question addressed in this article is of utmost importance by showing that weather-related events represent a real threat for French farmers.

### 2.1.1 Are weather-related events a real threat?

In the survey, farmers ranked, in terms of importance according to their perception, the following six major categories of risk: weather-related events, variations in crop prices, pests and diseases, legislative and regulatory changes, increases in input costs, and lack of production outlets. The following graph shows the breakdown of the rankings of the 288 respondents (Fig. 1).

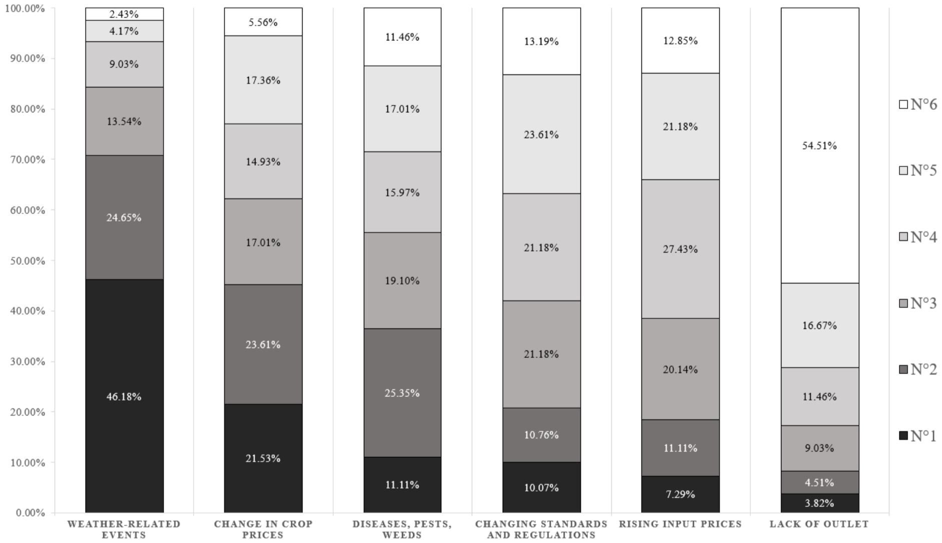


Figure 1: Classification of different sources of risk.

In our sample, weather-related events are the major risk that farmers have to cope with since 46.18% of our sample ranked this proposal as number one and it appears to be one of the two main sources of risk for 70% of them. Each of these risks involves various management tools. The variation in crop prices can be controlled by a contractual or future market process (contract for the sale of production upstream of the harvest at a set price). Pests, weeds and diseases are generally controlled by the use of chemical inputs, particularly pesticides (insecticides, herbicides and fungicides). Weather-related events may be insured.

Now that we have shown that weather-related events represent a major threat for French farmers, we analyse the way that farmers perceive climate change that will affect these events. In weather-related events, we include the "Disease, pests, weeds" category in order to discuss their insurability.

#### 2.1.2 The three variables of interest: climate change perception, expected impact and adaptation strategy

We focused on the questions from the survey that dealt with climate change perception, impact and adaptation. More precisely, we focused our analysis on three variables.

The first variable was linked to the farmers' perceptions of climate change. Four possible answers were available: doesn't believe in climate change, climate change doesn't impact and will not affect my farm, climate change will soon impact my farm, climate change is already impacting my farm.

The second variable was about the perceived impact of climate change. We asked the farmers who believe in climate change if climate change means an increase, decrease or no change in the frequency and intensity of six hazards on their farm (drought, storm, flooding, frost, hail, "diseases, pests, weeds" (D.P.W)). We chose to separate the dimensions of frequency and intensity of the proposed risks since they require different risk management tools. For a hazard whose frequency but not its intensity is expected to increase, farmers could rely on farm-level tools or insurance. On the contrary, if the farmer expected the hazard to remain stable or to decrease in frequency but increase in intensity, he or she could expect to rely on the disaster scheme,[3] for example.

The last variable of interest was related to adaptation. More precisely, we asked the farmers who believe in climate change to select the proposals that would best qualify the response to protect them from the effects of climate change (adaptation strategy) with five possible options: diversification of crops ($DCROP$), greater use of insurance schemes ($INS$), changing crop management practices ($PRA$), diversification of income sources ($DINC$)), no particular change ($NOCH$).

### 2.1.3 Characteristics of the farms and the farmers

We also used other variables collected during the survey. These variables are presented in Table 1 and divided into two parts: farmers' characteristics and farm characteristics. This table allows us to precisely describe our sample.

Concerning the farmers' characteristics, we can observe that the sample is composed of 80% of men, with a mean age of 50 years and a mid education level. We divided France into four zones: North, West, East and South. The least represented zone is North, with 10.76% of the sample, and the most well-represented zone is South, with 36.46%. The household is composed of four or more person for more than one-third of the sample. Income level presents a high variability, with 8% of the sample living with less than €1000 per month and 5.56% with more than €5000. The most well-represented interval is between €1000 and €2000. More than half of the farmers have a spouse working outside the farm, and almost 40% receive non-agricultural income. We can also observe that the farmers in our sample are quite impatient, with a low degree of impulsiveness,[4] and that they are risk-averse (coefficient of relative risk aversion of 1.32).[5]

Concerning the farm characteristics, we observe that the mean agricultural area in the sample

[3]In France, a public fund has existed since 1964 to compensate farmers for particularly devastating weather events. The reform of the crop insurance scheme, which has been in operation since 2023, sets the fund's intervention threshold at losses in excess of 50% of historical yield (for most crops).

[4]Impatience and impulsiveness are captured with self-assessment scales from 0 = very impatient (resp. not impulsive) to 10 = very patient (resp. very impulsive).

[5]Farmers' preferences towards risk are measured with an Ordered Lottery Selection task adapted from Eckel and Grossman (2002, 2008).

is almost 100 hectares. The farmers have extensive experience in terms of management, with an average of 20 years as farm manager. Several types of agriculture are present in the sample, with field crops and wine representing more than half of the sample. Almost 30% of the farmers use irrigation and are involved in a contractualisation process, 80% are members of a cooperative and 60% of a trade union. More than 60% of the farmers are owners or tenants. Most of the farms were previously managed by a family member. Some farmers are certified (36.46%), use employees on the farm (51.04%), supply nitrogen to crops (83.33%), have already received disaster payments (48.61%) and have suffered from yield losses due to weather events in the last 2 years (65.97%). The farms have a level of exposure to risk of 3.31/5.[6]

[6]The level of exposure towards risk of the farm is measured through a self-assessment scale from 0 = very little to 5 = very strongly.

Table 1: Statistics of the sample

| Variables | Detail | |
|---|---|---|
| **Farmers characteristics** | | |
| Age | Age of the farmer | 49.65 (10.3) |
| Gender | 1 for men | 0.816 |
| | | in % |
| Location | (1) = North of France | 10.76 |
| | (2) = West of France | 29.17 |
| | (3) = East of France | 23.26 |
| | (4) = South of France | 36.81 |
| Education | (1) = No diploma | 1.04 |
| | (2) = General Certificate of Secondary Education | 18.06 |
| | (3) = High School Diploma | 27.08 |
| | (4) = 1 and 2 years university level | 27.08 |
| | (5) = 3 years university level | 27.43 |
| | (6) = 4 years university level | 4.51 |
| | (7) = 5 years university level | 11.46 |
| | (8) = 6 to 8 years university level | 1.39 |
| Marital | (0) = Single | 15.28 |
| | (1) = Married or Civil-union | 70.83 |
| | (2) = Divorced or Widowed | 8.68 |
| | (3) = NSPP | 5.21 |
| HouseholdSize | (1) = 1 person | 12.15 |
| | (2) = 2 people | 31.94 |
| | (3) = 3 people | 19.44 |
| | (4) = 4 or more people | 36.46 |
| Income | (1) = <€1000 | 7.99 |
| | (2) = [1000:2000[ | 31.94 |
| | (3) = [2000:3000[ | 23.61 |
| | (4) = [3000:4000[ | 17.36 |
| | (5) = [4000:5000] | 6.60 |
| | (6) = >€5000 | 5.56 |
| | (7) = Prefers not to answer | 6.94 |
| SpouseOccupation | (0) = I live alone | 16.32 |
| | (1) = Spouse works outside of farm | 53.82 |
| | (2) = Spouse doesn't work outside of farm | 29.86 |
| NonAgriIncome | Non-agricultural activity income | 41.32 |
| Patience | 0=very impatient to 10=very patient | 5.98 (2.4) |
| Impulsiv | 0=not impulsive to 10=very impulsive | 4.28 (2.5) |
| CoeffRA | 0=neutral | 1.32 (1.0) |
| **Farms characteristics** | | |
| Surface area | Cultivated hectares | 98.13 (100.7) |
| FarmExp | Years as farm manager | 20.51 (12.7) |
| | | in % |
| TypeAgri | Agricultural activity (1) = Field Crops | 27.43 |
| | (2) = Wine | 28.82 |
| | (3) = Field Crops and Breeding | 17.36 |
| | (4) = Breeding | 9.03 |
| | (5) = Diversification (all others) | 17.36 |
| Irrigation | Irrigation user | 29.17 |
| Contract | In a contractualization process | 28.47 |
| Coop | Member of a cooperative | 78.47 |
| Syndicate | Member of a trade union | 57.64 |
| Statut | (1) = Owner | 23.26 |
| | (2) = Tenant | 13.19 |
| | (3) = Tenant-Owner | 63.54 |
| FamilyFarm | Farm previously managed by a family member | 71.88 |
| Label | Certification | 36.46 |
| WorkForce | Working with others on the farm | 51.04 |
| Nitrogen | Nitrogen supply to crops | 83.33 |
| Disaster | Already received a disaster payment | 48.61 |
| RecentLoss | Yield losses due to weather events in the last 2 years | 65.97 |
| Compensation | Having received compensation for crop losses from an insurer | 55.21 |
| FarmExposure | 0=very little to 5=very strongly | 3.31 (0.98) |

## 2.2 Method

We proceeded in three steps. These steps are represented in Figure 2.

First (Step 1 in Fig. 2), we looked at the descriptive statistics concerning our variables of interest: perception of climate change, impact of climate change and adaptation. We attempted to identify some trends in the results. In addition, we computed two additional

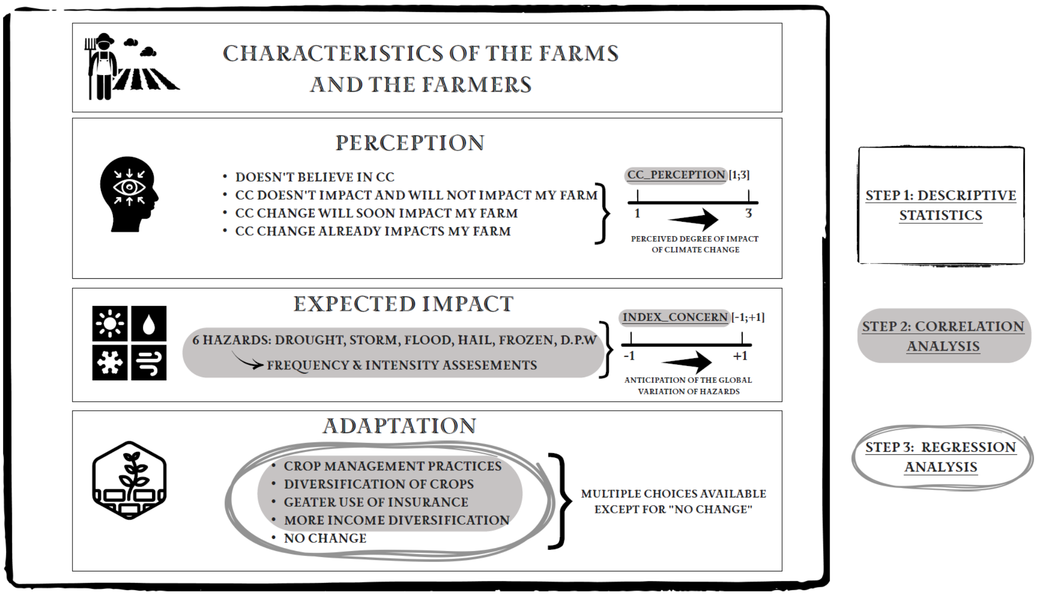


Figure 2: Variables and steps of the approach

variables: $CC\_PERCEPTION$ and $INDEX\_CONCERN$. The first one deals with the perceived degree of impact of climate change and varies between 1 and 3 with 1 = climate change doesn't impact and will not affect my farm, 2 = climate change will soon impact my farm, 3 = climate change is already impacting my farm. The higher the value of the variable $CC\_PERCEPTION$ is, the higher the perceived impact will be. The second variable is related to the expected impact of climate change. It is an aggregated variable computed as follows: for each hazard and for both frequency and intensity, we assumed that if the farmer selects a decrease, then the variable equals "-1", an increase "+1" and no change "0". This means that for each farmer, we have an index that is an average of 12 variables (six (hazards) $\times$ 2 (freq. and intensity)) coded between -1 and +1. The higher the score is, the greater the farmer's concern towards the impact of climate change will be.

Second (Step 2 in Fig. 2), we proposed a correlation analysis for the variables linked to adaptation and impact. Indeed, we wanted to observe if the adaptation strategies were correlated among themselves. In addition, we wondered whether or not the perceived hazards were correlated among themselves as well. For that purpose, we presented the results of the Pearson correlation coefficients in correlation matrices.

Finally (Step 3 in Fig. 2), the last step is dedicated to the regression analysis. We conducted three different regressions. The first regression is an ordinal logit regression that aims to identify determinants of the variable $CC\_PERCEPTION$ using characteristics of the farms and the farmers as potential explanatory variables. The second regression is a Tobit regression that attempts to identify the determinants of the variable $INDEX\_CONCERN$ using the characteristics as explanatory variables as well. Finally, the last regressions are intended to identify some determinants of the adoption of each of the four adaptation strategies and the "no particular change" option. For that purpose, we could argue that adaptation strategies are either independently adopted or simultaneously selected. Thus, under the first option, we ran five independent probit regressions for each of the strategies and the "no change" option. For a complementary analysis, we ran a multivariate probit model using the *cmp* command in Stata (Roodman, 2011). The results are presented in Table 11 in the Appendix. For all models, the explanatory variables are the characteristics of the farms and the farmers as well as the variables related to the perception and impact of climate change.

The first model analyses the factors explaining the degree of perception of climate change. Our variable of interest $CC\_PERCEPTION$ comprises, as a reminder, three modalities. Using an Ordered Logistic Model, we attempted to estimate how farm and farmers' characteristics influence climate change perception. The model takes the following form:

$$\ln\left(\frac{P(W_i \leq j|X_i, V_i)}{1 - P(W_i \leq j|X_i, V_i)}\right) = \alpha_j - \beta_1 X_i + \beta_2 V_i \tag{1}$$

where $W$ is the dependent variable of climate change perception, $j$ is the different modalities of the $CC\_PERCEPTION$ variable, $X$ is a vector of farmers' characteristics and $V$ a vector of farm characteristics (Table 1).

The second model investigates the parameters that explain the intensity of the $INDEX\_CONCERN$ variable. Our interest variable is continuous over the interval [-1;+1]. The closer to 1 the farmer's index is, the more the farmer thinks that the hazards will increase due to climate change in terms of frequency and intensity. Using a Tobit model bounded between -1 and +1, the model takes the following form:

$$Pr(Z_i|X_i, V_i) = \begin{cases} -1 & \text{if } z_i^* < -1 \\ \beta_1 X_i + \beta_2 V_i + \epsilon_i & \text{if } z_i^* - 1 < y < +1 \\ +1 & \text{if } z_i^* > +1 \end{cases} \tag{2}$$

where $Z$ is the dependent variable of concern, $X$ is a vector of farmers' characteristics, $V$ a vector of farm characteristics (Table 1) and $\epsilon$ is a random error term ($\epsilon \sim \mathcal{N}(0, \sigma^2)$).

The last models are run for each of the five adaptation strategies considered: $PRA$, $DCROP$, $INS$, $DINC$, $NOCH$. All five adaptation strategies are assumed to be independent and are therefore not considered as explanatory variables in the other models. Since the modalities can only be "No" (=0) or "Yes" (=1) to the question of whether they intend to adopt each strategy, we ran five similar probit models:

$$Pr(y_s = 1|X_i, V_i) = \Phi[\beta_{1s}X_i + \beta_{2s}V_i] \tag{3}$$

where $y$ is the binary variable relative to the adaptation strategy, $s$ is the adaptation strategy analysed, $X$ is a vector of farmers' characteristics and $V$ a vector of farm characteristics (Table 1).

# 3 Results

The results are presented following the three steps of the method described in Fig. 2.

## 3.1 Descriptive statistics

The descriptive statistics related to perception of climate change and adaptation are presented in Table 2.

Table 2: Perception of climate change and adaptation

| **Variables** | **Detail** | in% |
|---|---|---|
| Perception | (1) Doesn't believe in CC | 2.78 |
| | (2) CC doesn't impact and will not affect my farm | 2.78 |
| | (3) CC will soon impact my farm | 17.01 |
| | (4) CC already impacts my farm | 77.43 |
| Adaptation strategy | | |
| PRA | Changes crop management practices | 54.02 |
| DCROP | Diversification of crops | 52.11 |
| INS | Greater use of insurance | 28.74 |
| DINC | More income diversification | 52.87 |
| NOCH | No change | 6.79 |
| | | Average [std dev] |
| CC_PERCEPTION | Perceived degree of CC impact | 2.77 [0.486] |
| Number Adapt. | Number of adaptation strategies selected | 1.88 [0.049] |

**Perception.** Out of our 288 respondents, 2.78% of the sample (i.e., eight farmers) did not believe in climate change, 2.78% thought they would not be impacted, 17.01% (i.e., 49 farmers) believed they would soon be affected, and a large majority, 223 farmers, already considered themselves impacted by climate change. This means that around 95% of the farmers were convinced of the climate change impacts. Our index of climate change perception $CC\_PERCEPTION$ has a mean value of 2.77, which is quite high. The eight respondents who said they did not believe in climate change did not have access to the following questions concerning adaptation and impact.

**Adaptation.** We then questioned the 280 respondents about adaptation. More than 50% of the sample (i.e., 141 farmers) were willing to change their crop management practices to adapt to climate change impact. Diversification in terms of income and crop was also selected by more than 50% of the farmers, whereas insurance seemed to be the least interesting adaptation tool, with only 28.74%. This means that few farmers intended to increase their use of insurance to adapt to climate change. We also observed that on average, each farmer selects 1.88 adaptation strategies among the four possible ones (variable $NumberAdapt.$). More precisely, 95 farmers selected only one strategy, 108 selected two strategies, 53 selected three strategies and only five selected the four possible strategies.

**Impact.** We also questioned the 280 respondents about their subjective belief of how the frequency and the intensity of the six considered hazards will vary as a result of climate change. The results are presented in Table 3. The farmers believe that all six proposed hazards will increase as a result of climate change, both in terms of frequency and intensity. However, only droughts are unanimously expected to increase. For the other hazards, we consistently have between 36% and 47% of our sample that expect no change in intensity or frequency. It appears that farmers expect slightly more of an increase in frequency than in intensity, but the results are fairly similar. Storm is ranked as the number two hazard expected to increase in our sample, even though the expected effect of climate change on this hazard is not clear in the literature (Jouzel and Planton (2022) and ONERC (2018)). One important result is that the category "Disease, pests, weeds" is not currently insured in the French MPCI contract, whereas this hazard appears to be important for the farmers, and more than 55% of them perceive that this hazard will increase both in frequency and intensity.

Table 3: Impact of climate change

| Hazard | Frequency | | | Intensity | | |
|---|---|---|---|---|---|---|
| | ↗ | = | ↘ | ↗ | = | ↘ |
| Drought | 265 | 13 | 2 | 257 | 21 | 2 |
| Storm | 178 | 101 | 1 | 171 | 105 | 4 |
| Flood | 158 | 114 | 4 | 164 | 112 | 4 |
| Disease, pests, weeds | 158 | 114 | 8 | 155 | 117 | 8 |
| Hail | 147 | 131 | 2 | 135 | 141 | 4 |
| Frost | 120 | 105 | 55 | 110 | 119 | 51 |
| | Average [Std dev] | | | | | |
| INDEX_CONCERN | 0.56 [0.278] | | | | | |

The expected variations of some hazards (floods, hail, frost) are different as a function of the location (North, West, East, South) and of the farmer's activity (field crops, wine, fields crops+breeding, breeding, diversification), as presented in Appendix 5. Indeed, Table 6 shows that South and West perceived to be more subject to floods as a result of climate change, both in terms of frequency and intensity, than North and East. In the same manner, Table 7 indicates that East and South perceived to be more subject to hail as a result of climate change, both in terms of frequency and intensity, than North and West. Finally, in Table 8, we observe that North and West expect a decrease of frost both in terms of frequency and intensity as a result of climate change, whereas the opposite is true for East and South.
Concerning the impact of the farmer's activity, Table 9 shows that independently of the farmer's activity, farmers never expect the frequency and intensity of hail to decrease. Although the more robust activities expect no change in this risk, the more vulnerable crops (wine and others) expect hail to increase. Finally, Table 10 shows that wine growers highly expect the frequency and intensity of frost to increase compared to the other farmers' activities.

The average of the variable $INDEX\_CONCERN$ is 0.56. It should be recalled that this variable ranges from -1 to +1. The distribution of this index is presented in Fig. 3.

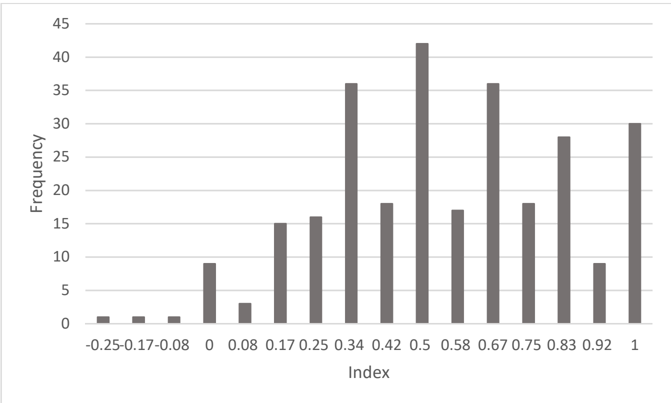


Figure 3: Distribution of the index of concern.

It should be noted that the index is rarely negative, only for three farmers. We can observe that 10.71% of the sample has always selected an increase (in frequency and intensity for all six of the hazards).

### 3.2 Correlation analysis

**Adaptation.** We looked at the potential correlation between the adaptation strategies through the following correlation matrix.

$$\text{Adapt. correlation} = \begin{bmatrix} & \text{PRA} & \text{DCROP} & \text{INS} & \text{DINC} \\ \text{PRA} & 1 & & & \\ \text{DCROP} & -0.02 & 1 & & \\ \text{INS} & -0.09 & -0.15^{**} & 1 & \\ \text{DINC} & -0.22^{***} & -0.01 & -0.18^{***} & 1 \end{bmatrix}$$

With [*] $p < 0.10$; [**] $p < 0.05$; [***] $p < 0.01$

We can observe that the correlation coefficients are always negative between the four adaptation strategies, meaning that they are substitute two-by-two. Some correlations are significant, e.g., insurance with diversification of crops and with income diversification. This is in accordance with the classical result of Ehrlich and Becker (1972) indicating that insurance and prevention are substitutes.

**Impact.** We looked at the potential binary correlation between: 1/ frequency and intensity for one hazard ("Hazard correlation" matrix); 2/ the frequency between hazards, two by two ("Freq. correlation" matrix); 3/ the intensity between hazards, two by two ("Intensity correlation" matrix). These three analysis correspond to the three correlation matrices below.

$$\text{Hazard correlation} = \begin{bmatrix} & \text{Drought} & \text{Flood} & \text{Frost} & \text{Storm} & \text{Hail} & \text{D.P.W.} \\ \text{Drought} & 0.45^{*} & & & & & \\ \text{Flood} & & 0.73^{*} & & & & \\ \text{Frost} & & & 0.79^{*} & & & \\ \text{Storm} & & & & 0.74^{*} & & \\ \text{Hail} & & & & & 0.74^{*} & \\ \text{D.P.W} & & & & & & 0.83^{*} \end{bmatrix}$$

With [*] $p < 0.10$; [**] $p < 0.05$; [***] $p < 0.01$

This first correlation matrix reveals that for each hazard, the frequency and the intensity are positively and significantly correlated. This result is in line with what we already observed in Table 3. The farmers who believe in climate change expect both the intensity and frequency of hazards to increase. Some correlations are associated with a high coefficient value like the intensity and frequency of D.P.W, whereas others are associated with a lower Pearson correlation coefficient like intensity and frequency of drought.

We then separated the analysis of the frequency and the intensity in order to study the potential correlation between hazards.

Freq. correlation =

| | Drought | Flood | Frost | Storm | Hail | D.P.W. |
|---|---|---|---|---|---|---|
| Drought | 1 | | | | | |
| Flood | $0.17^{***}$ | 1 | | | | |
| Frost | 0.05 | 0.07 | 1 | | | |
| Storm | $-0.01$ | $-0.05$ | 0.02 | 1 | | |
| Hail | $0.15^{**}$ | $0.13^{**}$ | $0.21^{***}$ | 0.06 | 1 | |
| D.P.W | $0.17^{***}$ | $0.16^{***}$ | $0.13^{**}$ | $0.19^{***}$ | $0.19^{***}$ | 1 |

With [*] $p < 0.10$; [**] $p < 0.05$; [***] $p < 0.01$

In this second correlation matrix, we can observe that storm is the hazard whose frequency is the least correlated with the frequency of another hazard. Indeed, the frequency of storm is only significantly and positively correlated with D.P.W. On the contrary, the frequency of some hazards is significantly and positively correlated with all the other hazard frequencies such as D.P.W and, to a lesser extent, Hail (except with Storm).

Intensity correlation =

| | Drought | Flood | Frost | Storm | Hail | D.P.W |
|---|---|---|---|---|---|---|
| Drought | 1 | | | | | |
| Flood | $0.18^{***}$ | 1 | | | | |
| Frost | $0.12^{*}$ | 0.05 | 1 | | | |
| Storm | $0.31^{***}$ | $0.26^{***}$ | 0.05 | 1 | | |
| Hail | $0.17^{***}$ | $0.27^{***}$ | $0.21^{***}$ | $0.43^{***}$ | 1 | |
| D.P.W | $0.17^{***}$ | $0.18^{***}$ | $0.12^{**}$ | 0.04 | $0.20^{***}$ | 1 |

With [*] $p < 0.10$; [**] $p < 0.05$; [***] $p < 0.01$

Several comments can be made on the basis of the third correlation matrix. First, the intensity of D.P.W is positively and significantly correlated with the intensity of all hazards except storm. This is currently the only hazard proposed here that is not included in the MPCI contract in France. Second, the intensity of drought is positively and significantly correlated with the intensity of all the other hazards.

## 3.3 Regression analysis

We first present the regressions aimed at identifying determinants of climate change perception and the index of concern, and we then present the results of the regression according to adaptation strategy.

### 3.3.1 Determinants of climate change perception and the index of concern

Table 4 presents the two regression analyses of the variables $CC\_PERCEPTION$ and $INDEX\_CONCERN$. The explanatory variables considered are those of Table 1.

Table 4: Regression results for perception and concern (N=280)

| | CC_PERCEPTION | INDEX_CONCERN |
|---|---|---|
| *TypeAgri* | | |
| 2.Wine | 0.577 | 0.130* |
| 3.FC and Breeding | 0.647 | 0.058 |
| 4.Breeding | 1.157 | 0.083 |
| 5.Diversified-other | −0.459 | 0.109* |
| *Location* | | |
| 2.West | −0.139 | 0.054 |
| 3.East | 0.530 | 0.076 |
| 4.South | −0.330 | 0.057 |
| Surface Area (ha) | −0.000 | 0.000 |
| Irrigation | 0.252 | −0.011 |
| Contract | −0.073 | 0.023 |
| WorkForce | −0.304 | −0.033 |
| Coop | −0.654 | 0.073 |
| Syndicate | 0.288 | −0.019 |
| FarmExp | 0.001 | −0.003 |
| FamilyFarm | 0.165 | −0.014 |
| Label | 0.389 | 0.022 |
| Nitrogen | −0.991 | −0.052 |
| Disaster | 0.636 | −0.034 |
| RecentLoss | 1.046** | 0.009 |
| Compensation | 0.738* | 0.090** |
| Age | −0.021 | 0.002 |
| Gender | 0.331 | −0.003 |
| Education | 0.349** | 0.009 |
| *Marital* | | |
| 1.Married or Civil union | 0.057 | −0.007 |
| 2.Divorced or Widowed | −0.169 | −0.103 |
| 3.NSPP | 1.060 | 0.087 |
| HouseholdSize | −0.112 | 0.008 |
| *SpouseOccupation* | | |
| 0.I live alone | 0.407 | 0.054 |
| 2.No | 0.181 | 0.013 |
| Income | 0.181 | 0.004 |
| NonAgriIncome | −0.218 | 0.008 |
| *Statut* | | |
| 2.Tenant | 0.900 | −0.093 |
| 3.Tenant-Owner | 0.229 | −0.069 |
| FarmExposure | 0.465** | 0.029* |
| CoeffRA | −0.133 | 0.023 |
| Patience | 0.125 | 0.004 |
| Impulsiv | 0.012 | 0.001 |
| Constant | | 0.200 |
| Log likelihood | −130.628 45 | −13.152 381 |
| Pseudo $R^2$ | 0.2064 | 0.6499 |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Concerning the variables with a significant and positive impact on the perception of climate change, we identified the variables $RecentLoss$, $Compensation$, $Education$ and $FarmExposure$. This means that having suffered losses in the past two years due to weather-related events and having already received an insurance compensation in the past are associated with a higher perception. A similar result is obtained concerning the level of education and the self-assessed level of exposure of the farm.

Concerning the variables with a significant and positive impact on the index of concern, we identified two types of crops ($Wine$, $Diversified - other$), the variables $Compensation$ and the self-assessment $FarmExposure$. Once again, this means that having already received an insurance compensation in the past is associated with a higher concern. A similar result is obtained concerning the self-assessed level of exposure of the farm.

### 3.3.2 Determinants of each adaptation strategy

The following table presents the regression results according to adaptation strategy. Several interesting comments can be made on this basis.

Table 5: Regression results for the adaptation strategies

| | Adaptation strategies | | | | |
|---|---|---|---|---|---|
| | PRA | DCROP | INS | DINC | NOCH |
| *TypeAgri* | | | | | |
| 2.Wine | 0.171 | $-1.961^{***}$ | 0.077 | 0.443 | 0.574 |
| 3.FC and Breeding | 0.291 | 0.064 | 0.050 | −0.220 | −0.025 |
| 4.Breeding | −0.202 | $-1.045^{**}$ | 0.179 | 0.648 | 0.483 |
| 5.Diversified-other | 0.213 | −0.233 | $-0.636^{*}$ | 0.231 | 0.071 |
| *Location* | | | | | |
| 2.West | 0.263 | 0.383 | −0.549 | 0.227 | −0.299 |
| 3.East | 0.197 | 0.328 | 0.168 | −0.036 | −0.432 |
| 4.South | 0.368 | $0.811^{**}$ | −0.358 | 0.335 | −0.071 |
| Surface Area (ha) | $-0.002^{*}$ | 0.001 | −0.001 | $0.003^{**}$ | 0.001 |
| Irrigation | 0.125 | −0.016 | 0.132 | 0.151 | −0.033 |
| Contract | 0.056 | 0.279 | 0.261 | $-0.368^{*}$ | −0.400 |
| WorkForce | 0.131 | 0.210 | 0.003 | $-0.591^{***}$ | −0.093 |
| Syndicate | −0.291 | −0.340 | 0.303 | −0.771 | −0.059 |
| Coop | −0.208 | −0.002 | −0.054 | 0.114 | −0.481 |
| FarmExp | 0.009 | −0.014 | −0.002 | 0.006 | 0.002 |
| FamilyFarm | −0.108 | 0.065 | 0.098 | 0.228 | 0.227 |
| Label | $0.404^{*}$ | 0.130 | 0.173 | $-0.518^{**}$ | −0.202 |
| Nitrogen | 0.084 | $-0.683^{**}$ | −0.057 | 0.283 | 0.084 |
| Disaster | 0.044 | 0.064 | −0.100 | −0.015 | 0.253 |
| RecentLoss | 0.296 | −0.084 | 0.067 | −0.041 | −0.184 |
| Compensation | −0.171 | −0.168 | $0.705^{***}$ | −0.178 | 0.110 |
| Age | −0.002 | −0.015 | 0.024 | −0.014 | 0.013 |
| Gender | $0.408^{*}$ | 0.254 | −0.122 | 0.040 | 0.160 |
| Education | 0.077 | $0.128^{*}$ | 0.031 | 0.094 | 0.058 |
| *Marital* | | | | | |
| 1.Married or Civil union | 0.197 | −0.049 | $-0.724^{*}$ | 0.040 | 0.509 |
| 2.Divorced or Widowed | −0.267 | 0.247 | −0.437 | 0.177 | 0.213 |
| 3.NSPP | 0.184 | 0.134 | −0.429 | $-1.012^{*}$ | 0.325 |
| HouseholdSize | $0.270^{**}$ | −0.055 | −0.193 | $0.227^{**}$ | 0.045 |
| *SpouseOccupation* | | | | | |
| 0.I live alone | $0.746^{*}$ | −0.158 | $-0.962^{**}$ | 0.166 | −0.001 |
| 2.No | −0.179 | 0.099 | 0.011 | $0.458^{**}$ | −0.064 |
| Income | $-0.194^{**}$ | 0.006 | 0.143 | −0.044 | −0.043 |
| NonAgriIncome | 0.139 | −0.160 | 0.345 | 0.234 | 0.175 |
| *Statut* | | | | | |
| 2.Tenants | $0.693^{**}$ | −0.072 | 0.126 | 0.238 | −0.505 |
| 3.Tenant-Owner | 0.299 | 0.034 | −0.099 | 0.275 | 0.002 |
| FarmExposure | $-0.164^{*}$ | −0.165 | $0.296^{***}$ | $0.207^{**}$ | 0.144 |
| CC_PERCEPTION | 0.089 | $-0.434^{**}$ | −0.146 | 0.023 | −0.340 |
| INDEX_CONCERN | 0.479 | 0.255 | 0.481 | −0.033 | −0.319 |
| CoeffRA | −0.017 | −0.005 | 0.116 | −0.056 | −0.037 |
| Patience | 0.011 | −0.018 | $-0.078^{*}$ | 0.011 | −0.004 |
| Impulsiv | 0.034 | 0.063 | 0.023 | −0.020 | 0.100 |
| Constant | −0.975 | $2.541^{**}$ | $-2.970^{**}$ | −1.628 | −2.731 |
| Observations | 261 | 261 | 261 | 261 | 280 |
| Log likelihood | −155.721 94 | −133.494 11 | −121.768 23 | −153.052 29 | −57.063 623 |
| Pseudo $R^2$ | 0.1352 | 0.2612 | 0.2221 | 0.1520 | 0.1784 |

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

First, when we look at the adaptation strategies, we can observe that eight variables may explain the changes in practices (PRA). Some variables have a positive impact like having a label, gender, the size of the household and being a tenant, and others have a negative impact like the area of the farm, the fact that the spouse works outside of the farm (positive effect of "I live alone" with respect to this modality), the level of risk exposure of the farm and income. The significant and negative impact of $SurfaceArea$ is interesting since it reveals a form of inertia: the greater the surface area is, the lower the probability of changing practices. This may correspond to a specialisation and investment effect. Similarly, having a label significantly increases the likelihood of changing practices. The labelling process is precisely a process of adapting previous cultivation practices to a new paradigm (in this case, the label specifications). To be awarded a label, the farmer has to follow precise specifications and generally make investments beforehand. We argue that if the farmers who have labels have been able to change their practices, it seems reasonable to think that they will be able to do so in the future to cope with new constraints. $FarmExposure$ has a negative and significant effect. This sign indicates that farmers who claim the greatest exposure of their farm to weather-related events are the least likely to change their farming practices in order to cope with climate change. In fact, these farmers are the most likely to want to diversify their income with respect to their farming activity (see the negative and significant correlation between the two practices in the adaptation correlation matrix and the influence of this same variable for the $DINC$ strategy).

Six variables have a significant impact on the diversification of crops (DCROP). The results indicate that winegrowers and livestock farmers will diversify significantly less than field crop growers. Vineyards are lands that are inherently dedicated to growing wine graps, where each hectare has a high economic value (depending on the terroir) and is therefore difficult to convert into another crop. As far as livestock farmers are concerned, the explanation is likely to lie both in land constraints and the impossibility of converting areas of pasture into arable land, but also in a structural debt that is a major handicap (Chartier and Chevrier, 2015). Livestock farming is a capital-intensive activity, with low returns and a very strong inertia effect. Being in the South has a significant and positive effect on the adoption of crop diversification compared to being located in the North. Farmers who use nitrogen are significantly less inclined to adopt crop diversification. The higher the education level is, the more often crop diversification will be selected as a potential adaptation strategy. Finally, climate change perception appears has negative and significant. This means that the higher the perception is, the lower the propensity to adopt crop diversification will be. This result reveals that being aware of climate change does not necessarily mean implementation of adaptation strategies, in particular, crop diversification.

The third adaptation strategy is insurance (INS), and several variables influence its adoption, some positively like $Compensation$, $Spouseoccupation$ (negative influence of living alone compared to the situation of the spouse working outside of the farm) and $FarmExposure$, whereas the others such as $TypeAgri5$, $Marital1$ and $Patience$ have a negative effect. Having received an insurance compensation in the past highly encourages farmers to adopt insurance. This result is in line with the literature that highlights an inertia effect regarding past experience with insurance on subsequent crop insurance adoption (Enjolras et al., 2012; Santeramo, 2019; Koenig and Brunette, 2023). Moreover, the higher the degree of exposure of the farm to risks, the higher the propensity to insure. Farmers who are married or in civil unions will adopt this strategy significantly less than single farmers. However, this appears to be counterbalanced if the spouse works off the farm. Finally, the fifth category of $TypeAgri$ that groups together the most diversified farms in the sample appears to be negative and significant in relation to the first category for field crop growers. Diversification and insurance are natural substitutes.

The last adaptation strategy is diversification of income (DINC). Eight variables have a significant impact. Diversification of income means seeking a source of income other than farming (from tourism or taking up a position in a third-party company, for example). We then easily understand that variables like $Contract$, $WorkForce$ or $Label$ have a significant and negative effect on the diversification of income. Regarding the family situation, both the number of people in the household and the fact that the spouse does not work outside of the farm (compared to the situation where he or she does), have a positive and significant influence on the probability of diversifying income. Embarking on a new entrepreneurial adventure may be easier if there are two people involved, or it may simply be easier for one of the partners to diversify the household income working outside of the farm if this is not yet the case. The degree of exposure to hazards also has a positive influence on the adoption of this strategy insofar as the farmer would be inclined to make his/her income less correlated with weather conditions.

Finally, the last column of Table 5 reveals no significant determinant for the "no change" (NOCH) planning.[7]

To conclude, it appears that $CC\_PERCEPTION$ is not a prerequisite to the adoption of adaptation strategies. This may be due to the fact that almost 80% of our sample already

[7]Running the same model without the $TypeAgri$ variable makes the impulsiveness positive and significant. The more the farmers define themselves as "impulsive", the more likely that they will not adopt any specific adaptation strategy.

feels the impact of climate change (modality 3). Nevertheless, it has a negative impact on one adaptation strategy: crop diversification. We can also note that although location seems to play a role on the perception of climate change impact (as discussed in Section 3.1 and presented in Appendix 5), it has no effect on the choices in terms of adaptation strategies. Indeed, the variables dedicated to location are never significant, except for the impact of *South* on crop diversification.

# 4 Discussion

## 4.1 The two paths of adaptation: farming adaptation vs. farming deviation

Our results suggest that French farmers are clearly aware of climate change. Starting from there, the way that they cope with it will be determined by their characteristics and those of their farms. We particularly argue that one crucial element is how exposed to weather-related events farmers consider themselves to be today. Two paths of adaptation arise from that distinction. The first path is about farming adaptation. The second one concerns the farmers who are willing to adapt by deviating their activity from farming. The first element that depicts this dichotomy is the negative coefficient of correlation between $PRA$ and $DINC$ in the *Adaptation* correlation matrix. The farmers will either change, adapt or modify their farming practices, or they will diversify their income sources. A look at the determinants of each strategy in Table 5 allows us to draw a fairly typical portrait. The farmers most likely to adopt the first path are characterised by an important inertia effect. This so-called inertia effect imposes a low degree of flexibility on farmers who manage farms, whereas "labelled" farms have natural barriers that prevent them from deviating from the agricultural activity (in particular, due to the investments made), and farm managers who have workers on their farms are also less likely to diversify their income source. Moreover, a distinct opposition is detectable regarding the $FarmExposure$ variable. The more the farmers consider themselves to be exposed to weather-related events today, the more likely they will deviate from pure farming activities and the less likely they will cope with climate change by modifying their farming practices. In summary, we distinguish, on the one hand, farmers who feel less exposed to weather-related events today, aware of the present and future impacts of climate change, and who will cope with it by adapting the operation of their farm. On the other hand, we distinguish farmers who feel particularly exposed to weather-related events today and who, since climate change impacts them, are likely to turn away from farming.

### 4.2 Implications for the development of crop insurance

Considering these two adaptation paths and the expected impacts of climate change has implications for the development of the crop insurance market. First of all, the *Adaptation* correlation matrix highlights the negative and significant correlation of insurance adoption with both diversification of crops and income. This means that these tools are substitutes: either the farmers insure or they implement diversification. Table 1 shows that the greater use of insurance is the least selected strategy (28.74% of the sample) despite being highly promoted (Drieux et al., 2019). One variable that clearly explains this adoption is *Compensation*, the fact of having already received compensation from an insurer in the past. This echoes the notion of farmers' trust in insurers mentioned in Koenig and Brunette (2023). Indeed, if farmers have already experienced a loss and have been compensated for it, then they trust their insurer and are more inclined to remain longer in the insurance scheme. Insurance appears as a fairly isolated strategy, which may be an important issue for the availability of such an instrument. Crop insurance adoption is already low today in France (around 30% of the French agricultural area without grassland insured by the main contract), which leads to the poor quality of pooling and structural losses for the insurer, with an average loss ratio of 101% between 2005 and 2018 (Koenig et al., 2022). Such losses threaten to drive private insurers out of the market, especially since expected climatic variations are likely to increase claims. These losses automatically lead to an increase in premiums. The market is currently in a situation where farmers perceive insurance to be too expensive, while premiums are too low from the insurers' point of view. It seems necessary to ask whether this low propensity to take out insurance might not be explained by the nature of the offer available to them. Expectations in terms of coverage and, in particular, the relationship between the price paid and the risks covered, may not be in line with what is currently on offer.

### 4.3 Multi-peril vs. single-peril crop insurance contract

In France, the only contract that entitles farmers to a premium subsidy is the unique multi-peril crop insurance contract that covers 15 hazards. Although the simplicity of such an offer and the number of hazards covered may seem attractive, farmers may find these contracts too expensive in relation to the coverage they would like to have. Indeed, all the hazards are not perceived in the same manner so that a unique insurance contract for all hazards does not seem to be the good option. Determining the level of the insurance premium is a delicate and not very transparent matter, but it takes a number of parameters into account such as the capital covered (type of crop, historical yield, etc.), the geographical location, the history of the farmer and, of course, the hazards covered. Therefore, the same farmer insuring the same crop on the same area with a multi-risk policy or a single-risk policy will not pay the same premium. For example, the average rate (ratio of premium/capital) for a field crop grower was 3.68% in 2018 for an MRC policy, compared to 1.45% for a single-risk hail policy (See the FFA study (p.c58-90) in the appendix of the Descrozaille (2021) report). The "relative cost" of an MRC contract compared to a hail contract was therefore 2.5 times higher in 2018 (for an average of 2.43 over the period 2012-2018). This difference is relatively the same for other types of crops with an average of 4.03% and 11.54%, respectively, on the MRC policy for vineyards and fruits, compared to 2.96% and 5.81% on the hail policy (for the same period). This difference is reflected in a substantial difference in premiums: the average premium paid by farmers insured under the MRC policy in 2018 was €4689, compared to €2220 for those insured under the hail policy (the differences in premiums paid are very large between crops, particularly in terms of premiums per hectare, but we do not have the precise data available.[8]

Since the cost of insurance is particularly significant, especially for the smallest farms, deviating from the strategy of a single contract in order to have an offer that provides less generic cover and that is more in line with farmers' expectations could convince them to enter the market. For example, farmers from North and West expect frost to decrease, so that the parameter related to the risk of frost in the calculation of the MPCI premium may discourage them from adopting the insurance contract. On the contrary, for wine-growers, the expected increase of this hazard may justify the adoption of a specific frost insurance contract that exists but is not currently subsidized. In other countries, single-peril crop insurance exists, like in Germany, where a mature single-peril hail insurance market for crops exists (Meuwissen et al., 2018) and in Spain, a country that has freed itself from the CAP in order to have more flexibility and that subsidizes the crop insurance premium with government funds.

Based on the assumption that variations in frequency or intensity do not involve the same management tools (although they are highly correlated with each other; see the "Hazard correlation" matrix), we can focus on the correlations in frequency between hazards ("Freq. correlation" matrix) to discuss the insurance tool. This matrix indicates that farmers do not perceive the increase in the frequency of certain hazards to be significantly correlated. For example, variations in the hazards *Frost* and *Storm* are only weakly correlated with the other hazards, while *Hail* and *D.P.W* are positively and significantly correlated with almost all the hazards. If the cost of insurance is expected to increase as a result of climate change and the systemic nature

[8] As an example, the Ariège prefecture simulated fictitious subscriptions in 2016 and the orders of magnitude were as follows: a net subsidy cost per hectare of MRC insurance of €31 for field crops, €116 for vineyards and €1,681.75 for fruit (these amounts are simply indicative of the orders of magnitude, as some examples differed depending on whether certain additional options were taken out).

it implies, this result indicates that farmers would be more inclined to take out specific policies for these correlated hazards. Similarly, Table 8 in the Appendix shows that over 60% of farmers in eastern France expect an increase in the frequency and intensity of frost events, whereas only 9.7% do in northern France (most of whom expect no change). If we carry out the analysis by crop type, we see in Table 9 that cereal growers do not expect an increase in the frequency and intensity of hail events, unlike wine growers, for example (38.5% compared to over 60%). The MPCI contract currently on offer covers the first four hazards (Drought, Flood, Frost, Storm and Hail), but does not cover the risk of crop pests (Disease, Pests, Weeds) unlike in the USA where plant disease cover is included in the Federal Crop Insurance Program (Skorbiansky et al., 2022). Moreover, important implications exist regarding the introduction of the cover of such risks since it could also be an instrument to promote the use of more environmentally-friendly farming practices by reducing the use of pesticides (Feinerman et al., 1992). However, empirical results indicate a positive correlation in the use of crop insurance and pesticides, underlining the importance of farmers' attitudes towards risk (Chakir and Hardelin (2014) and Möhring et al. (2020)). Reducing the use of these chemical inputs is a major objective of the Common Agricultural Policy and of the European Green Deal (Lefebvre et al. (2015) and Tataridas et al. (2022)), even more so with the emergence of pesticide resistance in treated pests (Beckie et al., 2019).

In our sample, this risk is ranked as even more worrisome than purely meteorological risks by at least 11.11% of our sample who ranked it first among the six sources of risk 1). Regarding the future use of crop insurance, our results suggest that "dual-risk" offers covering a meteorological hazard and the risk of pests and diseases could be of interest to farmers. However, the pricing of such a contract is subject to many uncertainties. Insurers lack the experience and data to measure this risk, so high premiums are to be expected.

### 4.4 Bundled contracts vs. separate ones

We can link the results of this article to the experimental economic literature about bundled insurance contracts vs. separate insurance contracts. The results are not unanimous since Slovic et al. (1977) and Schade et al. (2012) showed that individuals have a greater willingness to pay for a bundled contract than for two separate ones, whereas Schoemaker and Kunreuther (1979) obtained the reverse result, and Robinson and Botzen (2022) intermediary results. Slovic et al. (1977) tested whether 151 subjects prefer to insure against a low-probability/high impact risk when insurance covers a likely risk of loss as well. They showed that subjects in their experiment were willing to spend 30% more on insurance that covers both risks than the sum of their expenditures for two separate policies. Schade et al. (2012) conducted a survey whereby 254 students were either offered insurance that covers the risk of fire and theft of an inherited painting or sculpture, or individual policies that cover these risks separately. The authors showed similar results. Schoemaker and Kunreuther (1979) obtained the opposite results on a sample of 158 students and 68 clients of an insurance agency. Finally, Robinson and Botzen (2022) showed that the demand is greater to insure separate risks than to cover all risks together in a bundled insurance policy in the UK, whereas no significant difference was found in the Netherlands.

The literature and our results indicate that there is a delicate trade-off between a simplified, generic offer and a specific, more complex offer.

## 5 Conclusion

In this article, we analysed the link between the perception of climate change, the expected impact of climate change, and adaptation strategies towards climate change. We tackled this question through a survey carried out on 288 French farmers in 2021. We approached the process of adaptation by farmers as a sequential process of perception: assessing the imminence of climate change, anticipating its impacts and then defining the best strategy or strategies to adopt. Our results show that the majority of farmers are already feeling the impact of climate change. However, the exposure felt today and the expected variations in the frequency and intensity of the various hazards differ according to the characteristics of the farm and the farmer. These same characteristics lead to a dichotomy in adaptation profiles. Farmers who feel relatively less exposed to meteorological hazards, and with the strongest farm "inertia" (salaried or "labelled" farmers), are more inclined to adapt their farming methods, while others, already feeling more exposed, are more likely to decouple their income with respect to meteorological conditions by diversifying their sources of income. Insurance as a tool for coping with the consequences of these meteorological hazards seems to be struggling to find its place, and is only now being adopted by farmers already familiar with the system. The prospect of increasing weather hazards does not specifically encourage farmers to take an interest in this instrument. The low uptake of insurance is already leading to problems of market equilibrium, despite the fact that the offer is heavily subsidized. Under these conditions, worsening weather conditions are likely to aggravate the situation and to compromise the availability of the insurance tool in the future. Our results suggest that diversifying the contracts on offer by making them less generic could potentially meet the expectations of certain farmers in terms of coverage needs. Dual-risk contracts (like the ones that existed in the past) and the integration of pest and disease risks are areas worth exploring.

Our study naturally has a number of limitations. Firstly, the analysis was carried out on a limited sample, which, although relatively well distributed geographically, was mainly made up of field crop growers and winegrowers. Greater representation of market gardeners and fruit growers could have provided valuable information. In addition, more precise options for adaptation strategies could have been proposed. These questions were included in a broader survey on perceived barriers to the adoption of crop insurance contracts, and were therefore constrained in terms of size and time. More elements included in the questionnaire could have enabled a study to be carried out within the framework of the analysis of the effect of uncertainty and ambiguity on the parameters studied, but the same conditions as indicated above constrained it. This field of study is particularly wide-ranging and calls for numerous studies. The prospect theory framework, for example, seems well-suited to better understanding farmers' perceptions and induced reactions. As far as the insurance market is concerned, the development of index-based and parametric products also offers interesting opportunities for improving and reducing the cost of the products offered.

# Appendix A

Table 6: Expected frequency and intensity variation of flood according to farmer location.

| FLOOD | Frequency | | | Intensity | | | |
|---|---|---|---|---|---|---|---|
| | ↗ | = | ↘ | ↗ | = | ↘ | N |
| North | 48.4% | 51.6% | 0% | 51.6% | 48.4% | 0% | 31 |
| West | 63% | 34.6% | 2.5% | 63% | 35.8% | 1.2% | 81 |
| East | 38.5% | 58.5% | 3.1% | 43.1% | 55.4% | 1.5% | 65 |
| South | 65% | 31.1% | 3.9% | 67% | 31.1% | 1.9% | 103 |

Table 7: Expected frequency and intensity variation of hail according to farmer location.

| HAIL | Frequency | | | Intensity | | | |
|---|---|---|---|---|---|---|---|
| | ↗ | = | ↘ | ↗ | = | ↘ | N |
| North | 45.2% | 54.8% | 0% | 45.2% | 48.4% | 6.5% | 31 |
| West | 42% | 56.8% | 1.2% | 38.3% | 61.7% | 0% | 81 |
| East | 56.9% | 41.5% | 1.5% | 55.4% | 43.1% | 1.5% | 65 |
| South | 60.2% | 39.8% | 0% | 52.4% | 46.6% | 1% | 103 |

Table 8: Expected frequency and intensity variation of frost according to farmer location.

| FROST | Frequency | | | Intensity | | | |
|---|---|---|---|---|---|---|---|
| | ↗ | = | ↘ | ↗ | = | ↘ | N |
| North | 9.7% | 54.8% | 35.5% | 9.7% | 54.8% | 35.5% | 31 |
| West | 30.9% | 37% | 32.1% | 24.7% | 51.9% | 23.5% | 81 |
| East | 61.5% | 32.3% | 6.2% | 61.5% | 27.7% | 10.8% | 65 |
| South | 50.5% | 35.9% | 13.6% | 45.6% | 40.8% | 13.6% | 103 |

Table 9: Expected frequency and intensity variation of hail according to farmer activity.

| HAIL | Frequency | | | Intensity | | | |
|---|---|---|---|---|---|---|---|
| | ↗ | = | ↘ | ↗ | = | ↘ | N |
| Field crops | 38.5% | 61.5% | 0% | 38.5% | 61.5% | 0 | 78 |
| Wine | 65.8% | 32.9% | 1.3% | 60.8% | 36.7% | 2.5% | 79 |
| Field crops + breeding | 48.9% | 48.9% | 2.1% | 42.6% | 55.3% | 2.1% | 47 |
| Breeding | 46.2% | 53.8% | 0% | 46.2% | 50% | 3.8% | 26 |
| Diversification | 60% | 40% | 0% | 50% | 50% | 0% | 50 |

Table 10: Expected frequency and intensity variation of frost according to farmer activity.

| FROST | Frequency | | | Intensity | | | |
|---|---|---|---|---|---|---|---|
| | ↗ | = | ↘ | ↗ | = | ↘ | N |
| Field crops | 21.8% | 47.4% | 30.8% | 17.9% | 56.4% | 25.6 | 78 |
| Wine | 75.9% | 21.5% | 2.5% | 69.6% | 26.6% | 3.8% | 79 |
| Field crops + breeding | 29.8% | 48.9% | 21.3% | 29.8% | 44.7% | 25.5% | 47 |
| Breeding | 23.1% | 46.2% | 30.8% | 15.4% | 57.7% | 26.9% | 26 |
| Diversification | 46% | 32% | 22% | 46% | 36% | 18% | 50 |

Table 11: Multivariate probit model (N=261)

| | Adaptation strategies | | | |
|---|---|---|---|---|
| | PRA | DCROP | INS | DINC |
| *TypeAgri* | | | | |
| 2.Wine | 0.157 | $-1.972^{***}$ | 0.172 | 0.403 |
| 3.FC and Breeding | 0.306 | 0.049 | 0.087 | $-0.250$ |
| 4.Breeding | $-0.224$ | $-1.059^{**}$ | 0.170 | 0.575 |
| 5.Diversified-other | 0.172 | $-0.252$ | $-0.584$ | 0.223 |
| *Location* | | | | |
| 2.West | 0.275 | 0.391 | $-0.546$ | 0.207 |
| 3.East | 0.216 | 0.320 | 0.152 | $-0.048$ |
| 4.South | 0.394 | $0.793^{**}$ | $-0.407$ | 0.283 |
| Surface Area (ha) | $-0.002^{*}$ | 0.001 | $-0.001$ | $0.003^{**}$ |
| Irrigation | 0.117 | $-0.003$ | 0.029 | 0.139 |
| Contract | 0.050 | 0.273 | 0.223 | $-0.375^{*}$ |
| WorkForce | 0.141 | 0.215 | $-0.012$ | $-0.597^{***}$ |
| Syndicate | $-0.302$ | $-0.308$ | 0.246 | $-0.081$ |
| Coop | $-0.213$ | $-0.012$ | 0.003 | 0.147 |
| FarmExp | 0.009 | 0.063 | $-0.001$ | 0.005 |
| FamilyFarm | $-0.101$ | 0.138 | 0.099 | 0.242 |
| Label | $0.403^{*}$ | 0.138 | 0.141 | $-0.457^{**}$ |
| Nitrogen | 0.102 | $-0.695^{**}$ | $-0.012$ | 0.276 |
| Disaster | 0.034 | 0.067 | $-0.072$ | $-0.013$ |
| RecentLoss | 0.274 | $-0.172$ | 0.065 | $-0.077$ |
| Compensation | $-0.178$ | $-0.018$ | $0.687^{***}$ | $-0.164$ |
| Age | $-0.002$ | $-0.018$ | 0.023 | $-0.013$ |
| Gender | 0.384 | 0.238 | $-0.088$ | 0.040 |
| Education | 0.079 | $0.126^{*}$ | 0.039 | 0.096 |
| *Marital* | | | | |
| 1.Married or Civil union | 0.178 | $-0.051$ | $-0.677^{*}$ | 0.048 |
| 2.Divorced or Widowed | $-0.280$ | 0.262 | $-0.405$ | 0.166 |
| 3.NSPP | 0.177 | 0.151 | $-0.349$ | $-0.984^{*}$ |
| HouseholdSize | $0.274^{**}$ | $-0.060$ | $-0.187$ | $0.223^{**}$ |
| *SpouseOccupation* | | | | |
| 0.I live alone | $0.725^{*}$ | $-0.173$ | $-0.943^{**}$ | 0.156 |
| 2.No | $-0.181$ | 0.091 | $-0.013$ | $0.435^{*}$ |
| Income | $-0.187^{**}$ | 0.004 | 0.148 | $-0.052$ |
| NonAgriIncome | 0.119 | $-0.156$ | 0.352 | 0.241 |
| *Statut* | | | | |
| 2.Tenants | $0.644^{**}$ | $-0.102$ | 0.182 | 0.150 |
| 3.Tenant-Owner | 0.280 | 0.006 | $-0.070$ | 0.259 |
| FarmExposure | $-0.162^{*}$ | $-0.165$ | $0.306^{***}$ | $0.223^{**}$ |
| CC_PERCEPTION | 0.098 | $-0.441^{**}$ | $-0.097$ | 0.018 |
| INDEX_CONCERN | 0.489 | 0.282 | 0.490 | $-0.007$ |
| CoeffRA | $-0.021$ | $-0.006$ | 0.119 | $-0.059$ |
| Patience | 0.011 | $-0.016$ | $-0.078^{*}$ | 0.007 |
| Impulsiv | 0.037 | 0.060 | 0.015 | $-0.025$ |
| Constant | $-1.727$ | $2.877^{**}$ | $-2.313$ | $-1.664$ |
| Log likelihood | | -500.91639 | | |

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

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