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Landowners' willingness to accept pesticide reduction in the Pipiripau River Basin (Brazil)

Leidimari Neves do Prado, Jens Abildtrup*

Bureau d'Economie Théorique et Appliquée (BETA), Université de Lorraine, Université de Strasbourg, AgroParisTech, CNRS, INRAE, Campus AgroParisTech, 14, Rue Girardet 54042, Nancy CEDEX, France

A R T I C L E I N F O

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A B S T R A C T

Brazil is the largest buyer of pesticides in the world and allows the use of chemicals that have long been banned in other countries. One in four Brazilian cities has water polluted by agrochemicals, and the poorest and most vulnerable suburban communities are considered to be suffering disproportionately from this exposure to pesticide contamination of drinking water. To increase the quantity and improve the quality of water, in 2012, the Pipiripau River Basin (PRB) was selected as the site of one of the main pilot studies in Brazil for the protection of water resources. However, the Payment for Environmental Services (PES) currently implemented in the Water Producer Programme (WPP) does not address pesticide use reduction as an environmental service. In this study, we report the result of a survey of land owners in the basin and in particular the results of a Discrete Choice Experiment (DCE) applied to estimate the potential Pipiripau Basin landowners' Willingness-To-Accept (WTA), compensation for reducing the use of agrochemicals on their land. This study is the first to apply a dce to analyse policies for pesticide reduction and the protection of water resources in Brazil, and there are very few studies worldwide on the topic to date. We find that the contract characteristics are important determinants of the WTA. Furthermore, farm and landowner characteristics also impact the estimated WTA, including, for example, the farm type, the current use of pesticides, and who is involved in the decision-making. We also find clear evidence that profit considerations are not the only determinant of landowners' decision to participate in a pesticide use reduction scheme.

1. Introduction

Brazil's environmental policy has changed drastically since 2019, coinciding with the arrival of the new Brazilian presidency. Bolsonaro's presidential campaign had been strongly supported by Brazil's powerful agribusiness lobby. As the largest buyer of pesticides in the world, the country allows the use of chemicals that have long been banned in other countries (Clarke, 2019).

With the recent approval of law-project 6299/2002, a bill that has been subject to 28 amendments and concerns agrochemicals in Brazil, the total number of allowable pesticides was increased to 2,232, considering the herbicides in circulation in the market (Sampaio, 2019).

In the first four months of Brazil's new administration, the government set a new pesticide release record in 2019 with 166 new products on the market and more than 1,500 new pesticides registered in January 2022.

However, this increased use of agrochemicals contradicts the trend followed in most other countries in the world that has been re-evaluating and prohibiting the use of several products. The policies related to agrochemical production and consumption activities in Brazil are disconnected from the evolution of the regulatory frameworks of developed countries that, notably, are among the main markets for Brazilian agricultural production.

There are concerns that the widespread use of pesticides could have major consequences (Clarke, 2019) in Brazil, which has among the richest biodiversity and the largest groundwater reserve in the world. The little-publicised decision to allow more pesticides multiplies the risk factors for health and the environment, especially river basins.

Water contamination has attracted the most attention, with Brazilian law, for example, allowing a limit of glyphosate 5,000 times higher than the maximum allowed in drinking water in Europe (Bombardi and Kfouri (2019) and Nogueira (2019)) and one out of every four Brazilian cities has water polluted by agrochemicals (Aranha and Rocha, 2019).

The poisoning of water is directly linked to the uncontrolled release of pesticides in the country, and figures reveal that water contamination is increasing by steady and large amounts. In 2014, 75% of the tests conducted detected pesticides in water, in 2015 it reached 84% and went to 88% in 2016, reaching 92% in 2017 (Aranha and Rocha, 2019). Tra-

* Corresponding author.
E-mail addresses: lnevesdopra@icloud.com (L. Neves do Prado), jens.abildtrup@inrae.fr (J. Abildtrup).

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ditional water treatment does not remove such chemicals from water. There is no effective decontamination method in the country.

At this rapid pace, in a few years, it may be difficult to find pesticide-free water in the country's taps.

This indiscriminate use of pesticides in the country contributes to increased poisoning. Bombardi (2017) showed that every two and a half days in Brazil, a person dies of agricultural pesticide toxicity. There is no doubt that people are being exposed to dangerous pesticides in the country and that the poorest and most vulnerable suburban communities are suffering disproportionately because of the lack of screening for hazardous pesticides.

To increase the quantity and improve the quality of the water in the whole country – not only in the PRB – the Brazilian Government approved the WPP. Due to (i) its location in the Federal District, (ii) its strategic importance as the main source of water for roughly a quarter of a million people, and (iii) the multiple economic, social and environmental factors involved, the PRB was selected in 2012 as one of the main pilot studies in Brazil.

The aim of the WPP is to apply the provider-recipient model through the pes, which is defined "as a voluntary transaction where a well-defined ES (or a land-use likely to secure that service) is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provider if and only if the ES provider secures ES provision (conditionality)" (Wunder, 2005).

In the present case, the idea is to use financial compensation to encourage landowners to contribute to the protection and recovery of water sources, assist in the recovery and/or maintenance of environmental services, and provide benefits for the river watershed and its population. However, the environmental services payment programme currently implemented in the basin does not target pesticide use reduction as an environmental service. The basis for developing a new scheme or for modifying the existing scheme to target pesticide reduction is relatively weak because a limited amount of research has considered schemes for pesticide reduction, particularly in Brazil. The present study will apply an empirical approach where landowners are interviewed and their preferences for contract design are revealed through a dce. While this method has been shown to be highly relevant for evaluating PES schemes (Tyllianakis and Martin-Ortega, 2021), only a few applications have considered pesticide reduction schemes.

This paper uses data from a survey and a dce analysing and assessing the potential Pipiripau Basin landowners' WTA a reduction in the use of agrochemicals with the overall objective of improving the basis for developing a PES scheme targeting pesticide use reduction through a better understanding of the preferences of the landowners. In contrast to previous studies on farmers' stated participation in PES schemes in Brazil (e.g. Alarcon et al., 2017; Richards et al., 2020), we address pesticide use reductions and estimate the WTA different contracts designs by different farm and household types. The remainder of the paper is organised as follows: In section 2, we present the study area and the currently implemented PES and describe the aims of the study. In section 3, we introduce the methodology used to obtain the results presented in section 4. Finally, section 5 is devoted to a discussion of our findings, and section 6 concludes with important management implications for agrochemical reduction policies.

2. Study aims and description of the context

The PRB is an endorheic basin that spreads across Goias State (9.7% of the basin's surface) and the northeast of the Brazilian Federal District (the remaining 90.3%) in Brazil. It has a drainage area of 235 km^2 in the Brazilian Savanna (Cerrado biome) (Neves-Do-Prado et al., 2022).

The PRB flows close to the nation's capital and downstream provides Brasilia's two main suburbs (Sobradinho and Planaltina) in the north with water, and upstream private landowners use Pipiripau's water mainly for irrigation of agricultural crops and, to a lesser extent, for cattle herding and eucalyptus plantations.

Two-thirds of the landowners (agriculture and horticulture) engage in activities that make intensive use of water and pesticides with several negative consequences. First, because the area's soil is poor, it needs to be constantly amended. Second, considerable sediment is carried downstream by the river, causing important costs in terms of water cleaning and purification. Third, and most important, the tenure of pesticides, herbicides and fungicides in the water increases greatly as these products are washed from the crops and the soil into the river.

To increase the quantity and improve the quality of the water in the Basin, in 2012, the Brazilian government established the WPP in the PRB. This programme consists in giving financial compensation to farmers and rural landowners through a PES policy. The current programme has three modalities of conservation: *(i) Soil Conservation* – which is designed to financially reward rural landowners that adopt or will adopt practices of soil conservation in their area of agriculture and/or pasture; *(ii) Restoration or Conservation of Areas of Permanent Protection (*APP*) and/or Legal Reserve (*LR*)*, two important environmental obligations demanded by the Brazilian Forest Code (BFC), law 12.651/2012, of all Brazilian landowners[1] – it is intended to financially reward rural landowners who restore or conserve the vegetation of the LR and APP related to springs, water courses, reservoirs, lakes and natural lagoons; and *(iii) Conservation of remnants of native vegetation* – which is intended to financially reward rural landowners who already protect the native vegetation on their property before the creation of the programme, circumventing the conversion of the native vegetation cover. WPP deviates substantially from other predominant approaches: All implementation costs for contract signatories are subsidised. Moreover, all landowners joining the contract are compensated by the Water Regulating Agency of the Federal District (ADASA) on a yearly basis for the total duration of the contract with an amount that is proportional to the total surface area protected. See Neves-Do-Prado et al. (2022) for further details on the WPP.

Through these actions, the programme targets the environmental regularisation of rural properties, i.e., favouring water infiltration in the soil and the consequent increase in the volume of drinkable water; increasing river flow during periods of drought; and reducing water turbidity and, in turn, the cost of water treatment. Conflicts over water use are thus expected to be significantly attenuated, and water supply to the urban area downstream is expected to increase.

In the Federal District, the WPP in the PRB represents a model to be followed by Brazil and other countries due to the results achieved and, mainly, by securing a network of partners including the Federal, District, Non-profit Organization (NGO)s and third sector (social service) institutions. Recently, the project was announced as one of the 12 finalists for the Water ChangeMaker 2020 award, which recognises initiatives from around the world that promote social and environmental change through water. This international recognition has become a source of pride among project partners and an indication of the success of this governance model (ADASA, 2020).

However, WPP does not include pesticide use reduction as an environmental service. The policies related to agrochemical production and consumption activities in Brazil are disconnected from the evolution of the regulatory frameworks of developed countries, which are among the main consumer markets for Brazilian agriculture. Therefore, although there may be no current political will to reduce pesticide use, it is necessary to consider potential instruments to do so (Lazzeri, 2017) that will, most likely, be implemented in the future. PES schemes represent here an important instrument that farmers, through the existing program, are familiar with despite not covering pesticides. However, the successful implementation of a new PES scheme requires knowledge of the impact of scheme design on landowners' participation. Therefore, the present case study area not only represents an interesting case for

[1] Neves-Do-Prado et al. (2022) explains in considerable detail how these area are computed.

testing a new PES scheme but may also generate information that may be relevant for other regions in Brazil or elsewhere.

One approach to investigate landowners' preferences regarding participation in a soil and water conservation programme is the DCE approach. DCE is a stated preference method, i.e., it involves choices between hypothetical alternatives, and is therefore applicable to the analyses of a policy that is not yet implemented and can provide important information *ex ante* (Tyllianakis and Martin-Ortega, 2021). While DCE approaches have been widely used in the environmental economics literature to estimate citizens' Willingness-To-Pay (WTP) for non-market environmental good and services (Adamowicz et al., 2014; Mariel et al., 2021), there is also increasing use of the method for estimating the WTA for contracts regarding environmental management. In a recent study, Tyllianakis and Martin-Ortega (2021) find in a meta analysis of the WTA of agri-environmental schemes that 25 or 26 studies applied choice experiments. Compared to other stated preference methods, the DCE approach allows the researcher to quantify how contract characteristics influence the WTA. In studies based on actual participation in schemes, there is often too little variation in scheme attributes to allow the impact of scheme design on participation to be assessed (Espinosa-Goded et al., 2010). The initial applications of DCE to analyse farmers' decision-making concerned preferences for breeding varieties (Roessler et al., 2008; Scarpa et al., 2003), while the first elicitations of farmers' preferences for agro-environmental scheme design included Ruto and Garrod (2009), Espinosa-Goded et al. (2010) and Horne (2006), who considered forest biodiversity conservation. The approach has proven useful to estimate WTA for farmers in both developing and developed countries (see the literature review in the supplemental material in Villanueva et al. (2015)) and Tyllianakis and Martin-Ortega (2021)), although few studies cover Latin America.

Torres et al. (2013) and Costedoat et al. (2016) analyse the WTA for forest PES schemes in Mexico, and Raes et al. (2017) estimate farmers' preferences for sylvopastoral systems in Southern Ecuador. In Brazil, Richards et al. (2020) employs a choice experiment to analyse farmer preferences for reforestation contracts in the Atlantic forest, Demarchi et al. (2021) applies the approach to analyse land owners' preferences for water-saving strategies on eucalyptus plantations, while Alarcon et al. (2017) adopts contingent valuation methods to evaluate farmers' choices regarding PES programs in the same region.

Only a few studies, however, have studied the WTA for pesticide use reductions. Christensen et al. (2011) estimate Danish farmers' WTA for establishing pesticide-free buffer zones and find that farmers WTA is lower for shorter and more flexible contracts, but there is important heterogeneity in the WTA among farmers. Kuhfuss Laure and Sophie (2014) analyse the willingness of wine growers in the Languedoc-Roussillon region (France) to enrol in agri-environmental schemes requiring limiting the use of herbicides, focusing on the impact of collective contracts and interaction with neighbours. Other studies have used DCE approaches to estimate farmers' willingness to adopt pesticide-reducing production techniques without considering contractual arrangements. Blazy et al. (2011) estimate the willingness to adopt new innovative management practices by Caribbean banana growers. Mélanie Jaeck (2014) assess the willingness to adopt alternative management practices and pesticide-free management by rice growers in the Camargue region of France, and Danne et al. (2019) analyse weed control preferences for German farmers, focusing on alternatives to the use of glyphosate. Chèze et al. (2020) shows that for French farmers, that risks related to reduction in pesticide use limit the willingness to reduce pesticide use regardless of the impact on the average profit. Thus far, to our knowledge, pesticide use reduction schemes have not been analysed in a Brazilian context applying the DCE approach. Therefore, the present study will introduce this methodology to investigate pesticide use reduction schemes in a developing country context and provide useful information for policy-makers on the landowners' preferences for such schemes. The results will also provide information on which landowner characteristics may influence participation in different types of contracts. This also includes the current use of pesticides and the current use of pesticide on neighbouring land properties, as it has been shown pesticide may depend on neighbors' applications (Aida, 2018; Grogan and Goodhue, 2012) as pests may diffuse over property limits if neighbour is reducing their use of pesticides, or if the neighbours continue to use pesticides this may also kill biological beneficial insects that prey on the pests.

3. Methodology

3.1. The discrete choice experiment approach

The DCE approach initially developed by Louviere and Woodworth (1983) is one option in a family of stated preference approaches where respondents are asked to choose between different hypothetical alternatives. In the present study, the choice is among different pesticide reduction contracts or not to sign a contract. Based on consumer theory (Lancaster, 1966), where the value of a good is derived from the characteristics of the good, it is assumed that the respondent chooses the alternative that maximises his or her utility, i.e., the contract (or no contract) with the preferred characteristics. The choices are analysed by applying the random utility model Random Utility Model (RUM), which assumes that the utility of an alternative is composed of observed (by the researcher) and unobserved utility.

A key design issue related to the development of a DCE design is the definition of alternatives and their attributes, which should be relevant for both policy-makers and landowners. The attributes and their levels were decided based on experiences from the current PES contracts implemented by the Brazilian National Water Agency (ANA), a review of the literature, a pilot study that accounted for the characteristics of the PRB and discussions with experts such as managers of the current payment programme for environmental services (WPP) implemented in 2012, specialists in hydrology, agronomy, ecology, and forestry, environmental economists and the local farming community. The number of attributes must be limited to avoid the cognitive burden of making very complicated choices as shown by Hanley et al. (2002).

We list the attributes, descriptions of them and the levels that they could take in Table 1, and Table 2 shows a sample choice card.

Agrochemical reduction: Three levels of the reduction in the use of agrochemicals are included to reflect that the marginal WTA reduction may not be linear. One might expect marginally decreasing productivity of pesticides (the last application has the lowest effect on productivity). However, the effect of reducing pesticide use may be discontinuous because a reduction passing a certain threshold may change the optimal production system (for example, other crop types will be optimal for a given farmer).

Contract length in years: Previous studies have shown that farmers prefer short-duration agri-environmental contracts (Ruto and Garrod, 2009), while it has also been argued that the optimal contract length is a trade-off between an ecological effect—long contracts increase the environmental benefits from one landowner—and an enrolment effect—long contracts decrease the number of landowners enrolled (Ando and Chen, 2011).

Possibility to cancel contract: The possibility of canceling the contract is divided into three options as follows:

Without penalty: The contract may be broken by either party at no cost.

With penalty: The penalty is dependent on the timing of cancellation of the contract, inspired by current contract schemes (The Water Producer Programme):

First-to-fifth-year contract penalty: If the contract termination occurs in the first year, the landowner is obliged to return the amount equivalent to the total amount invested by the partners in construction work on the property plus the amount paid for environmental services. If the contract termination occurs in the second year, the landowner is obliged to return an amount equivalent to 80% of the amount invested

Table 1
Attributes and levels .

Attributes	Description	Levels
Agrochemical reduction	Reduction in the use of agrochemicals over the mean annual use (in percentage terms)	10% - 25% - 50%
Contract length in years	Programme engagement in years	5 - 10 - 15
Possibility to cancel contract	Contractual Restrictions	Without penalty - With penalty - Unbreakable
Amount of subsidy in Brazilian reais (R$)	Related to an annual remuneration per ha	71,200 - 1.425,00 - 2.135,00 - 3.250,00

Table 2
Sample choice card .

Attributes	Alternative 1	Alternative 2	Alternative 3 **Status quo (sq)***
Agrochemical reduction (`pestireduction`)	25%	25%	
Contract length in years (`contract_length`)	5	15	
Possibility to cancel contract (`type_contract`)	Unbreakable	Without penalty	
Amount of subsidy in Brazilian Reais (R$) (`subsidy`)	3.250,00	1.425,00	
pestireduction.sq			0
contract_length.sq			0
type_contract.sq			0
subsidy.sq			0
Choice question:	()	()	()

* The status quo will always be the same for all respondents because pesticide reduction is not implemented in the current WPP.

by the partners in work carried out on the property plus 80% of the total PES received. If the termination of the agreement happens in the third year, the landowner is obliged to return an amount equivalent to 60% of the total amount invested by the partners in work carried out on the property plus 60% of the total PES received. If the termination of the agreement happens in the fourth year, the landowner is obliged to return an amount equivalent to 40% of the total amount invested by the partners in work carried out on the property plus 40% of the total PES received. If the termination of the agreement happens in the fifth year, the landowner is obliged to return an amount equivalent to 20% of the total amount invested by the partners in work carried out on the property plus 20% of the total PES received.

Sixth-to-tenth-year contract penalty: If the contract termination occurs in the sixth year, the landowner is obliged to return the total amount of the last PES received plus 20% of the total amount invested by the partners in work carried out on the property. If the contract termination occurs in the seventh year, the landowner is obliged to return the total amount of the last PES received plus 15% of the total amount invested by the partner in works carried out on the property. If the termination of the agreement happens in the eighth year, the landowner is obliged to return the total amount of the last PES received plus 10% of the total amount invested by the partners in work carried out on the property. If the termination of the agreement happens in the ninth year, the landowner is obliged to return the total amount of the last PES received plus 5% of the total amount invested by the partners in work carried out on the property. If the termination of the agreement happens in the tenth year, the landowner is obliged to return the total amount of the last PES received plus 2% of the total amount invested by the partners in work carried out on the property.

Eleventh-to-fifteenth-year contract penalty: If the contract termination occurs in the eleventh year, the landowner is obliged to return the total amount of the last PES received plus 2% of the total amount invested by the partners in work carried out on the property. If the contract termination occurs in the twelfth year, the landowner is obliged to return an amount equivalent to 60% of the total last PES received. If the termination of the agreement happens in the thirteenth year, the landowner is obliged to return an amount equivalent to 40% of the total last PES received. If the termination of the agreement happens in the fourteenth year, the landowner is obliged to return an amount equivalent to 20% of the total last PES received. If the termination of the agreement happens in the fifteenth year, nothing happens.

Unbreakable: To ensure the continuity of the programme, the parties agree that if the property or property ownership/possession entered into the project is to be transferred to a third party during the term of this agreement, the obligations acquired under this agreement will also be transferred to the new owner or new dealer. For this purpose, a copy of this agreement shall follow the property deeds or title and must be included in the relevant public record.

Subsidy: The guiding principle for setting the subsidy levels were the estimated opportunity costs of agricultural production based on different sources. The Federal District (FD) is the federal unit with the highest average salary in the country. The FD has agricultural productivity above the national average in several crops, according to data from the Brazilian Institute of Geography and Statistics (IBGE) and the 5th grain harvest survey by the National Supply Company (CONAB). The FD's very dry climate favours the genetic improvement of seeds. Multinationals operating in Brazil, such as Syngenta, Down Science, Werma and Pionner, multiply soybean seeds from FD crops and then sell those genetically improved soybeans for cultivation in other states in Brazil[2]. Production per hectare in the Federal District is double that recorded in other regions[3]. This also includes the cultivation of grains in large areas and the production of vegetables and fruits in small properties owned by family farmers. Soybeans, corn, beans, sunflowers, passion fruit, grapes, guava, lemon, sweet potatoes, peppers and manioc are some items that have a productivity higher than the national average, which implies a higher opportunity cost per hectare.

Following Agricultural Cooperative of the Federal District (COOPA-DF), the average gross revenue is R$ 3.3 thousand per hectare in the study region.

For this case study in the PRB located in the FD we used four annual remuneration values per hectare as follows: R$712,00; R$1.425,00; R$ 2.135,00; and R$3.250,00 for participation in a pesticide use reduction contract.

3.2. Survey design and data collection

This study uses data from a discrete choice experiment intended to elicit Pipiripau Basin landowners' willingness-to-accept compensation

[2] https://bit.ly/3ix2zZr
[3] https://www.agenciabrasilia.df.gov.br/2021/03/01/df-tem-produtividade-agricola-maior-que-media-nacional/

for reducing the use of agrochemicals. Since our Choice Experiment (CE) study of the valuation of landowners' preferences for water resource protection is based on the Water Producer Programme, we began first by organising meetings with representatives of the programme with the aim of identifying which and how many properties had already signed a contract.

Following Louviere et al. (2000) and Street et al. (2005), we applied experimental design techniques to choose the option sets that yield maximum information about interviewee preferences. The attributes and their levels were combined into choice tasks using Ngene software (ChoiceMetrics 2014). We first conducted a pilot study where the design was estimated without parameter priors. Second, we ran an MNL updating the design based on information obtained from the pilot study of 32 respondents. From the MNL, we obtained the parameters to again run the final Bayesian D-optimal where efficiency is determined based on minimising the D-error. Efficient designs lead to lower standard errors than orthogonal designs, particularly for small sample sizes (Bliemer and Rose, 2011; Greiner et al., 2014; Rose and Bliemer, 2013).

The final design is not fully characterised by balance at the attribute level but rather considering viable real-life options where constraints were introduced to not produce irrelevant or fully dominant alternatives. Our experimental design led to 24 different choices.

Thereafter, we conducted face-to-face interviews with farmers and forest owners from May to July 2016. Surveys were conducted in Portuguese, and the interviews lasted, on average, ninety minutes. When the study was conducted, 221 properties had been identified, numbered and registered in the census by ADASA (Neves-Do-Prado et al., 2022). Of these, only 217 had known owners[4] We were able to randomly contact 160 of them: Two landowners refused to participate in our research. Then, we organised meetings with 158 respondents. However, we nevertheless followed Hanley et al. (2002) and limited the number of choices to avoid the cognitive burden of making very complicated choices; all landowners interviewed answered the general questions, but a number of respondent did not answer the choice experiment. Some said that they didn't believe that they had the necessary competences to choose between the different contract alternatives. This also related to a scepticism based on bad experiences in dealing with the Brazilian government and that the choice experiment was presented as a new program to be implemented by the government. We believe ignoring these owners in our sample will not lead to biased estimates as the rejection of answering is not linked to their marginal cost of reducing pesticide use.

Then, our final sample consisted of 122 landowners from `trechos` 1, 2 and 3. For a more detailed view of the location and distribution of the owners interviewed, see Figs. 1 and 2[5]

The first part of the questionnaire was dedicated to general questions regarding the properties' characteristics which were expected to influence the WTA of pesticide reductions and used as explanatory variables in the choice modeling. The questions were based on literature and the initial workshops carried out by the researchers in the case area. For the main productive we retained the following: Agriculture (`AGRIHORTICULTURE`) for properties producing crops or horticulture/fruticulture. We also have forest plantations (`FOREST`),[6] cattle raising (`CATTLE`) and farms dedicated to raising pigs and/or chicken (`PIG-CHICK`). For example, Zanella et al. (2014) find for three Brazilian PES schemes that opportunity costs are important for entering a contract, and we believe that the opportunity cost of pesticide use reduction will depend on the type of production activity. Chèze et al. (2020) find that the WTA for pesticide use reduction depends on crop types. Nong et al. (2021) find that the production activities were important determinant of the WTA of adapting sustainable farm management practices.

We also asked owners how long they had owned the property (`OWN_LONG`) and about their property's surface area (`PROP_SURFACE`). Subsequently, properties were included in three separate classes according to the property area: `SMALL_SURF` for properties whose area ranges from 5 to 20 hectares; `MED_SURF` for areas ranging from 20 to 75 hectares; and `BIG_SURF` for property areas exceeding 75 hectares. Our classification follows the legal and fiscal treatment used locally.[7] Examples from the literature have found that the acceptance of pesticide reduction measures depends on farm size (Blazy et al., 2011; Danne et al., 2019). On the one hand, we believe that with a smaller property size the owner could easilier find alternatives to pesticide applications while larger larger will have relatively lower transaction costs per hectare for entering a contract.

We also gathered information regarding whether the property was in conformity with the BFC and how often pesticide, herbicide and fungicide applications were used on the property per year per hectare. We coded this information in a variable named `AGROCHEMICAL_YEAR`. We expect that frequent use of pesticides will increase marginal cost of a percentage reduction of the pesticide use. Furthermore, we included a variable representing the average pesticide use on adjacent, neighbouring properties.

We also retained the geo-referenced the localisation of the properties, further denoted as `pi`, when property was located in `trecho 2` (Pipiripau Village), `ta` when the property was located in `trecho` 1 (Taquara Village), and `pita` when property was located in `trecho` 3, i.e., the more sparsely populated area located between `trechos` 1 and 2. We include this location variable to account for effect of unobserved spatial context factors.

In the second part of the survey, we explained the choice experiment to the respondents in detail for the four attributes. Our field teams had previously been trained to handle the questionnaire, and we took great care to provide objective and neutral information, all in the same way, with the same first and second set of examples, if necessary for better understanding by the owners.

The total set of 24 different choices was answered by the same family members. The twenty-four choice sets were then presented, and the family group was asked to chose their favourite option. To detect protest responses, families choosing the status quo in all choice sets were asked about why they did so. An example choice set is given in Table 2.

After presenting the choice sets, we also obtained some key individual characteristics. Farmers' age, educational level, income have shown to be important characteristics to explain adoption of sustainable management practices (see for example (e.g. Nong et al., 2021)). The education variable is defined as a categorical variable ranging from 1 to 7[8],

[4] There are four abandoned properties in trecho 2. See Fig. 2 for further details.

[5] In Fig. 2 we see that there are land plots occupied by leaseholders who belong to the Landless Workers Movement (MST). They are undergoing a procedure of land regularisation, but they are also competing for the use of water resources and contributing to increase the basin's conflicts and degradation.

[6] Although this variable accounts for all types of forest plantations, there was only one tree species represented among all the owners interviewed who had tree plantations, i.e., eucalyptus.

[7] Fiscal modules (*Módulo fiscal* in Portuguese) are the unit of measure for the classification of property size in Brazil. The size of a fiscal module is established by law (INCRA's Special Instruction of 1980) and varies from one state to another ranging from 5 to 110 hectares. In the Federal District, each fiscal module represents an area of 5 hectares. Properties with less than 4 fiscal modules (i.e., less than 20 hectares) have a different legal and fiscal treatment.

[8] 1= early childhood education; 2= primary school; 3= high school; 4= vocational education (definition: education based on occupation or employment, also known as career and technical education (CTE) or technical and vocational education and training (TVET) is education that prepares people for specific trades, crafts and careers at various levels from a trade, a craft, technician, or a high professional practitioner position in engineering, accountancy, nursing, medicine, architecture, pharmacy, law, etc.); 5= higher education teaching in technology; 6= four-year college (bachelor's, premed); 7= supplementary academic education (master's degree and/ or PhD); 0= No Certificate (illiterate).

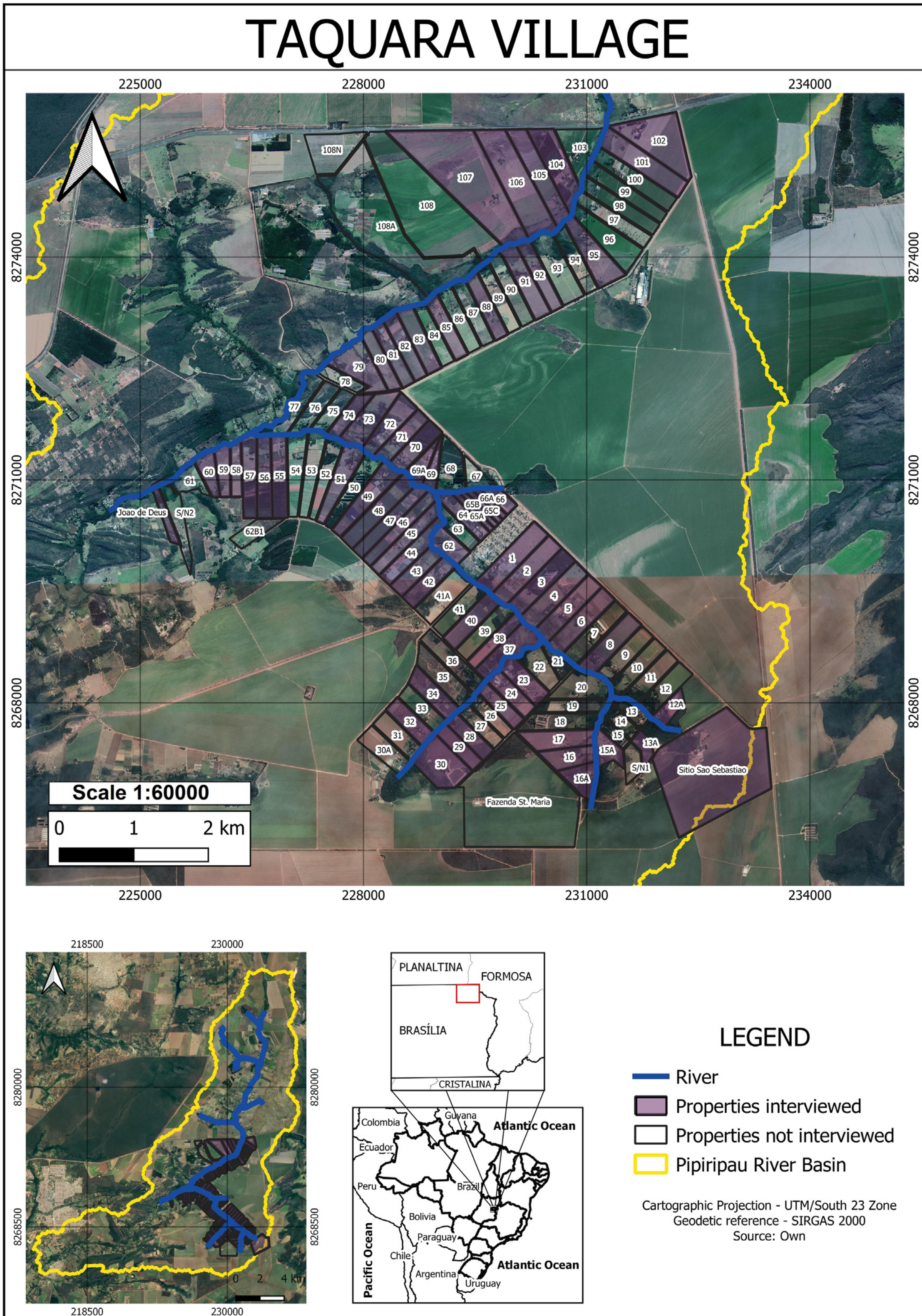

Fig. 1. Properties in `trechos` 1 and 3 with owners who were interviewed appear in violet. Properties without interviews appear with no colour..

where 7 is the highest level. We asked the owners about the monthly income of their family (including all the members in the household) before taxes (i.e., gross) and including all other sources of income, e.g., retirement pension, rent from other properties, and on his/her understanding of the choice sets. We coded this `INCOME` variable as a multiple of Brazil's legal minimum wage.[9] We also included a question about who are making management decisions. The person who usually takes

[9] The concept of socio-economic class most widely adopted in Brazil classifies income in letters from A to E, where A is the highest level.

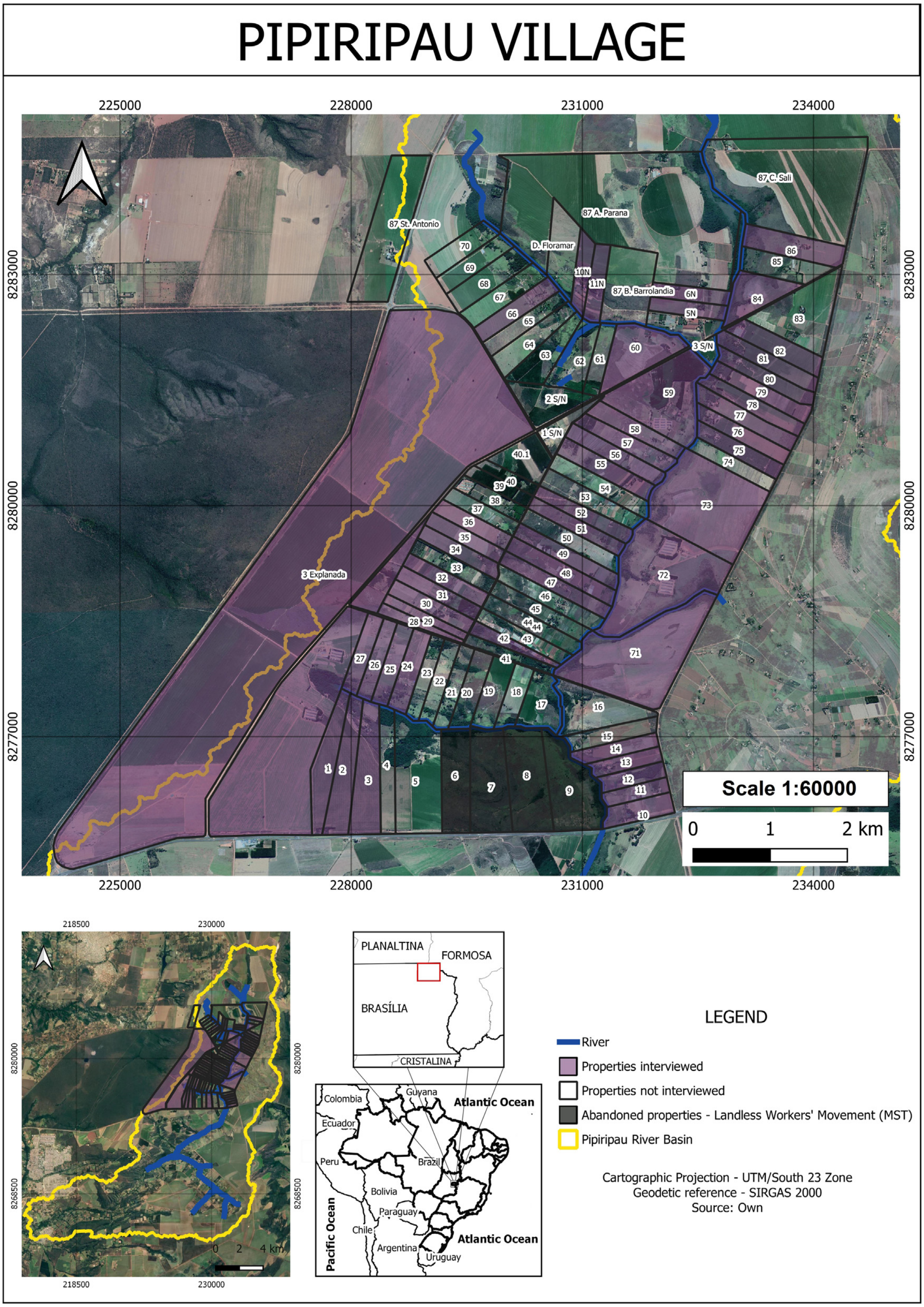

Fig. 2. Properties with owners interviewed in *trecho* 2 appear in violet. Properties with no interviews appear with no colour. Abandoned properties appear in black..

the decisions on/about the property is denoted as (OWN_DEC) when the owner makes decisions alone, (FAMILY_DEC) when the owner makes decisions together with other family members, or (EXT_DEC) when the owner makes decisions with other co-owners, business partners or with a technician or a specialist in the field. We expect that the willingnes to accept a contract is higher for owners working with external experts Taylor and Van Grieken (2015).

We obtained a total of 122 completed sets of 24 different choices, which corresponds to 122 families living in the PRB.

Table 3
Summary statistics ($N = 122$) .

Variable	Description	Average	Std. Dev.	Min	Max	Mode
AGROCHEMICAL_YEAR	how many pesticide, herbicide and fungicide applications per year/hectare	39.377	69.084	1	394	1
AGROCHEMICAL_HIGHER-USE	more than 50 applications of agrochemicals per year/hectare	0.3	0.44	0	1	0
AGROCHEMICAL_LOWER-USE	fewer than 50 applications of agrochemicals per year/hectare	0.7	0.44	0	1	1
$\overline{X}$neigh-pesticide-use	average application of agrochemicals per year/hectare of the two direct neighbors	30.143	45.693	0	242.5	
OWN_LONG	how long they had owned the property (years)	19.156	11.702	1.5	54	20
PROP_SURFACE	property's area in hectares	39.605	130.308	4.5	1440	20
SMALL_SURF	area ranges from 5 to 20 hectares	0.443	0.499	0	1	
MED_SURF	area ranges from 20 to 75 hectares	0.508	0.502	0	1	
BIG_SURF	property's area exceeded 75 hectares	0.049	0.217	0	1	
MED.BIG_SURF	property's area exceeded 20 hectares	0.557	0.499	0	1	
INCOME	Amount of minimum legal wage	10.066	3.369	2	14	14
INCOME_D	from 2 to 4 four times the minimum legal wage	0.049	0.217	0	1	
INCOME_C	from 4 to 10 times the minimum legal wage	0.377	0.487	0	1	
INCOME_B	from 10 to 20 times the minimum legal wage	0.369	0.484	0	1	
INCOME_A	income above 20 times the minimum legal wage	0.205	0.405	0	1	
AGE	owners' age in years	56.540	10.959	25	84	50
GENDER	1 if woman, 0 otherwise	0.074	0.262	0	1	
EDUC	from 1 to 7 where 7 is the highest education level	3.622	2.145	1	7	6
AGRIHORTICULTURE	agriculture and/or horticulture/fruticulture is the main productive activity	0.623	0.487	0	1	
CATTLE	cattle raising is the main productive activity	0.270	0.446	0	1	
PIG-CHICK	raising pigs and/or chickens is the main productive activity	0.066	0.249	0	1	
FOREST	Tree plantations (i.e., eucalyptus) are the main productive activity	0.049	0.217	0	1	
OWN_DEC	the owner makes decisions on/about the property alone	0.328	0.471	0	1	
FAMILY_DEC	the owner makes decisions together with other family members	0.434	0.497	0	1	
EXT_DEC	the owner makes decisions with business partners or a specialist in the field	0.234	0.427	0	1	
PIPIRIPAU	when property is located in *trecho 2* (Pipiripau Village)	0.418	0.495	0	1	
TAQUARA	when the property is located in *trecho* 1 or *trecho* 3 (Taquara Village)	0.581	0.495	0	1	

In Table 3, we present some key socio-demographic characteristics of our sample.

3.3. Econometric models

3.3.1. Estimation of choice model

The modelling is based on the RUM framework, which is a common approach in the analysis of discrete choice data (McFadden, 1974). This model assumes that respondents select their most preferred alternative among the I alternatives offered, i.e., the alternative that maximises the perceived utility, u_{ni}, for respondent n is given by Equation 1:

$$u_{ni} > u_{nj}, \forall j \neq i \quad \text{and} \quad \text{where} \quad u_{nj} = X_{nj}\beta + \varepsilon_{nj} \quad j = 1, .J \tag{1}$$

Where the vector X_{nj} is a row vector of K attributes characterising alternative j, β is a column vector of K parameters associated with these attributes, and ε_{ij} is an error term that captures the utility unobserved by the researcher.

The RUM is the standard approach in choice modelling (Hess and Daly, 2014). There may be other ways people make choices (Daniel et al., 2018) this is, however, not the objective to investigate such other decision processes in the present paper.

If we assume that the error term in the RUM is Identically and Independently Distributed (IID) with a Gumbel distribution, then we can apply the well-known conditional logit model to estimate the parameters. Equation 2 defines the probability of choosing alternative i

$$P(i|\beta) = \frac{\exp \beta X_i}{\sum_j \exp \beta X_j} \tag{2}$$

The conditional logit model assumes that choices conform to the Independence of Irrelevant Alternatives (IIA) and does not allow one to exploit the panel structure of the choice data or individual preference heterogeneity. Therefore, we also estimated the more flexible mixed logit model (Revelt and Train, 1998). This allows us to make individual-specific preference parameters and to allow for non-standard substitution patterns between choice alternatives.

The mixed logit model (Equation 3) accounting for the panel structure can be written for our case with three alternatives J=3 and 24 choice sets, t=1,... 24:

$$u_{njt} = \begin{cases} X_{njt}\beta_n + \varepsilon_{njt} & j = 1 \\ X_{njt}\beta_n + \varepsilon_{njt} & j = 2 \\ SQ + \varepsilon_{njt} & j = 3 \end{cases} \tag{3}$$

Where SQ_n is the status quo (no contract) constant, which is denoted SQ.

The mixed logit probability of household n choosing alternative i over the 24 choice sets is given by Equation 4:

$$P(i, \theta) = \int \frac{\exp \tilde{\beta} X_i}{\sum_j \exp \tilde{\beta} X_j} f(\tilde{\beta}|\theta)\, d\beta \tag{4}$$

where $\tilde{\beta}$ includes β and SQ and θ is a matrix of mean and variance for the random parameters' distributions. f is the density function for the random parameters. The corresponding log likelihood can be maximised using maximum simulated likelihood methods and in the present study is done using the R procedure gmnl (Sarrias and Daziano, 2017).

Finally, we also estimated a latent class model that allows for discrete preference heterogeneity (Boxall and Adamowicz, 2002). This model allows us to group farmers into classes with similar contract preferences that can facilitate the interpretation and the communication to policy makers. For each class c, its utility has fixed parameter values β_c, and the probability of household n belonging to class c is s_c where $s_1 + \ldots s_c + \ldots + s_C = 1$ and C is the number of classes. Then, the probability of choosing alternative i for a household can be calculated through Equation 5:

$$P(i|\beta_1, \ldots, \beta_C) = \sum_{c=1}^{C} s_c \frac{\exp \beta_c X_i}{\sum_j \exp \beta_c X_j} \tag{5}$$

The number of classes is determined based on information criteria and the interpretation of the classes. We also included landowner characteristics to predict class membership based on the following multinomial model presented in Equation 6:

$$s_{cn} = \frac{\exp \lambda_c z_n}{\sum_c^C \exp \lambda_c z_n} \tag{6}$$

where z_n is a vector of variables representing the characteristics of the landowner, n, and λ_c is a vector of parameters to be estimated. The parameters of the first class λ_1 are normalised to zero for identification of the model. We decided to present the result of the mixed logit model, as we find statistically significant standard deviations of the attribute preference parameters. We also include the results of latent class model as this provides an intuitive way to present the preference heterogeneity.

3.3.2. Estimation of willingness-to-accept

From the estimated indirect utility function, we can calculate the WTA in monetary terms. The marginal WTA for the different attributes is defined as the marginal rate of substitution between an attribute and the subsidy attribute, and when using a linear utility function, it can be calculated as the ratio between the parameter of the attribute a and the parameter of the subsidy parameter multiplied by (-1)

$$WTA_a = -\frac{\beta_a}{\beta_s} \tag{7}$$

In the cases where the utility function includes interactions between the attributes and farmer characteristics,z_m, the WTA will depend on the farmer characteristics. For example, Equation 7 with an interaction between attribute a and a gender variable $z_{male}x_a\beta_{male,a}$ where x_{male} =1 and zero otherwise, the WTA for attribute a for male farmer is calculated as Equation 8:

$$WTA_a(male) = -\frac{\beta_a + \beta_{male,a}}{\beta_s} \tag{8}$$

We estimated the WTA using the mean of the distributions of the random parameters. This is general not recommended when the results are used as input for cost benefit analysis as the estimated values only represent the WTA of an average farmer (Sillano and de Dios Ortúzar, 2005). However, we are not using the results for a cost benefit analysis but estimate WTA for specific types of landowners and therefore this rather simple approach is reasonable. To estimate standard errors and confidence intervals of the WTA estimates, we apply the Krinsky and Robb method (Krinsky and Robb, 1986).

3.3.3. Individual-specific WTA: A spatial analysis

Finally, we also estimate individual-specific WTA which we will use in a second stage estimation of spatial effects (Abildtrup et al., 2013; Campbell et al., 2009; Toledo-Gallegos et al., 2021). Applying a mixed logit model provides the ability to calculate estimates of individual–specific preferences by deriving the conditional distribution based on their known sequence of choices (Revelt and Train, 2000; Train, 2009). These individual estimates are obtained using Bayes' theorem. It is important to mention that these conditional estimates are strictly same-choice-specific in the sense that they are the mean of the subpopulation that makes the same choices (Sarrias, 2020). Therefore, it is important that each respondent have been presented a larger number of choices which is the case in present CE, i.e. 24 choice set for each landowner. Then, in a second stage analysis we regress the individual-specific WTA on the average pesticide use on neighboring farms. Not all farmers accepted to answer the choice experiment part of the questionnaire while we have still information about the annual pesticide use. We apply a simple linear regression as we assume the annual pesticide use as exogenous. The estimated WTA is based on the choices between alternatives from an exogenous statistical design. One could imagine that these choices account for how they may expect neighbors will answer to the choice experiment. However, due to the hypothetical nature of choice experiment we believe that it makes not sense to address the simultaneous spatial effects, e.g. including a spatial autocorrelation variable. An alternative approach would have been to include the annual use of pesticides on neighbouring farms as an interaction terms with attribute variables. However, we did not choose this option as the number of parameters was already high and the neighboring pesticide use was correlated with the pesticide use.

4. Results

4.1. Estimation results for investigating landowners' WTA pesticide reduction

PRB landowners' preferences for pesticide reduction schemes are estimated applying the conditional (Appendix Appendix A) and mixed logit models (Table 4). While the results based on the conditional and mixed logit models are similar, we also observe some differences. For example, the marginal utility of a 25% pesticide reduction and the interaction terms with this attribute are not significant in the conditional logit model. The results of this model also show that there is no significant difference between contracts with and without penalties. We observe significant heterogeneity for all parameters in the mixed logit model since all of the standard deviations are significant. This indicates that the mixed logit model is the correct model, and we will consequently base our interpretations on this model. Estimation results for the mixed logit model are reported in Table 4.

The model comprises contract characteristics, variables representing characteristics of the farms and the landowners, and fixed trecho-specific effects. The latter terms account for unobserved regional heterogeneity, while the farm and landowner characteristics are included to account for observed heterogeneity. The interaction terms are considered to be non-random.

We apply dummy coding to model the impacts of pesticide use reduction and contract length to allow for non-linear effects. A contract with 10% pesticide reduction, 5-year contract length, and no penalties is defined as the reference contract. Therefore, the SQ variable represents the utility of having no contract relative to a 5-year contract with a 10% reduction in pesticide use and no penalty. We model property size also as dummy variable to capture the difference between properties larger or smaller than 20 hectares.[10] The annual pesticide use was also defined as a dummy variable as some few farmers had exceptional high amount of pesticide use (see Table 3) and could therefore influence the results excessively.

We account for the panel structure of the data and allow for preference heterogeneity in the contract attribute parameters by letting them be random, assuming a normal distribution for all parameters except for the subsidy. A triangular distribution is assumed for the subsidy parameter to avoid the issue of infinite tails (Sarrias, 2016). The attribute coefficients are the mean of the random distribution, and the standard deviation of the these parameters are reported in the last rows of the table. The model was estimated by simulation using 20,000 Halton draws.

The estimated marginal utility parameters of the contract attributes are statistically significant at conventional levels and have expected signs, except for the `withpenality` parameter that has a positive sign relative to the baseline (`withoutpenality`), however not statistically significant.

Many of the interaction terms between the contract attributes and landowner characteristics are statistically significant. The area of the property, the production type, decision-maker type, age, level of education, and income are variables which are statistically significant in interaction with at least one of the attributes.

The marginal utility of an owner being without a contract relative to signing a contract represented by the status quo (`SQ`) parameter was not significant, meaning that there is no significant difference in the utility of having no contract relative to a 5-year contract with a 10% reduction in pesticide use and no penalty or subsidy. It is important to note that the status quo also reflects how the respondent consider the current situation and expectations about future prices and policies but this is no different from a real choice situation.

[10] In the bfc (Law n° 12.651/2012) the size of the property is used as a legal parameter for its application in different contexts, and in this region below 20 hectares it is considered small property.

Table 4
Mixed logit results and marginal WTA of contract attributes .

	Marginal utility (θ)					WTA		
Variables:	Coef.	Std.Error	z-value	Pr(>|z|)		MWTA	2.5%	97.5%
SQ	-0.2091	0.4471	-0.4676	0.6400		16.268	-51.258	86.334
pestireduction_25%	-12.0998	2.3026	-5.2548	0.0000	***	941.388	604.762	1297.695
pestireduction_50%	-19.7873	2.4675	-8.0192	0.0000	***	1539.493	1188.952	1914.784
contract_10years	4.8860	2.3311	2.0960	0.0361	*	-380.144	-739.135	-25.503
contract_15years	-37.0914	4.8059	-7.7179	0.0000	***	2885.783	2204.495	3609.005
withpenality	1.7332	1.6255	1.0663	0.2863		-134.850	-378.741	116.210
unbreakable	-6.0811	2.2151	-2.7453	0.0060	**	473.119	143.945	800.744
subsidy	0.0129	0.0011	12.0569	< 2.2e-16	***			
pestireduction_25%:INCOME	0.1762	0.1110	1.5866	0.1126		-13.707	-30.885	3.268
pestireduction_25%:AGE	0.0822	0.0307	2.6734	0.0075	**	-6.395	-11.259	-1.768
pestireduction_25%:EDUC	0.3842	0.1773	2.1664	0.0303	*	-29.890	-55.885	-3.252
pestireduction_25%:SMALL_SURF	0.0016	0.0019	0.8381	0.4020		-0.126	-0.425	0.177
pestireduction_25%:TAQUARA	-3.7558	0.6770	-5.5481	0.0000	***	292.208	198.918	386.350
pestireduction_25%:FOREST	-3.9402	2.1176	-1.8607	0.0628	.	306.555	-18.202	623.057
pestireduction_25%:CATTLE	-0.1561	0.7477	-0.2088	0.8346		12.146	-101.531	129.538
pestireduction_25%:PIG_CHICK	-3.8713	1.1858	-3.2647	0.0011	**	301.193	127.821	476.400
pestireduction_25%:OWN_DEC	1.0850	0.6914	1.5693	0.1166		-84.416	-188.572	21.626
pestireduction_25%:FAMILY_DEC	-0.4657	0.7462	-0.6241	0.5325		36.234	-79.146	149.374
pestireduction_25%:AGROCHEMICAL_HIGHER-USE	-2.9417	0.8451	-3.4810	0.0005	***	228.871	99.269	356.526
pestireduction_50%:INCOME	0.2696	0.1129	2.3877	0.0170	*	-20.979	-38.720	-4.256
pestireduction_50%:AGE	0.1160	0.0343	3.3874	0.0007	***	-9.028	-14.375	-3.754
pestireduction_50%:EDUC	0.1193	0.2097	0.5688	0.5695		-9.280	-40.088	23.458
pestireduction_50%:SMALL_SURF	-0.0261	0.0158	-1.6558	0.0978	.	2.033	-0.405	4.444
pestireduction_50%:TAQUARA	2.1202	0.7200	2.9445	0.0032	**	-164.953	-283.046	-52.747
pestireduction_50%:FOREST	0.1453	2.5158	0.0578	0.9539		-11.306	-397.067	373.932
pestireduction_50%:CATTLE	1.4943	0.7939	1.8824	0.0598	.	-116.263	-241.333	6.817
pestireduction_50%:PIG_CHICK	-5.7867	1.6645	-3.4766	0.0005	***	450.214	205.836	704.137
pestireduction_50%:OWN_DEC	-1.5307	0.8706	-1.7582	0.0787	.	119.095	-11.676	259.499
pestireduction_50%:FAMILY_DEC	2.3272	0.9859	2.3605	0.0183	*	-181.059	-336.168	-29.997
pestireduction_50%:AGROCHEMICAL_HIGHER-USE	-2.3537	1.0796	-2.1801	0.0293	*	183.124	22.164	339.965
contract_10years:INCOME	6.7585	0.6780	9.9684	< 2.2e-16	***	-525.828	-643.059	-423.173
contract_10years:AGE	-1.1671	0.1130	-10.3319	< 2.2e-16	***	90.806	73.816	110.241
contract_10years:EDUC	-8.7695	0.8467	-10.3571	< 2.2e-16	***	682.285	555.487	825.952
contract_10years:SMALL_SURF	0.0338	0.0039	8.7074	< 2.2e-16	***	-2.632	-3.308	-2.027
contract_10years:TAQUARA	17.1893	1.6454	10.4472	< 2.2e-16	***	-1337.366	-1579.150	-1122.816
contract_10years:FOREST	-14.6478	2.6059	-5.6210	0.0000	***	1139.626	735.863	1583.455
contract_10years:CATTLE	14.5627	1.8854	7.7240	0.0000	***	-1133.009	-1466.380	-837.645
contract_10years:PIG_CHICK	-6.4324	1.6474	-3.9045	0.0001	***	500.456	247.211	765.238
contract_10years:OWN_DEC	1.1726	1.0088	1.1624	0.2451		-91.228	-257.270	62.378
contract_10years:FAMILY_DEC	16.5558	1.7974	9.2110	< 2.2e-16	***	-1288.078	-1571.849	-1030.763
contract_10years:AGROCHEMICAL_HIGHER-USE	2.1672	0.9172	2.3628	0.0181	*	-168.612	-306.200	-28.945
contract_15years:INCOME	4.8363	0.5064	9.5508	< 2.2e-16	***	-376.276	-449.733	-306.806
contract_15years:AGE	-0.0843	0.0299	-2.8157	0.0049	**	6.558	2.059	11.150
contract_15years:EDUC	-4.7063	0.5015	-9.3850	< 2.2e-16	***	366.163	300.115	438.363
contract_15years:SMALL_SURF	0.0080	0.0022	3.6015	0.0003	***	-0.621	-0.974	-0.283
contract_15years:TAQUARA	-17.4461	1.7827	-9.7862	< 2.2e-16	***	1357.343	1095.813	1644.894
contract_15years:FOREST	-5.3152	2.5183	-2.1106	0.0348	*	413.530	30.561	813.460
contract_15years:CATTLE	5.6227	1.0130	5.5506	0.0000	***	-437.454	-604.959	-286.870
contract_15years:PIG_CHICK	-41.9351	4.3684	-9.5996	< 2.2e-16	***	3262.634	2642.440	3917.505
contract_15years:OWN_DEC	8.5612	1.1754	7.2835	0.0000	***	-666.075	-858.641	-489.262
contract_15years:FAMILY_DEC	9.6470	1.2780	7.5483	0.0000	***	-750.553	-941.537	-569.904
contract_15years:AGROCHEMICAL_HIGHER-USE	-18.0431	2.0204	-8.9306	< 2.2e-16	***	1403.787	1114.846	1719.004
withpenality:INCOME	0.0927	0.0776	1.1946	0.2323		-7.215	-19.329	4.788
withpenality:AGE	-0.0369	0.0225	-1.6377	0.1015		2.872	-0.563	6.204
withpenality:EDUC	-0.1148	0.1365	-0.8413	0.4002		8.932	-12.480	29.465
withpenality:OWN_DEC	-0.6751	0.6421	-1.0514	0.2931		52.527	-44.218	153.097
withpenality:FAMILY_DEC	-0.8602	0.6323	-1.3604	0.1737		66.925	-32.399	166.611
unbreakable:INCOME	-0.2334	0.1266	-1.8434	0.0653	.	18.162	-1.160	37.911
unbreakable:AGE	0.0078	0.0289	0.2694	0.7877		-0.606	-4.982	3.841
unbreakable:EDUC	0.7714	0.2130	3.6223	0.0003	***	-60.016	-92.120	-28.939
unbreakable:OWN_DEC	-1.4673	0.6065	-2.4191	0.0156	*	114.158	21.137	211.325
unbreakable:FAMILY_DEC	-0.8877	1.0014	-0.8864	0.3754		69.065	-79.526	227.075
sd:pestireduction_25%	1.7795	0.2892	6.1542	0.0000	***	-138.449	-187.485	-93.969
sd:pestireduction_50%	2.8830	0.4122	6.9942	0.0000	***	-224.303	-282.675	-167.777
sd:contract_10years	41.7754	3.9418	10.5980	< 2.2e-16	***	-3250.208	-3933.631	-2660.453
sd:contract_15years	30.5809	2.9775	10.2707	< 2.2e-16	***	-2379.258	-2818.449	-1969.775
sd:withpenality	0.5050	0.2702	1.8688	0.0617	.	-39.292	-80.752	2.079
sd:unbreakable	6.5032	0.6517	9.9782	< 2.2e-16	***	-505.960	-695.575	-359.402
sd:subsidy	0.0194	0.0017	11.1604	< 2.2e-16	***	-1.507	-1.551	-1.458

Mixed log likelihood: -1146.7 N° of choices: 2928 N° iterations: 547 Simulation based on 20,000 draws Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The attribute coefficients without interactions with farm and landowner characteristics show that a land owner is less likely to participate in a scheme if the contract implies a large reduction of pesticide use (pestireduction_25% and pestireduction_50%), the contract has a duration of fifteen years, and the contract is unbreakable relative to a contract without penalties (Table 4). On the other hand, a landowner is more likely to participate if the subsidy is high.

Based on the interaction terms, a landowner is more likely to reduce pesticide use by 50% per hectare (pestireduction_50%) when he or she lives in the southernmost region of the basin (TAQUARA), land use on his or her property is dedicated to cattle raising (CATTLE), and when he or she takes the decisions about the property with his or her family members (FAMILY_DEC). The older (AGE) and wealthier (INCOME) the owners are, the more likely they are to halve current pesticide use. However, educational level (EDUC) influenced only the preferences for schemes with a 25% reduction of pesticide use, i.e. respondents with a high level of education choose a 25% reduction more often than those with a low level of education).

A land owner is less likely to participate in a PES scheme restricting pesticide use by 50% if he or she owns a smaller property of 20 hectares (SMALL_SURF), is raising pigs and/or chickens (PIG_CHICK) as the main productive activity and is making decisions about the property alone (OWN_DEC).

Landowners are less inclined to reduce pesticide use by 25% when eucalyptus plantations (FOREST) and/or raising pigs and chickens (PIG_CHICK) are the main productive activities relative to agriculture and/or horticulture (AGRIHORTICULTURE – the baseline) and they are located in TAQUARA.

As expected, the amount of agrochemicals used per hectare-year (AGROCHEMICAL_HIGHER-USE) negatively influences participation in a PES program that requires a high percentage of pesticide reduction (25% or 50%).

The landowner and farm characteristics also influence the preferences for contract length. We find that an owner older than 60 years (OLDER), has a high level of education (EDUC), and operates a eucalyptus plantation (FOREST) and/or raises pigs and chickens (PIG_CHICK) as the main productive activities is less likely to sign long contracts (contract_10years and contract_15years) relative to a five-year contract. However, a wealthy landowner (INCOME), owning a smaller property of 20 hectares (SMALL_SURF), raising CATTLE and making decisions about the property with his or her family members (FAMILY_DEC) is more likely to participate in a PES scheme with long contractual duration.

Table 4 also shows also the estimated marginal WTA for the attributes and the impact of the socio-demographic variables on the marginal WTA. The last two columns are the confidence intervals estimated with the Krinsky and Robb method. The estimated WTA values are based on the mixed logit model.

We see that for the reference landowner, the WTA increases by R$941.39 and R$1539.49 for 25% and 50% increases in pesticide use reduction, respectively, relative to 10%. Contract length has a marginal WTA of R$2885.78 for a fifteen-year contract and a WTA of R$473.11 unbreakable contracts.

We found a negative marginal impact on WTA of R$-134.85 (however, not significantly different from zero) and R$-380.14 for the withpenality and for contract_10years attributes, respectively. These results mean that landowners will prefer a contact with penalisation relative to one without penalisation and a ten-year contract relative to a five-year contract even without compensation. Note that this result concerns the reference landowner without accounting for the interaction terms. The impact of the interaction terms is investigated further by using the owner profiles defined in the next section (see Figs. 5 and 6). Note further that the standard deviation (sd) values, which measure the heterogeneity in preferences for the withpenality and contract_10years attributes presented in the Equation 4, were significantly different from zero, meaning that the data indicate that farmers are heterogeneous with respect to these variables – some will be more likely to participate with penalties while others will be less likely to do so. Moreover, none of the interaction terms were significant with respect to withpenality, indicating that unobserved heterogeneity is important for the preferences for this scheme attribute.

4.2. Spatial heterogeneity of neighboring pesticide use in WTA variation

The results above show, as expected, that acceptance of pesticide reduction is strongly dependent on current pesticide use. In Table 5 we show the results of the regression of the marginal individual-specific WTA of reducing the pesticide use by 25% and 50% on the pesticide use on neighbouring properties (section 3.3.3).

Results presented in Table 5 show that the amount of pesticides used from the two directly neighbourhoods (right and left side) does not affect the individual specific WTA, using conventional levels of statistical significance. Pesticides use reduction is dependent on their own pesticide use.

4.3. Heterogeneity of the preferences

Given the complexity of the results in Table 4, we summarised the utility parameters for four profiles to illustrate the heterogeneity of the preferences. These four profiles where chosen by identifying the most frequent profiles in our database, and we created them based on key socio-demographic characteristics (Table 3). For each profile, we calculated the marginal attribute utility. As an example Table 6 presents in details how the marginal utility parameters were calculated for profile 1[11]:

The marginal utility represents how much utility is gained or lost by landowners as a result of the increase or decrease of one unit of the contract feature. For the four profiles the marginal utilities are presented in Figs. 3 and 4.

In Figure 3 and 4, we see a clear difference between the profiles since there are considerable differences in terms of estimated marginal utilities from one profile to another.

For example, in three of the four attributes, PROFILE 4 presents the most extreme values, which implies that this profile has the most negative values for pesticide reduction (25%) and for unbreakable contracts but highest valeus for penalty attribute. In other words, PROFILE 4 prefers medium length of contracts, ten-year period relative to five-years and 15 years contracts, but has the most negative utility from pesticide reductions of 50% (-13.77) and unbreakable contracts (-5.44). The estimated coefficients suggest that the more pesticide reduction needed per year, the less likely this landowner profile is to have a PES contract relative to the reference contract. Owners belonging to this profile group are also less likely to participate if the contract has the longest contract length (contract_15years) and they do highly care about unbreakable contracts. Their socio-demographic variables are detailed in Figure 4, and their current intensive use of pesticide may be an important explanation for their preferences.

From Figure 3, the results show that PROFILE 2 prefers short contracts (negative utility for both 10- and 15-year contract lengths) and do not seek flexibility since they prefer unbreakable contracts (51.09).

A surprising result is that PROFILE 3, which uses pesticides less frequently, has the highest income, and with the main activity being raising cattle on the property, is less likely to reduce pesticide use by 25% (-10.54) than by 50% (-5.91).

PROFILE 1 represents an average profile and is less likely to participate in a scheme if the contract implies a high reduction of pesticide

[11] Note that in the equation for profile 1 (Fig. 4), the following attributes do not appear as the attribute level represents the reference of the dummy variable (=0) : decision maker (External - EXT_DEC), region (TAQUARA), land use (AGRIHORTICULTURE) and property surface (MED.BIG_SURF)

Table 5
Neighbouring affect on WTA pesticide reduction .

	$\overline{X}$neigh-pesticide-use ID-WTA_pestireduction_25%	(Intercept)	ID-WTA_pestireduction_50%	$\overline{X}$neigh-pesticide-use (Intercept)
Estimate	24.86	(-5481.01)	54.06	(-7474.65)
Std.Error	66.73	(3642.42)	82.05	(4478.89)
t-value	0.372	(-1.505)	0.659	(-1.669)
Pr(>|t|)	0.710	(0.135)	0.5112	(0.0978)

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Table 6
Marginal utility parameter calculation for Profile 1 defined in Fig. 4.

pestireduction_25% (R$) =
β pestireduction_25% (-12.0998)
+ βpestireduction_25%:AGE (0.0822) × Average AGE (56.5)
+ β pestireduction_25%:AGROCHEMICAL_HIGHER-USE (-2.9417) × AGROCHEMICAL_LOWER-USE (0)
+ β pestireduction_25%:EDUC (0.3842) × Average EDUC (3.6)
+ β pestireduction_25%:INCOME (0.1762) ×Average INCOME (10)
pestireduction_50% (R$) =
β pestireduction_50% (-19.7873)
+ β pestireduction_50%:AGE (0.1160) × Average AGE (56.5)
+ β pestireduction_50%:AGROCHEMICAL_HIGHER-USE (-2.3537) × AGROCHEMICAL_LOWER-USE (0)
+ β pestireduction_50%:EDUC (0.1193) × Average EDUC (3.6)
+ β pestireduction_50%:INCOME (0.2696) ×Average INCOME (10)
contract_10years (R$) =
β contract_10years (4.8860)
+ β contract_10years:AGE (-1.1671) × Average AGE (56.5)
+ β contract_10years:AGROCHEMICAL_HIGHER-USE (2.1672) × AGROCHEMICAL_LOWER-USE (0)
+ β contract_10years:EDUC (-8.7695) × Average EDUC (3.6)
+ β contract_10years:INCOME (6.7585) ×Average INCOME (10)
contract_15years (R$) =
β contract_15years (-37.0914)
+ β contract_15years:AGE (-0.0843)× Average AGE (56.5)
+ β contract_15years:AGROCHEMICAL_HIGHER-USE (-18.0431)× AGROCHEMICAL_LOWER-USE (0)
+ β contract_15years:EDUC (-4.7063) × Average EDUC (3.6)
+ β contract_15years:INCOME (4.8363) ×Average INCOME (10)
withpenality =
β withpenality (1.7332)
+ β withpenality:AGE (-0.0369)×Average AGE (56.5)
+ β withpenality:EDUC (-0.1148)× Average EDUC (3.6)
+ β withpenality:INCOME (0.0927) ×Average INCOME (10.06)
unbreakable =
β unbreakable (-6.0811)
+ β unbreakable:AGE (0.0078) ×Average AGE (56.5)
+ β unbreakable:EDUC (0.7714) × Average EDUC (3.6)
+ β unbreakable:INCOME (-0.2334)× Average INCOME (10.06)

use or the contract has a long duration. Only the profiles 3 and 4 seek flexibility in a PES contract for pesticide reduction since they are the only to have negative utilities for unbreakable contracts.

We use the same four profiles defined above to investigate the WTA per contract feature and profile. The WTA was calculated according to the same principles as for the marginal utility (Table 6). In Figure 5 and 6, the clear differences between the profiles are confirmed.

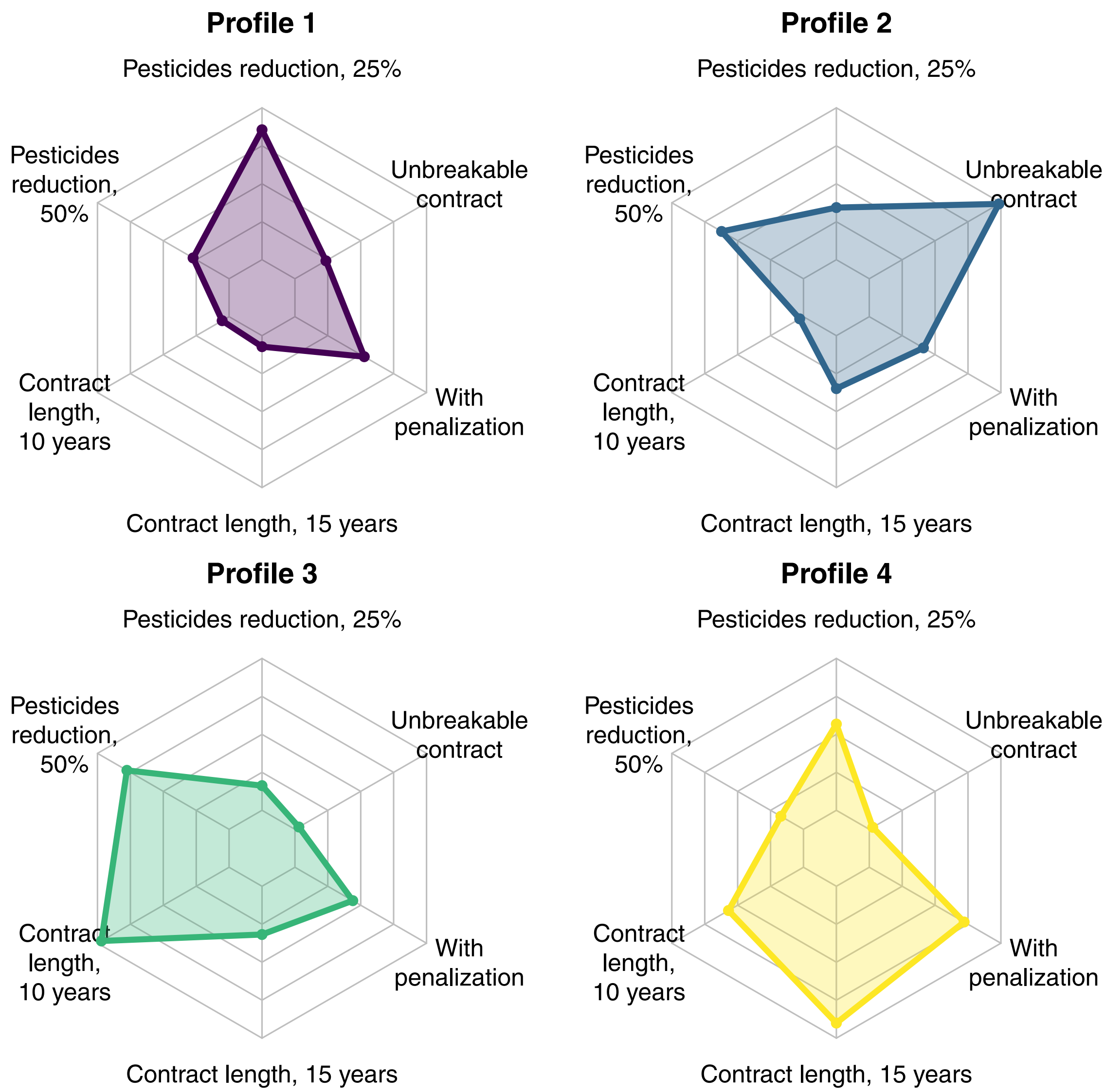
Again, using the four most frequent profiles in our database, the results presented in Figs. 5 and 6 indicate that the more frequent their use of pesticides is, the higher their WTA. Owners in PROFILE 1, PROFILE 2, and PROFILE 4 are apply pesticides more than 50 times annually.

These three profiles have the highest marginal WTA for reducing pesticide use by 50%. PROFILE 3 represents owners with properties larger than 20 hectares located in Taquara Village, with livestock as the main activity and less frequent use of pesticides, and owners in this profile present the lowest WTA when faced with halving annual pesticide use (R$276,46) while featuring a slightly higher WTA of R$590,99 to reduce pesticide use by 25%.

Using the estimated WTAs corresponding to each unit of the contract attributes, presented in Figure 5, we obtained the subsidy necessary to compensate each of the four profiles for each of seven different contract scenarios presented in Figure 7. We see that the necessary compensation (WTA) varies among profiles for the different scenarios. These seven scenarios presented in Figure 7 are part of the 24 choice sets presented to owners at the time of data collection and was selected to represent the diversity of potential contract types.

When comparing Scenario 09 Prog 2 and Scenario 11 Prog 1, we observe that all profiles maintain an orientation towards flexibility, as both hypothetical scenarios require the same amount of pesticide reduction in the same period of time, but Scenario 11 Prog 1 is an unbreakable contract, while the other is withtpenality. Contracts that are unbreakable have higher WTA per hectare/year for all PROFILES. When the owner is young, uses pesticides frequently, takes decisions with an external professional specialised in the production field, lives in Pipiripau and owns a small property that does not exceed 20 hectares (PROFILE 4), the total WTA for a five-year contract that required a 50% reduction in pesticide use with a penalty is R$852 per hectare/year. When only one factor of the contract changes, from with penalty to unbreakable, the value for this same contract for the same owner profile changes to R$1,379 per year and per hectare.

Figure 7 shows that for owners being on average 56 years old, having eucalyptus plantations as their main activity, applying pesticides less than 50 times per year on small properties located in Taquara Village (the southernmost part of the basin), making decisions on the prop-



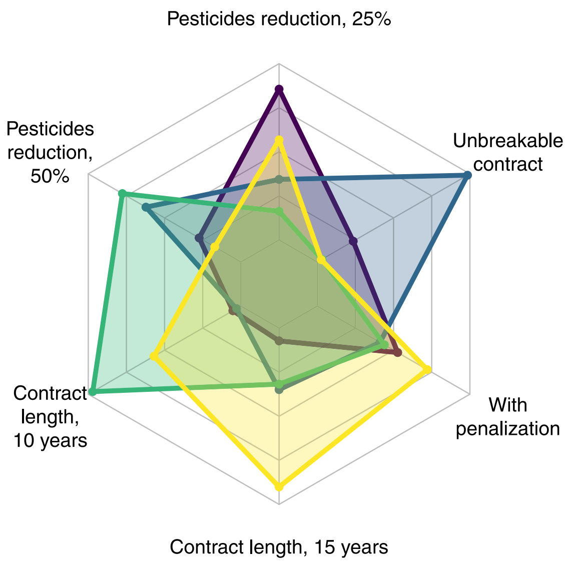
	Pesticides reduction (25%)	Pesticides reduction, 50%	Contract length (10 years)	Contract length (15 years)	With penalization	Unbreakable contract
Profile 1	–4.3	–12.44	–22.47	–28.19	0.16	6.9
Profile 2	–8.91	–7.91	–24.08	–21.28	–0.53	51.09
Profile 3	–10.54	–5.91	39.01	–22.06	–0.36	–5.22
Profile 4	–6.89	–13.77	12.16	–7.48	1.32	–5.44

Fig. 3. Spider chart of marginal utility based on the profiles and their mixed logit model coefficients.

erty alone and with an average income (14 times the minimum wage) (PROFILE 2) have strong preferences for contracts with short duration. Their WTA for a 25% reduction in pesticides in a fifteen-year contract without penalty is estimated to be the highest value among the four profiles, at R$3,965 per hectare/year (Scenario 23 prog 2).

A surprising result is that PROFILE 3 owners have the highest WTA to reduce pesticide usage by a moderate percentage. This can be seen by comparing Scenario 17 Prog 1 and Scenario 11 Prog 1 for PROFILE 3. The amount needed in Brazilian reais per year/hectare is higher for a 25% reduction in pesticides than the total amount for a 50% reduction in pesticides with the same contract conditions: 5 years and unbreakable. However, for the same scenarios, we can see that owners using the highest amounts of pesticides per hectare/year have a higher WTA for pesticide reduction (PROFILE 4).

Another interesting result is that PROFILE 3 and PROFILE 4 presented a negative WTA when faced to a contract that required a 10% reduction in pesticides in a ten-year contract without penalty (Scenario 14 Prog 1). These results mean that these two profiles will prefer that contract even without compensation. However, importantly, this is only the case if the pesticide use reduction is small over a ten-year contract, as these profiles are sensitive to pesticide reduction levels.



	Profile 1	Profile 2	Profile 3	Profile 4
Age	Average	Average	Mode	Min
Annual pesticides application	>50	>50	<50	>50
Decision maker	EXTERNAL	OWN	FAMILY	EXTERNAL
Education level	Average	Max	Mode	Average
Income	Average	Mode	Max	Average
Land use	Agriculture	Forest	Cattle	Agriculture
Property surface	Med/Big	Small	Med/Big	Small
Region	Piriripau	Taquara	Taquara	Piriripau

Fig. 4. Spider chart of marginal utility for landowners profiles.

Our results suggest that when the contract is shorter, the amount of pesticide reduction is the most important factor to drive higher values of WTA, but when faced with long contracts, farmers respond differently than we would expect from a simple profit-maximising assumption.

4.4. Latent class model

We suspect that distinct subgroups or categories of individuals exist and a latent class model was used to model unobserved heterogeneity by identifying classes of landowners with similar preferences. Landowner and farm characteristics are used as predictors for class membership. In contrast to the mixed logit model, in the latent class model, we used continuous variables for pesticide use reduction and contract length, i.e. linear effect of reduction level and contract length within a group, as our main objective is here to identify groups with different contract preferences.

The results based on the latent class model confirm that there is significant heterogeneity in the sampled landowners. We show the results of a model with three classes in Table 7 because this model described the data best. We can consequently describe the landowners in the PRB in the following classes:

1. The first class represents owners who are concerned only with the duration of the contract and do not consider the subsidy. Surprisingly, this group does not consider subsidies, and this may indicate that economic factors are not important for their decision to participate in a contract. On the other hand, the status quo is not significant, which leads us to interpret them as owners who do not prefer long contracts. Owners belonging to this class do not consider contract penalties and pesticide use reduction. Their socio-demographic characteristics are as follows: older people, low education, large properties areas located in the villages of Taquara or Pipiripau, owners having forests or cattle with high income and those making decisions together with other family members (FAMILY_DEC).
2. The second class represents owners who are positively inclined towards pesticide reductions but do not want long contracts and do care about subsidies. They prefer contracts with penalties but do not care about unbreakable contracts. As with the first class, pesticide use reduction is not seen as a cost. However, as the SQ coefficient is statistically significant and negative, landowners in this class prefer to have contracts over having no contract. Their socio-demographic characteristics relative to class one are as follows: high education, larger properties areas located in Taquara village, low income, less likely to have cattle or forests but more likely to be raising pigs and/or chickens as the main productive activity and not likely to take decisions with their family (FAMILY_DEC).
3. The third class, the most frequent, represents those landowners who are negatively inclined towards pesticide reduction but prefer long contracts. The status quo coefficient is positive and statistically significant, indicating that they prefer to have no contract. Their socio-demographic characteristics relative to class one are as follows: owners with large property areas located in Pipiripau village, large consumers of pesticides, having agriculture as the main productive activity and are less likely to take decisions alone or with family, i.e., taking decisions with business partners or an expert in the area (EXT_DEC).

To summarise the results from the latent class model, we find that an important number of respondents do not care about the level of pesticide use reduction (class 1 and class 2), and for class 1, even the subsidy level is not important. This may indicate that some respondents are not using economic criteria in their decision-making. However, for the most frequent class (class 3), the decision-making seems more in line with economic criteria.

5. Discussion

The aim of this study was to investigate, through a DCE, Pipiripau Basin landowners' potential WTA compensation for reducing the use of agrochemicals in the PRB. To date, these are the first results on farmers' willingness to accept the reduction of pesticide use in Brazil. Our results contribute to the literature (e.g. Alarcon et al., 2017; Richards et al., 2020) by measuring the various aspects that influence landowners' willingness to adopt a conservation approach to protect water resources by reducing the use of agrochemicals.

We identified the four most frequent profiles in our sample defined by socio-economic and farm characteristics and evaluated how these profiles consider different contract features: pesticide reduction, unbreakable contract, penalisation, and contract length. We tested three levels of pesticide reduction (10%, 25% and 50%) combined with four amounts of payments per hectare/year (R$712,00; R$1.425,00; R$ 2.135,00; and R$3.250,00) and three types of contract length (5, 10 and 15 years). Contracts could be unbreakable, with penalisation or without penalisation.

We applied mixed logit model to estimate landowners' WTA and a latent class model that allows us to account for discrete preference heterogeneity and group owners with similar contract preferences. All the

	Pesticides reduction (25%)	Pesticides reduction, 50%	Contract length (10 years)	Contract length (15 years)	With penalization	Unbreakable contract
Profile 1	564.28	969.37	1779.74	2215.54	−12.58	404.45
Profile 2	922.04	798.77	1704.6	3059.57	41.45	387.2
Profile 3	590.99	276.46	−286.17	312.15	28.25	406.06
Profile 4	765.59	971.4	−1083.29	2008.34	−103.05	423.53

Fig. 5. Spider chart of landowner profiles' marginal WTA of contract attribute in Brazilian reais (R$) per hectare .

models presented in Section 4 were coded in the open-source software *R* and the mixed logit model and latent class model were estimated using the maximum simulated likelihood (the `gmnl` package – it supports both cross-sectional and panel data (Sarrias and Daziano, 2017)) – and by maximum conditional likelihood (the `support.CEs` and `survival` packages). `Qgis` software was used to build the maps.

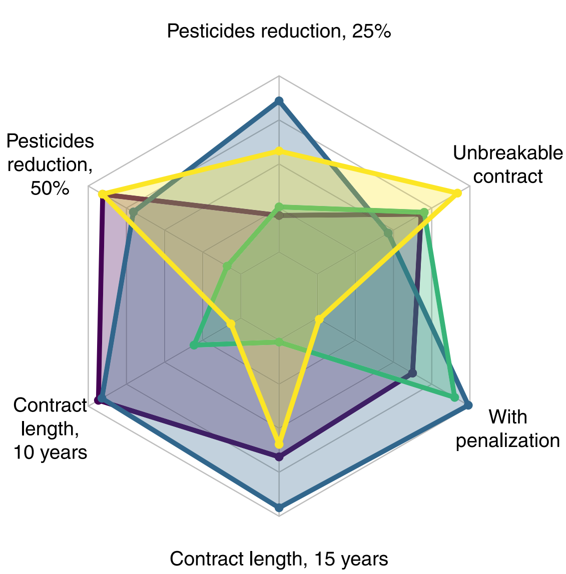
All models applied in this study suggest that pesticide reduction is strongly dependent on current annual pesticide use and the main profitable economic activity on the property. This result is supported by previous results involving decisions of Brazilian landowners in the literature. Richards et al. (2020) finds that property characteristics in Brazil play an important role in landowner decisions for reforestation contracts. However, we did not find statistically significant evidence that the frequency of pesticide applications by neighboring landowners influences the WTA.

Another finding identified by the latent class model is that owners who are positively inclined towards pesticide use reduction prefer short contracts with penalties relative to contracts without penalties. In a previous study, Costedoat et al. (2016) finds that landowners prefer short contracts relative to long contracts, and Ruto and Garrod (2009) showed that preferences for shorter contract lengths were higher for older farmers. Our results show that Pipiripau River Basin's

Table 7
Latent class model .

Coefficients:	Estimate	Std. Error	z-value	Pr(>|z|)	
class.1.SQ	-1.7088	9027.5000	-0.0002	0.9998	
class.1.pesticidesreduction	-1.3194	902.4100	-0.0015	0.9988	
class.1.contractlenght	-0.2908	0.0938	-3.1006	0.0019	**
class.1.withpenal	11.4570	232.5300	0.0493	0.9607	
class.1.unbreakable	9.6454	232.5300	0.0415	0.9669	
class.1.subsidy	-0.0008	0.0582	-0.0145	0.9884	
class.2.SQ	-0.9319	0.2685	-3.4705	0.0005	***
class.2.pesticidesreduction	0.0082	0.0035	2.3087	0.0210	*
class.2.contractlenght	-0.4916	0.0266	-18.5003	< 2.2e-16	***
class.2.withpenal	1.1726	0.1783	6.5767	0.0000	***
class.2.unbreakable	-0.1024	0.1514	-0.6759	0.4991	
class.2.subsidy	0.0747	0.0073	10.2881	< 2.2e-16	***
class.3.SQ	1.0040	0.2556	3.9284	0.0001	***
class.3.pesticidesreduction	-0.0598	0.0034	-17.6232	< 2.2e-16	***
class.3.contractlenght	0.1009	0.0139	7.2334	0.0000	***
class.3.withpenal	1.9647	0.2204	8.9153	< 2.2e-16	***
class.3.unbreakable	-1.5777	0.1368	-11.5340	< 2.2e-16	***
class.3.subsidy	0.1069	0.0075	14.3014	< 2.2e-16	***
(class)2	3.4510	0.5024	6.8692	0.0000	***
(class)3	4.1310	0.5336	7.7421	0.0000	***
class2:INCOME	-0.1976	0.0255	-7.7353	0.0000	***
class3:INCOME	-0.0060	0.0270	-0.2231	0.8234	
class2:AGE	0.0051	0.0063	0.8208	0.4118	
class3:AGE	-0.0088	0.0066	-1.3250	0.1852	
class2:EDUC	0.1622	0.0402	4.0372	0.0001	***
class3:EDUC	0.0518	0.0429	1.2080	0.2270	
class2:SMALL_SURF	-1.6835	0.1578	-10.6667	< 2.2e-16	***
class3:SMALL_SURF	-1.1354	0.1590	-7.1391	0.0000	***
class2:TAQUARA	0.7883	0.1466	5.3792	0.0000	***
class3:TAQUARA	-1.4816	0.1448	-10.2333	< 2.2e-16	***
class2:FOREST	-1.2058	0.2840	-4.2463	0.0000	***
class3:FOREST	-0.8584	0.2998	-2.8634	0.0042	**
class2:CATTLE	-0.4856	0.1477	-3.2877	0.0010	**
class3:CATTLE	-0.7997	0.1579	-5.0651	0.0000	***
class2:PIG-CHICK	0.3735	0.2912	1.2827	0.1996	
class3:PIG-CHICK	-0.1183	0.3027	-0.3908	0.6959	
class2:AGROCHEMICAL_YEAR	0.0004	0.0010	0.4013	0.6882	
class3:AGROCHEMICAL_YEAR	0.0018	0.0011	1.6885	0.0913	.
class2:OWN_DEC	0.0235	0.2176	0.1082	0.9138	
class3:OWN_DEC	-0.8030	0.2213	-3.6291	0.0003	***
class2:FAMILY_DEC	-0.7756	0.1907	-4.0680	0.0000	***
class3:FAMILY_DEC	-1.6063	0.1962	-8.1862	0.0000	***
Frequencies of categories:					
3 = 0.459					
1 = 0.299					
2 = 0.242					

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Optimisation of log-likelihood by BFGS maximisation Log likelihood: -1765.5; number of observations: 2928; number of iterations: 589 Exit of MLE: successful convergence



	Profile 1	Profile 2	Profile 3	Profile 4
Age	Average	Average	Mode	Min
Annual pesticides application	>50	>50	<50	>50
Decision maker	EXTERNAL	OWN	FAMILY	EXTERNAL
Education level	Average	Max	Mode	Average
Income	Average	Mode	Max	Average
Land use	Agriculture	Forest	Cattle	Agriculture
Property surface	Med/Big	Small	Med/Big	Small
Region	Piriripau	Taquara	Taquara	Piriripau

Fig. 6. Spider chart of marginal WTP for landowner profiles.

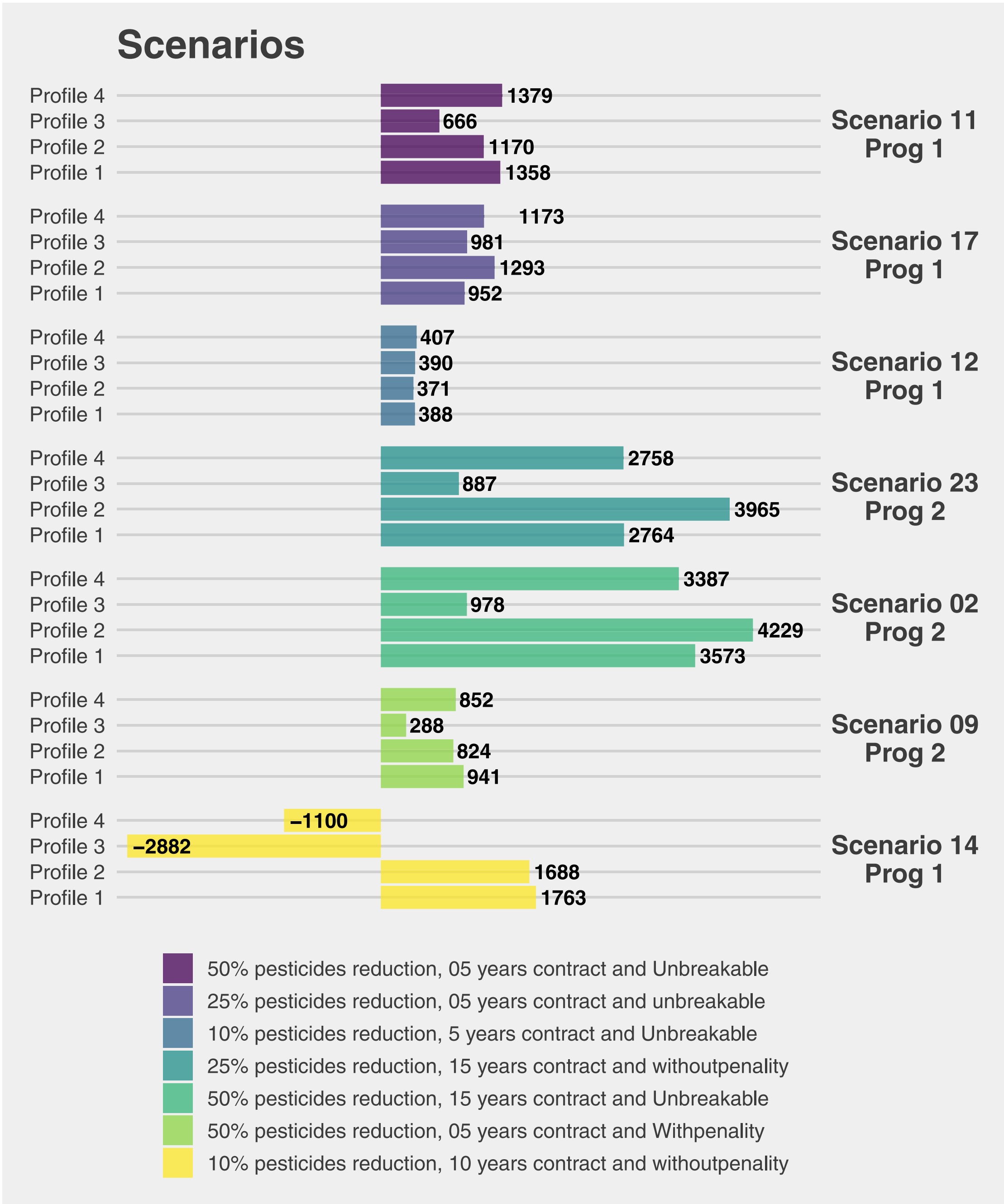


Fig. 7. Total amount to be paid for seven different scenarios and four profiles (Scenario and Prog numbers refer to the number of the choice card and choice alternative, respectively, in the DCE) .

private landowners seek flexibility in PES contracts. Similar results are reported by Christensen et al. (2011), showing that the major decision criteria for Danish farmers to reduce the use of pesticides was the contract's flexibility. Another finding was that landowners in the PRB prefer contracts with penalties and that owners are homogeneous with respect to this contract attribute. One explanation for this result might be that the current WPP contracts can be interrupted by the Brazilian government at any time, and knowing this, the owners fear insecurity and losing the opportunity cost resulting from a production activity in which the use of pesticides was reduced but the contract was broken. Many landowners during data collection reported being afraid of doing business with the Brazilian government due to its instability. This is well in line with Christensen et al. (2011), who reports that a lack of trust in authorities was a barrier to adhering to agri-environment subsidy schemes for pesticide-free buffer zones in Denmark.

The results obtained also show that landowners who prefer long contracts are negatively inclined to reduce the amount of pesticides used on their property (class 3 in Table 7). This result cannot be ignored, as this class of owners consumes the most pesticides and thus present the highest WTAs for pesticide reduction. With this result, we captured landowners' bearing risks of large production losses. The preference for longer contracts for this group could also be related to the relatively high transaction costs of short contracts or capacity adjustments that involve fixed costs. This would be the case if they have to invest in new technology to adapt to the contract restrictions on pesticide use, for example, by converting from chemical fertilisation and pest management to ecological management, including searching for agro-ecological innovations and pest-tolerant crops. Therefore, they may prefer long contracts to make such investment profitable.

Our results confirmed that landowners' preferences for agri-environmental schemes are highly heterogeneous. We showed that an important part of this heterogeneity can be explained by socio-demographic characteristics and confirm the literature review on the importance of these factors in landowners' susceptibility to participate in environmental programmes in Siebert et al. (2006). Educational level was detected as an important factor influencing landowners' interest in joining a PES with a focus on pesticide reduction. This result is line with Ruto and Garrod (2009). However, this characteristic cannot be analysed in isolation, since the combination with other variables might change its direction of influence. For example, based on our four analysed owner profiles, we found that for owners living in the southernmost region of the basin, raising pigs and/or chickens on small properties, and having a high education level were more positively inclined toward pesticide reduction than other profiles. However, the same socio-demographic characteristics combined with owning small properties located in the northernmost region of the basin, with agriculture as the main activity and a high level of pesticide reduction were the most negatively inclined towards participation and consequently had the highest WTA. Similar findings are reported by Alarcon et al. (2017) who found that the level of education was important in a study on a forest conservation and forest restoration PES programme in the Brazilian Atlantic Forest region. Moreover, it was only important when considering the minimum amount of money expected for private owners to join the PES programme and for no other payment levels.

Based on both the mixed logit and latent class models, we find that who takes the management decisions has a significant influence on the participation decision. Owners taking decisions with family members (FAMILY_DEC) are more inclined towards pesticide reductions than other decision-makers.

6. Conclusion

This study conducted in the PRB contributes to the literature on choice experiments involving pesticide reduction. Regardless of whether pesticide reduction is implemented as part of the WPP, our findings provide valuable information and contribute to the creation and planning of conservation policies.

It is important to highlight that the article demonstrates an approach that allows researchers to better understand the influence of specific landowner characteristics. This study is the first to apply a DCE to analyse policies for pesticide reduction and the protection of water resources and consequently the health of the community that depends on this resource in Brazil, and there are very few studies worldwide on the topic to date. Through this research, we show that it is possible to intervene in an explicit dialogue with landowners that can reveal their preferences in monetary terms. The estimated WTA constitutes an important basis for evaluating new policies and PES schemes. However, the use of the DCE and economic valuation does not exclude that other higher quality approaches can supplement this dialogue initiated about the sustainable protection and use of freshwater. All these points are considered in the United Nations (UN) Sustainable Development Goals (SDG), and our results contribute to these objectives.

Our results clearly show that when the pesticide reduction is drastic, that is, reducing the current use by fifty percent, a frequent current use of pesticides significantly increases the demand for compensation. However, the WTA can drastically change when the length of the contracts changes. And and in many cases we see that the is not be directly related to the frequency of pesticide use, clearly demonstrating that there are some farmers responding differently than we would expect from a simple profit-maximising assumption. Further research on the underlying non-profit motivations for the use of pesticides, and for reductions in use, is necessary.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Conditional Model

Table A1
Estimation results based on Conditional Model .

	CONDITIONAL				
Variables:	Coef.	Std.Error	z-value	Pr(>|z|)	
SQ	-0.1374	0.1388	-0.9910	0.3219	
pestireduction_25%	-0.3056	0.5828	-0.5240	0.6000	
pestireduction_50%	-3.6570	0.5327	-6.8640	0.0000	***
contract_10years	-2.4790	0.6491	-3.8200	0.0001	***
contract_15years	-2.0230	0.5570	-3.6310	0.0003	***
withpenality	1.5770	0.5455	2.8920	0.0038	**
unbreakable	-1.9430	0.4785	-4.0610	0.0000	***
subsidy	0.0007	0.0000	18.3130	< 2e-16	***
pestireduction_25%:INCOME	-0.0390	0.0303	-1.2900	0.1972	
pestireduction_25%:AGE	0.0023	0.0080	0.2840	0.7763	
pestireduction_25%:EDUC	0.0051	0.0484	0.1060	0.9156	
pestireduction_25%:PROP_SURFACE	0.0009	0.0009	1.0470	0.2950	
pestireduction_25%:TAQUARA	-0.0457	0.1700	-0.2690	0.7883	
pestireduction_25%:FOREST	-0.5378	0.4156	-1.2940	0.1956	

(continued on next page)

Table A1 (*continued*)

	CONDITIONAL				
Variables:	Coef.	Std.Error	z-value	Pr(>|z|)	
pestireduction_25%:CATTLE	-0.2722	0.1930	-1.4100	0.1584	
pestireduction_25%:PIG_CHICK	0.1149	0.3482	0.3300	0.7413	
pestireduction_25%:OWN_DEC	-0.0033	0.2221	-0.0150	0.9883	
pestireduction_25%:FAMILY_DEC	-0.1563	0.2184	-0.7160	0.4742	
pestireduction_25%:AGROCHEMICAL_HIGHER-USE	0.0759	0.1845	0.4110	0.6809	
pestireduction_50%:INCOME	-0.0230	0.0268	-0.8570	0.3915	
pestireduction_50%:AGE	0.0323	0.0074	4.3820	0.0000	***
pestireduction_50%:EDUC	-0.0629	0.0435	-1.4480	0.1476	
pestireduction_50%:PROP_SURFACE	-0.0040	0.0031	-1.2920	0.1964	
pestireduction_50%:TAQUARA	0.6690	0.1512	4.4240	0.0000	***
pestireduction_50%:FOREST	-0.7138	0.4170	-1.7120	0.0869	.
pestireduction_50%:CATTLE	0.2765	0.1677	1.6490	0.0991	.
pestireduction_50%:PIG_CHICK	0.3204	0.2901	1.1040	0.2694	
pestireduction_50%:OWN_DEC	0.7044	0.2072	3.3990	0.0007	***
pestireduction_50%:FAMILY_DEC	0.3978	0.2081	1.9120	0.0559	.
pestireduction_50%:AGROCHEMICAL_HIGHER-USE	-0.1190	0.1620	-0.7350	0.4625	
contract_10years:INCOME	0.1635	0.0332	4.9240	0.0000	***
contract_10years:AGE	-0.0006	0.0087	-0.0690	0.9452	
contract_10years:EDUC	-0.0798	0.0509	-1.5690	0.1168	
contract_10years:PROP_SURFACE	0.0015	0.0010	1.5330	0.1252	
contract_10years:TAQUARA	-1.9030	0.1796	-10.5960	< 2e-16	***
contract_10years:FOREST	-0.7343	0.4895	-1.5000	0.1336	
contract_10years:CATTLE	0.1239	0.2053	0.6030	0.5463	
contract_10years:PIG_CHICK	-0.2295	0.3608	-0.6360	0.5248	
contract_10years:OWN_DEC	-0.5353	0.2300	-2.3270	0.0199	*
contract_10years:FAMILY_DEC	-0.6144	0.2268	-2.7100	0.0067	**
contract_10years:AGROCHEMICAL_HIGHER-USE	0.5850	0.1943	3.0110	0.0026	**
contract_15years:INCOME	0.1618	0.0285	5.6710	0.0000	***
contract_15years:AGE	0.0015	0.0075	0.1970	0.8435	
contract_15years:EDUC	-0.0764	0.0438	-1.7450	0.0809	.
contract_15years:PROP_SURFACE	0.0014	0.0007	1.8850	0.0594	.
contract_15years:TAQUARA	-1.9380	0.1546	-12.5360	< 2e-16	***
contract_15years:FOREST	-0.5863	0.4112	-1.4260	0.1540	
contract_15years:CATTLE	0.0646	0.1759	0.3670	0.7134	
contract_15years:PIG_CHICK	-0.3393	0.3051	-1.1120	0.2662	
contract_15years:OWN_DEC	-0.4487	0.1975	-2.2720	0.0231	*
contract_15years:FAMILY_DEC	-0.5973	0.1980	-3.0170	0.0026	**
contract_15years:AGROCHEMICAL_HIGHER-USE	0.5198	0.1653	3.1450	0.0017	**
withpenality:INCOME	0.0030	0.0273	0.1110	0.9114	
withpenality:AGE	-0.0191	0.0077	-2.4840	0.0130	*
withpenality:EDUC	0.0353	0.0445	0.7930	0.4280	
withpenality:OWN_DEC	-0.4607	0.2280	-2.0210	0.0433	*
withpenality:FAMILY_DEC	-0.6085	0.2228	-2.7320	0.0063	**
unbreakable:INCOME	-0.0246	0.0239	-1.0310	0.3027	
unbreakable:AGE	0.0130	0.0066	1.9880	0.0468	*
unbreakable:EDUC	0.1378	0.0372	3.7080	0.0002	***
unbreakable:OWN_DEC	-0.0163	0.1773	-0.0920	0.9269	
unbreakable:FAMILY_DEC	-0.0620	0.1789	-0.3470	0.7288	

Conditional likelihood ratio test= 2020 Wald test = 1093 (on 62 df, p=<2e-16) Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

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