Farmers' willingness to adopt silvopasture practices

– investigating compensation claims using a contingent valuation approach among Swedish cattle producers

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Abstract

To mitigate greenhouse gas emissions and biodiversity loss from cattle production in Sweden, it is particularly crucial to incentivize cattle producers to adopt silvopasture practices. To investigate cattle producers' willingness to adopt silvopasture practices and the related compensation claims, a contingent valuation survey was conducted among cattle producers in Sweden. The theory of planned behaviour was additionally used to explain how underlying psychological constructs influence farmers' decisions to adopt silvopasture practices. It is found that the adoption decision is negatively correlated with the female gender and the belief that silvopasture leads to higher management costs, and positively correlated with the farmers' level of education and attitude. Furthermore, the related compensation claims are negatively correlated with the pastures size and the farmers' confidence in benefiting from alternative sources of income, while positively correlated with the distance between the farm and the nearest city, the level of education and income. The overall mean compensation claim per year per hectare is estimated at SEK 3107.17. Although the obtained results are only preliminary estimates, they can be used for discussing and illustrating scaling up possibilities of silvopasture practices in Sweden. Accordingly, training programs, governmental expenditure, as well as increased recognition of silvopasture in the Common Agricultural Policy and its direct payments scheme are necessary to increase silvopasture implementation, respectively by enhancing knowledge around silvopasture practices and internalizing the non-market benefits of silvopasture.

Keywords: Silvopasture practices, willingness to adopt, compensation claims, contingent valuation method, survey, theory of planned behaviour, cattle production, Sweden

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Abbreviations

CAP	Common Agricultural Policy
CS	Compensating Surplus
CVM	Contingent Valuation Method
EU	European Union
GHG	Greenhouse gas
OLS	Ordinary Least Square
TPB	Theory of Planned Behaviour
WTA	Willingness to Accept

1. Introduction

The numerous damages caused by livestock production, and notably, the intensive grazing systems, are now well known (Steinfeld et al., 2006; Bilotta et al., 2007; Gill et al., 2010). In Sweden, particularly, the negative impacts of intensive cattle production on the environment are mainly characterized by increases in both carbon emissions and biodiversity loss. Today, around 13% of Sweden's total greenhouse gas (GHG) emissions emanates from livestock production, reflecting a release of more than 6,5 million tons of carbon dioxide each year (Swedish board of agriculture, 2018a). Simultaneously, the many plant and animal species linked to pastoral landscapes that can traditionally be found in pastures and meadows, have been crowded out in recent years, due to increasingly specialized and intensive livestock production systems (Naturvårdsverket, 2020). However, if managed sustainably, pastures still have the potential to contribute positively to the mitigation of GHG emissions from livestock and the preservation of farmland species and habitats (Swedish board of agriculture, 2019). Especially, the agroforestry practice of silvopasture that combines forage and trees into a single integrated system for raising livestock is a solution to both challenges while remaining viable and competitive (Gold et al., 2000; Clason and Sharrow, 2000). Specifically, silvopasture is estimated to have a carbon sequestration capacity that is up to five to ten times higher than treeless pastures by storing carbon in both soil and tree biomass (Lal et al., 2018) and is demonstrated to provide many resources and refuges to wildlife and native plant species (Alavalapati and Nair, 2001; Jose et al., 2017). Additionally, farmers are considered better protected from risk since silvopasture practices are more diversely productive and resilient (Kurtz et al., 2000), respectively, by providing diversified sources of income on different time horizons (Hawken (Ed.), 2017) and improving animal welfare through shade and shelter (Broom et al., 2013; da Silva and Maia, 2013). Silvopasture practices therefore lead to win-win or trade-off relations between farmers and the environment (Ellis et al., 2019).

The re-introduction of trees to pastures may seem innovative and contemporary to the climate emergency but silvopasture is, in fact, an ancient agricultural practice (Casey, 1983; Coomes, 1991; Asplund and Björklund, 2016). Although it has recently returned to the agricultural landscape for both its on-site and environmental benefits, the practice remains fairly unknown and lacks implementation. This is especially true in that silvopasture operates against farming norms and is not only slow to implement but costly too (Hawken (Ed.), 2017). While most of the benefits of silvopasture are external to farmers, the costs associated with learning, implementation, maintenance, and potential reduced cattle outputs, are internally covered by the farmers (Shrestha and Alavalapati, 2003). Although a well-managed silvopasture can offset some of its costs, the benefits of silvopasture do not give full immediate compensation (Shrestha and Alavalapati, 2003). Farmers may thus have no interest in adopting silvopasture techniques unless monetary incentives are provided to internalize the external benefits (García de Jalón et al., 2017). Even so, the decision to adopt silvopasture practices can additionally be influenced by behavioural drivers, specific to each farmer (Hansson et al., 2019), such that the adoption decision would not only be driven by profit maximisation. Moreover, combining agriculture and forestry is no easy task as the high complexity level of silvopasture implementation has been highlighted in previous studies (e.g., Schaffer et al., 2019). Therefore, on the one hand silvopasture represents a suitable solution to the environmental issues related to intensive grazing in Sweden, as well as providing financial benefits in the long run, but on the other hand, faces important barriers to adoption such as a lack of knowledge of the practice and, more generally, of the climate emergency, high costs of implementation and other behavioural barriers.

Accordingly, to enhance knowledge around decision drivers and encourage silvopasture implementation, this study aims to investigate empirically farmers' willingness to adopt silvopasture systems and the related compensation claims, in a sample of Swedish cattle producers. Further subsidiary aims are to examine the influence of various characteristics on the adoption decision and mean compensation claim. Among those characteristics, the psychological constructs of the theory of planned behaviour (TPB) are included to better examine the role of behavioural determinants in the decision process (Ajzen, 1991). The use of the TPB is justified by being one of the most widely used approaches for understanding determinants of behaviour (Hansson et al., 2019), thereby suggesting that the behaviour of farmers is not only influenced by profit maximization (Gasson, 1973; Howley, 2015). Finally, this study discusses scaling up possibilities of silvopasture implementation and how policymaking can support this. The objectives are achieved using a contingent valuation method (CVM) consisting of a survey to gather data from Swedish cattle producers, followed by the Heckman two-stage model to quantitatively analyze cattle producers' willingness to adopt silvopasture and the related compensation claims. Further, exploratory factor analysis is used to obtain measures of the TPB constructs.

As the need for agroforestry practices in agriculture has grown more urgent in recent years, an increasing amount of literature has focused on farmers' perception of such practices, silvopasture included (e.g., Calle et al., 2009; Gregory et al., 2012, Jerneck and Olsson 2013; Meijer et al. 2015). These works of literature acknowledge the complexity of silvopasture implementation, thus trying to assess what determinants favour adoption and what do not, while often ignoring farmers' behavioural characteristics. In most cases, such literature refers to case studies in tropical climates whereas relatively small research was conducted in Europe, until more recently, García de Jalón et al. (2017) and Schaffer et al. (2019) also demonstrated the need for silvopasture systems within European countries. Consequently, it has especially been found that a sufficient level of monetary compensation would encourage the development of silvopasture practices (e.g., Calle et al., 2009; García de Jalón et al., 2017). However, only less than a handful of works of literature has tried to empirically assess such economic incentive (e.g., Shrestha and Alavalapati, 2003; Buckley et al., 2012), and even so, the obtained compensation claims are often set in specific settings (i.e., Texan ranch, riparian buffer zones) and omit the most common attributes found on silvopastoral systems.

Thereby, this study differs from previous empirical literature by considering the TPB to account for behavioural drivers influencing the decision-making. Underlying psychological constructs such as attitude, subjective norm and perceived behavioural control are assumed to play a significant role in farmers' decisions regarding the strategy they adopt (Ajzen, 1991) and require consideration to understand in more depth the need for compensation payment. Additionally, the study investigates cattle producers' willingness to reforest treeless pastures, conditional to compensation payments, such that the results obtained in this paper can, not only be beneficial to Sweden by providing valuable advice to policymaking but also, contribute to the existing literature regarding the farmers' perceptions of silvopasture and act as a reference point for similar cattle productions found in temperate climate.

2. Silvopasture in Sweden

Silvopasture and other agroforestry practices have received little attention in Sweden (Asplund and Björklund, 2016). Although some agroforestry associations exist, such as Agroforestry Sverige[1], agroforestry measures are not sufficiently implemented and therefore lack visibility in both the Common Agricultural Policy (CAP) and Swedish rural development programs. In fact, all agroforestry practices combined, i.e., arable agroforestry, livestock agroforestry and high value tree agroforestry, account for only 1.1% of the total territorial area, reflecting 15.2% of all utilized agricultural area of Sweden (den Herder et al., 2017). Of which, livestock agroforestry, i.e., silvopastoral systems, constitutes 99% of all agroforestry practices currently in place in Sweden.

Silvopastoral systems either results when forage is deliberately introduced in a timber production system, or when timber is deliberately introduced in a forage production system (Klopfenstein et al., 1997). The former, also called grazed woodlands, amounts to roughly 60% of the total practice of silvopasture in Sweden, whereas the latter, also known as grassland with sparse tree cover, corresponds to approximately 37%. The difference in percentage between the two main silvopastoral systems is especially due to the country's extensive forest cover and its traditional use amongst the Sami people, letting large herds of semi-domesticated reindeer graze freely in mountains and forests (Schaffer et al., 2018). Even though grazed woodlands are essentials, particularly in the process of establishing new pastures, the need for a transition towards sustainable agriculture in Sweden primarily requires that the already existing grasslands are converted to silvopasture. In fact, paired with growing trends in plant-based diets inducing that the space dedicated to livestock production need not expand further (Erb et al., 2016), the reforestation of current treeless pastures should be a priority for scaling up.

However, not all pasture systems in Sweden contribute to the negative environmental impacts caused by livestock production. Silvopasture practices are particularly aimed at mitigating intensive systems in which cattle are being fed soymeal and other types of grain. In that sense, semi-natural pastures, i.e., grasslands created by continuously low-intensive grazing on non-cultivated land (Jakobsen and Waldén, 2017), are especially exempted as they are considered positive to the environment from both a biodiversity and climate perspective. Along

[1] Agroforestry Sverige (Agroforestry Sweden), Stockholm, Sweden. www.agroforestry.se

with grazed woodlands, semi-natural pastures substantially constitute the agricultural heritage of Sweden and have filled an important function for the development of milk and meat production (Jakobsen and Waldén, 2017). Such pastures are one of the most species-rich habitats found in Sweden (Olsson, 2015) and parallelly, are highly threatened due to intensified agriculture (Stoate et al., 2009). Since the end of the 19th century, semi-natural pastures have declined to less than one percent of the initial area (Bernes, 1994). Although silvopasture practices are not considered semi-natural pastures, similitudes can be drawn between both systems. Simply, the re-introduction of trees to cultivated land is notably derived from semi-natural pastures and can be considered to perpetuate the cultural and biological values of semi-natural pastures in Sweden.

3. Literature review

As the need for agroforestry practices in agriculture has grown more urgent in recent years, an increasing – although relatively small – amount of literature has focused on farmers' perception of such practices, silvopasture included (e.g., Calle et al., 2009; Gregory et al., 2012, Jerneck and Olsson 2013; Meijer et al. 2015). These works of literature acknowledge the complexity of silvopasture implementation, thus trying to assess what determinants favour adoption and what do not. Specifically, Gregory et al. (2012) explored various market, social and biological factors that influence whether the farmer will adopt silvopasture in Argentina. Calle et al. (2009) assessed other motivations, feedback, and difficulties that determined Colombian farmers' decision-making in accepting compensation for silvopasture. While Gregory et al. (2012) found that social norms do not play a significant role in the adoption of silvopasture, Calle et al. (2009) concluded that the farmer's motivation and knowledge and suitable compensation payment are key factors. Furthermore, both papers agree that although silvopasture is beneficial to the farmers, the adoption decision relies on the perception of the costs and benefits compared to traditional systems. Jerneck and Olsson (2013) and Meijer et al. (2015) both refer to Sub-Saharan farmers' attitudes towards agroforestry practices and their lack of adoption. While Meijer et al. (2015) used the theory of planned behaviour to assess the influences on farmers' reported behaviour, both papers conclude that the social structure and household needs are greater priorities to the farmers compared to the adoption of agroforestry practices.

Although these studies potentially contributed to the implementation of silvopasture practices through a better understanding of the barriers to adoption, they mostly refer to case studies in tropical climates. In Europe, literature about agroforestry practices remained relatively scarce. Notably, Graves et al. (2009) and Graves et al. (2017) respectively analysed farmer perceptions of silvoarable systems throughout Europe and evaluated farmers' views on silvoarable benefits, constraints, and opportunities in England. The practice of silvopasture, however, remained fairly unknown to research, until more recently, García de Jalón et al. (2017), assessed how key stakeholders perceived the development of agroforestry practices in Europe. The paper found that the improvement of the environmental value of agriculture represented the main benefit of agroforestry while, specific to silvopasture, the positive factors concerned animal health and welfare, biodiversity and wildlife habitats and landscape aesthetics. Issues related to increased labour, added administrative burden, higher complexity of work and disease and weed control were seen as the greatest barriers to silvopasture adoption by European farmers. Similarly, the research conducted by Schaffer et al. (2019) discussed the potentials of agroforestry systems such as edible forest gardens, silvopasture and silvoarable systems in Sweden. The authors tested the different forms of agroforestry across 12 Swedish farms. The results obtained by the authors regarding silvopasture revealed a particular interest of the farmers in the practice. However, the experience highlighted some problems related to a lack of knowledge regarding the contributions of such multifunctional pasture systems, inadequate financial evaluations of trees and tree-derived products and insufficient supports from authorities. Additionally, the introduction of trees presented some practical complications such as the difficulty to plant new trees in an area where animals graze without many resources and with high labour costs or the difficulty to prevent fallen fruit from becoming contaminated on the ground. As these agroforestry experiences were conducted without economic incentive, some of the problems highlighted in the paper may be solved through a compensation payment, i.e., the purpose of the present thesis. Nevertheless, the paper captured how complex it can be to implement modern sustainable practices such as silvopasture systems despite the farmers' initial interest.

Consequently, it has especially been found from such studies that a sufficient level of monetary compensation would encourage the development of silvopasture practices, by overcoming the high complexity and investments costs of their implementations. However, only less than a handful of works of literature has tried to empirically assess such economic incentive through contingent valuation methods (e.g., Shrestha and Alavalapati, 2003; Buckley et al., 2012). Shrestha and Alavalapati (2003) assessed cattle rangers' willingness to adopt silvopasture in Florida through a dichotomous contingent valuation. The dichotomous choice experiment consisted of asking rangers to provide a "yes or no" response to a randomly assigned amount and led the authors to find that ranchers would require a direct payment of $9.32 per acre per year. They also found that natural attributes, such as wildlife presence, recreational hunting opportunities, and the presence of creeks increased the probability that ranchers would adopt silvopasture. Equivalently, Buckley et al. (2012) investigated the willingness of farmers in the Republic of Ireland to plant riparian buffer zones on their fields. Out of the 247 farmers surveyed, 53 percent were opposed to the adoption, 40 percent were willing to accept if compensated by a mean price $1.51 per meter per year and 7 percent were willing to accept free of charge. The paper also demonstrates that interference with production, nuisance effects and loss of production in small fields were key obstacles to silvopasture adoption. These two papers also confirm that the use of contingent valuation methods is judicious, not only in valuating environmental services, but specific to the adoption of silvopasture. Yet, the obtained compensation claims outlined above are set in specific settings (i.e., Texan ranch, riparian buffer zones) and omit common attributes found on classic silvopastoral systems.

Similarly supporting the efficiency of contingent valuation methods in environmental projects, the paper by Mäntymaa et al. (2018) additionally lays the foundation of an appropriate theoretical and econometric framework to jointly investigate the adoption decision and compensation claims of an environmental service. More precisely, the paper analysed forest owners' willingness to participate in voluntary forest landscape conservation and the related compensation claims in the Ruka-Kuusamo area, Finland. The authors sensibly introduced the use of Heckman's sample selection model in the context of contingent valuations, in which two models, respectively relating to the program's participation and compensation claims, are consecutively estimated. The methodology used in Mäntymaa et al. (2018) provides the basis for the model used in this thesis.

Accordingly, the contributions of the present thesis to the existing literature on the agroforestry practice of silvopasture in Europe and Sweden particularly, are straightforward. Firstly, silvopasture practices considered here are such that treeless pastures are reforested among cattle production systems that are mostly found in temperate climate. Secondly, the use of the contingent valuation method provides the means to further the knowledge around decision drivers and barriers to silvopasture adoption in Sweden. Especially, to fully understand farmers' perceptions of silvopasture adoption, the theory of planned behaviour (Ajzen, 1991) is included to account for behavioural drivers influencing the decision-making and provide evidence that silvopasture adoption is not only driven by profit maximization. Finally, this thesis also illustrates first estimates in the related compensation claims to silvopasture adoption, such that the preliminary results obtained in this paper can be used for policy recommendations and scaling up possibilities.

4. Conceptual framework

The contingent valuation method is a stated preference technique that involves the use of surveys to elicit the willingness to pay or accept compensation for specific hypothetical goods and services (Hoyos and Mariel, 2010). The name of the method refers to the fact that respondents are to reveal their values, contingent on a hypothetical project or service.

As CVM is deeply rooted in welfare economics and more particularly, in the neoclassical concept of economic value under the framework of individual utility maximization (Hoyos & Mariel, 2010), the indirect utility function of a farmer is defined as the following:

$$V(I(l), Q(l), X), \qquad (1)$$

Where l is the farmer's land uses[2], $I(l)$ captures the farmer's income, i.e., revenues from any kind of market activities, including monetary benefits from land uses, $Q(l)$ represents non-market land uses factors such as environmental factors and X is a vector that accounts for other demographic, social and property characteristics that affect decisions on agricultural practices.

Now considering the adoption of silvopasture, its value relates to the impact that it has on the farmer's welfare, measured in monetary terms. Amongst the Hicksian welfare measures of economic value holding utility constant, the compensating surplus (CS) measures losses relative to the initial utility level (Hicks, 1943). Thus, CS is the change in income that will decrease his/her initial welfare position after adopting silvopasture. This way, the farmer's indirect utility function after adoption can be rephrased in terms of willingness to accept (WTA) silvopasture as the compensating welfare measure (CS):

$$V0(I(l0), Q(l0), X) = V1(I(l1) + WTA, Q(l1), X), \qquad (2)$$

Where WTA is the minimum compensation required by farmers to change from conventional grazing to silvopasture. Here, the hectares of silvopasture are assumed to be perfect substitutes in utility terms with the hectares of conventional grazing such that the farmer doesn't have any interest in having both types of pastures

[2] For simplicity, the farmer, being a cattle producer, is assumed to only manage grazelands. Land uses, therefore, relates to the management and productivity of pastoral systems.

simultaneously. Thus, the adoption of silvopasture simply implies a complete change in land uses from its current pasture $l0$ to silvopasture $l1$. Accordingly, a switch from conventional grazing to silvopasture leads to changes in income, from $I(l0)$ to $I(l1)$ where $\Delta \mathrm{I} = I(l0) - I(l1) \geq 0$ is the income loss from adopting silvopasture, and changes in non-market factors, from $Q(l0)$ to $Q(l1)$ that, although beneficial to e.g., the environment, are external to the farmer.

Farmers are now faced with two options. First, they can choose not to adopt silvopasture and manage their pastures according to their preferred objectives, holding utility at $V0$. Second, they may be willing to accept silvopasture conditional to some compensation. In this case, the selection of silvopasture over conventional grazing implies a sufficient compensation level such that the utility of adopting silvopasture is equal to or greater than the initial utility function:

$$V1(I(l1) + WTA, Q(l1), X) \geq V0(I(l0), Q(l0), X), \qquad (3)$$

The farmer's utility is heterogeneous and determined by various factors. Socio-demographic factors such as age, gender, education, income, etc., as well as farm characteristics such as size, biodiversity, access to nearest city, etc., are considered to be important determinants in contingent valuations (Buckley et al., 2012; Lindhjem & Mitanib, 2012; Mäntymaa et al., 2018; Shrestha and Alavalapati, 2003). Yet, these factors, alone, may not have a sufficiently strong explanatory power in analyzing decision-making for agroforestry innovations (Meijer, 2015). Focusing solely on explaining how the factors relating to property and socio-demographic characteristics that influence decisions would, therefore, ignore other farmers' factors such as social and psychological influences in farmer decision-making.

Hence, to better represent farmer's behaviour towards the adoption of silvopasture, the theory of planned behaviour (TPB), i.e., a socio-psychological model often used in behavioural economics to explain human behaviour, is included (Ajzen, 1991). TPB establishes that the adoption behaviour emanates from the farmer's intention to adopt, which is consecutively determined by three psychological constructs: attitude, subjective norm, and perceived behavioural control (Ajzen, 1991). Capturing both the level of understanding and appreciation of a behaviour, the attitude refers to an individual's positive or negative evaluation of the behaviour while the subjective norm is the individual's perception of the social pressure put upon him/her to perform the behaviour, and finally, the perceived behavioural control relates to the individual's perception of his/her own ability to successfully perform the behaviour (Hansson et al., 2019). As argued by Hansson et al. (2012), studies based on the TPB framework provide deeper insight into farmers' behaviour than other socio-psychological methods to study adoption decisions. Hence, previous applications of TPB have demonstrated its effective use in agriculture, from studies related to organic farming (Läpple and Kelley, 2013) to diversification (Hansson et al., 2012; Senger et al., 2017). The use of the theory of planned behaviour has also been proven to successfully understand farmers' intention to adopt modern sustainable practices (e.g., Borges et al. 2014a). In the following, the behavioural intention that emanates from the psychological constructs will contribute to a deeper understanding of adoption drivers, by using each construct as a variable to adequately capture the farmers behaviour towards their willingness to adopt silvopasture practices. Accordingly, the attitude, subjective norm, and perceived behavioural control, are referred to the possibility to, respectively, describe the farmers' evaluation of adopting silvopasture, measure the importance of the perceived social pressure put upon farmers to adopt silvopasture, and identify the farmers' perceptions about their ability to adopt and implement silvopasture.

Additionally, monetary characteristics of silvopasture such as management costs, alternative sources of income, etc., are also considered. Such factors remain of significance in decision-making and contribute to a balanced representation of farmer's behaviour towards adoption (Howley, 2015). Finally, the farmer's utility depends equally on the compensation payment (WTA) received from adopting silvopasture. Therefore, by rearranging eq. (3) that depicts the decision whether to adopt silvopasture, we obtain the following equation:

$$WTA \geq V0(I(l0), Q(l0), X) - V1(I(l1), Q(l1), X), \qquad (4)$$

Illustrating the condition for the sufficient compensation payment level, eq. (4) shows that the factors that determine the adoption decision also determine the farmer's compensation payment. Although it is possible to use the same factors to explain both the decision to accept silvopasture and the compensation payment, it is more likely that some factors will have deeper impacts on either one of these (Mäntymaa et al., 2018). In fact, it is expected that the intention to adopt, i.e., the attitude, subjective norm, and perceived behavioural control, will have a stronger influence on the decision to adopt silvopasture than on the level of compensation, as demonstrated by Borges et al. (2014a), in which the author found that the presence of various factors in each TPB construct facilitate adoption. Inversely, monetary factors (e.g., income, expectation of economic benefit from silvopasture, etc.) will likely determine the compensation payment more strongly, as suggested in Mäntymaa et al. (2018).

5. Materials and methods

5.1. Contingent valuation method

CVM first originates from a paper by Ciriacy-Wantrup, in which the author assessed the benefits of preventing soil erosion (Ciriacy-Wantrup, 1947), but it is the economist Robert K. Davis that designed and implemented the first contingent valuation survey to elicit the value of hunters and wilderness lovers for a particular recreational area (Davis, 1963). CVM has, since, become one of the most widely used methods for estimating non-use values. This is particularly true for the valuation of ecosystems and environmental services since, without CVM, economists have acknowledged the difficulty to measure the aspects of environmental goods and services (Carson, 2001). Accordingly, numerous CVM studies are related to willingness to pay or accept compensation for conservation programs (e.g., Lindhjem and Mitanib, 2012; Mäntymaa et al, 2018), recreational amenities (e.g., Bateman et al., 2002) or landscape quality (e.g., Cooper et al., 1996). CVM studies are also applicable to the valuation of agroforestry practices, as demonstrated by e.g., Shrestha and Alavalapati (2003) and Buckley et al. (2012). Accordingly, the use of the contingent valuation method is appropriate to elicit farmers' willingness to adopt silvopasture practices.

5.1.1. Survey design

Based on the contingent valuation method, a survey[3] consisting of four sections was designed to collect data. The first section consisted of a brief introduction of the study, including a description of the questionnaire's objective and an explanation of silvopasture and the practice's potential benefits. The description of silvopasture has been purposely made as condensed as necessary since an extensive and detailed explanation of what the practice entails and requires from the producers would have potentially affected and biased the results. The section also contained a reassurance that the survey will not track confidential information, as the responses were anonymous. The second section included natural attribute and socio-demographic questions related to the farm and farmer characteristics. In the third section, the respondents were asked to provide behavioural information concerning their intention to adopt silvopasture. To that end, commonly used statements were utilized to elicit explicitly each of the three psychological constructs, as shown in

[3] The complete English version of the survey can be found in Annexe I.

Table 1 (Senger et al., 2017; Borges et al. 2014a). Finally, in addition to including questions related to monetary characteristics, the fourth section aimed to determine the respondents' willingness to adopt silvopasture and the compensation payment they would claim for converting their current grazelands to pastures with sparse tree cover.

5.1.2. Sample and procedure

The sample frame of 663 cattle producers was derived from an official list with names and contact information of 1500 farmers, which was obtained from the agricultural register administered by Statistics Sweden. The sample was formed by targeting all reachable cattle producers on the list, whether they only manage cattle or cattle paired with other livestock productions and/or land uses, e.g., crops. No selection was made regarding the producers' holdings, as silvopasture is thought feasible on all pasture sizes. Accordingly, the farmers' holdings represented in the sample variated between 0.1 and 100ha. The sample mostly included southern and northern parts of Sweden, reflecting 14 out of the 21 counties of Sweden. More precisely, the counties of Blekinge, Gävleborg, Halland, Jämtland, Norrbotten, Örebro, Skåne, Södermanland, Stockholm, Uppsala, Västerbotten, Västernorrland, Västmanland, and Västra Götaland were included in the sample frame. This geographical selection was purposely made in the context of prior studies included in the LIFT project[4].

The survey was conducted as electronic questionnaires sent out via emails as the use of the Internet in contingent valuation methods do not seem to be significantly different or biased compared to face-to-face interviews (Lindhjem and Navrud, 2011). The survey was implemented in March 2021 and active for 2 weeks. It achieved a response rate of 17%. A total of 30 questionnaires contained significant numbers of missing values and were deleted from the final data. After eliminating the unusable questionnaires, 85 usable responses were left, resulting in an overall adjusted response rate of 12%. This is a bit low compared to other WTA surveys (e.g., Lindhjem & Mitanib, 2012; Mäntymaa et al., 2018). Despite two email reminders, a reason behind the low response rate is notably the use of a single method of contacting the farmers, i.e., through emails.

5.1.3. Elicitation method

An open-ended WTA question asking about the minimum compensation payment was chosen to elicit the respondents' compensation claims. The Open-ended questions format is the simplest of the elicitation methods and consists of asking

[4] Low-Input Farming and Territories (LIFT) is a research project aiming to identify and understand how socio-economic and policy drivers affect the development of ecological approaches to farming and assess the performance and sustainability of such approaches. https://www.lift-h2020.eu

directly the respondents to state freely the minimum compensation value they would require for a hypothetical good or service (Walker and Mondello, 2007). In addition to benefiting from its simplicity, the open-ended method lowers drastically the risks of vehicle biases such as cognitive bias and strategic bias (Schuck, 1995). Additionally, to facilitate the respondents' elicitation task, they were asked to express an amount per hectare and year. The annual payment, being the most common form of compensation in practice, was used over a one-time payment (Lindhjem & Mitanib, 2012). However, as to every elicitation method, there are also some drawbacks to the open-ended WTA format which leads to no simple answer to the question of which elicitation methods to use when establishing contingent valuations (Schuck, 1995). The solution depends on whether the weaknesses are outbalanced by the strengths of the elicitation method, specific to the study in question. In this case, the disadvantages of the open-ended format are mostly characterized by taking the risk to obtain a significant amount of protest answers due to the challenging tasks of coming up with an amount of their own (Bateman et al., 2002; Walker and Mondello, 2007). Such protest answers accounted for 16,47% of the total responses collected from the survey. This percentage is in line with a review of 254 environmental CVM studies in which it has been found that around 18% of the respondents protested (Meyerhoff and Liebe, 2010).

5.2. Exploratory factor analysis

5.2.1. TPB statements

TPB psychological constructs such as attitude, subjective norm and perceived behavioural control can either be elicited by being derived from individual beliefs, respectively, behavioural, normative and control beliefs, or by using statements to assess each construct (Läpple and Kelley, 2013). The second approach was chosen and a total of 13 statements were developed and used as measurement indicators to measure the attitude (5), subjective norm (3) and perceived behavioural control (5), see Table 1.

The statements were formulated based on the wording used in Borges et al. (2014a) and Senger et al. (2017). The measurement of the TPB constructs was made using five-point scale, with one being the most negative answer and five, the most positive one. Five-point scales have been effectively used in other agriculture literature (Hansson et al., 2012; Senger et al., 2017).

Table 1. Statements, scales and descriptive statistics used to measure, attitude (ATT), subjective norm (SN) and perceived behavioural control (PBC).

Statements		Scale (1-5)	Mean	Std. Dev.
ATT1	For you, the adoption of silvopasture is	Extremely bad – extremely good	2.93	.833
ATT2	For you, the adoption of silvopasture is	Not at all – extremely advantageous	2.76	.970
ATT3	For you, the adoption of silvopasture is	Not at all – extremely possible	3.06	1.004
ATT4	For you, the adoption of silvopasture is	Not at all – extremely important	2.53	1.074
ATT5	For you, the adoption of silvopasture is	Not at all – extremely necessary	2.23	.992
SN1	Most people who are important to you think that you should adopt silvopasture.	Strongly disagree – strongly agree	2.25	1.157
SN2	Most people whose opinion you value would approve that you adopt silvopasture.	Strongly disagree – strongly agree	2.19	1.047
SN3	Most farmers like you will eventually adopt silvopasture.	Strongly disagree – strongly agree	2.01	1.018
PBC1	If you want to adopt silvopasture, you have sufficient knowledge.	Strongly disagree – strongly agree	2.28	1.179
PBC2	If you want to adopt silvopasture, you have sufficient resources.	Strongly disagree – strongly agree	2.41	1.058
PBC3	How confident are you that you could overcome barriers that prevent you to adopt silvopasture?	Not at all – extremely confident	2.77	1.034
PBC4	The adoption of silvopasture depends only on you.	Strongly disagree – strongly agree	3.79	1.269
PBC5	The decision to adopt silvopasture is totally under your control.	Strongly disagree – strongly agree	3.57	1.327

The statements were formulated based on the wording used in Borges et al. (2014a) and Senger et al. (2017). The measurement of the TPB constructs was made using five-point scale, with one being the most negative answer and five, the most positive one. Five-point scales have been effectively used in other agriculture literature (Hansson et al., 2012; Senger et al., 2017).

5.2.2. Measurement model

The use of measurement indicators implies a causal relationship between the measures and the underlying latent psychological constructs (Götz et al., 2010). Depending on this causal link, the model can either be reflective or formative (Hansson and Lagerkvist, 2014). Specifically, the reflective measurement model assumes causality going from the latent constructs to the indicators whereas formative measurement model assumes the opposite, i.e., causality going from the indicators to the latent constructs (Hanson et al., 2012; Hansson and Lagerkvist, 2014). Here, because the latent constructs are regarded as causing the measurement indicators, the model is considered reflective.

5.2.3. Type of factor analysis

Following the reflective measurement model, there are two distinct methods to obtain the measurement indicators of the latent psychological constructs, either through exploratory factor analysis or through confirmatory factor analysis

(Hansson et al., 2012). The latter requires knowledge about previous applications of TPB in similar settings since the analysis starts with a hypothesis about how many factors there are, and which items load on which factors (Hurley et al., 1997). Given that the TPB constructs have not been previously used to characterize the behavioural intention to adopt silvopasture practices before, such knowledge on measurements indicators is not available. Meanwhile, the exploratory factor analysis seeks to discover the number of factors and does not specify which factors underlies which items (Hurley et al., 1997). Therefore, because the intent was to identify a latent factor solution (Fabrigar et al., 1999), the analysis in this study is based on exploratory factor analysis.

5.2.4. Analysis

The analysis was conducted with Stata version 13.0. Bartlett's test of sphericity (Bartlett, 1954) was used to ensure that the correlation matrix was not random and the KMO statistic (Kaiser, 1974) was required to be above a minimum of .50. Orthogonal Varimax rotation, being the most common rotational method used in factor analysis, was used to provide uncorrelated factors and easier interpretation of results (Williams et al., 2010). Given the number of respondents, the criteria for determining significant factor loadings was established that pattern coefficients $\geq$ .5 were considered statistically significant. Statements that did not load significantly on any factor were removed from the analysis, one at a time, until significant pattern coefficients remained, as in Hansson et al. (2012). Cronbach's alpha (Cronbach 1951), inter-item correlation and item-to-total correlation were used to report internal consistency of scales (Hair et al., 2010).

5.3. Econometric approach

5.3.1. Heckman two-step model

Based on the conceptual framework outlined above, the Heckman two-step model was used to quantitatively analyze cattle producers' willingness to adopt silvopasture and their respective compensation claims. The fact that only the respondents who were willing to adopt silvopasture revealed their compensation claims in the survey, can consequently lead to selection bias arising when only the outcomes of treated observations are observable (Greene, 2008). Therefore, to control for such selection bias, Heckman's two-step method estimates, in the first step, a correction term, i.e., the inverse Mills ratio, and later uses it as an additional explanatory variable in the second step (Heckman, 1979). Accordingly, in the first step of Heckman's method, also called the selection model, the decision to adopt silvopasture was analyzed with a probit model on independent variables. In the second step, named the outcome model, the compensation claim was regressed using ordinary least squares (OLS) on independent variables and the inverse Mills ratio (Wolfolds and Siegel, 2018). In the following, the selection model and outcome model will respectively be named the adoption model and compensation model. The Heckman two-step model has been previously used and proven successful in contingent valuations, especially in the context of voluntary forest landscape conservation (Mäntymaa et al., 2018).

5.3.2. Variables

The variables employed in Heckman two-step model as well as their definition and descriptive statistics regarding the two models can be seen in Table 2. The dependent variable of the adoption model (Adoption) describes the cattle producer's decision on whether to adopt silvopasture or not. Thus, the dependent variable is defined as Adoption = 0 if the producer does not want to adopt and Adoption = 1 if he or she does. The dependent variable of the compensation model (Claims) is a continuous variable corresponding to the compensation claimed by producers for the adoption of silvopasture. In both models the value of the dependent variable depends on socio-demographic, farm, and monetary characteristics, and on the intention to adopt silvopasture, captured by the theory of planned behaviour psychological constructs, namely, attitude, subjective norm, and perceived behavioural control.

The first set of explanatory variables described socio-demographic characteristics which may play a role in both the dependent determination of a farmer’s adoption and compensation claim.

Most variables included here such as age, gender, education, experience and income are commonly used in standard contingent valuation studies (e.g., Lindhjem and Mitanib, 2012, Borger et al., 2014b). The variables of education (Educ) and experience in the agricultural sector (Exp) work in similar ways. They respectively indicate that producers who have obtained a degree in an agricultural university or have many years of working experience in the field may be better able to understand the benefits of silvopasture and therefore, require lower compensation. Additional dummy variables that specify whether the producer is specialized in dairy or meat products (Dairy) and whether the producer is a member of various farmer (Farmorga) and environmental (Envorga) organizations are included.

Table 2. Variables included in the model, definitions and descriptive statistics

Variables	Definitions	Mean	Std. Dev
Dependent variables			
Adoption model			
Adoption	Dummy variable: decision to adopt silvopasture.	.5238095	
Compensation model			
Claims	Compensation claims for the adoption of silvopasture (SEK/ha/year).	3107.17	2620.395
Independent variables			
Socio-demographic characteristics			
Age	Age of the producer	56.78	11.239
Female	Dummy variable: sex of the producer	.23	
Educ	Categorical variable: education level of the producer	3.02	1.219
Exp	Years of working experience in the agricultural sector	32.75	14.295
Dairy	Dummy variable: type of cattle production	.32	
Inc	Categorical variable: Income before tax of the producer	4.09	1.733
Farmorga	Dummy variable: membership in farming organization	.85	
Envorga	Dummy variable: membership in environmental organization	.13	
Farm characteristics			
Size	Total size of the pastures (ha)	51.77	98.748
Ncity	Distance to the nearest city (km)	61.84	134.017
Cattle	Total number of cattle individuals	104.61	127.513
Organic	Categorical variable: Type of farm certification	1.68	.519
Biod	Categorical variable: On-site richness of the biodiversity	2.28	.758
Evengr	Dummy variable: Topography of the pastures	.19	
Forestcov	Dummy variable: Presence of forest cover on the land	.90	
Vegzone	Categorical variable: Farm glocalization within Sweden's three main vegetation zone	1.51	.722
Envconst	Dummy variable: Presence of environmental constraints	.14	
TPB constructs			
Attitude	Solution factor of the attitude statements	-3.06	.938
Social norm	Solution factor of the social norm statements	2.43	.947
Perceived behavioral control	Solution factor of the perceived behavioral control statements	3.12	.870
Monetary characteristics			
Mgtcosts	Categorical variable: management costs of silvopasture	2.32	.925
Altinc	Categorical variable: alternative income from silvopasture	3.23	.967
Ecobene	Dummy variable: Expected economic benefits from silvopasture	.37	

The second set of variables, farm characteristics, first included the total size of pastures. It is expected that respondents owning large pasture areas may be better able to absorb opportunity costs of converting their grazelands to silvopasture. Thus, in the adoption model the coefficient of Size should have a positive sign but in the compensation model a negative sign (Mäntymaa et al., 2009). Then again, other traditional variables in contingent valuations for ecosystem services (e.g., Lindhjem and Mitanib, 2012) are added such as access to the nearest city (Ncity), the richness of the biodiversity (Biod), the farm's organic certification (Organic), and the farm's location (Vegzone). Finally, farm characteristics that are thought to be more specific to the practice of silvopasture are also included as variables. Excepting the variable that concerns the producer's number of cattle in his holding (Cattle), the topology of the pastures (Evengr), the current forest cover present on the farmland (Forestcov) and the environmental constraints are all dummy variables that, if positive, would increase adoption and lower compensation claims.

The following set of variables consists of the statements summarized by the common factor analysis into three factors, each reflecting one the underlying constructs of attitude, subjective norm, and perceived behavioural control. The more favourable these three constructs are, the stronger the individual's intention to perform the behaviour (Ajzen, 1991) and consequently, the higher the willingness to adopt and the lower the compensation claim.

Finally, the last set of variables describes some monetary characteristics. The first variable of this set asks (Mgtcosts) the respondents if they agree with the statement that silvopasture results in higher management costs. The producer who thinks that the practice means temporary economic losses from switching to silvopasture, will assumably not be willing to adopt silvopasture practices or claim a greater compensation. Inversely, the two next variables that acknowledges the income diversification opportunities (Altinc) and expectation to gain economic benefits (Ecoben) from silvopasture, if favorable, will induce a positive adoption decision and lower compensation claims.

An important condition for the use of Heckman two-step model is that the variables of both models are only partially explained with the same independent variables. Previous literature suggests that the selection model must contain at least one variable unrelated to the dependent variable in the outcome model (e.g., Lalonde, 1986; Greene, 2008). If this condition was not respected, the dependency between the sample of the two models and the dependent variables could cause problems of multicollinearity. Also, the addition of the correction term to the outcome equation may have led to estimation difficulties and unreliable coefficients (Briggs, 2004).

5.3.3. Descriptive statistics

Fifty-two percent of the respondents answered positively towards the adoption of silvopasture practices if given adequate compensation. Of which, 34% of the related compensation claims were removed from the analysis due to inadequate responses and protest answers. This result is similar to Lindhjem and Mitanib (2012), in which the authors obtained 65% of non-zero WTA claims.

From Table 2, it appears that the pastures have an average size of 51.8 ha, supporting an average herd size of 104 cows, and are mostly located in the Boreal vegetation zone (61.9%). The share of farms certified organic is 34.52%. The respondents are predominantly male (77.38%), meat producers (67.85%) and the mean age is 57. The observations from the sample depict a moderately appropriate representation of the average Swedish agricultural holding and holder as the average herd and arable land size are respectively, 89 cows and 41 hectares (Swedish board of agriculture, 2018b). However, the opposite from the observations is true regarding the farm holdings' predominant location, those being mainly condensed towards the south of Sweden (Swedish board of agriculture, 2018b). Concerning the farmers' characteristics, similar results are found to those of the observations. The farmers' average age is high, with 74 % of the agricultural population being older than 50 years (Swedish board of agriculture, 2018b), the female share of self-employed entrepreneurs is 29.16% (Swedish board of Agriculture, 2020) and the dairy production reflects 20% of the total cattle production in Sweden (Swedish board of agriculture, 2018b). Finally, the organic share of farmed land in Sweden is 18%, which is lower than the organic share of the observations (Swedish Board of Agriculture, 2017).

6. Results

6.1. Factor solution

The results of the significant factor loadings can be found in table 3. Similar to Hansson et al. (2012), three factors were kept considering that TPB suggests three latent constructs, respectively, attitude, subjective norms and perceived behavioural control.

Table 3. Significant factor loadings of theory of planned behaviour statements

	Statements	Factor 1 *Attitude*	Factor 2 *Subjective norm*	Factor 3 *Perceived behavioural control*
ATT1	For you, the adoption of silvopasture is good.	0.8411		
ATT2	For you, the adoption of silvopasture is advantageous.	0.8625		
ATT3	For you, the adoption of silvopasture is possible.	0.6440		
ATT4	For you, the adoption of silvopasture is important.	0.7511		
ATT5	For you, the adoption of silvopasture is necessary.	0.6119		
SN1	Most people who are important to you think that you should adopt silvopasture.		0.8247	
SN2	Most people whose opinion you value would approve that you adopt silvopasture.		0.8766	
SN3	Most farmers like you will eventually adopt silvopasture.		0.7043	
PBC3	How confident are you that you could overcome barriers that prevent you to adopt silvopasture?		0.5521	
PBC4	The adoption of silvopasture depends only on you.			0.8053
PBC5	The decision to adopt silvopasture is totally under your control.			0.7987

Range of item-to-total correlations	0.7964 - 0.9142	0.7249 - 0.9137	.
Range of item-to-item correlations	0.6829 - 0.8601	0.5239 - 0.8290	0.7255 (avg)
Cronbach’s alpha	0.9169	0.8633	0.8409

Two statements, i.e., PBC1 and PBC2, did not load significantly on any factor and were therefore excluded from the final analysis. PBC3, stating the confidence of the respondents to overcome barriers preventing the adoption of silvopasture, did not load significantly on the factor relating the perceived behavioural control but, surprisingly, loaded significantly on factor 2, labelled subjective norm. A hypothetical explanation may either be that barriers to adoption can be associated with the producer’s social network or that their social network can help them in overcoming such barriers.

The results of Bartlett’s test of sphericity indicated that the correlation matrix was not random, Chi-square of 693.623, $p < .001$, and the KMO statistic was .8092, therefore, determining that the correlation matrix was appropriate for factor analysis. Item-to-total correlations, as well as item-to-item correlations, were all well above the cut-off value of 0.5 and all Cronbach’s alpha values were above the cut-off value of 0.7 (Hair et al., 2010). Taken together, these indicators suggest that the measurement scales obtained are reliable.

6.2. Regression results

6.2.1. Participation and compensation model

Both the cattle producer adoption and compensation model are presented in Table 4. The compensation model is a reduced model where it is assumed to be a function of *Experience, Size Nearest city, Management costs, Alternative income, Dairy, Even grounds, Economic benefits, Education and Income* whereas the likelihood of adoption is a function of *Sex, Farming organization, Environmental organization, Forest cover, Environmental constraints, Biodiversity, Organic, Vegetation zone, Attitude, Subjective norm, Perceived behavioural control* and implicitly, compensation claims via the inclusion of the variables that are taught to determine compensation claims[5]. The coefficient of inverse mills ratio is reported as λ. It is insignificant with t-value = -0.24. That means, in this case, that selection bias is not a significant issue. Another signal for minor selection bias is the correlation coefficient rho = -0.12549, being close to zero.

[5] Age and Cattle have been purposely dropped to reduce the number of missing values and accordingly, drastically increase the number of observations.

As in the case of many WTA studies, only few variables are statistically significant (Lindhjem and Mitanib, 2012). This is especially due to the difficult task of coming up with a compensation claim. Nevertheless, in the adoption model, several variables were significant in explaining cattle producer's decisions to adopt silvopasture. First, in line with the expected sign, the variable *Management costs* is negative and significant. This means that if a cattle producer thinks that silvopasture practices will result in high management costs, he or she will be less inclined to adopt. Notably, the estimates of *Alternative income* and *Economic benefits* are not significant, indicating that the joint assumption of gaining economic benefits from diversified sources of income from silvopasture was not important to the respondents when considering the decision to adopt.

The socio-demographic variables *Sex* and *Education* were both found statistically significant. The negative sign of the *Sex* coefficient shows that women have a lower probability of silvopasture adoption while the positive sign of the *Education* estimate illustrates that the higher the level of education, the higher the probability to adopt silvopasture practices. The other cattle producer characteristics, as well as all farm characteristics, are not significant regarding the adoption decision.

Table 4. Regression results

	Compensation model			Adoption model		
	Coef.	z-score	95% CI	Coef.	z-score	95% CI
Experience	-3.615	(-0.19)	(-41.15, 33.92)	-0.0115	(-0.66)	(-.045, .022)
Size	-6.469*	(-2.03)	(-12.7, -.24)	-0.00103	(-0.48)	(-.005, .003)
Nearest city	12.02***	(8.03)	(9.09, 14.95)	-0.000387	(-0.28)	(-.003, .002)
Management costs	-538.3	(-1.52)	(-1230.95, 154.31)	-0.641*	(-2.06)	(-1.25, -.032)
Alternative income	-857.8*	(-2.18)	(-1629.66, -86.01)	0.167	(0.51)	(-.473, .808)
Dairy	-97.13	(-0.19)	(-1080.51, 886.26)	0.128	(0.23)	(-.958, 1.21)
Even grounds	659.7	(0.94)	(-720.74, 2040.14)	0.0227	(0.03)	(-1.35, 1.39)
Economic benefits	-497.2	(-0.82)	(-1680.9, 686.5)	0.125	(0.25)	(-.86, 1.11)
Education	720.3**	(3.01)	(250.62, 1189.99)	0.472*	(2.38)	(.083, .862)
Income	311.7*	(2.38)	(55.13, 568.32)	0.202	(1.58)	(-.049, .453)
Sex				-1.880*	(-2.09)	(-3.65, -.113)
Farming organisation				0.665	(0.99)	(-.654, 1.98)
Environmental organisation				0.485	(0.65)	(-.984, 1.95)
Forest cover				0.106	(0.10)	(-2.08, 2.29)
Environmental constraints				-0.353	(-0.57)	(-1.56, .855)
Biodiversity				-0.0969	(-0.34)	(-.65, .456)
Organic				0.534	(0.97)	(-.548, 1.61)
Vegetation zone				0.183	(0.47)	(-.575, .942)
Attitude				1.309**	(-3.23)	(.514, 2.10)
Subjective norm				0.222	(-0.90)	(-.263, .707)
Perceived behavioural control				-0.585	(1.52)	(-1.34, .169)
Constant	2974.7	(1.31)	(-1470.87, 7420.19)	-2.911	(-1.19)	(-7.69, 1.87)
mills (lambda)	-134.7	(-0.24)	(-1246.82, 977.35)			
Rho:	-0.12549					
Sigma	1073.6137					
χ^2 (10) = 134.03, p < 0.0001						

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

Finally, the estimate of *Attitude*, illustrating the attitude construct, is found to be positive and significant. Accordingly, the more positive one value and perceive silvopasture practices, the more likely it is that he or she will decide favourably on the adoption. This result is in line with previous studies such as Meijer et al. (2015), in which the authors showed that attitudes had a significant positive influence on smallholder farmers' behaviour towards tree planting. Similar to Gregory et al. (2009), the estimates of the factors reflecting the constructs of subjective norm and perceived behavioural control were not significant, showing that the pressure of others and on him/herself to adequately adopt and manage silvopasture practices are unimportant to the respondents.

Regarding the second stage of the Heckman approach, the compensation model shows a negative and significant relationship with the total size of the pasture (*Size*), i.e., larger pasture areas give lower compensation claims. Following Lindhjem and

Mitanib (2012), it can be ambiguous to estimate how size would affect WTA from theory, but as expected, one potential reason could be that the respondents owning large pasture areas may be better able to absorb the opportunity costs of converting their grasslands to silvopasture. A second farm characteristic, *Nearest city*, is proven to be significant. Because this is a log-level model, we can interpret the coefficient of *Nearest city* as follows: an increase of one kilometer in the distance from the farm to the nearest city tends to increase claims by SEK12/ha/year.

Similar to the adoption model, the Educ variable is positively significant. This means that a higher level of education, in addition to increasing the probability of silvopasture adoption, will also increase the related compensation claims. Also concerning producer characteristics, the positive and significant *Income* estimate shows that those who earn more income will claim SEK 312 more compensation annually for each hectare.

Finally, only the negative estimate of *Alternative income* variable out of the monetary characteristics is found significant, implying that the respondents who expect to increase their sources of income after adoption of silvopasture, will demand an annual compensation claim that is SEK 858 lower per hectare than the rest of the respondents.

6.2.2. Mean compensation claim and contextualization

Based on Mäntymaa et al. (2019), Constant shows the average reference compensation payment that is not captured by the other explanatory variables, specifically the annual monetary amount of SEK 2,975 per hectare, claimed by the producers to adopt silvopasture practices, as seen in Table 4. However, as this coefficient is not found to be statistically significant, the calculated mean compensation claim is a preferred estimate. Accordingly, the mean compensation claim is SEK 3,107.17 per year and hectare.

To assess whether this amount would be cost-efficient for the Swedish government (or any other actor) to compensate farmers who adopt silvopasture practices and, consequently, to mitigate the increase of both GHG emissions and biodiversity loss from cattle production, the results from the survey can be contextualized and investigated more deeply. Accordingly, the implementation of silvopasture on the respondents' cumulative pasture size of 1,641.00 hectares (approximately five times the size of Central Park) would imply a total compensation claim of SEK 4,442,350 per year. Meanwhile, for the target set by the Riksdag to be achieved, that Sweden will have net zero greenhouse gas emissions by 2045, support for climate investments have recently been improved (Government offices of Sweden, 2020a). Notably, the budget allocated by the Swedish government for 2021 to reduce climate emissions, increase investments to protect natural areas and develop measures for the protection of valuable natural environment are respectively SEK 1,88, 1,59 and 0,6 billion (Government offices of Sweden, 2020a). Based on the significant carbon sequestration capacity and increased biodiversity potential of silvopasture systems, such compensation payments are therefore justified. This is especially true since, for comparison, a compensation payment targeting the same environmental objectives as silvopasture to enrol forest ecosystems in habitat protection area and nature reserve in Sweden is 12,500 Euros/ha (depending on type of forest) (Thomasson, 2011).

7. Discussion

7.1. Decision drivers

As mentioned previously, only few variables are found statistically significant, similarly to many WTA studies (Lindhjem and Mitanib, 2012). Although some farm-related variables have significant influence in the compensation model (i.e., *Size*, *Nearest city*), none were found statistically significant in the adoption model. Such characteristics would have provided greater knowledge for strategic planning and sustainable development of silvopasture practices across Sweden (Hansson et al., 2019). Additionally, like previous literature, the effects of the socio-demographic factors were found to be mixed while the level of education appeared to have a consistent positive influence on both models (Mozzato et al., 2018; Lastra-Bravo et al., 2015; Tey and Brindal, 2012; Liu et al., 2018). Moreover, the results outlined above suggest that the use of the TPB was judicious in explaining how underlying psychological constructs influence farmers in their decisions to adopt silvopasture practices, with the attitude construct showing significant estimates. The fact that attitude is the only psychological construct of the TPB to be statistically significant in the present paper is not surprising. The attitudinal construct is often considered to have the most significant influence in decision making (e.g., Hansson and Lagerkvist, 2014; Meijer et al., 2015). This is notably true because the attitude construct, as such, captures the individual's understanding of the value of silvopasture practices and the individual's level of appreciation of it. Still, the subjective norm and perceived behavioural control constructs, not being statistically significant, bring valuable information in that cattle producers do not feel their peers' pressure and their ability to adopt silvopasture practices as decision drivers, therefore confirming the results previously found by Gregory et al. (2009). Consequently, even with a significant influence of a monetary characteristic (*Management costs)* on adoption, the significant attitudinal construct brings empirical evidence that decision making regarding silvopasture among Swedish cattle producers is not purely driven by profit maximization.

7.2. Scaling up possibilities

The survey analysis suggests that the majority of the respondents are motivated to adopt silvopasture, despite the lack of knowledge surrounding the practice. This implies that the potential of trees to mitigate emissions and protect and enhance the biodiversity-related to pasture landscapes is consistent with the reasons they own and manage agricultural land (Kline et al., 2000). Perhaps silvopasture implementation of at least a portion of cattle producers in Sweden could thus be feasible through relatively low-cost training programs to provide technical assistance and education. Similarly, García de Jalón et al. (2017) argue that education is necessary not only to promote novel agroforestry practices, but farmers' environmental awareness too. Further, demonstration sites are similarly important in introducing farmers to real life applications of agroforestry systems (García de Jalón et al., 2017).

For silvopasture to become a more widespread approach, however, changes must also be made at the regime level (Schaffer et al., 2019). These changes present policy makers with an opportunity to achieve targeted environmental objectives in Sweden, such as those set by the Riksdag or through Sweden's long-term strategy for reducing greenhouse gas emissions of the Paris Agreement (Government offices of Sweden, 2020b). Yet, for policies to be effective in this particular case, they must focus on the interests of cattle producers. Including farmers' economic objectives to silvopasture implementation may yield greater acceptance and greater cooperation in the adoption process, notably by establishing ways to generate as much revenue during the costly period of transition to silvopasture systems. Accordingly, policies providing economic incentives, such as tax relief, cost sharing and particularly, governmental expenditure, are required to induce silvopasture adoption of a greater proportion of Swedish cattle producers (Kline et al., 2000). Indeed, because it is the non-market characteristic of the many environmental benefits of silvopasture practices that has mainly led to the current sub-optimal situation in silvopasture and agroforestry adoption (Shrestha et Alavalapati, 2003; García de Jalón et al., 2017), there is primarily a necessity for the government to compensate farmers who adopt silvopasture practices for the environmental and social benefits that they provide. Hence, allocating a budget for agroforestry practices and designing an appropriate direct payments scheme to enhance implementation especially requires prior information about the expected costs of silvopasture implementation. Consequently, the mean compensation claim of SEK 3107.167 per year per hectare obtained in the present thesis brings valuable information. Additionally, the government may especially save some costs by targeting large pasture holdings and farms closest to cities first since such "price discrimination" may be acceptable in a rural policy perspective, as argued by Lindhjem and Mitanib (2012).

However, the requirement to compensate cattle producers who adopt silvopasture practices may not only fall under the responsibility of the Swedish government. In fact, a direct payment scheme being notably very similar to a conservation program, can also be implemented through existing institutions (Shrestha et Alavalapati, 2003), such as the European Union (EU). Since Sweden has entered the EU in 1995, Sweden has taken part in the CAP and decided on 16 national environmental objectives. Among these, a Varied Agricultural Landscape and a Rich Diversity of Plant and Animal Life are of relevance to silvopasture practices. The former objective state the importance of meadows and pastures, the conservation of natural and cultural environments and the preservation and strengthening of biodiversity while the latter encourage favourable preservation of natural habitats and species, the protection of endangered species, and the maintaining of a sufficient genetic diversity inside and between populations. According to these two environmental objectives, silvopasture in Sweden can thus be eligible to take part in the agri-environmental scheme from the EU and beneficiate from the CAP's direct payments scheme.

7.3. Limitations

The choice of the contingent valuation method to estimate economic values for environmental services is evident since, without CVM, economists have acknowledged the difficulty to measure their non-market characteristics (Carson, 2001). By its great flexibility, CVM allows the valuation of a wide variety of non-market environmental goods and services, silvopasture practices included. In fact, CVM successfully circumvented the absence of markets for the many environmental benefits of silvopasture by presenting producers with the opportunity to state their values for its implementation. Accordingly, the method provided interesting results and adequate answers to the research questions. However, CVM still faces some limitations. The fact that the method is based on directly asking the agents to reveal their values, as opposed to observing their actual behaviour, as in the revealed preferences methods, represents the main criticism. The paper by Breidert et al. (2006) additionally argues that the hypothetical market setting and the complexity for respondents to reveal their true preferences and consequently, their true economic values, can hinder the reliability of the results. Other limitations about the CVM includes the potential disregard of important information in the surveys (Fischhoff and Furby, 1988), and the influence of strategic behaviour, cognitive and contextual biases on the results (Carson, 2001; Brown and Slovic, 1988).

Such limitations imply that the results of the present thesis may need to be interpreted with caution but can equally turn out useful if taken as recommendations for future research. Accordingly, regarding the question whether the CVM was able to capture cattle producers' true preferences and compensation claims, it is true that the difficult task for respondents of revealing their claims may have affected the reliability of the results. Similarly, the potential presence of strategic biases implies that it is a possibility that some respondents may have answered strategically, e.g., by inflating their compensation claims. Hence, it is judicious for future research to employ different elicitation methods (e.g., the payment card elicitation method) with the intention to examine and compare the reliability and robustness of the results obtained from using the open-ended format.

Additionally, the sample frame, being based on a subset of a larger dataset and additionally reduced by protest answers and omitted variables, yielded a lower number of observations than expected. Hence, despite a relatively good fitness of the observations compared to the population, the results could not be directly extended to the whole population of cattle producers in Sweden, nor could the results be as robust as in the case with many observations. Consequently, the yielded results depict more of an illustration of what silvopasture means in terms of WTA and compensation claims rather than absolute values, although it has been found by Austin and Steyerberg (2015) that two subjects per variable tend to permit accurate estimation of regression coefficients in a linear regression model estimated using OLS. For future research, nonetheless, it can be necessary to increase the size of the sample frame such that deeper conclusions can be drawn from the results.

Moreover, although TPB constructs are included in the model to account for behavioural drivers as well as other property, socio-demographic and monetary characteristics to account for a complete identification of the potential determinants to adoption, other drivers may have been omitted in the models. Hence, further studies could test for other variables affecting silvopasture adoption and compensation claims in Swedish cattle productions.

Finally, this thesis represents the respondents' intention to adopt silvopasture practices, conditional to compensation claims, rather than the actual behaviour of adoption. Therefore, the compensation claims obtained in this study may be different than what could be observed. The potential presence of such hypothetical bias could be thus interesting to investigate for future research.

8. Conclusion

The Swedish cattle production systems are currently a major contributor to GHG emissions and biodiversity loss in Sweden since pastures both occupy an ever-growing proportion of all habitable land area and become increasingly specialized and intensive. However, if those same cattle production systems converted to regenerative and sustainable production methods such as the practice of silvopasture, they have the potential to become a key part of the solution.

Accordingly, the main purpose of this paper was to investigate the willingness to adopt silvopasture practices and the related compensation claims using a contingent valuation method among cattle producers in Sweden and second, to assess decision drivers and how policy making can help increase silvopasture implementation in Sweden. This study further uses the TPB to explain how underlying psychological constructs influence cattle producers in their decisions to adopt silvopasture practices.

The analysis concluded that 52% of the surveyed producers are willing to adopt silvopasture practices and that the related mean compensation claim is SEK 3107.167 per year and per hectare. Moreover, the results indicate that, in addition to socio-demographic and monetary characteristics, respectfully *Education*, *Gender* and *Management costs*, the results demonstrate that the underlying psychological constructs suggested by TPB play a significant role in farmers' adoption decision, with the *Attitude* construct being statistically significant. Consequently, this provides empirical evidence that the producers' decision making regarding silvopasture adoption is not only driven by profit-maximization since the farmers' understanding and appreciation level towards silvopasture practices are of significant influence. Concerning the factors influencing the related compensation claims, the results show that the farm-related characteristics of *Size* and *Nearest city*, the socio-demographics characteristics of *Education* and *Income* and the monetary characteristics of *Alternative income* are statistically significant.

However, the paper's limitations imply that the above results need not be taken as absolute values, but rather as an illustration of what silvopasture currently implies in terms of WTA levels and compensation payments. Accordingly, the limitations can be used as recommendations for further research. Notably, due to the difficult task of coming up with a compensation amount, it could be judicious to employ different elicitation methods with the intention to examine and compare the reliability and robustness of the results from using the open-ended format.

Additionally, given the low response rate from farmers, it is necessary to increase the size of the sample frame.

Nevertheless, the obtained preliminary estimates can still be used for discussing scaling up possibilities of silvopasture practices in Sweden such that training programs, governmental expenditure, as well as increased recognition of silvopasture in the CAP and its direct payments scheme, are necessary to increase silvopasture implementation in Sweden, respectively by enhancing knowledge around silvopasture practices and internalizing the non-market benefits of silvopasture.

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Appendix 1 – Questionnaire (English)

Start of Block: Description

Hi!

Thank you for agreeing to take part in this survey. The survey is being conducted for the purpose of a master's thesis carried out at the Swedish University of Agricultural Science (SLU).

The purpose of the study is to assess the willingness of Swedish cattle producers to adopt silvopasture and specifically, the minimum compensation payment required for the adoption of such practice.

Silvopasture is an agroforestry practice that combines forage and trees into a single integrated system for raising livestock. By adding trees to pastures, silvopasture offers many potential benefits to both the farmer and the environment. Particularly, potential environmental benefits include the improvement of the following: the carbon dioxide sequestration capacity, the soil and water quality, and the wildlife and biodiversity. Potential financial benefits may result from an improvement in animal welfare, a diversification of the production to forestry products, such as nuts, fruits, and mushrooms, and overall greater insulation from risk.

The survey contains 35 questions and should take approximately 10 minutes to answer all questions.

The information in the questionnaire will be treated confidentially and will be used for scientific research purposes only. The responses provided will not be linked to individual names or addresses. The information will only be presented in an overall way to ensure that no person can be traced back to individual responses.

Thank you very much in advance for taking the time to answer the survey!

Sincerely,
Harold Opdenbosch
Student at the Department of Economics, SLU.

If you have any questions, please feel welcome to contact Harold Opdenbosch by email: haop0001@stud.slu.se or Helena Hansson: Helena.Hansson@slu.se.

Start of Block: Questions related to the farmer characteristics

Q1 Which year were you born?

Q2 What is your gender?

- Female
- Male
- Prefer not to say

Q3 What is your level of education?

- Primary school
- High school
- Agricultural high school
- University
- Agricultural university

Q4 How many years of working experience in the agricultural sector do you have?

Q5 What do you produce?

- Meat
- Dairy

Q6 What is your current annual income (before tax)?

- Less than SEK 100,000
- SEK 100,000 - SEK 199,999
- SEK 200,000 - SEK 299,999
- SEK 300,000 - SEK 399,999
- SEK 400,000 - SEK 499,999
- SEK 500,000 - SEK599,999
- SEK 600,000 - SEK 699,999
- SEK 700,000 - SEK 799,999
- SEK 800,000 - SEK 899,999
- SEK 900,000 - SEK 999,999
- SEK 1,000,000 - SEK 1,499,999
- More than SEK 1,500,000
- Prefer not to say

Q7 Are you a member of any farming organization? If so, which one(s)?

Q8 Are you a member of any environmental organization? If so, which one(s)?

Start of Block: Questions related to the farm characteristics

Q9 How many hectares of pasture do you have in total?

Q10 How far is the nearest city from your farm? (in Kilometers)

Q11 How many cattle individuals do you have?

Q12 Is your farm certified organic?

- Yes
- No
- Under transition

Q13 How rich is the wildlife and biodiversity on your farm?

- 1 - Extremely rich
- 2
- 3
- 4
- 5 - Not at all rich

Q14 Are your pastures situated on even/flat grounds?

- Yes
- No

Q15 Does a forest cover currently exists on your farm?

- Yes
- No

Q16 In which kommun is your farm located in Sweden?

Q17 Does your land currently suffer from environmental constraints such as drought, soil erosion, pollution, etc.?

- Yes
- No

Start of Block: Questions related to the attitude towards the adoption of silvopasture

Q18 For you, the adoption of silvopasture is:

- 1 - Extremely good
- 2
- 3
- 4
- 5 - Extremely bad

Q19 For you, the adoption of silvopasture is:

- 1 - Extremely advantageous
- 2
- 3
- 4
- 5 - Not at all advantageous

Q21 For you, the adoption of silvopasture is:

- 1 - Extremely possible
- 2
- 3
- 4
- 5 - Not at all possible

Q21 For you, the adoption of silvopasture is:

- 1 - Extremely important
- 2
- 3
- 4
- 5 - Not at all important

Q22 For you, the adoption of silvopasture is:

- 1 - Extremely necessary
- 2
- 3
- 4
- 5 - Not at all necessary

Start of Block: Questions related to the subjective norm

Q23 Most people who are important to you think that you should adopt silvopasture.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q24 Most people whose opinion you value would approve that you adopt silvopasture.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q25 Most farmers like you will eventually adopt silvopasture.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Start of Block: Questions related to the perceived behavioral control

Q26 If you want to adopt silvopasture, you have sufficient knowledge.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q27 If you want to adopt silvopasture, you have sufficient resources.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q28 How confident are you that you could overcome barriers that prevent you to adopt silvopasture?

- 1 - Extremely confident
- 2
- 3
- 4
- 5 - Extremely unconfident

Q29 The adoption of silvopasture depends only on you.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q30 The decision to adopt silvopasture is totally under your control.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Start of Block: Questions related to monetary characteristics

Q31 Silvopasture results in higher management costs (e.g., learning, maintenance costs).

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q32 Silvopasture offers alternative sources of income.

- 1 - Strongly agree
- 2
- 3
- 4
- 5 - Strongly disagree

Q33 Do you expect to gain economic benefits from silvopasture.

- Yes
- No

Start of Block: Questions related to the willingness to accept silvopasture

Q34 Are you willing to adopt silvopasture conditional to some compensation payment?

- Yes
- No

Q35 If you answered yes at the previous question (Q34), what is the compensation amount you would require to adopt silvopasture?
