Ecosystem Services 57 (2022) 101476

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Full Length Article

Estimating the value of ecosystem services in agricultural landscapes amid intensification pressures: The Brazilian case

Lucilia Maria Parron[a,*], Anastasio Jose Villanueva[b], Klaus Glenk[c]

[a] EMBRAPA Forestry, Colombo, Parana, Brazil
[b] Institute of Agricultural Research and Training (IFAPA), Centre Camino de Purchil, Granada, Spain
[c] Land Economy, Environment and Society Group, Scotland's Rural College (SRUC), King's Buildings, Edinburgh EH9 3JG, UK

ARTICLE INFO

Keywords:
Choice experiments
Social preferences
Willingness to pay
Farmland biodiversity sustainable agriculture
Land use change

ABSTRACT

The Brazilian agricultural commodities market and the agribusiness sector are facing an increasing international demand for improved environmental standards, such as those regarding climate change and biodiversity loss. Although there are many studies on the structural determinants of sustainable agriculture related to the production systems, markets, and governance, there is a paucity of studies focusing on the valuation of ecosystem services (ES) provided by agricultural landscapes for which no market exists. In this context, the present paper provides estimates of the value of ES related to changes in land use and management in intensive agricultural landscapes in Brazil, using a discrete choice experiment. The results show a significant demand for changes in land use and management to deliver improved ES provision, with marginal willingness to pay (WTP) estimates falling within the R$104-541 interval (€18-93) per household and year. According to WTP, ES are ordered as follows: improved biodiversity, soil conservation, carbon storage, and aesthetics. Preference heterogeneity points to novel effects worth of closer look in future research. The results provide evidence of social support for a change to a more sustainable agricultural production model.

1. Introduction

The ecosystem services (ES) concept has informed discourses and policies for improved the development of sustainable agricultural systems (Bethwell et al., 2022; DeClerck et al., 2016). Brazil has consolidated its position as a big player in relation to the world's food supply (Chaplin-Kramer et al., 2015). This comes at a cost in terms of a severe decline in ES provided by natural and agricultural landscapes, including the safeguarding of biodiversity and climate change mitigation and adaptation (IPBES, 2019). Despite ample evidence that highlights the crucial importance of ES provision to underpin economic well-being (Tisovec-Dufner et al., 2019), policy measures aimed at promoting sustainable land use and management have thus far been ineffective (e.g., in halting biodiversity loss) (Rafael et al., 2018). However, the agricultural commodities market and the agribusiness sector are facing an increasing international demand for improved environmental standards that is channelled through market mechanisms, voluntary agreements, certifications, and product labelling (Zilli et al., 2020). Failure to meet environmental production standards can impact Brazil's world-leading position as the largest food producer (Valdes et al., 2020), especially since the future of Brazilian agriculture depends on improving productivity to adapt to the impacts of climate change (Gil et al., 2019).

By ratifying the 2015 Paris Climate Agreement that recognises the value of ecosystem conservation in addressing climate change and that encourages parties to take action to conserve and enhance the ecosystems (Masson-Delmotte et al., 2019), Brazil assumed a pioneering position with respect to climate commitments among developing countries. Among the actions subsequently taken, a national policy has been implemented to reduce agricultural emissions through credit support initiatives for those landowners who apply sustainable agricultural practices (Milhorance et al., 2021). The policy does not address the loss of biodiversity, although synergies between climate change mitigation and biodiversity conservation in agricultural landscapes often exist (Bernués et al., 2019; Garrett et al., 2020).

Historically, the dilemma between economic development and nature conservation has played out in favour of development in large parts of Brazilian society, and as a result many farmers perceive conservation areas on their land primarily as a loss of productive land. The Forest Code is the main national law about ecosystem conservation. The previous version of the Forest Code (from 1965 to 2012) was quite

* Corresponding author.
E-mail addresses: lucilia.parron@embrapa.br (L.M. Parron), anastasioj.villanueva@juntadeandalucia.es (A.J. Villanueva), klaus.glenk@sruc.ac.uk (K. Glenk).

https://doi.org/10.1016/j.ecoser.2022.101476
Received 12 January 2022; Received in revised form 19 August 2022; Accepted 26 August 2022
Available online 7 September 2022
2212-0416/

protective of the natural areas within rural properties, but not following the Code was almost the rule. From the landowner's perspective, full compliance with the Forest Code offered few economic benefits (Azevedo et al., 2017). This, coupled with weak law enforcement, resulted in low policy effectiveness, which has also been observed in other environmental policies (e.g. focusing on soil and water) implemented in Brazil (Brancalion et al., 2017). The 2012 Forest Code established reduced requirements for protected areas on private land. The law did not change the requirement to conserve (or create) a minimum of 20 % native vegetation on the rural properties (except to the Amazon biome, where that requirement varies between 20 % and 80 %), and to designate environmentally sensitive areas as riparian areas and hilltops. However, specific requirements were considerably eased, for example regarding the minimum width of riparian forests around water resources. The 2012 Forest Code also introduces mechanisms to address payments for ecosystem services (PES), and establishes a rural environmental registry (Mello et al., 2021). Using this registry, the land areas can be monitored remotely, which could assist the establishment of PES. While a PES mechanism has been included in the new law, existing PES schemes are at pilot stage and hence experimental and small-scale.

Although there are many studies on the structural determinants of sustainable agriculture adoption in Brazil related to the crops, markets, and governance (Latawiec et al., 2017), there is a paucity of studies focusing on the valuation of ES provided by Brazilian agricultural landscapes for which no market exists, either from the demand or supply side. The few studies doing so especially centre on natural ecosystems. For example, Resende et al. (2017) use the contingent valuation method (CVM) to value ES of a protected area. To the best of our knowledge, only Seroa da Motta and Ortiz (2018) and Popak et al. (2019) focus on agroecosystems, with the former using CVM in a supply-side valuation exercise aimed at estimating farmers' willingness to accept (WTA) for participating in PES, and the latter using an avoided cost approach to value pollination services in a Brazilian river basin.

In this context, the research presented here aims at estimating the value of ES related to changes in land use and management in agricultural landscapes in Brazil which can be used to facilitate an efficient design of environmental policy instruments. To the authors' knowledge, there is no study that specifically assesses and values improvements in a range of ES provided by Brazilian agricultural landscapes. The valuation of ES in this study is based on a discrete choice experiment (CE) as an increasingly common valuation method (Mariel et al., 2021), making use of the basic principle that there is a correlation between land use and management and ES provision. As a case study, we focus on Paraná State (southern Brazil), where approximately 90 % of its area supports a large agricultural economy (SOS Mata Atlântica and INPE, 2019). Overall, the information on ES valuation presented here can support the efficient implementation of environmental policies (especially PES) aimed at sustainable land use and management in Brazil.

2. Materials and methods

2.1. The study area: Farm management evolution

Parana State has 199.315 km^2 of territorial area and a population of 11 million inhabitants. It is characterised by a subtropical climate, with around 97 % of its area being part of the Atlantic Forest climate type (Kauano et al., 2012). The total area of Parana State is divided into croplands (33 %), especially soybeans, corn, and wheat; pastures (25 %); Atlantic Forest (16 %); planted forests (7 %); and others (water resources, perennial agriculture, urbanization, mining) (19 %) (SOS Mata Atlântica and INPE, 2019).

Land use in Paraná State has shown significant changes since most of the original forest was removed (in the first half of the 20th century). Probably the most remarkable change relates to the conversion of coffee permanent cropping systems (which do not need to be replanted after harvesting) to annual cropping systems (especially grain) and pastures, which took place from 1980 amid agricultural mechanization, favouring conventional tillage sometimes associated with terracing and planting on contour lines (Leite et al., 2012). This gave rise to agricultural intensification, which resulted in the prominence of greatly simplified landscapes and higher rates of soil loss in a majority of areas (Telles et al., 2022).

By the end of the 20th century and beginning of the 21st century, concerns grew over great losses of soil as a result of conventional tillage management. As a response to this, government programs for soil and water conservation guided farmers to adopting no-tillage (NT) practices (Sá et al., 2013), a soil conservation system aimed at halting soil degradation, improving water management, and soil structural properties (Freitas & Landers, 2014, Friedrich et al., 2012). From the perspective of ES provision, that strategy was positive for soil and water conservation and soil organic carbon (SOC) storage. However, it also led to an increased use of fertiliser and pesticides (Derpsch et al., 2014), while maintaining landscape homogeneity and habitat fragmentation.

In the past decade, integrated production systems have been presented as an upgrade of NT, and thus as a promising strategy to increase the restoration of degraded soils. By integrating NT crop and livestock (ICL), or NT crop, livestock, and forestry (ICLF), production at farm scale, soil fertility, and organic matter increase, favouring biomass production and allowing for higher animal stocking rates in pasturelands (Cortner et al., 2019). Whilst integrated systems are emphasised to facilitate the introduction of the forestry component into farms (Cortner et al., 2019), most of the time this component only comprises non-native species, typically *Eucalyptus sp*. A environmental benefit of ICL and ICLF is to increase SOC stocks and the capture of atmospheric carbon by soil, which is why these systems are believed to be effective in mitigating climate change. From the perspective of the other ES, the landscape is more heterogenous compared to the NT system, favouring biodiversity and aesthetics.

Agroforestry systems have been cultivated mainly in small farms and mountainous areas (Santos et al., 2019) and their arrangements include annual and perennial crops and native species (Lacerda et al., 2020). In any case, these systems represent a feasible option to move towards more multifunctional landscapes with an improved provision of ES (Landis, 2017), especially because, depending on their configuration, agroforestry systems associated with native vegetation can be maintained as a legal reserve area on rural properties, facilitating compliance with the Forest Code.

In accordance with the types of land use and land management introduced above, the scenarios considered in this study describe ES outcomes resulting from a move from a current policy focused on the NT system to other systems that are more diversified in terms of management, such as agroforestry systems and ICLF.

2.2. Attribute selection: links between land use and ES provision in Parana

The CE method was adopted (Adamowicz et al., 1998) to elicit preferences and derive willingness to pay (WTP) estimates for more sustainable land uses and related provision of important ES which are not traded in markets.

Non-monetary attributes and a monetary attribute were selected for the CE application. The non-monetary attributes included in the CE relate to the expected improvements in ES provision from farmland and were selected based on literature review (Appendix A) and expert consultation. Given that the aim was to elicit social preferences, the attributes were selected in relation to land use and management, which could be influenced and controlled by land managers. The main criterion established for selecting the attributes related to ES was the relevance in terms of impact by changes in farm management. Furthermore, the number of ES should be small enough to easy the respondent's cognition and at the same time, the models can be estimated considering the expected sample size. Provisioning ES (food, timber) were not included as attributes, but respondents were told that changes to different forms of land management can be profitable for farmers over time (Kay et al., 2019).

As a result of this selection, the non-monetary attributes included were: 1) visual amenity/appearance of the agricultural landscape (cultural ES), 2) reduction of soil loss, which improves soil conservation and water quality (supporting and regulating ES), 3) carbon storage (regulating ES), and 4) presence and diversity of animals and plants, which refers to the conservation of biodiversity (related to supporting ES). Although there is still an ongoing debate on whether biodiversity is an ES (MEA, 2005, TEEB 2010, IPBES 2019), we included the conservation of biodiversity as an attribute because biodiversity has been prominent in ES assessments (Malinga et al., 2015) and it comprises ecosystem outputs that the general public appreciate and are more familiar with. Below we describe the ES considered in this study:

- *Visual amenity/appearance of the agricultural landscape*. Agricultural landscapes constitute a cultural ES (Plieninger et al., 2014) with a non-extractive direct use value. The visual quality of productive and natural landscapes depends on factors such as the extent of the forest cover and land use, though they are often subject to individuals' subjective perception (van Zanten et al., 2016). It is expected that the adoption of more sustainable systems, like agroforestry or ICL/ICLF systems, would greatly improve the visual quality of Paraná agricultural landscapes.
- *Soil conservation*. Soil erosion by water is considered one of the major threats to soil functions and ES (García-Ruiz et al., 2017). The adoption of soil conservation systems has been widely used around the world to improve soil and water processes (Keesstra et al., 2016). Despite the conservation effectiveness of NT systems, it is part of a package that usually includes glyphosate-resistant seeds, monocultures, and intensive agrochemicals use (Ofstehage & Nehring, 2021), all of them related to ecosystem disservices (Power, 2010). Consequently, remarkable improvements are expected from the adoption of more sustainable systems in the case study area.
- *Carbon storage*. Conservation management of soils has a large technical potential to increase SOC and offset anthropogenic emissions (Lal, 2012), while building fertility and restoring soil functions (Das et al., 2022). Sequestration of SOC creates a positive soil/ecosystem C budget, that implies that C input incorporated through adding biomass to the soil exceeds the cumulative loss caused by erosion, mineralization, and leaching (Lal et al., 2018). The depart from NT to more sustainable systems can contribute to enhance C sequestration.
- *Biodiversity*. The diverse and complex biological community generates numerous ES (Pascual et al., 2015), which are affected by land use and soil management systems (Creamer et al., 2016). Managed ecosystems especially jeopardise the good habitat condition for wild species (Reed et al., 2013). While agricultural intensification tends to maximise provisioning services at the expense of regulating, cultural, and supporting ES, the adoption of soil conservation systems enhance biodiversity and strengthens ecological functions and ES (Berthet et al., 2022). Accordingly, it is reported that the adoption of more sustainable systems in the case study area would produce great improvements in terms of biodiversity (see Appendix A).

The implementation of changes in land use management related to increases in the provision of the ES considered will imply a cost to farmers whilst the benefits are largely accrued by the wider public. If demand for ES provision outweighs cost of provision, there is a case for government intervention to enhance ES provision. Payments in the survey are framed to create funds to provide financial incentives to support management changes in rural landscapes.

Each of the non-monetary attributes takes three different levels. The lowest levels stand for the current status while the highest levels stand for the best possible performance (i.e. that related to adopting ICLF in the whole farmland area). The payment vehicle of the monetary attribute was a general annual cost to be paid as a tax (in the electricity or water bill) over the next 10 years by each household to finance the implementation of the specified agricultural and environmental policies. Such a payment vehicle was used due to familiarity of respondents with utility bills, and the fact that these are often subject to taxes for environmental reasons. Ten years were considered as a reasonable period of time to ensure a long-lasting policy implementation, for example allowing for the development of a PES mechanism promoting the sustainable management systems described above. Table 1 provides an overview of the attributes and levels used.

Willingness to pay estimates for bundles of attributes are estimated for two hypothetical scenarios characterising shifts in current predominant land use systems. The *status quo* entails a mix of crops and planted forests, reproducing the most common land uses where NT systems to croplands (e.g., soy, corn, or sugarcane) or large extensions of forest plantation (Eucalyptus or Pinus) are found. Scenario 1 is described through attribute levels SOIL1, CARB1, BIOD1, and LAND1, and it is characterised by moderate changes. The environmental benefits related to some adoption of ICLF systems could reduce soil erosion rates by up to 20 %, while SOC could be increased by up to 25 %, with overall significant benefits to biodiversity and aesthetics (Bieluczyk et al., 2020; Zago et al., 2020).

We also estimate WTP for the bundle of attributes characterising an ambitious environmental improvement scenario. Scenario 2 is described through attribute levels SOIL2, CARB2, BIOD2, and LAND2. This would imply a large adoption of agroforestry systems and/or afforestation processes, resulting in more heterogenous landscapes where supply of ES is significantly enhanced while largely maintaining the capacity to deliver provisioning services.

2.3. Experimental design

The software package Ngene (ChoiceMetrics, 2018) was used to generate an experimental design with the selected attributes and their respective levels. The design was a Bayesian efficient design optimised for a multinomial logit (MNL) model with priors derived from a pilot study that used an efficient design based on beliefs regarding signs of attribute effects.

The final design comprised 24 choice sets which were blocked into 4 groups. The different choice set blocks were randomly distributed among the respondents who were asked to select their preferred scenario for each of the six choice tasks presented to them. An example of a choice set is shown in Fig. 1.

2.4. Sampling and data collection

The survey was designed to collect the responses from the adult population of Paraná State. The survey was built based on the choice

Table 1
Description of the attributes of the choice experiment (status quo underlined).

ES attribute	Description	Level
Visual amenity/ appearance of the agricultural landscape	Perception of improvement of the complexity of agricultural landscapes	<u>simple</u>, medium complexity (LAND1), complex (LAND2)
Soil conservation	Expected % of reduction of the soil loss rates	<u>0</u>, 20 (SOIL1), 50 (SOIL2)
Carbon storage	Expected % of increase of organic carbon in soil	<u>0</u>, 25 (CARB1), 50 (CARB2)
Biodiversity, presence and diversity of animals and plants	Expected % of increase of floristic and wild animal diversity	<u>0</u>, 30 (BIOD1), 60 (BIOD2)
Annual cost (per year per household over a ten-year period)	Monetary attribute that represents the program cost to the respondent	<u>R$0</u>, R$20, R$50, R $100, R$150, R$300, R $500

R$=Brazilian Real (1R$=0.172€ on average during the survey year -i.e. 2020).

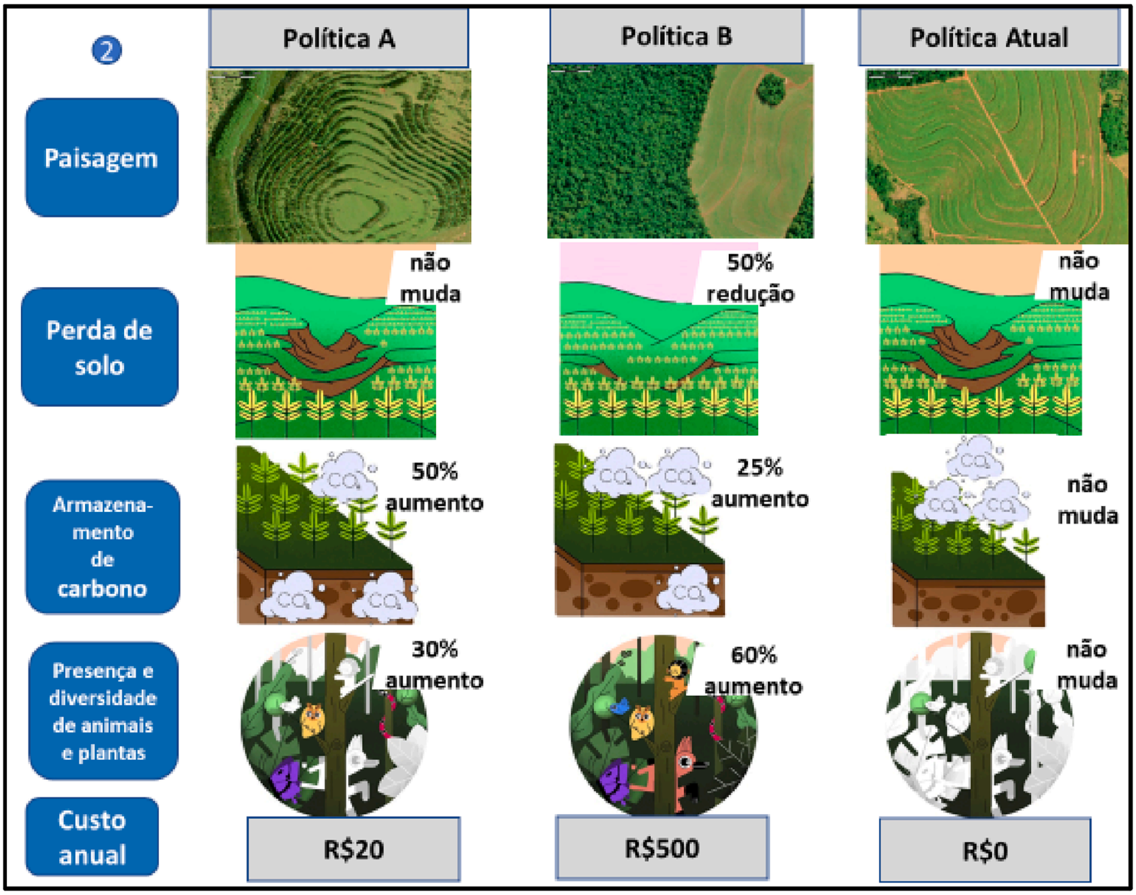

Fig. 1. Example choice set (in Portuguese). The third column ("Política atual" or current policy) stands for the status quo alternative while the other two are policy programs to improve ecosystems services provision.

experiment literature for ES valuation of non-market goods in agro-ecosystems (e.g. Alcon et al., 2020, Bernués et al., 2019) and considered the most important environmental issues evident in Brazil, as highlighted in Section 2.3. A pilot study was conducted in September 2020 with 153 respondents to inform the experimental design and check for issues with other questions. Some modifications in questions and answer options were made that were believed to ease understanding. 1,012 respondents over age 18 self-completed the survey, which was administered by a globally operating professional market research company between October and November 2020. The composition of the sample followed representative quotas for gender and age. The median completion time was 13 min. At the beginning of the survey, the purpose of the study, the project, and the four-part structure of the questionnaire were explained. The parts of the questionnaire included: i) the CE, including the description of the attributes and levels; ii) questions about respondents' knowledge and attitudes regarding agricultural practices and related policies; and iii) questions related to the Covid-19 pandemic (to identify whether there were effects of the declared impacts of the Covid pandemic on the WTP) and main socio-economic characteristics (see Appendix B).

Interviewees who always chose the status quo option were asked to state the reasons for this to identify potential 'protest' responses and distinguish them from legitimate zero bids. 5 % of the responses were classified as 'protesters' and were excluded from the analysis of the choice data, following standard procedure in the stated preferences literature (Dziegielewska and Mendelshon, 2007). The omission of protest responses had little effect on the model results and the conclusions drawn in this paper.

2.5. Model specification

In line with random utility theory (McFadden 1974), a utility function is specified that is described by the attributes of the experimental design in a linear and additive fashion, and a random error term ε. The utility function U for respondent n and alternative i in choice task t is written as:

$$U_{nit} = -\alpha_n p_{nit} + \beta_n{}' x_{nit} + \varepsilon_{nit} \quad (1)$$

where α, **β** are parameters to be estimated for attribute levels in the alternative $\boldsymbol{x}$, and a cost attribute p. The random error term ε is assumed to be identically and independently distributed (*iid*) and related to the choice probability with a Gumbel distribution with error variance Var$(\varepsilon_{ni}) = \mu_n^2(\pi^2/6)$. μ_n denotes a scale factor that is respondent specific.

If we divide equation (1) by μ_n, a scale-free utility function can be derived with a new error term that is constant across respondents (Train & Weeks, 2005):

$$U_{nit} = -(\alpha_n/\mu_n)p_{nit} + (\beta_n/\mu_n)' x_{nit} + \varepsilon_{nit} \quad (2)$$

where ε_{nit} is *iid* with constant error variance $\pi^2/6$. If $\gamma_n = \alpha_n/\mu_n$ and $c_n = \beta_n/\mu_n$ are parameters to be estimated, a model in preference space is derived (Train & Weeks, 2005). The utility function can be modified to reflect WTP space estimates, that is, to allow direct estimation of the distributions of marginal WTP for non-monetary attributes. Because marginal WTP for changes in non-monetary attributes is $w_n = c_n/\gamma_n$, the utility function can be written in WTP space as:

$$U_{nit} = -\gamma_n p_{nit} + (\gamma_n w_n)' x_{nit} + \varepsilon_{nit} \quad (3)$$

We next define the sequence of choices over T_n choice tasks for respondent n as $y_n = \langle i_{n1}, i_{n2}, \cdots, i_{nT_n} \rangle$. The multinomial logit (MXL) model enables estimation of heterogeneity across respondents by allowing γ_n and $\boldsymbol{w}_n$ to deviate from the population means according to a random distribution. The unconditional choice probability of respondent n's sequence of choices can be expressed as:

$$PrPr(\gamma_n, w_n) = \int \prod_{t_1=1}^{T_n} \frac{exp(-\gamma_n p_{nit} + (\gamma_n w_n)' x_{nit})}{\sum_{j=1}^{J} exp(-\gamma_n p_{njt} + (\gamma_n w_n)' x_{njt})} f(\Omega) d\eta_n \quad (4)$$

where $f(\Omega)$ describes the joint density of the vector for parameters related to cost and non-monetary attributes, $[\gamma_n, w_n]$, η_n is a vector of the random parameters, and Ω refers to the parameters of these distributions. Because the integral does not have a closed form, it requires approximation through simulation (Train, 2003). This was done using 10,000 (scrambled) Sobol draws (Sobol, 1967). In the estimation, we allow for correlation of all random parameters (full covariance). The cost attribute parameter is assumed to follow a log-normal distribution. The marginal WTP coefficients of the remaining non-monetary attributes, and of an alternative specific constant (ASC) for the status quo option, are assumed to follow a normal distribution. 95 % confidence intervals are estimated using the Delta method (Greene, 2008).

To investigate preference heterogeneity, we use so-called 'individual-specific' WTP values for each sampled respondent based on individual conditional distributions resulting from the MXL model, which are then used in subsequent regression of 'individual-specific' WTP with a range of explanatory (socio-economic, attitudinal) variables. For the regressions, we apply a random effects model. This is derived by creating a pseudo-panel based on stacking individual WTP estimates for the WTP estimates of non-monetary attribute levels (Yao et al., 2014). Consequently, an indicator of all but one of the attribute levels also enters the model in addition to explanatory variables. The choice models and conditional WTP were estimated using the *Apollo* package in R (Hess & Palma, 2019).

3. Results

3.1. Descriptive results

Among the 1,012 respondents, 53 were identified as protesters (mainly due to a lack of trust in public institutions, mainly related to the implementation and payment vehicle -i.e. taxes) and 63 as non-valid for other reasons (less than 1 min completion time for the CE part). These respondents were omitted from the sample, leaving data from 896 respondents for further analysis.

Table 2 shows the sociodemographic characteristics of the valid respondents and, where possible, a comparison with official population statistics of the target population. The average age of the sample was 40 years, 75 % are employed or self-employed, and 53 % live with a monthly household income up to €1,608. The survey is representative in terms of gender and age but over-represents wealthier respondents. The sample is also skewed towards higher education levels.

Table 2
Descriptive statistics of the socio-economic characteristics of the valid sample (N = 896 respondents).

Variable	Proportion of respondents (%)	Proportion of Paraná State* (%)
Gender (female)	52	50.9
Age distribution		
18 to 29 yr	29	24.5
30 to 39 yr	23	19.9
40 to 49 yr	24	18.1
50 and above	25	37.4
*Household income (€/month)***		
Up to 643.1***	31.1	41.4
Between 643.1 and 1607.7	22.3	48.1
Between 1607.7 and 3215.4	12.7	7.0
More than 3215.4	20.8	2.6
Prefer not to say	13.1	–
Highest educational level		
Lower education	0	4.9
Primary education	2.3	42.0
Secondary education	39.4	30.8
Higher education	37.9	21.1
Postgraduate education	20.3	1.2

* Population over 18 years old for 2020: 8.9 million inhabitants (Brazilian Institute of Geography and Statistics -https://sidra.ibge.gov.br).
** 1€ = R$5.814 (in 2020), *** The value corresponds to 3.6 times the monthly minimum wage in Brazil in October 2020.

3.2. Choice models

Mean estimates, derived standard deviations and goodness-of-fit statistics of the MXL model are shown in Table 3. The model has a good fit with a pseudo R^2 value of 0.24, mirroring those found in similar studies like Bernués et al. (2016) or Müller et al. (2020), and all main parameters are significantly different from zero (at the 0.1 % level). A majority of the correlated parameters (see Appendix C) are significant, meaning there is significant behavioural and scale heterogeneity (Mariel & Artabe, 2020).[1] The ASC_{SQ} is significant and negative, implying a systematic preference for alternatives representing policy scenarios of improvements compared to the status quo alternative (SQ). As parameters are estimated in WTP space, they directly represent (re-scaled) WTP values.

3.3. Preferences and willingness to pay analysis

The choice model results shown in Table 3 evidence the positive impact on utility of the increase in the supply of ES. This demonstrates a social demand for the environmental benefits associated with increased biodiversity (BIOD), reduced soil erosion (SOIL), carbon sequestration in the soil (CARB), as well as cultural ES provided by landscape diversification (LAND). Regarding CARB, there is no further gain in utility for the level reflecting maximum improvement (CARB2) over moderate

[1] A comprehensive explanation of correlated parameters is beyond the paper's scope. In any case, by observing them, several main points can be made. First, as expected, all correlated parameters with the ASC are significant and with the expected sign, i.e. positive with parameters of non-monetary attributes and negative with the monetary attribute. Second, most of the significant correlations are among non-monetary parameters. While this result indicates that preferences (and scale) towards the different ES considered are related, the fact that most of them (18 out of 28) are positive refers to the very concept of joint consumption of environmental public goods (OECD, 2001). The only systematic negative correlation involves SOIL1 (for which 8 out of 8 correlated parameters are negative), suggesting that respondents may not understand (prefer) improvements in the levels of the other ES without a significant reduction in soil erosion (i.e. greater than the level represented by SOIL1, i.e. −20% of soil loss).

Table 3
Mixed logit (MXL) model in WTP-space.

		Mean		S.E.	SD		S.E.
Parameters of the utility function	ASCSQ (Status quo alternative specific constant)	−0.0298	***	0.0037	0.0104	**	0.0043
	LAND1 (Visual amenity-intermediately complex)	0.1035	***	0.0192	0.2317	***	0.0198
	LAND2 (Visual amenity-highly complex)	0.2353	***	0.0195	0.3295	***	0.0226
	SOIL1 (Soil loss reduction by 20 %)	0.2227	***	0.0221	0.2740	***	0.0211
	SOIL2 (Soil loss reduction by 50 %)	0.2971	***	0.0248	0.3459	***	0.0234
	CARB1 (Carbon storage increased by 25 %)	0.2367	***	0.0213	0.2887	***	0.0230
	CARB2 (Carbon storage increased by 50 %)	0.1928	***	0.0201	0.2276	***	0.0233
	BIOD1 (Biodiversity increased by 30 %)	0.3748	***	0.0229	0.2701	***	0.0193
	BIOD2 (Biodiversity increased by 60 %)	0.5414	***	0.0351	0.5309	***	0.0300
	COST	1.6205	***	0.1063	1.5548	***	0.1629
Goodness-of-fit statistics	LL	−4491.795					
	Parameters	65					
	Pseudo R^2	0.240					
	AIC/N	1.695					
Observations (individuals)		5376 (896)					

** and *** denotes significance at 1% and 0.1% levels, respectively. For the sake of readability, correlated parameters are reported in Appendix C. The COST attribute is scaled (100:1) and its sign has been reversed to directly yield positive values reflecting respondents' WTP for a change in the attributes. The ASC was scaled by the factor 10.

changes (CARB1).

While estimates in Table 3 reflect marginal WTP, Table 4 gives an overview over re-scaled estimates for each attribute, and Fig. 2 shows visualised marginal WTP distributions. Respondents are willing to pay R $541 per household and year, on average, to increase biodiversity by 60 % (BIOD2) over the status quo. Likewise, reducing erosion rates and increasing SOC storage by 50 % (SOIL2 and CARB2, respectively) would imply a WTP of R$297 and R$193 per household and year. In addition, the respondents revealed their desire to support the change in the current land use system, in a way to support a shift to more diverse agricultural ecosystems where the natural forests are present (attribute levels LAND1 and LAND2).

All estimates are significant at 0.1 % level. Estimates were calculated following the Delta method.

A complementary analysis exploring preference heterogeneity is shown in Appendix D (Table D1), where the random-effects regression model is presented. Results show that the preference heterogeneity towards ES provided by farmland in Paraná is related to respondent socioeconomic characteristics (especially income, profession, and education level), lifestyle (leisure activities related to the environment), and attitudes (especially towards policy and environmental threads). We find an intuitively plausible positive relationship between respondents' WTP and (i) the level of agreement with rewarding farms with larger naturally vegetated areas in less developed regions; and (ii) considering climate change as one of the major problems for the society. Similarly indicating differing degrees of concern about environmental issues, we also find negative associations between WTP and (i) respondents in professions or studies unrelated to the primary sector or the environment; and (ii) respondents who do not carry out leisure, cultural or spiritual activities related to the environment. However, in contrast to expectations based on previous literature that WTP increases with income, we find a positive relationship between WTP and respondents with lower income levels.

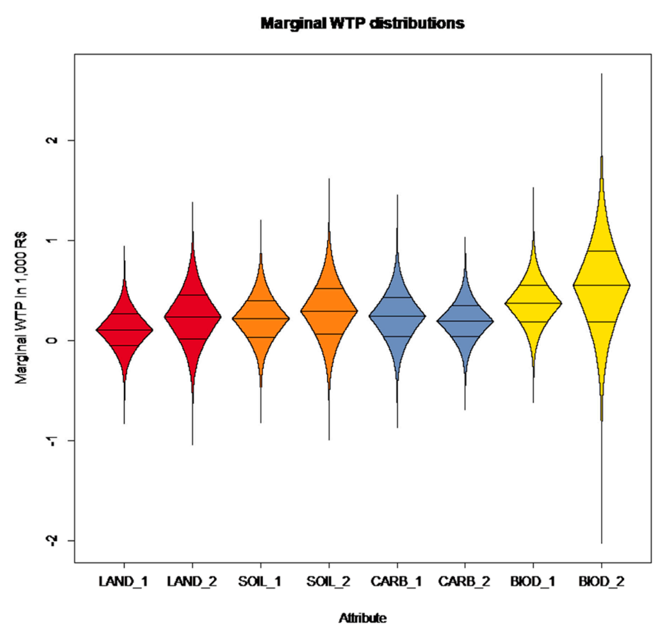

Fig. 2. Marginal WTP distributions (in 1000 R$) for attributes.

Table 4
Marginal WTP of each change in the provision of ES and total WTP for attribute bundles (scenarios).

Attribute level	Mean	S.E.	Conf. interval (95 %)	
			Lower bound	Upper bound
ASCSQ	297.60	37.28	224.52	370.67
LAND1	103.54	19.21	65.88	141.20
LAND2	235.32	19.52	197.06	273.57
SOIL1	222.74	22.14	179.35	266.14
SOIL2	297.12	24.77	248.56	345.68
CARB1	236.71	21.27	195.02	278.40
CARB2	192.80	20.07	153.47	232.14
BIOD1	374.76	22.90	329.86	419.65
BIOD2	541.44	35.14	472.58	610.31
Scenario 1	1131.80	62.29	1009.72	1253.89
Scenario 2	1564.28	76.43	1414.48	1714.08

4. Discussion

There is a growing interest in Brazilian society in environmental issues. The environmental agenda is at the centre of national and international debate about the future of Brazil's rich natural environment and resources. The WTP estimates found in this CE study indicate that there is a high demand for changes in agricultural land use and management to deliver improved ES provision in the Brazilian state of Paraná. Our results regarding the sign and magnitude of the ASC also provide evidence that respondents prefer to move away from outcomes implied by current policy (Aslam et al., 2017; Hynes et al., 2021; Meyerhoff & Liebe, 2009). The overall results point to preferences for greater landscape complexity that combine production and environmental conservation. Observing the WTP estimates for each ES, policy design should promote biodiversity enhancement at a larger extent, but also soil conservation, carbon sequestration, and landscape amenities. This demand for multifunctional agricultural areas has been previously evidenced, with the relative values for attributes related to biodiversity and landscape amenity in line with the results obtained for Mediterranean agricultural ecosystems (Alcon et al., 2020; Bernués et al., 2014; Rodríguez-Ortega et al., 2016). In addition, this work corroborates earlier findings (Dupras et al., 2017) on landscape amenity as an important ES. These results particularly add an important aspect to ES valuation studies focusing on agricultural systems, in which improvements in the visual landscape quality due to the adoption of more sustainable systems related to a greater landscape complexity are often been disregarded.

Surveyed respondents also show sensitivity to the level of change in ES provision. WTP is greater for greater levels of ES provision. This is the case for all ES considered, except carbon sequestration. However, preference patterns seem to be different between ES, with WTP more than doubling for larger changes, compared to moderate ones, for landscape amenities, which is different from changes in WTP encountered for soil conservation and biodiversity. For these two attributes, attribute levels reflecting larger changes double the improvement in ES provision for both soil conservation and biodiversity compared to attribute levels reflecting moderate changes, but WTP increases by just 33 % and 44 %, respectively. As for carbon sequestration, this suggests a pattern of diminishing marginal benefits for three of the four ES investigated. Similar preference patterns for ES have also been reported previously for agricultural systems (e.g., Bernués et al., 2014) and forest systems (Sagebiel et al., 2017), but are for the first time reported for Brazil.

Whereas command-and-control instruments have been largely and comprehensively used to achieve such environmental goals in Brazil, they proved to be ineffective due to lack of farmers' involvement (Rajão et al., 2020), government enforcement capacity and political will. Therefore, a need arises for testing and developing alternative policy instruments that can assist command-and-control laws to improve effectiveness of environmental protection.

Several instruments including market-based instruments such as PES have been proposed to facilitate the implementation of strategic policies about environmental issues. Those instruments are considered by a significant number of Brazilian actors as an innovative way of implementing environmental policies and are increasingly taken into account in national regulations (Filoche, 2017, Sauquet et al., 2014). The PES schemes implemented in Brazil so far are generally experimental with currently small scale coverage (Viani et al., 2019, Santos et al., 2020). However, a more wide-spread implementation faced two fundamental problems. First, what is the justification for payment and, related to this, who should pay. Second, how much to be paid. With regards to the first issue, our results lend support to financing policy programs with public money (e.g., through regional taxes) aimed at improving the provision of ES in agricultural areas.

With regards to the second issue, the WTP estimates could be used to set maximum payments below which PES schemes would yield net social benefits.[2] In particular, taking the mean WTP per household and year for Scenario 1 (R$1,132) and Scenario 2 (R$1,564), as shown in Table 4, aggregate annual WTP is estimated to be R$1,700 million for Scenario 1 and R$ 2,350 million for Scenario 2 (considering the 1.5 million households with available income in Paraná State[3]). These results reflect maximum funds to yield net social benefits of R$226/ha/y and R$313/ha/y for policy programs aligned with Scenario 1 and 2, respectively, considering 300,000 rural properties in Paraná (average area of 50 ha) and an enrolment rate of 50 %. These figures are proxy estimates that nevertheless give strong support for the implementation of environmental policies and programs in the Paraná State to reward farmers that are in agreement with the environmental laws in terms of protected areas and further maintain additional areas of conservation in their properties. Our estimates are of the same order of magnitude as the average payments (around R$300/ha/y, according to government sources) of a PES financed by the Sao Paulo State government for set-aside farmland for native vegetation conservation and restoration and production systems improvements (a description of the scheme is available in Santos et al., 2020). The Sao Paulo PES determines values of compensation based on opportunity cost related to not using part of the farmland. The comparison of the WTP estimates with such a payment indicates the potential of a PES scheme in Paraná State to pass a benefit cost test, especially because the WTP estimates provided relate to less stringent policy scenarios not entailing farmland set-aside (as implied in the Sao Paulo PES).

The results also show a high degree of preference heterogeneity, similar to previous findings on the impact on individual's WTP of socioeconomic characteristics and attitudes and opinions (Colombo et al., 2006; Faccioli et al., 2020). However, among the results, two findings are particularly worth commenting due to their novelty. First, the positive relationship between respondents' WTP and agreement with rewarding highly-naturally vegetated farms in less developed regions clearly indicates that some respondents would be more in favour of targeting the related policy in such areas. We interpret this as an indication of individuals' sense of fairness. Fairness requires a concern for relative payoffs between oneself and others or between third parties. A key component of the human sense of fairness is inequity aversion, defined as the willingness to sacrifice material payoffs for the sake of greater equality (Brosnan & de Waal, 2014). In this sense, van Hecken et al. (2012) also find fairness to be key for individuals' WTP for ES produced in agricultural systems. Our survey established a connection between climate change and the need for more sustainable farming practices to meet the growing demand for food while protecting the environment. We argue that part of the reason why people are sensitive to these causes is a sense of fairness to ensure that farmers are not left alone facing the social cost of a transition towards more complex rural landscapes as a solution to dealing with climate issues.

Second, a closer look is deserved for the counterintuitive result reflected in the positive relationship of WTP and lower-income levels, as it opposes most of the previous studies (e.g. Rodríguez-Entrena et al., 2012) which find positive income effects. There is little evidence that income shapes the environmental preferences of Brazilian respondents. In particular, Aklin et al. (2013), using a wide sample on the Brazilian population, find non-linear income effects on (general) environmental preferences. Interestingly, while our results specifically focus on ES provided by agricultural systems, they are in keeping with the cited study where it is found that those with income higher than 10 minimum wages (between 2 and 5 minimum wages) are less (more) pro-environmental. As for Aklin et al. (2013), we interpret this result as indicating that Brazilian high-income people usually have less trust in public institutions with regards to the implementation of environmental policies. In any case, the fact that the effect found here is significant at a 10 % level recommends cautiousness and calls for further research on this issue.

Our study has limitations regarding the sample, the ES representation, sampling period, and spatial criteria, that are worth pointing out. First, despite having quotas on age, gender, and income, the survey failed to reach the sub-group of the population without internet access (which is linked to low income and education). CE using online surveys does have some advantages over other modes. Among them are randomisation of questions, choice tasks, and alternatives and attributes within choice tasks, which are easier to implement in online surveys (Mariel et al., 2021). Online surveys also do not suffer from interviewer effects. In our case, to reach those without internet access by face-to-face surveys would have improved sampling and thus strengthened the robustness of our findings. De Leeuw et al. (2008) and Mariel et al. (2021) argue that mixed-mode surveys that combine different survey

[2] This does not include any transaction costs.

[3] Information given by the Brazilian Institute of Geography and Statistics (https://sidra.ibge.gov.br).

modes are a way of taking advantage of the strengths and compensating for the weaknesses of each mode. However, using different survey modes also provides challenges regarding bias arising from survey mode effects, and thus advantages and disadvantages of mixed-mode surveys need to be carefully evaluated (Watson et al., 2019).

Second, the survey was carried out after the first wave of pandemic and 66 % of our respondents stated they had not been affected by Covid 19 at the time of the survey. A detailed analysis of Covid impacts on WTP is beyond the scope of the paper, but an initial analysis using conditional WTP estimates shows that there is a little systematic effect of stated Covid impacts on WTP. This may be because implications had not been fully felt yet at the time of the survey. More optimistically, it is encouraging to see WTP for more sustainable land use options despite Covid 19, perhaps also due to raised awareness of human-nature interactions in creating pandemics (Soga et al., 2021).

Finally, this study has not been spatially explicit while the provision of some ES is (Glenk et al., 2020; Granado-Díaz et al., 2020). Biodiversity, soil erosion, and carbon may all carry considerable non-use value, which may be arguable related to comparatively lower spatial discount effects. Yet, landscape amenity is probably an aspect that is most important if directly exposed to landscapes (i.e. high use values), for example through living in *peri*-urban or rural areas, or through regular travel or commute through agricultural landscapes, or because of an interest to use landscapes for recreation (Hatan et al., 2021).

5. Conclusions

The study presents the results of a choice experiment (CE) conducted through an online survey among residents in Paraná State to elicit preferences towards more sustainable land use and management scenarios. The results show a positive and considerable WTP for the enhanced supply of ecosystem services (ES) and specifically biodiversity improvements, soil erosion reduction, carbon sequestration, and a more complex visual appearance of landscapes. Together the findings indicate that the level of landscape complexity associated with the increase in ES is an important issue for citizens of Paraná State and that land use scenarios that combine production and environmental conservation are preferred. This adds an important aspect to ES valuation studies focusing on farmland, in which landscape amenity impacts related to higher landscape complexity are frequently overlooked.

The study supports economic appraisals of land use scenarios and the development of policy initiatives towards this end. The shift from a landscape dominated by monocultures to a multifunctional mosaic landscape that promotes the recovery of natural ecosystems and sustainable agricultural and forestry practices would safeguard food security while offering synergies with biodiversity, cultural, and regulating ES. Our study shows that there is a local demand for transitioning towards more sustainable agricultural systems in Brazil as one of the powerhouses of global agricultural production. In particular, results indicate that there would be a case for the implementation of instruments (e.g. incentive-based ones such as PES) aimed at that objective. The results, including those focusing on preference heterogeneity, particularly point to the need of implementing further economic appraisals like the present study in affected regions and across Brazil, where this type of appraisal is remarkably scarce.

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.

Data availability

Data will be made available on request.

Acknowledgments

LMP acknowledges support through the scholarship CNPq 203224/2019-1. KG acknowledges support through the Scottish Government Rural Affairs and the Environment Portfolio Strategic Research Programme 2022-2027.

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2022.101476.

References

Adamowicz, W., Boxall, P., Williams, M., Louviere, J., 1998. Stated preference approaches for measuring passive use values: choice experiments and contingent valuation. Am. J. Agric. Econ. 80 (1), 64–75. https://doi.org/10.2307/3180269.

Aklin, M., Bayer, P., Harish, S.P., Urpelainen, J., 2013. Understanding environmental policy preferences: New evidence from Brazil. Ecol. Econ. 94, 28–36. https://doi.org/10.1016/j.ecolecon.2013.05.012.

Alcon, F., Marín-Miñano, C., Zabala, J.A., de-Miguel, M.D., Martínez-Paz, J.M., 2020. Valuing diversification benefits through intercropping in Mediterranean agroecosystems: A choice experiment approach. Ecol. Econ. 171 https://doi.org/10.1016/j.ecolecon.2020.106593.

Aslam, U., Termansen, M., Fleskens, L., 2017. Investigating farmers' preferences for alternative PES schemes for carbon sequestration in UK agroecosystems. Ecosyst. Serv. 27, 103–112. https://doi.org/10.1016/j.ecoser.2017.08.004.

Azevedo, A.A., Rajão, R., Costa, M.A., Stabile, M.C.C., Macedo, M.N., Reis, T.N.P., Alencar, A., Soares-Filho, B.S., Pacheco, R., 2017. Limits of Brazil's Forest Code as a means to end illegal deforestation. PNAS 114 (29), 7653–7658. https://doi.org/10.1073/pnas.1604768114.

Bernués, A., Rodríguez-Ortega, T., Ripoll-Bosch, R., Alfnes, F., 2014. Socio-cultural and economic valuation of ecosystem services provided by Mediterranean mountain agroecosystems. PLoS ONE 9 (7). https://doi.org/10.1371/journal.pone.0102479.

Bernués, A., Tello-García, E., Rodríguez-Ortega, T., Ripoll-Bosch, R., Casasús, I., 2016. Agricultural practices, ecosystem services and sustainability in High Nature Value farmland: Unraveling the perceptions of farmers and nonfarmers. Land Use Policy 59, 130–142. https://doi.org/10.1016/j.landusepol.2016.08.033.

Bernués, A., Alfnes, F., Clemetsen, M., Eik, L.O., Faccioni, G., Ramanzin, M., Ripoll-Bosch, R., Rodríguez-Ortega, T., Sturaro, E., 2019. Exploring social preferences for ecosystem services of multifunctional agriculture across policy scenarios. Ecosyst. Serv. 39 https://doi.org/10.1016/j.ecoser.2019.101002.

Berthet, E.T., Bretagnolle, V., Gaba, S., 2022. Place-based social-ecological research is crucial for designing collective management of ecosystem services. Ecosyst. Serv. 15, 101426 https://doi.org/10.1016/j.ecoser.2022.101426.

Bethwell, C., Sattler, C., Stachow, U., 2022. An analytical framework to link governance, agricultural production practices, and the provision of ecosystem services in agricultural landscapes. Ecosyst. Serv. 53, 101402 https://doi.org/10.1016/j.ecoser.2021.101402.

Bieluczyk, W., de Piccolo, M., Pereira, M.G., de Moraes, M.T., Soltangheisi, A., de Bernardi, A.C., Pezzopane, J.R.M., Oliveira, P.P.A., Moreira, M.Z., de Camargo, P.B., dos Dias, C.T., Batista, I., Cherubin, M.R., 2020. Integrated farming systems influence soil organic matter dynamics in southeastern Brazil. Geoderma 371. https://doi.org/10.1016/j.geoderma.2020.114368.

Brancalion, P. H. S., Lamb, D., Ceccon, E., Boucher, D., Herbohn, J., Strassburg, B., & Edwards, D. P. (2017). Using markets to leverage investment in forest and landscape restoration in the tropics. In *Forest Policy and Economics* (Vol. 85, pp. 103–113). Elsevier B.V. https://doi.org/10.1016/j.forpol.2017.08.009.

Brosnan, S.F., de Waal, F.B.M., 2014. Evolution of responses to (un)fairness. Science 17 346 (6207), 1251776. https://doi.org/10.1126/science.1251776.

Chaplin-Kramer, R., Sharp, R.P., Mandle, L., Sim, S., Johnson, J., Butnar, I., Milà I Canals, L., Eichelberger, B.A., Ramler, I., Mueller, C., McLachlan, N., Yousefi, A., King, H., Kareiva, P.M., 2015. Spatial patterns of agricultural expansion determine impacts on biodiversity and carbon storage. PNAS 112 (24), 7402–7407. https://doi.org/10.1073/pnas.1406485112.

ChoiceMetrics. (2018). *Ngene 1.2 User manual & reference guide: the cutting edge in experimental design*. www.choice-metrics.com.

Colombo, S., Calatrava-Requena, J., Hanley, N., 2006. Analysing the social benefits of soil conservation measures using stated preference methods. Ecol. Econ. 58 (4), 850–861. https://doi.org/10.1016/j.ecolecon.2005.09.010.

Cortner, O., Garrett, R.D., Valentim, J.F., Ferreira, J., Niles, M.T., Reis, J., Gil, J., 2019. Perceptions of integrated crop-livestock systems for sustainable intensification in the Brazilian Amazon. Land Use Policy 82, 841–853. https://doi.org/10.1016/j.landusepol.2019.01.006.

Creamer, R.E., Hannula, S.E., Leeuwen, J.P.V., Stone, D., Rutgers, M., Schmelz, R.M., 2016. Ecological network analysis reveals the inter-connection between soil biodiversity and ecosystem function as affected by land use across Europe. Appl. *Soil Ecol.* 97, 112–124. https://doi.org/10.1016/j.apsoil.2015.08.006.

Das, S., Chatterjee, S., Rajbanshi, J., 2022. Responses of soil organic carbon to conservation practices including climate-smart agriculture in tropical and subtropical regions: A meta-analysis. Sci. Total Environ. 805, 150428 https://doi.org/10.1016/j.scitotenv.2021.150428.

De Leeuw, E. D., Hox, J. J. & Dillman, D. A. (2008), The cornerstones of survey research. In De Leeuw, J. Hox & D. Dillman (eds.), International handbook of survey methodology (pp. 1-17), London: Routledge, p.8.

DeClerck, F.A.J., Jones, S.K., Attwood, S., Bossio, D., Girvetz, E., Chaplin-Kramer, B., Enfors, E., Fremier, A.K., Gordon, L.J., Kizito, F., Lopez Noriega, I., Matthews, N., McCartney, M., Meacham, M., Noble, A., Quintero, M., Remans, R., Soppe, R., Willemen, L., Zhang, W., 2016. Agricultural ecosystems and their services: the vanguard of sustainability?. In: *Current Opinion in Environmental Sustainability*, Vol. 23. Elsevier B.V, pp. 92–99, 10.1016/j.cosust.2016.11.016.

Derpsch, R., Franzluebbers, A.J., Duiker, S.W., Reicosky, D.C., Koeller, K., Friedrich, T., Sturny, W.G., Sá, J.C.M., Weiss, K., 2014. Why do we need to standardize no-tillage research? Soil Tillage Res. 137, 16–22. https://doi.org/10.1016/j.still.2013.10.002.

Dupras, J., Laurent-Lucchetti, J., Revéret, J.P., DaSilva, L., 2017. Using contingent valuation and choice experiment to value the impacts of agri-environmental practices on landscapes aesthetics. Landscape Res. 43 (5), 679–695. https://doi.org/10.1080/01426397.2017.1332172.

Dziegielewska, D.A., Mendelshon, R., 2007. Does "No" mean "No"? A protest methodology. Environ. Resour. Econ. 38, 71–87. https://doi.org/10.1007/s10640-006-9057-4.

Faccioli, M., Czajkowski, M., Glenk, K., Martin-Ortega, J., 2020. Environmental attitudes and place identity as determinants of preferences for ecosystem services. Ecol. Econ. 174 https://doi.org/10.1016/j.ecolecon.2020.106600.

Filoche, G., 2017. Playing musical chairs with land use obligations: Market-based instruments and environmental public policies in Brazil. Land Use Policy 63, 20–29. https://doi.org/10.1016/j.landusepol.2017.01.012.

Freitas, P.L., Landers, J.N., 2014. The transformation of agriculture in brazil through development and adoption of zero tillage conservation agriculture. Int. Soil Water Conserv. Res. 2 (1), 35–46. https://doi.org/10.1016/S2095-6339(15)30012-5.

Friedrich, T., Derpsch, R., & Kassam, A. (2012). *Overview of the global spread of conservation agriculture. Field Actions Science Reports Special Issue 6. Reconciling poverty eradication and protection of the environment. http://factsreports.revues.org/1941*. Online since 06 November 2012, Connection on 06 November 2012. http://factsreports.revues.org/1941.

García-Ruiz, J. M., Beguería, S., Lana-Renault, N., Nadal-Romero, E., Cerdà, A., & (2017). Ongoing and emerging questions in water erosion studies. *Land Degradation and Development, 28*, 5–21 https://doi: 10.1002/ldr.2641.

Garrett, R.D., Ryschawy, J., Bell, L.W., Cortner, O., Ferreira, J., Garik, A.V.N., Gil, J.D.B., Klerkx, L., Moraine, M., Peterson, C.A., dos Reis, J.C., Valentim, J.F., 2020. Drivers of decoupling and recoupling of crop and livestock systems at farm and territorial scales. Ecol. Soc. 25 (1) https://doi.org/10.5751/ES-11412-250124.

Gil, J.D.B., Reidsma, P., Giller, K., Todman, L., Whitmore, A., van Ittersum, M., 2019. Sustainable development goal 2: Improved targets and indicators for agriculture and food security. Ambio 48 (7), 685–698. https://doi.org/10.1007/s13280-018-1101-4.

Glenk, K., Johnston, R.J., Meyerhoff, J., Sagebiel, J., 2020. Spatial dimensions of stated preference valuation in environmental and resource economics: methods, trends and challenges. Environ. Resour. Econ. 75 (2), 215–242. https://doi.org/10.1007/s10640-018-00311-w.

Granado-Díaz, R., Gómez-Limón, J.A., Rodríguez-Entrena, M., Villanueva, A.J., 2020. Spatial analysis of demand for sparsely located ecosystem services using alternative index approaches. Eur. Rev. Agric. Econ. 47 (2), 752–784. https://doi.org/10.1093/erae/jbz036.

Greene, W. H. (2008). *Econometric analysis. 6th Ed. New Jersey: Vol. 6th Ed.* (N. P.-Hall. Upper Saddle Rive, Ed.). Prentice Hall.

Hatan, S., Fleischer, A., Tchetchik, A., 2021. Economic valuation of cultural ecosystem services: The case of landscape aesthetics in the agritourism market. Ecol. Econ. 184 https://doi.org/10.1016/j.ecolecon.2021.107005.

Hess, S., Palma, D., 2019. Apollo: A flexible, powerful and customisable freeware package for choice model estimation and application. J. Choice Modell. 32 https://doi.org/10.1016/j.jocm.2019.100170.

Hynes, S., Chen, W., Vondolia, K., Armstrong, C., O'Connor, E., 2021. Valuing the ecosystem service benefits from kelp forest restoration: A choice experiment from Norway. Ecol. Econ. 179 https://doi.org/10.1016/j.ecolecon.2020.106833.

IPBES. (2019). *Summary for Policymakers in the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Díaz, S., Settele, J., Brondízio E. S., Ngo, H. T., Guèze, M., Agard, J., Arneth, A., Balvanera, P. … (eds.). IPBES secretariat, Bonn, Germany. 56 pages. www.ipbes.net.

Kauano, E.E., Torezan, J.M.D., Cardoso, F.C.G., Marques, M.C.M., 2012. Landscape structure in the northern coast of Paraná State, a hotspot for the Brazilian Atlantic Forest conservation. Revista Árvore 36 (5), 961–970.

Kay, S., Graves, A., Palma, J. H. N., Moreno, G., Roces-Díaz, J. V., Aviron, S., Chouvardas, D., Crous-Duran, J., Ferreiro-Domínguez, N., García de Jalón, S., Măcicăşan, V., Mosquera-Losada, M. R., Pantera, A., Santiago-Freijanes, J. J., Szerencsits, E., Torralba, M., Burgess, P. J., & Herzog, F. (2019). Agroforestry is paying off – Economic evaluation of ecosystem services in European landscapes with and without agroforestry systems. In *Ecosystem Services* (Vol. 36). Elsevier B.V. https://doi.org/10.1016/j.ecoser.2019.100896.

Keesstra, S., Pereira, P., Novara, A., Brevik, E.C., Azorin-Molina, C., Parras-Alcántara, L., Jordàn, A., Cerdà, A., 2016. Effects of soil management techniques on soil water erosion in apricot orchards. Sci. Total Environ. 551, 357–366. https://doi.org/10.1016/j. scitotenv.2016.01.182.

Lacerda, A.E.B., Hanischff, A.L., Nimmo, E.R., 2020. Leveraging traditional agroforestry practices to support sustainable and agrobiodiverse landscapes in Southern Brazil. Land 9 (6). https://doi.org/10.3390/LAND9060176.

Lal, R., Smith, P., Jungkunst, H.F., Mitsch, W.J., Lehmann, J., Nair, P.K.R., McBratney, A. B., Moraes Sá, J.C.M., Schneider, J., Zinn, Y.L., Skorupa, A.L.A., Zhang, H.L., Minasny, B., Srinivasrao, C., Ravindranath, N.H., 2018. The carbon sequestration potential of terrestrial ecosystems. Soil Water Conserv. 73 (6), 145A–152A. https://doi.org/10.2489/jswc.73.6.145A.

Lal, R., (2012). Climate change and soil degradation mitigation by sustainable management of soils and other natural resources. *Agric. Res., 1*(3):199–212 https://doi10.1007/s40003-012-0031-9.

Landis, D.A., 2017. Designing agricultural landscapes for biodiversity-based ecosystem services. In: Basic and Applied Ecology, Vol. 18. Elsevier GmbH, pp. 1–12. https://doi.org/10.1016/j.baae.2016.07.005.

Latawiec, A.E., Strassburg, B.B.N., Silva, D., Alves-Pinto, H.N., Feltran-Barbieri, R., Castro, A., Iribarrem, A., Rangel, M.C., Kalif, K.A.B., Gardner, T., Beduschi, F., 2017. Improving land management in Brazil: A perspective from producers. Agric. Ecosyst. Environ. 240, 276–286. https://doi.org/10.1016/j.agee.2017.01.043.

Leite, C. C., Costa, M. H., Soares-Filho, B. S. & Hissa, L.B.V. (2012). Historical land use change and associated carbon emissions in Brazil from 1940 to 1995, *Global Biogeochemistry Cycles, 26, GB2011,* https:/doi:10.1029/2011GB004133.

Malinga, R., Gordon, L.J., Jewitt, G., Lindborg, R., 2015. Mapping ecosystem services across scales and continents – a review. *Ecosyst.* Serv. 13, 57–63. https://doi.org/10.1016/j.ecoser.2015.01.006.

Mariel, P., Artabe, A., 2020. Interpreting correlated random parameters in choice experiments. J. Environ. Econ. Manage. 103 https://doi.org/10.1016/j.jeem.2020.102363.

Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jacobsen, J. B., Liebe, U., Olsen, S., Sagebiel, J., & Thiene, M. (2021). *Environmental valuation with discrete choice experiments guidance on design, implementation and data analysis* (SpringerBriefs in Economics. https://doi.org/10.1007/978-3-030-62669-3, Ed.). Springer. www.springer.com:series;8876.

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J. B. R., Chen, Y., Zhou, X., Gomis, M. I., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (2019). *Global warming of 1.5°C An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty Edited by Science Officer Science Assistant Graphics Officer Working Group I Technical Support Unit*. www.environmentalgraphiti.org.

SOS Mata Atlântica, & INPE. (2019). *Atlas dos Remanescentes Florestais da Mata Atlântica. Período de 2016-2017.* http://mapas.sosma.org.br.

MEA [Millennium Ecosystem Assessment], 2005. *Ecosystems and human well-being*: synthesis. Island Press, Washington, DC.

Mello, K., Fendrich, A.N., Sparovek, G., Simmonds, J.S., Maron, M., Tavares, P.A., Brites, A.D., Rodrigues, R.R., Joly, C.A., Metzger, J.P., 2021. Achieving private conservation targets in Brazil through restoration and compensation schemes without impairing productive lands. Environ. Sci. Policy 120, 1–10. https://doi.org/10.1016/j.envsci.2021.02.014.

Meyerhoff, J., Liebe, U., 2009. Status quo effect in choice experiments: empirical evidence on attitudes and choice task complexity. Land Econ. 85 (3), 515–528.

Milhorance, C., Sabourin, E., Chechi, L., Mendes, P., 2021. The politics of climate change adaptation in Brazil: Framings and policy outcomes for the rural sector. Environ. Politics. https://doi.org/10.1080/09644016.2021.1907097.

Müller, A., Olschewski, R., Unterberger, C., Knoke, T., 2020. The valuation of forest ecosystem services as a tool for management planning – A choice experiment. J. Environ. Manage. 271 https://doi.org/10.1016/j.jenvman.2020.111008.

OECD, 2001. Multifunctionality: Towards an Analytical Framework. OECD Publishing, Paris, 10.1787/9789264192171-en.

Ofstehage, A., Nehring, R., 2021. No-till agriculture and the deception of sustainability in Brazil. Int. J. Agric. Sustainability. https://doi.org/10.1080/14735903.2021.1910419.

Pascual, U., Termansen, M., Hedlund, K., Brussaard, L., Faber, J.H., Foudi, S., Lemanceau, P., Jørgensen, S.L., 2015. On the value of soil biodiversity and ecosystem services. Ecosyst. Serv. 15, 11–18. https://doi.org/10.1016/j.ecoser.2015.06.002.

Plieninger, T., van der Horst, D., Schleyer, C., Bieling, C., 2014. Sustaining ecosystem services in cultural landscapes. Ecol. Soc. 19 (2), 59. https://doi.org/10.5751/ES-06159-190259.

Popak, A.E., Markwith, S.H., Strange, J., 2019. Economic valuation of bee pollination services for passion fruit (Malpighiales: Passifloraceae) cultivation on smallholding farms in São Paulo, Brazil, Using the Avoided Cost Method. J. Econ. Entomol. 112 (5), 2049–2054. https://doi.org/10.1093/jee/toz169.

Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philos. Trans. R. Soc. B 365, 2959–2971. https://doi.org/10.1098/rstb.2010.0143.

Rafael, G.C., Fonseca, A., Jacovine, L.A.G., 2018. Non-conformities to the Forest Stewardship Council (FSC) standards: Empirical evidence and implications for policy-making in Brazil. Forest Policy Econ. 88, 59–69. https://doi.org/10.1016/j.forpol.2017.12.013.

Rajão, R., Soares-Filho, B., Nunes, F., Börner, J., Machado, L., Assis, D., Oliveira, A., Pinto, L., Ribeiro, V., Rausch, L., Gibbs, H., Figueira, D., 2020. The rotten apples of Brazil's agribusiness. Science 369 (6501), 246–248. https://doi.org/10.1126/science.aba6646.

Reed, M.S., Hubacek, K., Bonn, A., Burt, T.P., Holden, J., Stringer, L.C., Beharry-Borg, N., Buckmaster, S., Chapman, D., Chapman, P., Clay, G.D., Cornell, S., Dougill, A.J., Evely, A., Fraser, E.D.G., Jin, N., Irvine, B., Kirkby, M., Kunin, W., Prell, C., Quinn, C. H., Slee, W., Stagl, S., Termansen, M., Thorp, S., Worrall, F., 2013. Anticipating and managing future trade-offs and complementarities between ecosystem services. Ecol. Soc. 18 (1), 5. https://doi.org/10.5751/ES-04924-180105.

Resende, F.M., Fernandes, G.W., Andrade, D.C., Néder, H.D., 2017. Valoração econômica de serviços ecossistêmicos fornecidos por uma área protegida no Cerrado Brasileiro: Aplicação do método de valoração contingente. Braz. J. Biol. 77 (4), 762–773. https://doi.org/10.1590/1519-6984.21215.

Rodríguez-Entrena, M., Barreiro-Hurlé, J., Gómez-Limón, J.A., Espinosa-Goded, M., Castro-Rodríguez, J., 2012. Evaluating the demand for carbon sequestration in olive grove soils as a strategy toward mitigating climate change. J. Environ. Manage. 112, 368–376. https://doi.org/10.1016/j.jenvman.2012.08.004.

Rodríguez-Ortega, T., Bernués, A., Alfnes, F., 2016. Psychographic profile affects willingness to pay for ecosystem services provided by Mediterranean high nature value farmland. Ecol. Econ. 128, 232–245. https://doi.org/10.1016/j.ecolecon.2016.05.002.

Sá, J.C.M., Santos, J.B., Lal, R., Moraes, A., Tivet, F., Sá, M.F.M., Briedis, C., Ferreira, A. O., Eurich, G., Farias, A., Friedrich, T., 2013. Soil-specific inventories of landscape carbon and nitrogen stocks under no-till and native vegetation to estimate carbon offset in a subtropical ecosystem. Soil Sci. Soc. Am. J. 77 (6), 2094–2110. https://doi.org/10.2136/sssaj2013.01.0007.

Sagebiel, J., Glenk, K., Meyerhoff, J., 2017. Spatially explicit demand for afforestation. Forest Policy Econ. 78, 190–199. https://doi.org/10.1016/j.forpol.2017.01.021.

Santos, F.A.M., Coelho-Junior, M.G., Cardoso, J.C., Basso, V.M., Marques, A.L.P., Silva, E.M.R., 2020. Program outcomes of payments for watershed services in Brazilian Atlantic Forest: How to evaluate to improve decision-making and the socio-environmental benefits. Water (Switzerland) 12 (9). https://doi.org/10.3390/w12092441.

Santos, P.Z.F., Crouzeilles, R., Sansevero, J.B.B., 2019. Can agroforestry systems enhance biodiversity and ecosystem service provision in agricultural landscapes? A meta-analysis for the Brazilian Atlantic Forest. For. Ecol. Manage. 433, 140–145. https://doi.org/10.1016/j.foreco.2018.10.064.

Sauquet, A., Marchand, S., Féres, J.G., 2014. Protected areas, local governments, and strategic interactions: The case of the ICMS-Ecológico in the Brazilian state of Paraná. Ecol. Econ. 107, 249–258. https://doi.org/10.1016/j.ecolecon.2014.09.008.

Seroa da Motta, R., Ortiz, R.A., 2018. Costs and perceptions conditioning willingness to accept payments for ecosystem services in a Brazilian Case. Ecol. Econ. 147, 333–342. https://doi.org/10.1016/j.ecolecon.2018.01.032.

Sobol, I.M., 1967. On the distribution of points in a cube and the approximate evaluation of integrals. USSR Comput. Mathem. Mathem. Phys. 1–27 https://doi.org/10.1016/0041-5553(67)90144-9.

Soga, M., Evans, M.J., Cox, D.T.C., Gaston, K.J., 2021. Impacts of the COVID-19 pandemic on human–nature interactions: Pathways, evidence and implications. People Nat. 3 (3), 518–527. https://doi.org/10.1002/pan3.10201.

TEEB, 2010. *The Economics of Ecosystems and Biodiversity*: Ecological and Economic Foundations. Earthscan, London and Washington.

Telles, T.S., Melo, T.R., Righetto, A.J., Didoné, E.J., Barbosa, G.M.C., 2022. Soil management practices adopted by farmers and how they perceive conservation agriculture. Revista Brasileira de Ciência do Solo 46, e0210151. https://doi.org/10.36783/18069657rbcs20210151.

Tisovec-Dufner, K.C., Teixeira, L., Marin, G.L., Coudel, E., Morsello, C., Pardini, R., 2019. Intention of preserving forest remnants among landowners in the Atlantic Forest: The role of the ecological context via ecosystem services. People Nat. 1 (4), 533–547. https://doi.org/10.1002/pan3.10051.

Train, K., Weeks, M., 2005. Discrete choice models in preference space and willingness-to-pay space. In: Applications of Simulation Methods in Environmental and Resource Economics. Springer-Verlag, pp. 1–16. https://doi.org/10.1007/1-4020-3684-1_1.

Train, K.E. (2003) Discrete Choice Methods with Simulation. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511753930.

Valdes, C., Hjort, K., & Seeley, R. (2020). *Brazil's Agricultural Competitiveness: Recent Growth and Future Impacts Under Currency Depreciation and Changing Macroeconomic Conditions. ERR-276, U.S. Department of Agriculture, Economic Research Service. 1-37p.* www.ers.usda.gov.

van Hecken, G., Bastiaensen, J., Vásquez, W.F., 2012. The viability of local payments for watershed services: Empirical evidence from Matiguás, Nicaragua. Ecol. Econ. 74, 169–176. https://doi.org/10.1016/j.ecolecon.2011.12.016.

van Zanten, B.T., Zasada, I., Koetse, M.J., Ungaro, F., Hafner, K., Verburg, P.H., 2016. A comparative approach to assess the contribution of landscape features to aesthetic and recreational values in agricultural landscapes. Ecosyst. Serv. 17, 87–98. https://doi.org/10.1016/j.ecoser.2015.11.011.

Viani, R.A.G., Bracale, H., Taffarello, D., 2019. Lessons learned from the water producer project in the atlantic forest, Brazil. *Forests* 10 (11). https://doi.org/10.3390/f10111031.

Watson, V., Porteous, T., Bolt, T.,& Ryan, M. (2019) Mode and frame matter: assessing the impact of survey mode and sample frame in choice experiments. Medical Decision Making, 39 (7), pp. 827-841. https://doi: 10.1177/0272989X19871035.

Yao, R.T., Scarpa, R., Turner, J.A., Barnard, T.D., Rose, J.M., Palma, J.H.N., Harrison, D. R., 2014. Valuing biodiversity enhancement in New Zealand's planted forests: Socioeconomic and spatial determinants of willingness-to-pay. Ecol. Econ. 98, 90–101. https://doi.org/10.1016/j.ecolecon.2013.12.009.

Zago, L.M.S., Ramalho, W.P., Silva-Neto, C.M., Caramori, S.S., 2020. Biochemical indicators drive soil quality in integrated crop–livestock–forestry systems. Agrofor. Syst. 94 (6), 2249–2260. https://doi.org/10.1007/s10457-020-00547-w.

Zilli, M., Scarabello, M., Soterroni, A.C., Valin, H., Mosnier, A., Leclère, D., Havlík, P., Kraxner, F., Lopes, M.A., Ramos, F.M., 2020. The impact of climate change on Brazil's agriculture. Sci. Total Environ. 740 https://doi.org/10.1016/j.scitotenv.2020.139384.