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# What Determines the Adoption of Conservation Agriculture? Evidence from Quebec

Guy Martial Takam Fongang[1] · Isambert Leunga Noukwe[2] · Jean-François Guay[1] · Charles Séguin[1,3]

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## Abstract
Conservation agriculture (CA) is promoted by various organisations and scholars as alternative to conventional agriculture to meet growing food demand with minimal damage on environment; but its factors of adoption have not been well identified. The study uses the recent composite index of adoption of CA developed by Takam Fongang et al. (2023) to analyse the factors of adoption of conservation agriculture among maize and soybean farmers in Quebec. Using data from 93 maize and soybean producers and a Fractional logit model, the study shows that adoption of CA increases with farmer's favourable perceptions of yield and easiness of implementing CA, off-farm employment and higher education. The study therefore indicates that higher education, technical assistance and popularisation of performance of CA can play a significant role in boosting adoption of CA in Quebec.

**Keywords** Sustainable agriculture · Adoption · Risk preference · Maize and soybean producers · Canada

## Introduction

Over the past decades, conservation agriculture (CA) has been promoted by various organisations like Food and Agriculture Organisation of the United Nations and scholars as alternative to conventional agriculture to meet growing food demand with minimal damage on environment (Hobbs et al. 2008; Lal 2018). CA is sustainable agricultural practice characterized by three pillars including the absence or minimum mechanical soil disturbance, the permanent soil cover by mulch and/or cover crop, and crop rotation involving ideally at least three crops (Kassam et al. 2018). Although initially developed with the aim of preventing soil erosion (Kassam et al. 2018), CA has been shown to provide different benefits to farmers and society including among others, the reduction of labour demand, production cost, greenhouse gas emission, the increase of water infiltration, organic matter, etc. (AFD 2006; Kassam et al. 2011; Knowler and Bradshaw 2007). For example, several studies have reported the positive effect of CA on soil quality and crop yield (Khonje et al. 2018; Manda et al. 2016; Sharma et al. 2011; Thierfelder et al. 2013), on mitigating the production risks (Kassie et al. 2015), and on household income (Tambo and Mockshell 2018). Good performances of CA are normally obtained through better water infiltration, better soil moisture and better soil organic matter (Sharma et al. 2011; Thierfelder et al. 2013), and through reduction of soil erosion, labour requirement, production cost and chemical fertilizer, etc. (Kassam et al. 2018). Even though some studies have also reported a negative effect of CA on crop yield especially under humid climate (Pittelkow et al. 2015), the statistics show an increasing adoption of CA over years (Fig. 1). For example, between, 2008/2009 and 2018/2019, CA cropland area has increased from 106.5 to 205.4 million hectares at the global level, and from 13.5 to 21.7 million hectares in Canada during the same period. Although the expansion of adoption has been largely farmer-driven, several factors such as the development of new seeding equipments, the introduction of broad-spectrum herbicide glyphosate, the development of new crop varieties increased public awareness and lower interest

✉ Guy Martial Takam Fongang
takam_fongang.guy_martial@courrier.uqam.ca

[1] Institut des Sciences de l'Environnement, Université du Québec à Montréal, Case postale 8888, succursale Centre-ville, Montréal, QC H3C 3P8, Canada

[2] Département d'économique, École de gestion, Université de Sherbrooke, 2500 Boulevard de l'université, Sherbrooke, QC J1K 2R1, Canada

[3] Département des sciences économiques, École des sciences de la gestion, Université du Québec à Montréal, Case postale 8888, succursale Centre-ville, Montréal, QC H3C 3P8, Canada

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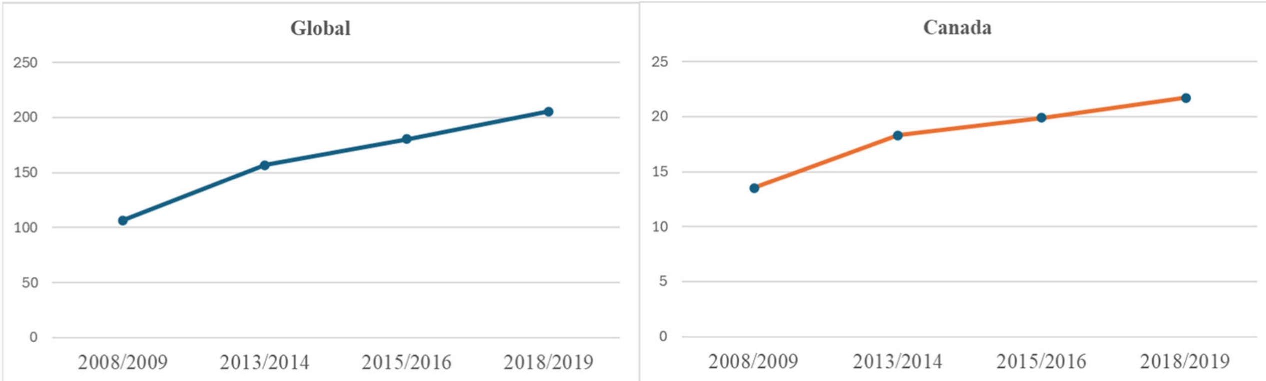


**Fig. 1** CA cropland area (in million hectares) at the global and Canada national levels. Source: Adapted from Kassam et al. (2022)

rate on machinery investment have served as catalyst for expansion of CA in Canada (Awada et al. 2014). For example, Awada et al. (2014) have shown in Canadian prairies although high prices of new seeding equipments and glyphosate initially acted as lagging factors of CA, the reduction of price of glyphosate relative to the price of fuel and the reduction of the cost of capital have fostered the adoption of CA in latter decades. Nowadays, several countries are now providing policy and institutional support to the adoption of CA (Kassam et al. 2022). A good example is the ministerial initiative for agro-environmental practice rewards recently proposed by Quebec government which provides monetary incentive to farmers that adopt agro-environmental practices. Another example is the programme Prime Vert whose aim is to encourage adoption of agro-environmental practices. One of the main objectives of this programme is to increase the adoption cover crops by providing financial assistance to farmers. Despite the increasing adoption of CA over the years, the proportion of global cropland under CA remains low and was estimated to 14.7% of the global cropland area in 2018/2019 (Kassam et al. 2022).

In Quebec for example, even if the cropland area under CA has been increasing, about 8781 farms (50.8% of total farm) and 468 889 hectares (36% of farmland) were still under conventional tillage in 2021 (Takam Fongang et al. 2023). More recently, a survey of maize and soybean farmers has also shown that only 21.5% of farmers were full adopters of CA in Quebec (Takam Fongang et al. 2023). We therefore ask ourselves the following question: Why do some farmers adopt CA and others do not? Understanding the factors of CA adoption is fundamental for sustainable agricultural development given the various benefits of CA, at least in terms of mitigating soil erosion.

Several studies have attempted to explain farmers' decision to adopt CA in the literature, but the results remain controversial and vary from a study to another.

Previous studies have classified factors of CA adoption into four main categories including farmer and farm household characteristics, exogenous factors, farm biophysical characteristics, and farm management/financial characteristics (Kagoya et al. 2018; Knowler and Bradshaw 2007).

## Farm Biophysical Characteristics, Farmer and Farm Household Characteristics

Several studies have identified farmer and farm household characteristics such as age, education, risk bearing, gender, namely, as well as farm biophysical characteristics such as soil erodibility, well drained soil, temperature, rainfall variability, etc. as factors of CA adoption (Ghazalian et al. 2009; Khonje et al. 2018; Tambo and Mockshell 2018; Wade and Claassen 2017; Ward et al. 2018). Specifically, Ward et al. (2018), using a Probit model showed in southern Malawi that CA adoption increased with farm size, level of education of farmer. When studying the factors of adoption of best management practices for enhancing water quality in Quebec, Ghazalian et al. (2009) found that education, age and farm size have a positive and significant effect on crop rotation adoption. Conversely to Ghazalian et al. (2009), Ramsey et al. (2019) found that age, education and farm size had no significant effect on adoption of conservative practices (continuous no till and conservation crop rotation) in Kansas. Moreover, Ramsey et al. (2019) have instead found that farmers who viewed conservative practices (continuous no till and conservation crop rotation) either as yield-risk reducing practice or as beneficial for soil improvement were more likely to adopt the conservative practices. Other factors such as perception of environmental benefits (Kolady et al. 2020), gender, climate condition and soil characteristics (Davey and Furtan 2008) have also been found to influence the CA adoption. Indeed, Davey and Furtan (2008) showed using a Probit model that adoption of conservation tillage in the prairies region of Canada were positively correlated with proportion of black and dark grey soil, average maximum temperature for April and the average maximum temperature of June of the previous year and negatively correlated with the proportion of brown soil and the gender. Kolady et al. (2020) however, have shown in eastern South Dakota, USA that favourable perception of environment benefits of CA has a positive effect on CA adoption.

## Exogenous Factors and Farm Management/financial Characteristics

Concerning the exogenous factors and farm management/financial characteristics, several authors have reported the significant effect of off-farm employment, membership in farmer organisation, family labour, land tenure, peer effect, participation in agri-environmental advisory activities (Bavorová et al. 2020; Fisher et al. 2018; Kagoya et al. 2018; Kolady et al. 2020; Tambo and Mockshell 2018; Tamini 2011; Ward et al. 2018; Zhong et al. 2015) For example, Tamini (2011), using nonparametric approach to study the impact of agri-environmental advisory activities on the adoption of six best management practices, found that the participation to agri-environmental advisory activities has a positive impact on the adoption of conservation tillage in Quebec. Kolady et al. (2020), on the other hand, found in eastern South Dokota that adoption of conservation tillage and crop rotation increases with the proportion of adopters of conservation tillage and crop rotation in a 30-mile radius and hence demonstrated the importance of spatial peer effect on the adoption of conservation agriculture. Other authors have instead focused on the effect of information sources on the adoption of conservation agriculture in the literature. This is the case of Fisher et al. (2018) who found in Malawi that while crop rotation adoption was positively correlated with government agent extension contacts, farmer field day visits, non governmental organisation contacts, village extension meeting, and negatively correlated with electronic media contacts; minimum tillage adoption was found to be negatively correlated with private agent extension contacts. The same authors also found that mulching adoption was positively associated with private agent extension contacts but negatively correlated with other farmer advice contacts and village extension meetings. Additionally, Zhong et al. (2015) using a Logit regression, found in Kentucky, USA that the percentage of farming income and the percentage of rented land had a positive and significant effect on adoption of No-till. The overall review is summarized in Table 1.

Despite the abundance of studies investigating the factors of adoption of conservation agriculture in the literature, it is important to note that almost all studies rely on the use of the traditional binary indicator which supposes that farmers are adopters or not of conservation agriculture whereas the data show that farmers often have a partial adoption of the principle of conservation agriculture (Grabowski and Kerr 2013; Mango et al. 2017; Takam Fongang et al. 2023). The main drawback of a binary approach is that it cannot account for the whole complexity of CA and hence is unable to discriminate among farmers who are full adopters, partial adopters or non-adopters of CA (Takam Fongang et al. 2023).

This study therefore contributes to the current debate by analysing the determinants of CA adoption in Quebec. Our contribution differs from previous ones as it uses the recent composite index of adoption of conservation agriculture (CIACA) developed by Takam Fongang et al. (2023) for measuring level of adoption of CA among farmers. The advantage of CIACA over the binary approach lies in the fact that it permits classification of farmers according to the level of adoption of the three principles of CA. Another advantage of the CIACA is related to the use of a three-year time scale which permits accounting for the minimum of three crops which indicates the adoption of the crop diversification principle of CA (Takam Fongang et al. 2023).

The study was guided by the hypothesis that there is a negative relationship between risk preference and CA adoption. Indeed, although previous studies have reported the effect of risk preference on adoption of agricultural innovations (Ghadim et al. 2005; Jin et al. 2020; Liu 2013; Mao et al. 2019; Mohan 2020), the effect of risk preference on CA adoption remain unclear. For example, while some studies have reported a positive effect of risk aversion and loss aversion on crop rotation adoption (Jin et al. 2020), other studies have reported no significant effect of loss aversion and risk aversion on zero tillage adoption, residue mulching adoption and intercropping adoption (Ward et al. 2018). Following Liu (2013), we modelled the risk preference of farmers under the cumulative prospect theory (Tversky and Kahneman 1992) and the risk elicitation experiment was inspired from Tanaka et al. (2010).

The remainder of the paper is organised as follows. Sections “Methodology” and “Results and discussion” present respectively the methodology of the study, and results and discussion. Section “Conclusion” provides the conclusion of the study.

# Methodology

## Econometric Model

Logit, Probit, Tobit, Fractional logit and multinomial Logit models have been regularly used to analyse the determinants

**Table 1** Summary of literature review

| Categories | Factors of adoption of CA | Signs | Studies |
|---|---|---|---|
| Farm biophysical characteristics | Farm size | + | (Ghazalian et al. 2009; Khonje et al. 2018; Wade and Claassen 2017; Ward et al. 2018) |
| | Proportion of black and dark grey soil | + | (Davey and Furtan 2008) |
| | the proportion of brown soil | - | (Davey and Furtan 2008) |
| | Average maximum temperature for April, average maximum temperature of June of the previous year, average temperature | + | (Davey and Furtan 2008) |
| | Temperature variability, average temperature | + | (Wade and Claassen 2017) |
| | High soil erodibility, well drained soil | + | (Wade and Claassen 2017) |
| | Rainfall index | - | (Khonje et al. 2018) |
| farmer and farm household characteristics | Level of education of farmer | + | (Tambo and Mockshell 2018; Ward et al. 2018) |
| | Age | + | (Ghazalian et al. 2009) |
| | Gender | - | (Davey and Furtan 2008) |
| | Beneficial for soil improvement | + | (Ramsey et al. 2019) |
| | Perception of environmental benefits | + | (Kolady et al. 2020) |
| | Yield-risk reducing practice | + | (Ramsey et al. 2019) |
| | Awareness of erosion | + | (Abdulai 2016) |
| farm management/financial characteristics | Share of rented land, land tenure | +/- | Bavorová et al. 2020; Kagoya et al. 2018; Zhong et al. 2015 |
| | Farm profitability | + | Bavorová et al. 2020; |
| | Credit access | + | (Abdulai 2016; Tambo and Mockshell 2018) |
| | Off-farm employment | - | (Tambo and Mockshell 2018) |
| | Percentage of farming income | + | Zhong et al. 2015 |
| | Household size | - | (Tambo and Mockshell 2018) |
| | Land security | + | (Tambo and Mockshell 2018) |
| Exogeneous factors | Agri-environmental advisory activities | + | (Tamini 2011) |
| | Peer effect | + | (Kolady et al. 2020); |
| | Private agent extension contacts, government agent extension contacts, farmer field day visits, non-governmental organisation contacts, village extension meeting, electronic media contacts | +/− | (Fisher et al. 2018); (Abdulai 2016) |
| | Membership in farmer organisation | + | (Abdulai 2016; Tambo and Mockshell 2018) |

of agricultural innovations adoption in the literature (D'Emden et al. 2008; Davey and Furtan 2008; Kassie et al. 2015; Khonje et al. 2015; Mango et al. 2017; Shiferaw et al. 2014; Takam-Fongang et al. 2019; Teklewold et al. 2013; Zeng et al. 2018). The choice of one or another model generally depends on the nature of the dependent variable (binary variable, continuous between 0 and 1, categorical variable). Thus, the Fractional logit model was used in this study to analyse the factors of CA adoption. This method was preferred over other methods because the dependant variable is a continuous variable which can take only the values from the interval 0 to 1. Fractional logit model was developed by Papke and Wooldridge (1996) and has been used extensively for analysing fractional dependent variable in the literature (Getahun et al. 2023; Mutyasira et al. 2018; Tran-Nam and Tiet 2022). Under the fractional logit model, the conditional expectation of CA adoption (CIACA$i$) on $\mathrm{X_i}$ and $\mathrm{Y_i}$ is as follows:

$$E(\mathrm{CIACA_i}/(\mathrm{X_i}, \mathrm{Y_i})) = G(\mathrm{X_i}\lambda + \mathrm{Y_i}\alpha) \quad (1)$$

where $\mathrm{CIACA_i}$ is CA adoption which can take any value from 0 to 1. $\mathrm{X_i}$ and $\mathrm{Y_i}$ are respectively the vector of risk preference parameters including risk aversion, loss aversion and probability weighting, and the vector of control variables. $\lambda$ and $\alpha$ are the vectors of parameters to be estimated and $G(\mathrm{X_i}\lambda + \mathrm{Y_i}\alpha) = \frac{e^{\mathrm{X_i}\lambda+\mathrm{Y_i}\alpha}}{1+e^{\mathrm{X_i}\lambda+\mathrm{Y_i}\alpha}}$ is a logistical function satisfying the following condition:

$$0 < G(\mathrm{X_i}\lambda + \mathrm{Y_i}\alpha) < 1 \quad (2)$$

**Table 2** Definition of variables used in the model

| Variables | Measurement |
|---|---|
| Key independent variables | |
| Risk aversion ($\sigma$) | Number |
| Loss aversion ($\lambda$) | Number |
| Probability weighting parameter ($\delta$) | Number |
| Control variables | |
| Farmer's perception regarding the yield of CA (prendac) | Mean of expected yield of CA over 20 years[a] |
| Farmer's perception regarding the risk of CA (priskac) | Variance of expected yield of CA over 20 years[a] |
| Membership to agri-environmental organization (agroenv) | 1 if the farmer belongs to an agri-environmental organisation and 0 otherwise |
| Secondary education (educs) | 1 if the farmer has a secondary education level and 0 otherwise |
| Collegial education (educc) | 1 if the farmer has a collegial education level and 0 otherwise |
| University education (educu) | 1 if the farmer has a university education level and 0 otherwise |
| Agricultural training (formagri) | 1 if farmer has received an agricultural training and 0 otherwise |
| Age of the farmer (age) | Years |
| Off-farm employment (travail) | 1if the farmer has an off-farm employment and 0 otherwise |
| Logarithm of farm size (logsup) | Hectares |
| Rented farmland (flocation) | Hectares |
| Farmer's perception regarding the easiness of implementing CA (fac) | 1 = CA is easy or very easy to implement 0 = CA is difficult or very difficult to implement |

[a] Explanation of the computerization of farmer's perception regarding the yield and risk of CA is presented below

The control variables were selected based on the literature and are presented in Table 2. The model was estimated by the quasi-maximum likelihood method which involved the maximization of the following Bernoulli loglikelihood function:

$$L(\lambda,\alpha) = \mathrm{CIACA_i}\log[G(\mathrm{X_i}\lambda + \mathrm{Y_i}\alpha)] + (1-\mathrm{CIACA_i})\log[1 - G(\mathrm{X_i}\lambda + \mathrm{Y_i}\alpha)] \quad (3)$$

The adoption of CA was measured by the composite index of adoption of conservation agriculture ($\mathrm{CIACA_i}$) recently developed by Takam Fongang et al. (2023) as follows:

$$\mathrm{CIACA_i} = \left[\frac{\sum_{t=1}^{3}(\mathrm{w_1PL_t} + \mathrm{w_2PC_t} + \mathrm{w_3PR_t})}{3}\right]_i \quad (4)$$

Where $\mathrm{CIACA_i}$ can take any value from 0 to 1 with 0 and 1 standing respectively for non adoption of conservation agriculture and full adoption of CA Any value between 0 and 1 will represents a partial adoption of conservation agriculture. $\mathrm{PL_t}$, $\mathrm{PC_t}$ and $\mathrm{PR_t}$ stand for respectively the proportions of farm under no or minimum mechanical soil disturbance principle, permanent mulch soil cover/cover crop principle and crop rotation principle in year t; and $\mathrm{w_1}$, $\mathrm{w_2}$ and $\mathrm{w_3}$ are their respective weights. These weights which measure the contribution of each principle to the sustainability of the CA were obtained from Takam Fongang et al. (2023).

To compute the two variables farmer's perception regarding the yield and risk of CA, we asked farmers to distribute a total of 20 coins over a series of possible maize yield values that could be obtained by a CA producer. The 20 coins stand here for 20 agricultural campaigns. The series of likely maize yields of CA is presented in Table 3 below.

**Table 3** Likely maize yield values under CA

| Maize yield (tonne/hectare) | 6 or less | 6.5 | 7 | 7.5 | 8 | 8.5 | 9 | 9.5 | 10 | 11 and over |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of coins | | | | | | | | | | |

Farmer's perception regarding the yield of CA is simply the mean of expected yields, and farmer's perception regarding the risk of CA is the variance of expected yields.

This way of computing farmer's perceptions was adapted from (Ghadim and Pannell 2003).

## Risk Preference Measurement

An online experiment based on cumulative prospect theory was used to elicit the risk preferences of farmers in Quebec. Following Tanaka et al. (2010), we assumed that the utility function of farmers is of the following form:

$$U(x,p;y,q) = \begin{cases} V(y) + w(p)[V(x) - V(y)]\ if\ x > y > 0\ or\ 0 < x < y \\ w(p)V(x) + w(q)V(y)\ if\ x < 0 < y \end{cases} \quad (5)$$

With

$$V(x) = \begin{cases} x^{\sigma} f\ or\ gains(x > 0) \\ -\lambda(-x)^{\sigma} f\ or\ losses(x < 0) \end{cases} \quad (6)$$

$$w(p) = \exp^{[-(-\ln p)^{\delta}]} \quad (7)$$

Where $p$ and $q$ are probabilities associated with outcomes $x$ and $y$; $w(p)$ is the probability weighting function and δ is a parameter that determines the curvature of the probability weighting function. If $\delta = 1$, we are in presence of absence of probability distortion as $w(p) = p$. On the other hand, if $\delta < 1$, we are in presence of probability distortion characterized by the overweighting of small probabilities and the underweighting of high probabilities. However, if $\delta > 1$, we are still in presence of probability distortion where individuals underweight small probabilities and overweight high probabilities (Bocquého et al. 2014). σ and λ measure respectively the degree of concavity of the value function and the degree of loss aversion. Based on the value of $\sigma$, a farmer can be characterized as risk lover ($\sigma > 1$), risk averse ($\sigma < 1$) or risk neutral ($\sigma = 1$) (Bocquého et al. 2014). A higher $\lambda$ will imply that the farmer is more loss averse (Liu 2013). Note that the cumulative prospect theory model will reduce to the expected utility model if $\delta = 1$ and $\lambda = 1$.

Three series of paired lotteries adapted from Tanaka et al. (2010) were used to estimate the risk parameters of farmers. The series of paired lotteries are presented in Table 4. The series were designed so as the expected payoff of difference between lotteries A and B (A-B) decreases as one go down. For each series of paired lotteries, farmers were successively asked to choose between A and B. In each series, the next paired lotteries was presented to farmers only if they selected the lottery A in the previous paired lotteries.

The three series were carefully designed so as any combination of choices made by farmers determined particular values of prospect theory parameters $\sigma$, δ and $\lambda$ (Tanaka et al. 2010). Indeed, for any farmer that switches from lottery A to lottery B at row N, we can conclude that the farmer prefers the lottery A over the lottery B at row (N-1) and prefers lottery B over the lottery A at row N. If the farmer switches at row 1 or never switches, we will have only one inequality and the lower/upper bound were arbitrarily determined like in Liu (2013). If for example, a farmer switches at row 5 in both series 1 and 2, we know that the following inequalities should be verified:

$$100^{\sigma} + exp^{[-(-\ln 0.3)^{\delta}]}(400^{\sigma} - 100^{\sigma}) > 50^{\sigma} + exp^{[-(-\ln 0.1)^{\delta}]}(930^{\sigma} - 50^{\sigma}) \quad (8a)$$

$$100^{\sigma} + exp^{[-(-\ln 0.3)^{\delta}]}(400^{\sigma} - 100^{\sigma}) < 50^{\sigma} + exp^{[-(-\ln 0.1)^{\delta}]}(1060^{\sigma} - 50^{\sigma}) \quad (8b)$$

$$300^{\sigma} + exp^{[-(-\ln 0.9)^{\delta}]}(400^{\sigma} - 300^{\sigma}) > 50^{\sigma} + exp^{[-(-\ln 0.7)^{\delta}]}(600^{\sigma} - 50^{\sigma}) \quad (8c)$$

$$300^{\sigma} + exp^{[-(-\ln 0.9)^{\delta}]}(400^{\sigma} - 300^{\sigma}) < 50^{\sigma} + exp^{[-(-\ln 0.7)^{\delta}]}(620^{\sigma} - 50^{\sigma}) \quad (8d)$$

A rational combination of $\delta$ and $\sigma$ ($\delta$, $\sigma$) that verifies theses inequalities is (0.7, 0.9). When more than one combination of $\delta$ and $\sigma$ ($\delta$, $\sigma$), verify the inequalities, we follow Liu (2013) and approximated $\delta$ and $\sigma$ by the midpoint of interval to one decimal place. Once the parameters $\sigma$ was calculated, it was then used to determine the loss aversion $\lambda$ using the choice made by farmer in series 3. Tables 5 and 6 were used to determine the combination of ($\delta$, $\sigma$) for the different switching points in series 1 and 2.

## Source of Data

Primary data were used to achieve the objective of the study. Data were obtained from an online survey of maize and soybean producers that was carried out from February to April 2021 in Quebec. An online survey was chosen for the purpose of this study as it allowed a survey of maize and soybean producers during the Covid 19 pandemic while maintaining the social distancing rules. A unique questionnaire was used to collect a variety of information on maize and soybean producers including socio-economic characteristics of farmers and farm characteristics. Out of the 298 maize and soybean producers that participated in the survey, 93 respondents (31%) completed the risk elicitation section. These 93 respondents were therefore retained for computing risk parameters and only 63 were retained for regression analysis because of missing values in other variables used in the model. The description of variables used in this study is presented in Table 7.

**Table 4** The series of paired lotteries

| Row | Lottery A | | Lottery B | | Expected payoff difference (A-B) |
|---|---|---|---|---|---|
| | Series 1 | | | | |
| 1 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 680 CAD | 90% winning 50 CAD | 77 |
| 2 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 750 CAD | 90% winning 50 CAD | 70 |
| 3 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 830 CAD | 90% winning 50 CAD | 60 |
| 4 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 930 CAD | 90% winning 50 CAD | 52 |
| 5 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 1060 CAD | 90% winning 50 CAD | 39 |
| 6 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 1250 CAD | 90% winning 50 CAD | 20 |
| 7 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 1500 CAD | 90% winning 50 CAD | −5 |
| 8 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 1850 CAD | 90% winning 50 CAD | −40 |
| 9 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 2200 CAD | 90% winning 50 CAD | −75 |
| 10 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 3000 CAD | 90% winning 50 CAD | −155 |
| 11 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 4000 CAD | 90% winning 50 CAD | −255 |
| 12 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 6000 CAD | 90% winning 50 CAD | −455 |
| 13 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 10000 CAD | 90% winning 50 CAD | −855 |
| 14 | 30% winning 400 CAD | 70% winning 100 CAD | 10% winning 17000 CAD | 90% winning 50 CAD | −1555 |
| | Series 2 | | | | |
| 1 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 540 CAD | 30% winning 50 CAD | −3 |
| 2 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 560 CAD | 30% winning 50 CAD | −17 |
| 3 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 580 CAD | 30% winning 50 CAD | −31 |
| 4 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 600 CAD | 30% winning 50 CAD | −45 |
| 5 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 620 CAD | 30% winning 50 CAD | −59 |
| 6 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 650 CAD | 30% winning 50 CAD | −80 |
| 7 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 680 CAD | 30% winning 50 CAD | −101 |
| 8 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 720 CAD | 30% winning 50 CAD | −129 |
| 9 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 770 CAD | 30% winning 50 CAD | −164 |
| 10 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 830 CAD | 30% winning 50 CAD | −206 |
| 11 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 900 CAD | 30% winning 50 CAD | −255 |
| 12 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 1000 CAD | 30% winning 50 CAD | −325 |
| 13 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 1100 CAD | 30% winning 50 CAD | −395 |
| 14 | 90% winning 400 CAD | 10% winning 300 CAD | 70% winning 1300 CAD | 30% winning 50 CAD | −535 |
| | Series 3 | | | | |
| 1 | 50% winning 250 CAD | 50% losing 40 CAD | 50% winning 300 CAD | 50% losing 210 CAD | 60 |
| 2 | 50% winning 40 CAD | 50% losing 40 CAD | 50% winning 300 CAD | 50% losing 210 CAD | −45 |
| 3 | 50% winning 10 CAD | 50% losing 40 CAD | 50% winning 300 CAD | 50% losing 210 CAD | −60 |
| 4 | 50% winning 10 CAD | 50% losing 40 CAD | 50% winning 300 CAD | 50% losing 160 CAD | −85 |
| 5 | 50% winning 10 CAD | 50% losing 80 CAD | 50% winning 300 CAD | 50% losing 160 CAD | −105 |
| 6 | 50% winning 10 CAD | 50% losing 80 CAD | 50% winning 300 CAD | 50% losing 140 CAD | −115 |
| 7 | 50% winning 10 CAD | 50% losing 80 CAD | 50% winning 300 CAD | 50% losing 110 CAD | −130 |

## Results and Discussion

### Risk Elicitation Results

The distribution of switching points obtained from the risk elicitation experiment shows the proportion of farmers that switch at the first row is the highest in series 2 and 3 with respectively 46.24 and 32.26% while in series 1 the highest proportion of farmers that never switch is 21.51% (Table 8). Based on the combination of switching points of farmers, we computed the risk parameters of farmers using information from Tables 4 and 5. The results show that risk aversion $\sigma$, probability weighting parameter $\delta$ and loss aversion $\lambda$ are respectively 0.88, 0.91 and 1.68. Using the t-test, we found that that the three risk parameters were statistically different from one at 5 percent significance level

**Table 5** Switching point in series 1 and approximations of values of $\delta$ and $\sigma$

| | | $\delta$ | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1 | 1.10 | 1.20 | 1.30 | 1.40 | 1.50 | 1.60 | 1.70 | 1.80 | 1.90 | 2 |
| $\sigma$ | 0.10 | 5 | 7 | 8 | 9 | 11 | 12 | 13 | 14 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| | 0.20 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| | 0.30 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| | 0.40 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 14 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| | 0.50 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 13 | 14 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| | 0.60 | 1 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 99 | 99 | 99 | 99 | 99 | 99 |
| | 0.70 | 1 | 1 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 99 | 99 | 99 | 99 | 99 |
| | 0.80 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 14 | 99 | 99 | 99 |
| | 0.90 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 14 | 99 | 99 |
| | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 14 | 99 |
| | 1.10 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 10 | 10 | 11 | 12 | 12 | 13 | 14 | 14 |
| | 1.20 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 10 | 11 | 12 | 13 | 13 | 14 |
| | 1.30 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 11 | 12 | 13 | 13 |
| | 1.40 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 11 | 12 | 12 | 13 |
| | 1.50 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 10 | 11 | 12 | 12 |
| | 1.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 9 | 10 | 11 | 11 | 12 |
| | 1.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 10 | 10 | 11 | 12 |
| | 1.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 10 | 11 |
| | 1.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 11 |
| | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 9 | 10 | 10 |

99 stands for the case where farmer keeps preferring lottery A over lottery B in all the 14 questions in series 1

**Table 6** Switching point in series 2 and approximations of values of $\delta$ and $\sigma$

| | | $\delta$ | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1 | 1.10 | 1.20 | 1.30 | 1.40 | 1.50 | 1.60 | 1.70 | 1.80 | 1.90 | 2 |
| $\sigma$ | 0.10 | 99 | 99 | 99 | 99 | 99 | 99 | 14 | 14 | 13 | 12 | 11 | 10 | 9 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 |
| | 0.20 | 99 | 99 | 99 | 99 | 99 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 |
| | 0.30 | 99 | 99 | 99 | 99 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 |
| | 0.40 | 99 | 99 | 14 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 |
| | 0.50 | 99 | 14 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0.60 | 14 | 13 | 12 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0.70 | 13 | 12 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0.80 | 12 | 11 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0.90 | 11 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1 | 10 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.10 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.20 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.30 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.40 | 7 | 6 | 5 | 4 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.50 | 6 | 5 | 4 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.60 | 6 | 4 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.70 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.80 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 1.90 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

99 stands for the case where farmer keeps preferring lottery A over lottery B in all the 14 questions in series 2

**Table 7** Descriptive statistics of farmer survey variables

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| CIACA | 63 | 0.77 | 0.26 | 0 | 1 |
| Risk aversion ($\sigma$) | 93 | 0.88 | 0.45 | 0.10 | 1.5 |
| Probability weighting parameter ($\delta$) | 93 | 0.91 | 0.34 | 0.10 | 1.5 |
| Loss aversion ($\lambda$) | 93 | 1.68 | 2.25 | 0.12 | 11.23 |
| Farmer's perception regarding the yield of CA | 63 | 8.74 | 1.17 | 6.65 | 11 |
| Farmer's perception regarding the risk of CA | 63 | 0.70 | 0.50 | 0 | 2.29 |
| Membership to agri-environmental organization | 63 | 0.54 | 0.50 | 0 | 1 |
| Secondary education | 63 | 0.32 | 0.47 | 0 | 1 |
| Collegial education | 63 | 0.41 | 0.50 | 0 | 1 |
| University education | 63 | 0.27 | 0.45 | 0 | 1 |
| Agricultural training | 63 | 0.65 | 0.48 | 0 | 1 |
| Age of the farmer | 63 | 52.43 | 12.23 | 24 | 72 |
| Off-farm employment | 63 | 0.19 | 0.40 | 0 | 1 |
| Logarithm of farm size | 63 | 5.31 | 0.97 | 3.22 | 7.89 |
| Rented farm land | 63 | 77.08 | 263.15 | 0 | 2023.47 |
| Farmer's perception regarding the easiness of implementing CA | 63 | 0.68 | 0.47 | 0 | 1 |

**Table 8** Distribution of switching points

| Switching point | Proportion of farmers | | |
|---|---|---|---|
| | Series 1 | Series 2 | Series 3 |
| 1 | 17.20 | 46.24 | 32.26 |
| 2 | 4.30 | 8.60 | 31.18 |
| 3 | 4.30 | 5.38 | 17.20 |
| 4 | 4.30 | 7.53 | 3.23 |
| 5 | 9.68 | 2.15 | 6.45 |
| 6 | 4.30 | 3.23 | 2.15 |
| 7 | 10.75 | 3.23 | 4.30 |
| 8 | 3.23 | 2.15 | |
| 9 | 6.45 | 2.15 | |
| 10 | 2.15 | 6.45 | |
| 11 | 6.45 | 1.08 | |
| 12 | 2.15 | 1.08 | |
| 13 | 3.23 | | |
| 14 | | | |
| 99 | 21.51 | 10.75 | 3.23 |
| Total | 100 | 100 | 100 |
| Number of observations | 93 | 93 | 93 |

thereby rejecting the expected utility framework in favour of cumulative prospect theory model. Indeed, the results show that maize and soybean producers in Quebec are risk averse (0.88). This result corroborates with previous studies in China (Hou et al. 2020) and France (Bocquého et al. 2014) which also found that farmers are risk averse although the degree of risk aversion were greater in those countries 0.64 in China and 0.51 in France. The results also shows that probability weighting parameter δ is 0.91 meaning that most farmers tend to overweight small probabilities and underweight high probabilities as predicted by the cumulative prospect theory (Tversky and Kahneman 1992). This result was also obtained in previous studies (Mao et al. 2019; Tanaka et al. 2010). A loss aversion of 1.68 indicates a higher sensitivity of farmers to loss than to equivalent gain.

## Econometric Results

The econometric results are presented in Table 9. Models 2 and 1 are respectively the estimation results of the model with and without the control variables. Prior to the estimation of the model, the pairwise correlation matrix was computed to check the existence of multicollinearity between independent variables. This pairwise correlation matrix which is presented in Annex shows a correlation between independent variables and therefore an absence of multicollinearity issue. This absence of collinearity issue is further confirmed by the lower variance inflation factor (1.50). Model 1 shows that risk aversion, loss aversion and probability weighting distortion does not affect the adoption of CA. This result remains unchanged even when we control for other factors of adoption of conservation agriculture (Model 2). The results contradict with previous studies such as Jin et al. (2020) who found that risk aversion and loss aversion have a positive effect on adoption of crop rotation in China. This absence of the effect of risk parameters on the adoption of conservation agriculture is in line with Ward et al. (2018) in Southern Malawi and can be explained by the fact that most maize and soybean producers are already familiar with the CA practices in Quebec. Indeed, all the 63 surveyed farmers declared to know the CA and according to a recent study, most maize and soybean producers (98.61%) are either partial or full adopters of CA in Quebec (Takam Fongang et al. 2023). It is worth noting that the level of subsidies can influence the ability of farmers to handle risk and their motivations to adopt CA. Indeed, some programmes like *Agri-Stabilité and Agri-Québec Plus* are specifically designed to protect farmer incomes from a drop of production margin and by doing so they help farmers to handle risk.

The relative high age of farmers can also affect their ability to handle risk and their motivations to adopt CA. While farming is dominated by older farmers in Quebec (Zombre 2019), the literature suggests that older farmers are often less risk averse that younger farmers (Leblanc et al.

**Table 9** Econometrics results

| Variables | Model 1 Coef | Model 1 ME | Model 2 Coef | Model 2 ME | Model 3 Coef | Model 3 ME | Model 4 Coef | Model 4 ME | Model 5 Coef | Model 5 ME |
|---|---|---|---|---|---|---|---|---|---|---|
| Risk aversion (σ) | −0.437 (0.481) | −0.076 (0.084) | −0.212 (0.427) | −0.034 (0.069) | −0.518 (0.538) | −0.092 (0.095) | −0.339 (0.416) | −0.052 (0.064) | −0.362 (0.436) | −0.056 (0.067) |
| Probability weighting parameter (δ) | 0.288 (0.595) | 0.050 (0.104) | 0.605 (0.512) | 0.097 (0.082) | 0.374 (0.607) | 0.066 (0.108) | 1.006* (0.544) | 0.155* (0.085) | | |
| Z | | | | | | | | | −0.636* (0.385) | −0.098 (0.059) |
| Loss aversion (λ) | 0.060 (0.073) | 0.010 (0.013) | 0.062 (0.078) | 0.010 (0.012) | 0.050 (0.077) | 0.009 (0.014) | 0.074 (0.080) | 0.011 (0.012) | 0.081 (0.088) | 0.012 (0.013) |
| Farmer's perception regarding the yield of CA | | | 0.592*** (0.214) | 0.095*** (0.032) | | | 0.860*** (0.169) | 0.133*** (0.027) | 0.825*** (0.168) | 0.128*** (0.026) |
| Farmer's perception regarding the risk of CA | | | 0.702 (0.435) | 0.112 (0.071) | | | 0.506 (0.428) | 0.078 (0.066) | 0.563 (0.467) | 0.087 (0.072) |
| Membership to agri-environmental organization | | | 0.177 (0.394) | 0.028 (0.063) | | | −0.231 (0.384) | −0.035 (0.059) | −0.123 (0.369) | −0.019 (0.057) |
| Collegial education | | | −0.177 (0.445) | −0.029 (0.073) | | | −0.150 (0.491) | −0.023 (0.077) | −0.148 (0.497) | −0.023 (0.078) |
| University education | | | 0.574 (0.530) | 0.085 (0.069) | | | 1.223** (0.564) | 0.158** (0.059) | 1.234** (0.582) | 0.160*** (0.059) |
| Agricultural training | | | 0.180 (0.393) | 0.029 (0.065) | | | 0.233 (0.414) | 0.037 (0.067) | 0.228 (0.419) | 0.036 (0.068) |
| Age of the farmer | | | 0.012 (0.019) | 0.002 (0.003) | | | 0.025 (0.020) | 0.004 (0.003) | 0.027 (0.020) | 0.004 (0.003) |
| Off-farm employment | | | 0.903* (0.510) | 0.121** (0.060) | | | 1.032 (0.652) | 0.130* (0.068) | 0.908 (0.629) | 0.118* (0.069) |
| Logarithm of farm size | | | 0.067 (0.241) | 0.011 (0.039) | | | 0.092 (0.278) | 0.014 (0.043) | 0.110 (0.273) | 0.017 (0.042) |
| Rented farm land | | | 0.001 (0.001) | 0.000 (0.000) | | | 0.001 (0.001) | 0.000 (0.000) | 0.001 (0.001) | 0.000 (0.000) |
| Farmer's perception regarding the easiness of implementing CA | | | 1.108*** (0.361) | 0.198*** (0.069) | | | 1.211*** (0.426) | 0.210*** (0.082) | 1.185*** (0.413) | 0.205*** (0.079) |
| Constant | 1.256* (0.764) | | −7.033*** (2.592) | | 1.223 (0.752) | | −10.389*** (2.499) | | | |
| Observations | 63 | 63 | 63 | 63 | 57 | 57 | 57 | 57 | 57 | 57 |

Robust standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1; ME stands for marginal effect

2020) and thereby less reluctant to adopt new agricultural innovations. Age is therefore considered as a sign of experience which can help farmers to handle risk associated with the adoption of new agricultural innovations such as CA.

Model 2 shows that only three variables, farmer's perception regarding the yield of CA, off-farm employment and farmer's perception regarding the easiness of implementing CA are statistically influencing the adoption of CA (Table 9). Indeed, the results show that farmers with favourable perception of the potential yield of CA tend to have higher level of adoption of CA. More precisely, if the expected yield of CA increases by 1 tonne/ha, the intensity of adoption of CA will increase by 0.1. This is not surprising as several studies have also reported that favourable perception of yield potential of an agricultural innovation tend to increase the level of adoption of that innovation (Ramsey et al. 2019; Takam-Fongang et al. 2019). This is the case of Ramsey et al. (2019) who showed in Kansas that farmers who viewed CA practices (no-till, crop rotation and cover crops) as yield-risk reducing practices tend to adopt them. The model 2 also shows that farmers with off-farm employment tend to increase level of adoption of CA by 0.1. This is in contradiction with some previous studies that found a negative effect of off-farm income on adoption of conservation agricultural practices (Manda et al. 2016; Ng'ombe et al. 2014). However, two likely reasons may explain this positive effect of off-farm employment on CA adoption. Firstly, off- farm employment as a source of income can contribute to finance the acquisition of machinery necessary for implementing CA. Secondly, farmer with off-farm employment will tend to adopt CA because it is a labour reducing practice (AFD 2006). This labour reducing effect has been documented in the literature. For example, Król-Badziak et al. (2021) have showed that no-till and reduced tillage require less labour (7.47 and 9.52 h/ha) than conventionnal tillage (10.80 h/ha) for the prodcution of maize in poland. However, this latter reason maybe challanged in other context like in Subsaharan Africa where it has been shown that adoption of CA instead increases farms' labour input requirements (Montt and Luu 2019). This is certainly why several authors have found a negative effect of off-farm income on adoption of conservation agricultural practices in some Sub-Saharan African countries (Manda et al. 2016; Ng'ombe et al. 2014). The results of model 2 further show that farmer's perception regarding the easiness of implementing CA has positive and significant effect on the adoption of CA. Farmers who view CA as easy or very easy to implement will have a level of CA adoption increased by 0.2. This positive effect which was also emphasized by Abdulai (2016) in Zambia, can be explained by the higher complexity of CA as compared with the traditional conventional tillage. Indeed, CA is made up of three interlink agricultural principles (absence or minimum mechanical soil disturbance, the permanent soil cover by mulch and/or cover crop, and crop diversity/rotation) which should be fully adopted in order to get the full potential of CA.

One likely problem that might emerge from the above estimations is whether all farmers really understand the risk elicitation experiment. For example, we noted that 8.6% of the 93 farmers that participated into the risk elicitation experiment have chosen either lottery B at the first question in all the three series or lottery A at all the questions in all the three series. So, we questioned ourselves if this subgroup of farmers really understood the operating rule of the risk elicitation experiment. If they did not understand the rule, the inclusion of these farmers in the data may have added bias in the estimation. Therefore, we followed Liu (2013) and removed these farmers from the sample; and recalculated the regressions. The results which are presented in model 3 and 4 are quasi consistent with previous estimations. The sign and significance of all parameters are maintained except for off-farm employment which is no longer statistically different from zero and probability weighting parameter which is now significant. Indeed, the results still show all the risk parameters do not have any significant effect on adoption of CA in Quebec except probability weighting parameter which has a positive effect on adoption of CA. To ease the interpretation of this latter factor, we created a dummy variable Z taking 1 if the farmer tends to overweight small probabilities ($\delta<1$) and 0 otherwise ($1 \leq \delta$); and we recalculated the regression in model 5. In model 5, one can see that farmers who overweight small probabilities also tend to reduce their level of CA adoption. Results from models 4 and 5 also show that the key determinants of adoption of CA are the farmer's perception regarding the easiness of implementing CA, farmer's perception regarding the yield of CA and level of education. Indeed, the results show obtaining a university degree will increase the level of adoption of CA by 0.16. This positive effect of education on adoption of CA is consistent with previous studies (Abdulai 2016; D'Emden et al. 2008; Ward et al. 2018). The literature explained this positive relationship by the increase in capacity of farmers to acquire and analyse information about agricultural technologies that ultimately help them to make the best decisions (Feder and Slade 1984). Another reason of the positive effect of education is related to the fact that CA is knowledge intensive practice rather than input intensive practice (Wall 2007) meaning that the success of CA will depend mainly on the good management of the farm rather than on the level of inputs used by farmers (Wall 2007). Education can then increase the management skill which can help farmers to adopt complex agricultural practice such as CA.

**Table 10** Econometric results with interactions

| VARIABLES | Model 1a | Model 2a | Model 3a | Model 4a |
|---|---|---|---|---|
| Risk aversion ($\sigma$) | −1.658 (2.118) | −0.923 (1.965) | −3.074 (2.653) | −2.807 (2.074) |
| Probability weighting parameter ($\delta$) | −0.802 (2.295) | 0.915 (1.920) | −1.736 (2.560) | 0.161 (1.978) |
| Interaction between $\sigma$ and $\delta$ | 1.555 (2.476) | 0.390 (2.088) | 2.763 (2.809) | 2.011 (2.087) |
| Loss aversion ($\lambda$) | 0.045 (0.594) | 0.299 (0.471) | −0.518 (0.841) | −0.197 (0.653) |
| Interaction between $\sigma$ and $\lambda$ | 0.225 (0.913) | 0.054 (0.544) | 0.883 (1.052) | 0.775 (0.656) |
| Interaction between $\delta$ and $\lambda$ | 0.041 (0.690) | −0.474 (0.512) | 0.508 (0.814) | −0.082 (0.636) |
| Interaction between $\sigma$, $\lambda$ and $\delta$ | −0.298 (1.149) | 0.148 (0.674) | −0.894 (1.167) | −0.510 (0.719) |
| Farmer's perception regarding the yield of CA | | 0.611*** (0.219) | | 0.912*** (0.180) |
| Farmer's perception regarding the risk of CA | | 0.917** (0.420) | | 0.854** (0.397) |
| Membership to agri-environmental organization | | 0.036 (0.410) | | −0.438 (0.364) |
| Collegial education | | −0.238 (0.462) | | −0.390 (0.536) |
| University education | | 0.597 (0.549) | | 1.085** (0.540) |
| Agricultural training | | 0.181 (0.414) | | 0.350 (0.419) |
| Age of the farmer | | 0.012 (0.019) | | 0.027 (0.020) |
| Off-farm employment | | 1.120** (0.549) | | 1.339* (0.695) |
| Logarithm of farm size | | −0.011 (0.236) | | 0.065 (0.267) |
| Rented farm land | | 0.001 (0.001) | | 0.001 (0.001) |
| Farmer's perception regarding the easiness of implementing CA | | 1.347*** (0.400) | | 1.540*** (0.473) |
| Constant | 2.079 (2.047) | −6.941* (3.583) | 3.205 (2.504) | −9.755*** (3.506) |
| Observations | 63 | 63 | 57 | 57 |

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Following the recommendation of an anonymous reviewer, we also ran several alternative models of which interactions between risk parameters are considered in the model. The objective of these models is to capture the potential interactions between risk parameters which are normally inherent from the process of calculating these parameters. Results are presented in Table 10. Model 1a and 2a are obtained using full sample while model 3a and 4a are obtained using limited sample like before. Results are quasi consistent with previous ones. All risk parameters and their interactions are insignificant in the four models. This further confirmed the lack of effect of risk parameters on the adoption of CA in Quebec. The results also confirm education, farmer's perception regarding the yield of CA, off-farm employment and farmer's perception regarding the easiness of implementing CA in addition to farmer's perception regarding the risk of CA, as key factors of adoption of CA.

Beyond the factors of CA adoption identified in this study, we believe that subsidies for the adoption of good agricultural practices, such as those promoted by the Prime-Vert programme and the ministerial initiative for agro-environmental practice rewards, could encourage the adoption of CA. Although the effect of subsidies was not explicitly considered in the estimates due to the lack of data or the launch of the programme after our survey, the number of producers (approximately 1850) who subscribed in just over 24 h after the opening of registrations for the ministerial initiative for agro-environmental practice rewards (Québec, 2023), demonstrates the significant role that financial incentives can play in the adoption of agro-environmental practices like CA. Therefore, these programmes must be maintained and enhanced to allow a greater number of producers to participate. This support is all the more necessary as CA provides numerous ecosystem benefits to society as a whole, such as carbon sequestration, reduction of watercourse eutrophication, soil erosion reduction, and other ecosystem services and goods (Corbeels et al. 2006; Scopel et al. 2005; Vincent-Caboud et al. 2017; Yadav et al. 2018).

It is also important to mention that the sample size in this study is relatively small, which limits the power of the statistical tests and the generalization of the results. Although 298 maize and soybean producers participated in the survey, this number was reduced during statistical analyses due to missing data and poorly answered questions by respondents. It is important to note that the survey was conducted during the COVID-19 pandemic, a context that could have influenced the participation rate of maize and soybean producers. Therefore, further studies are needed to improve our understanding of the issue of adopting CA in Quebec. These studies should include a larger number of maize and soybean producers and consider variables that capture the effects of different agri-environmental subsidy programmes in the analysis.

## Conclusion

This study uses the recent composite index of adoption of CA developed by Takam Fongang et al. (2023) to analyse the factors of adoption of CA among maize and soybean farmers in Quebec. Specifically, the study tests the empirical relationship between risk parameters and adoption of CA in Quebec. Using data from 93 maize and soybean producers and a Fractional Logit model, the study globally shows that risk parameters do not have any significant effect on the adoption of CA. The study instead identifies (1) farmer's perception regarding the easiness of implementing CA; (2) farmer's perception regarding the yield of CA,(3) off-farm employment and (4) higher education as the main factors of adoption of CA among maize and soybean farmers in Quebec. More precisely, the study shows that farmers tend to adopt CA when they have a university education, have an off-farm employment and, perceive CA as easy to implement and having greater expected yields. The study therefore formulates two main recommendations including the promotion of education especially higher education among farmers and the provision of technical assistance, in order to boost the adoption of CA. Education and technical assistance are particularly important for boosting adoption of CA because they improve farm management skills of farmers which are necessary to handle a knowledge-intensive practice like CA. Government should also popularize the performance of CA. Such activities will shape farmers' perception regarding the yield of CA and thereby increase the level of adoption of CA.

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## Compliance with ethical standards

**Conflict of interest** The authors declare no competing interests.

## Appendix

Correlation matrix

| Variables | CIACA | $\sigma$ | $\delta$ | $\lambda$ | prendac | Priskac | agroenv | educc | educu | formagri | age | travail | logsup | flocation | fac |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CIACA | 1.000 | | | | | | | | | | | | | | |
| $\sigma$ | −0.140 | 1.000 | | | | | | | | | | | | | |
| $\delta$ | 0.048 | 0.042 | 1.000 | | | | | | | | | | | | |
| $\lambda$ | 0.110 | −0.197 | −0.106 | 1.000 | | | | | | | | | | | |
| prendac | 0.303 | −0.068 | −0.119 | −0.042 | 1.000 | | | | | | | | | | |
| priskac | 0.103 | −0.103 | 0.052 | 0.263 | −0.334 | 1.000 | | | | | | | | | |
| agroenv | 0.142 | −0.139 | 0.016 | −0.084 | 0.116 | −0.056 | 1.000 | | | | | | | | |
| educc | 0.042 | −0.038 | −0.008 | 0.105 | 0.360 | 0.108 | 0.127 | 1.000 | | | | | | | |
| educu | 0.073 | 0.005 | −0.101 | −0.139 | −0.255 | −0.093 | 0.059 | −0.510 | 1.000 | | | | | | |
| formagri | 0.125 | −0.033 | −0.144 | 0.105 | 0.084 | 0.120 | 0.192 | 0.411 | 0.145 | 1.000 | | | | | |
| age | 0.063 | −0.043 | 0.132 | 0.099 | −0.052 | 0.058 | 0.009 | −0.250 | 0.079 | −0.213 | 1.000 | | | | |
| travail | 0.082 | 0.010 | −0.117 | −0.077 | −0.094 | 0.161 | 0.124 | 0.004 | 0.252 | 0.271 | −0.177 | 1.000 | | | |
| logsup | 0.104 | 0.026 | 0.172 | 0.044 | 0.037 | 0.005 | −0.025 | 0.191 | −0.157 | −0.099 | −0.259 | −0.094 | 1.000 | | |
| flocation | 0.084 | −0.032 | 0.091 | 0.049 | −0.159 | −0.106 | −0.146 | −0.069 | −0.112 | −0.109 | −0.071 | −0.033 | 0.448 | 1.000 | |
| fac | 0.288 | 0.013 | 0.032 | 0.046 | 0.110 | −0.077 | −0.014 | −0.052 | −0.046 | −0.142 | 0.055 | −0.451 | 0.044 | 0.060 | 1.000 |

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