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Feasibility of Landscape Value Trade between Landowners and Citizens in Reducing the Landscape Damage Caused by Wind Power

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ABSTRACT

A mechanism of payment for ecosystem services (PES) to implement landscape value trade may partly address the visual disturbance caused by wind turbines by encouraging forest owners to change their forest management practices near housing areas close to wind farms. Here, we analyze the feasibility of implementing this mechanism in the case of landscape shields reducing the visual impacts of wind power using previous results and data on citizen and forest owner preferences. We evaluate the feasibility at various spatial scales. The results demonstrate that at the county level, willingness to pay (WTP) exceeds willingness to accept (WTA) compensation. Finally, if a PES mechanism is site-specific, its feasibility depends on how the demand for and supply of the service meet at the narrowest geographical level. In our study, the probability of agreement was low at the wind farm level (2%) but higher at the landscape shield level (41%).

Keywords: payments for ecosystem services; harmful effects of wind turbines; forest landscapes; landscape value trade; willingness to pay; willingness to accept, feasibility of a PES mechanism

JEL Codes: Q21, Q23, Q42, Q51

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1 Introduction

Payment for ecosystem services (PES) is a market-based approach to finance environmental improvements. PES is based on two principles: those who benefit from environmental services should pay for such services and those who contribute to generating these services should be compensated for providing them (Wunder, 2005; Pagiola and Platais, 2006; Engel *et al.*, 2008; Whittington and Pagiola, 2012). PES programs have the potential to be efficient, as they conserve ecosystem services whose benefits exceed the cost of providing them and do not conserve services when the opposite is true. In this study, we analyze the feasibility of implementing PES in the case of landscape values related to the visual effects of wind power.

The strong increase in the number of wind farms in different parts of the world has created new environmental challenges that might at least partly be solved by applying PES. The effects of wind turbines may be perceived to cause harm at the local level (Groothuis *et al.*, 2008). Tall wind turbines near homes, vacation homes, or outdoor recreation areas are often seen as visually disturbing (Konstantinidis and Botsaris, 2016; Zerrahn, 2017). The shadows from the towers or the shadow flicker of the turbine blades may disturb people. Mäntymaa *et al.* (2021) and Mäntymaa *et al.* (2023) have suggested a type of PES, landscape value trade (LVT), as a solution for the scenic problems caused by wind power. Introducing the mechanism of LVT could encourage forest owners to change their forest management practices near housing areas close to wind farms to minimize the harmful effects (Mäntymaa *et al.*, 2021), while residents might be interested in buying the landscape services (Mäntymaa *et al.*, 2023). Mäntymaa *et al.* (2021) and Mäntymaa *et al.* (2023) have illustrated how the economic valuation of environmental change can be used to assess the willingness of landowners or residents to participate in a PES program. By providing estimates of willingness to pay (WTP) for using the services and willingness to accept (WTA) compensation to provide them, valuation studies can help determine whether a PES agreement can be expected. Valuation can show whether the PES program would improve welfare and reassure policy makers that PES is a potential tool to solve environmental challenges (Whittington and Pagiola, 2012).

Although there have been previous studies on LVT, they have mostly considered the interest of landowners (Tyrväinen *et al.*, 2021) or citizens (Mäntymaa *et al.*, 2018) separately. By applying a PES mechanism in a nature tourism area in northern Finland, Mäntymaa *et al.* (2018) and Tyrväinen *et al.* (2014) analyzed the potential demand and WTP of visitors and Tyrväinen *et al.* (2021) the potential supply and WTA compensation of forest owners to maintain the landscape. Although the data sets were collected at the same time in the same area, the studies did not compare WTP and WTA and did not assess the feasibility of the mechanism in detail in the area. Grammatikopoulou *et al.* (2013) analyzed whether these interests match concerning the agricultural landscape, but only provided relative information regarding the compensation demand of landowners, i.e., compensation compared to their expenses (more, equal, less). Beyond landscape values, Barr and Mourato (2009) assessed the potential for PES in the marine environment by assessing fishermen's WTA for alternative employment outside of the fishing sector, compensated by the marine-based tourism sector's WTP in Espíritu Santo Marine Park, Mexico. Xuan and Sandorf (2020) elicited the public's WTP to reduce the environmental impact of conventional shrimp aquaculture on the Vietnamese coast and, using a credit subsidy as a payment vehicle, elicited farmers' WTA to invest in high-tech production methods to reduce the impact. However, apart from these few examples, studies on PES have focused on assessing the potential for PES schemes mostly through either examining WTP for an environmental improvement or WTA compensation for implementing the improvement. Rarely have both sides of a policy been considered in the same study.

We extend the collection of feasibility studies to a land use-based application focusing on landscape services. The participants in the PES application are residents and landowners in wind power-oriented counties of southwest Finland. To ease the implementation of wind power plans, there is a clear need to investigate the opportunities for LVT by analyzing the match of forest owners' compensation requests with residents' WTP.

The previous studies by Mäntymaa *et al.* (2021) and Mäntymaa *et al.* (2023) and the available data sets from these studies concerning the preferences of forest owners and citizens provide an excellent opportunity to evaluate LVT. In the case of LVT with respect to wind farms, the spatial setting of the PES scheme, as well as that of the survey, is more complex than in previous evaluations by Barr and Mourato (2009) and Xuan and Sandorf (2020), who conducted their analyses at only one level, namely the regional level. The feasibility of LVT can be analyzed at several spatial levels: county, municipal, wind farm, or landscape shield. Analyses at the wind farm and landscape shield levels utilize detailed spatial information on the actual prerequisites of LVT. The analyses take advantage of GIS databases providing information on forest characteristics, housing areas, and land ownership.

The aim of this study is to evaluate the feasibility of the PES mechanism in LVT regarding wind power, both operating and planned. We first compare landowner WTA and citizen WTP at the aggregate level in the two counties. We then proceed to a more detailed spatial analysis, i.e., to the levels of municipalities, wind farms, and landscape shields, and define where and under what conditions LVT may take place if local forest characteristics are taken into account. We are unaware of any previous studies in which the feasibility of a PES mechanism has been analyzed as comprehensively as in this study. Finally, we discuss the prerequisites of LVT and summarize its feasibility in the case of wind power.

2 Previous Literature: Characteristics of a PES Scheme

We define PES narrowly as a voluntary transaction of a well-defined ecosystem service (ES) between service users and service providers that is conditional on agreed rules of natural resource management (Wunder, 2015; Wunder, 2005). PES is especially applicable in the case of externality-driven ES. A defining feature of PES is conditionality: the principle of reducing or stopping payments when ES are not being adequately provided. PES thus represents a voluntary, contractual approach, where ES providers choose whether to join a PES scheme, but ES users or funders in principle only pay for what they get (Angelsen, 2017).

The literature distinguishes between several types of PES (Smith *et al.*, 2013; Grammatikopoulou *et al.*, 2013; Grima *et al.*, 2016; Sattler *et al.*, 2013). PES can be defined according to the type of good or service provision, for example trade of landscape values. It can also be defined based on the type of the actors. For example, buyers can be private or public, implying a user-financed or government-financed program. Furthermore, PES can be classified according to the type of payment, e.g., flexible payments instead of fixed predefined payments. The associated financing arrangement can be customer-charged instead of tax-based payments.

The characteristics of PES define the efficiency of the program. User-financed PES programs are expected to be more efficient than government-financed ones if the conditions of the Coase theorem are met, i.e., property rights are clearly defined and transaction costs are low (Coase, 1960). Markets will ensure the efficient management of resources. As Coase would propose, if property rights are defined, the user of externality and the landowner will negotiate (Coasean bargaining) and will find the most efficient market solution. Thus, "…an arrangement of [property] rights will only be undertaken when the increase in the value of production resulting from the rearrangement is greater than the costs that would be involved in bringing it about" (Coase, 1960: 15–16).

However, if these conditions are not met (Engel *et al.*, 2008), there will be incentives for free-riding behavior. For example, if the number of heterogeneous beneficiaries increases, the mechanism's effectiveness may be imperiled by high transaction costs and further free-riding behavior (Hackl *et al.*, 2007). Local user-financed PES schemes are likely to be efficiently targeted if a small number of actors with a high level of information about the service and its value are directly involved. Free-riding behavior can be eliminated due to strong social ties and social pressure when actions can be easily monitored and judged (e.g., Grammatikopoulou *et al.*, 2013). Transaction costs are highest when many smallholders and multiple PES actors are involved, when institutions and property rights are weak, and when the costs of obtaining baseline information and of monitoring land use and service provision are high (Wunder, 2007).

The level of the payment is crucial for a PES scheme to be socially efficient. Payments should be sufficient to stimulate the adoption of practices, but at a level that it would not exceed the value of services/benefits. To ensure that a landowner participates, the compensation should be higher than the landowner's participation cost. The participation cost accounts for the forgone income from alternative land uses, as well as the transaction and protection costs (Wünscher *et al.*, 2008). The cost will differ among heterogeneous landowners and be dependent on individual aspects such as the area of land, land use, infrastructure, and the landowner's socio-demographic characteristics. To meet the cost-efficiency criterion, compensation payments should also be spatially heterogeneous (Wätzold and Drechsler, 2005).

Scales in space and time must be taken into consideration when planning or evaluating a PES implementation, since they influence the efficiency of targeting and outcome (Kinzig *et al.*, 2011; Sattler *et al.*, 2013). Kaiser *et al.* (2021) argue that the scale at which PES operates has so far received very little attention in the literature. However, spatial scales play a crucial role in science-advised policy planning and actions Gibson *et al.* (2000), especially in the case of ecosystem services if ES provide benefits at a variety of spatial scales, ranging from local to global. Phenomena observed at one scale are often not generalizable to other scales, implying the need for careful consideration of scale.

There are limitations to the spatial scale of a PES system. For example, an EU-wide approach might not be able to fully take into account local conditions. Nevertheless, economies of scale appear to reduce average transaction costs in larger-scale schemes, such as nationwide payment schemes (Wunder, 2007). Unfortunately, this often comes at the cost of lower service-delivery targeting and additionality. Previous studies have indicated that local and regional-scale PES programs are more effective than national ones (Agrawal *et al.*, 2014; Grima *et al.*, 2016). In analyzing existing PES schemes in Latin America, Grima *et al.* (2016) found that with respect to scale, 60% of the studied cases had been implemented at the local scale, whereas had been implemented 30% at the regional scale and only 10% at the national level. The efficiency of local solutions can be explained, for example, with the incorporation of local and/or indigenous knowledge (Grima *et al.*, 2016; Paudyal *et al.*, 2016). Local knowledge eases decision and policy making and potentially increases the social learning of the PES participants (Lockie, 2013; Grima *et al.*, 2016). Furthermore, easier identification and matching of buyers and sellers has the potential to significantly lower the transaction and enforcement costs. Local schemes are also promising because of the higher motivation of stakeholders to participate in PES programs, as well as because the appreciation of ES tends to increase with a smaller distance to the location providing them (Kaiser *et al.*, 2021). However, a trade-off can be observed between involving enough participants and being as local as possible (Banerjee *et al.*, 2013; Lockie, 2013; Sorice *et al.*, 2018).

To produce information on the feasibility of PES, Wunder (2007, p. 54) suggested that a full economic valuation is not always necessary, since the agreement between providers and buyers is the right price. Therefore, draft calculations to reveal a price range are adequate to determine whether a PES scheme is feasible. In the literature, cost–benefit analysis has been the most widely applied spatial targeting approach at different scales, including county, regional, and watershed scales (e.g., Guo *et al.*, 2020). Guo *et al.* (2020) recommend improving the accuracy and applicability of spatial targeting of PES by integrating landowners' willingness to accept a PES with measurement of the conservation benefits and costs, i.e., citizen WTP.

In our analysis, it is justified to examine the feasibility of PES at both the county and municipal levels, because in Finland, regional councils define the potential areas for wind farms in a regional land-use plan and because municipalities have the right to decide on detailed land use planning in their areas. Therefore, a municipality has the power to either grant or deny permission to build a wind farm in its area. Both regional authorities and municipalities have the potential to offer help to contract makers and act as intermediary facilitators and service providers. Analysis at the wind farm and landscape shield levels is justified, as the potential for voluntary agreements increases the more spatially detailed the approach is, since the potential parties are very aware of the conditions and care for their specific situation.

3 Material

3.1 PES Case

Mäntymaa *et al.* (2021) proposed a PES scheme, i.e., LVT, to control the negative externalities of wind power using landscape shields. In forests near housing areas, the disturbing effects of wind turbines may be reduced through forest management practices. Since the introduction of these practices would reduce forest owners' revenues, compensating for the economic loss of forest owners would increase their probability of participating in the scheme. Of course, the case could also be that the compensation demanded by forest owners is higher than the benefits perceived by citizens. In this case, the program would not be feasible or worth implementing.

The case study area is located in southwestern Finland. In the two counties we focus on, Varsinais-Suomi and Satakunta (Figure 1), there are already a considerable number of wind farms, and wind electricity production has been predicted to expand in the near future (Huttunen, 2017). In addition, the population density of the region is higher than in northern Finland, which increases the possibility of conflicts in relation to increasing wind power and the need for new types of arrangements to reduce the harm caused by wind

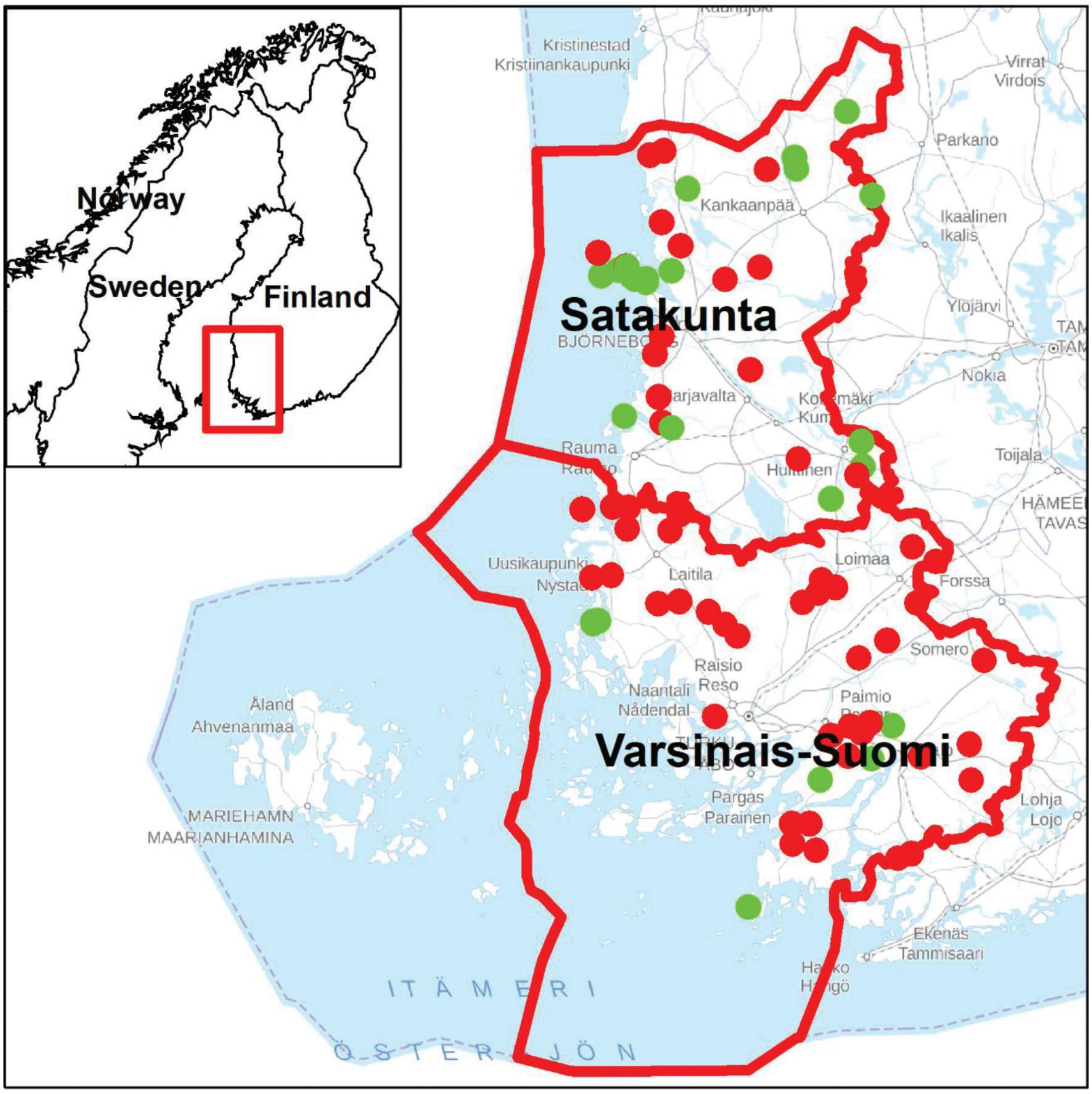

Figure 1: Case study area: the counties of Satakunta and Varsinais-Suomi. Legend: green points = existing wind farms, red points = planned wind farms.

farms. The regional land-use plans have listed and mapped the sites suitable for the construction of wind electricity farms (Regional Council of Southwest Finland, 2011; Regional Council of Satakunta, 2014). These sites are mostly located in rural areas, often in the border areas of two or more municipalities, and have dispersed settlements of farms and villages but are not uninhabited.

Regarding the supply side of the suggested LVT, in this part of the country, most of the forests are privately owned, as 78% of the forest area is owned by non-industrial private forest owners, including private people (Finnish Forest Centre, 2020), whereas the corresponding figure in the whole country is 59% (Natural Resource Institute Finland, 2022). Here, forest holdings are usually quite small, with an average size of 30 ha. The ownership structure of private forests is divided so that 30% own 5–9.9 hectares, 30% 10–19.9 hectares, 27% 20–49.9 hectares, 10% 50–99.9 hectares, and 4% at least 100 hectares of forest (Kulju *et al.*, 2023). The average age of forest owners in the area is 59 years, which is slightly lower than in the whole country (62 years) (Karppinen *et al.*, 2020). The objectives of forest owners have importance for their management decisions. Karppinen *et al.* (2020) found that in southern Finland, 33% of the forest owners were *Multi-Objective*, 15% *Recreational Users*, 16% *Living in Forest*, 29% emphasizing *Financial Security*, and 8% *Uncertain*.

Related to the demand side of LVT in the region, 76% of the inhabitants of the study area live in urban and 24% in rural areas, and 47% of the population lives in the three largest cities, Turku, Pori, and Salo (Statistics Finland, 2022b). There are almost 70,000 vacation homes in the study area, which is about 14% of the total number for the whole country (Statistics Finland, 2022a).

3.2 Data on Landowner Interest and WTA

Here, we apply the data and analysis of Mäntymaa *et al.* (2021), who examined the interest of forest owners in LVT with a survey directed to non-industrial private forest owners in southwestern Finland, i.e., in the counties of Satakunta and Varsinais-Suomi. In the valuation scenario, Mäntymaa *et al.* (2021) described to forest owners a situation where a landscape shield could be used to prevent a wind turbine from being visible in the vicinity of local residents' homes and vacation homes. This would mean that the landowner avoids forest logging between residential areas and wind farms or would apply lighter forest management near residential areas towards wind farms, for example continuous cover forestry or extended rotation periods. This would allow most trees to be preserved, obscuring wind turbines from sight. Respondents were asked to imagine that an agreement to provide a landscape shield for a limited time would be possible in the area where they own a forest lot. They were told that in the arrangement, the landscape shield would be offered for either 15 or 30 years, of which the former corresponds to a quarter and the latter half of the expected operating time of a turbine. However, the length of the contract periods had no statistically significant effect on the average WTA. For a landowner, leaving the stand standing would mean that logging income would be delayed until the landscape sign was offered, but logging would again be possible after that. The owners were then asked to indicate the lowest possible annual compensation per hectare they would accept for such a contract. A payment card contingent valuation method was used to determine the monetary value for the compensation.

The sample of 1,165 revealed 73.6% of forest owners to be certainly or possibly interested in the proposed LVT (Mäntymaa *et al.*, 2021). This is a relatively large number compared to the observation of Xuan and Sandorf

(2020), for example, that about 38% of farmers were not willing to make trade-offs. The annual mean WTA of the respondents for providing a landscape shield was € 297.6 per hectare (std dev. € 248.8/ha/year) and the median class was € 200.01–300/ha/year. The modeling results for WTA by Mäntymaa *et al.* (2021) revealed that an increase in the area of commercial cutting in the respondent's forest or having an occupation in agriculture or forestry increased the compensation claim. The compensation claim decreased if the level of education of the respondent was higher or if the respondent's occupation was in environmental protection or related areas.

Beyond these reported average participation rates and WTAs, the data include spatial information on the forest lots owned by the landowners. In the survey, the respondents were asked to mark on a map the locations of sites where they own agricultural or forest land. They were asked to mark on the map only the point where the forest lots are located, not the exact boundaries of the lots. The WTA question was also not targeted at specific hectares and the respondents were not asked customized questions, but everyone was asked the same general question in a hypothetical situation. Each respondent could map several locations. Forest lots were distinguished from agricultural farms by assessing whether the marked location was on forest land. This information on the counties and municipalities for the forest lots allowed the participation interest and WTA to be defined at a more detailed spatial scale.

3.3 Data on Citizen Interest and WTP

Mäntymaa *et al.* (2023) reported citizens' interest in participating in an LVT initiative and their WTP for purchasing a landscape shield to minimize the landscape degradation caused by wind turbines in the counties of Varsinais-Suomi and Satakunta, in the same study area as Mäntymaa *et al.* (2021). Just as for forest owners, Mäntymaa *et al.* (2023) also informed the selected residents (i.e., non-forest owners) that the negative landscape effects of wind turbines may be reduced by changing forest management practices. As the change in practices would lead to a reduction in the revenue of forest owners, the owners would probably not implement them without compensation. The residents were asked to consider the importance of the landscape benefits brought about by the shield, not any other possible benefits. The scenario then described a possible LVT agreement and an opportunity to pay forest owners to provide a landscape shield. Also here, the respondents were told that in the arrangement, the landscape shield would be offered for either 15 or 30 years. As before, the length of the contract periods had no statistically significant effect on the average WTP. It is worth noting that the scenario explicitly linked the WTP question to the valuation of the landscape benefit produced by one hectare, since even a narrow belt of forest would be enough to hide a turbine from view. As in the case of forest owners, the payment card CV technique was used to reveal respondents' WTP.

In the survey, residents were asked to mark the place where they live on a map. However, it was not known which hectares of forest would cover turbines located near residential areas. Thus, the survey did not ask about WTP related to specific hectares, but everyone was asked the same general question regarding a hypothetical situation.

The results were based on data from an Internet survey with a sample of 1,271 citizens. A clear majority (83.7%) were interested in participating in the PES mechanism (Mäntymaa *et al.*, 2023). This is a high figure, as Xuan and Sandorf (2020), for example, found that roughly 28% of respondents in public data sets did not make trade-offs. The annual mean WTP was € 80.9 per hectare (std dev. € 215.6/ha/year) and the median class was € 10–€ 14.9/ha/year. The participation interest and WTP were explained with several attitudinal variables, but the spatial aspects were not considered. Here, we used the GIS information from the data set of Mäntymaa *et al.* (2023) to locate the interested residents and obtain a spatially explicit picture of the possibilities for establishing LVT.

4 Methods

We conducted the feasibility analysis at four spatial levels, i.e., county, municipality, wind farm, and individual shield level. First, the comparison of annual aggregate WTP and WTA was conducted both at the individual *county level* in Varsinais-Suomi and Satakunta and in the combination of these counties. The aggregate annual WTP was calculated as the product of the adult population, participation rate, and median and mean WTP. The aggregate WTA was calculated as the product of the number of forest owners, their participation rate, and WTA. Beyond the comparison of the aggregates, we also calculated how many hectares of forest the total WTP would cover based on the average compensation request (WTA).

The second spatial level was the *municipal level*, analyzing the feasibility of LVT over the 43 municipalities of the study counties. At this level, total WTP was calculated in similar way as the county aggregates by multiplying the adult population in the municipality by the municipal participation rate and the mean and median municipal level WTP. From the data of Mäntymaa (2021), we also calculated the mean and median WTA at the municipal level. With this information, we calculated the number of hectares for each municipality that would be covered with the municipal aggregate WTP if targeted at certain hectares instead of being spread over various forest stands across each municipality.

The third spatial level was the most precise, the *wind farm level*. At this level of analysis, we used GIS information to define potential landscape shields. We identified the operating and planned wind farms from data provided by the Finnish Wind Power Projects Database, which at the time of downloading the material, in January 2020, was maintained by the Finnish Wind Power Association (https://tuulivoimayhdistys.fi/en/) and Etha Wind. At the time of access (January 2020), the database had last been updated in February 2019. The information contained in the database included the approximate point location, name and phase of the projects, the number of turbines, planned megawatts, and the owner. We created 4-km buffers around each point location for wind farms to describe the location of the entire wind farm and its area of influence.[1]

In the area of each 4-km wind farm buffer, we identified residential buildings. Data on residential buildings were derived from the Topographic Database of the National Land Survey of Finland (2023c) from the year 2018. For each residential building, we defined the potential landscape shield or shields as follows (see an example in Figure 2). First, we created a straight line from each building towards a wind farm. Then, from this line, starting from the residential building, review points were determined every 10 meters. For each point, we assessed the mean height of trees based on the Finnish Multi-Source National Forest Inventory (MS-NFI 2019) database (Tomppo *et al.*, 2008; Tomppo *et al.*, 2011), with a pixel size of 16 m × 16 m. We also determined a reference value for tree height that would be sufficient to cover the view from the building to a wind turbine if the highest point of the wind turbine was 270 m. For each point, two additional points were assigned to a 16-meter perpendicular line on both sides of the point, and the mean height of trees was assessed. Finally, the three-point group was chosen that was located closest to

[1] The 4-km buffer was selected based on three reasons. First, in the literature, there are relatively few indications of distance-acceptance thresholds (Dobbers, 2019 for a review). However, Swofford and Slattery (2010) reported in a study from Texas that respondents living more than five kilometers away from an existing wind farm were more open regarding future developments of wind farms in their surroundings. In Finland's more forested landscape, we could expect a lower threshold for proximity. Second, we conducted calculations for the visual effect of a landscape shield if the height of the trees was approximately 20 meters and height of the turbines 270 m. We estimated that for distances over 4 km from a windfarm, for the landscape shield to be effective, it could be located at a distance of 300 m from the observer at maximum. If the distance of the observer from a wind farm increases, even more distant landscape shields would prevent the landscape damage. However, with longer distances to the shield, the benefits of the shield would be less clear for the observer. Third, the database included point data, which did not necessarily indicate the exact location of an individual wind turbine, but rather the approximate location of existing or planned wind farms that might contain several wind turbines. Therefore, while we did not have the exact locations for wind turbines, a 4-km buffer around the point location provided some flexibility. If the wind turbine buffer extended over several municipalities, it was divided into units of analysis by municipalities.

Figure 2: Identification of possible landscape shields based on GIS information for the residential buildings near wind farms. Legend: blue points = residential buildings; yellow line = straight line from a residential building to a wind farm; group of three perpendicular yellow points = potential landscape shield where the height of the trees is sufficient to hide the wind turbine from view; green three-point group = potential landscape shield closest to the residential building.

the residential building and where the height of trees at all points was sufficient to prevent the wind turbine from being seen.

For each wind farm location, we further calculated the area of potential landscape shields by multiplying the number of residential buildings that had a sufficient landscape shield by the shield area of 3×16×16 m. The number of forest owners with a potential landscape shield was calculated based on real property unit identification numbers in selected forest properties. Data on property boundaries were derived from the Cadastral Index database (National Land Survey of Finland, 2023a) provided by the National Land Survey of Finland. For each wind turbine in one municipality, we calculated the total WTP by multiplying the number of residential buildings, the average size of a household in the municipality, the municipal level participation rate, and mean WTP. For each wind turbine in one municipality, the total WTA was calculated by multiplying the number of shield hectares, the municipal level participation rate, and the municipality estimate for mean WTA.

The fourth spatial level was the *landscape shield level.* At this level, each shield would provide an opportunity for trade between a few households and

Table 1: Variables in the simulated data.

Shield characteristics	Source of the distribution information	Simulation functions
Number of households per shield	GIS analysis	Random values from negative binomial distribution
Adults per household	Survey data for citizens	Distribution from the survey data
Participation rate of residents	Survey data for citizens	Random values from beta distribution
WTP per shield	Survey data for citizens	Random values from normal distribution (transformation to positive values)
Participation rate of forest owners	Survey data for forest owners	Random values from beta distribution
WTA per shield	Survey data for forest owners	Random values from normal distribution (transformation to positive values)

a forest owner. However, the survey data sets were spatially too sparse for comprehensive analysis of all the identified shields or even a sample of them using survey observations. Therefore, the survey information as well as GIS information on the shield characteristics was used to simulate the data for 10,000 landscape shields. In the analysis, the spatial unit was a shield instead of one hectare, as a shield corresponded to the real target of trade. For the shield-level data, the variable distributions as well as the means and standard deviations were adjusted to correspond to either the GIS or the survey data (Table 1).

In the simulated data, the total WTP was determined for each shield by multiplying the simulated variables, i.e., the number of adults per household, the number of households, the participation rate, and WTP per shield per resident. In the data, the total WTA per shield was obtained from the shield area in hectares (3×16×16 m, i.e., 0.077 ha for each shield), the WTA per hectare, and the participation rate. By taking participation rates into account, we assumed that shields did not necessarily provide full coverage if the participation rate was lower than 100%. At the shield level, we could compare the total WTP and total WTA per shield. For the shields, we conducted the comparison of means with the t-test. The t-test was applied for simulated variables comparing the total WTP for shields either exceeding or conceding total WTA. The spatial analyses and visualization were carried out using ESRI ArcGIS for Desktop software version 10.6.1 (ESRI, 2011).

5 Results

5.1 County Level

We first analyzed the feasibility of LVT at the county level, i.e., Satakunta and Varsinais-Suomi (Table 2). Because we knew the numbers of adult residents and participation rates on the demand side, we were able to calculate the number of participants in the two counties. By multiplying these figures by the median and mean annual WTP per participant, we obtained the total WTP based on the median (Satakunta € 742,899; Varsinais-Suomi € 4,353,760) and total WTP based on the mean (Satakunta € 7,868,661; Varsinais-Suomi € 29,350,960), as well as the respective totals for the whole research area (€ 5,945,475; € 38,569,487). In the same way, on the supply side, assuming that one forest owner sells one hectare, we could calculate the total median-based WTA (Satakunta € 671,616; Varsinais-Suomi € 842,108) and total mean-based WTA (Satakunta € 1,194,394; Varsinais-Suomi € 1,181,586), as well as the respective totals (€ 1,272,600; € 2,388,528). The differences in WTA between the counties follow the (National Land Survey of Finland, 2023b), clearly indicating lower forest land prices in Satakunta than in Varsinais-Suomi.

Finally, we were able to evaluate the feasibility of LVT by comparing the total WTP and total WTA, and we found that the former exceeded the latter in both counties in terms of both the median and mean. Taking into account the total WTP and total WTA, we calculated that, based on the median, LVT contracts could be concluded in Satakunta for 2,972 hectares and based on the mean for 17,698 hectares. The corresponding figures in Varsinais-Suomi were 12,439 hectares and 59,766 hectares, and in both counties a total of 23,782 hectares and 82,199 hectares, respectively.

5.2 Municipal Level

Table 3 presents the respective findings at the municipal level in the two counties. We obtained the figures by first calculating the statistics for each municipality and then the statistics over all municipalities. As the total WTP was € 138,884 based on the median and € 898,033 based on the mean, and the corresponding WTA values were € 248,114 and € 571,032, the differences between these were −€ 177,752 and € 348,544, respectively. The above observation indicates that at the municipal level, the total WTP would not be sufficient to cover the total WTA if the calculation was based on the medians, but if based on the means, it would be sufficient. The last two figures in Table 3 indicate that the median and mean WTP were sufficient for contracts covering 23,888 or 82,297 hectares, respectively, if forest owners were paid compensation according to the median or mean WTA.

Table 2: Feasibility of LVT in the study counties.

Demand	Satakunta	Varsinais-Suomi	Total
Adult residents, number	157,728	411,217	568,945
Participation rate	0.79	0.85	0.84
Participants, number	124,740	350,898	475,638
Annual WTP/ ha/ participant (median)	6.0	12.5	12.5
Annual WTP/ ha/ participant (mean)	63.6	84.3	81.1
Total WTP based on median	742,899	4,353,760	5,945,475
Total WTP based on mean	7,868,661	29,350,960	38,569,487
Supply			
Forest owners, number	3,816	3,384	7,200
Participation rate	0.70	0.71	0.71
Participants, number	2,685	2,405	5,090
Annual WTA/ha (median)	250.0	350.0	250
Annual WTA/ha (mean)	444.6	491.1	469.2
Total WTA (if one owner sells one hectare) (median)	671,616	842,108	1,272,600
Total WTA (if one owner sells one hectare) (mean)	1,194,394	1,181,586	2,388,528
Opportunity for trade			
Total WTP – total WTA (median)	71,283	3,511,652	4,672,875
Total WTP – total WTA (mean)	6,674,267	28,169,374	36,180,959
Hectares (total WTP/ WTA per ha, based on median)	2,972	12,439	23,782
Hectares (total WTP/ WTA per ha, based on mean)	17,698	59,766	82,199

Figure 3 illustrates how the contract hectares of a potential LVT mechanism would be distributed in the study area if they were broken down by municipality according to the reported WTPs and WTAs. According to the figure, the largest numbers of hectares would be located in urban municipalities with a large population and thus a large total WTP.

Table 3: Feasibility of an LVT agreement at the municipal level.

Demand	Statistics over municipalities
Adult residents, number	13,278
Participation rate	0.84
Participants, number	11,111
Annual WTP/ ha/ participant (median)	12.5
Annual WTP/ ha/ participant (mean)	80.8
Total WTP based on median	138,884
Total WTP based on mean	898,033
Supply	
Forest owners, number	1,730
Participation rate	0.71
Participants, number	1,224
Annual WTA/ha (median)	250
Annual WTA/ha (mean)	471
Total WTA (if one owner sells one hectare) (median)	248,114
Total WTA (if one owner sells one hectare) (mean)	571,032
Opportunity for trade	
Total WTP – WTA (median at the municipality level)	−177,752
Total WTP – WTA (mean at the municipality level)	348,544
Hectares (total WTP/ WTA per ha, based on median)	23,888
Hectares (total WTP/ WTA per ha, based on mean)	82,297

A similar pattern is also revealed by Table 4 in the sense that as a municipality's population increases, the potential agreement areas increase, i.e., the more payers there are, the larger is the number of agreements. For example, in a municipality with less than 2,000 people, the average LVT area was 283 hectares, whereas in a municipality with more than 30,000 people, the corresponding area was 15,030 hectares.

5.3 Wind Farm Level

With the help of GIS information, we were able to analyze a more detailed spatial level of feasibility, i.e., the potential for trade at the level of landscape shields against wind farms, of which there were 50 in the study area (Table 5).

Table 4: The number of hectares that could be traded in municipalities with different population levels and the average compensation requests.

Adult population in the municipality	Number of municipalities	Demand: Total WTP/municipality (mean)	Supply: WTA/ha (mean)	Opportunity for trade: Average traded hectares in municipalities
Less than 2,000	11	102,848	419	283
2,000–6,000	10	349,532	495	742
6000–10,000	10	523,708	541	1,046
10,000–30,000	8	1,309,747	422	3,027
More than 30,000	4	11,510,869	419	15,030
Total	43			2,449

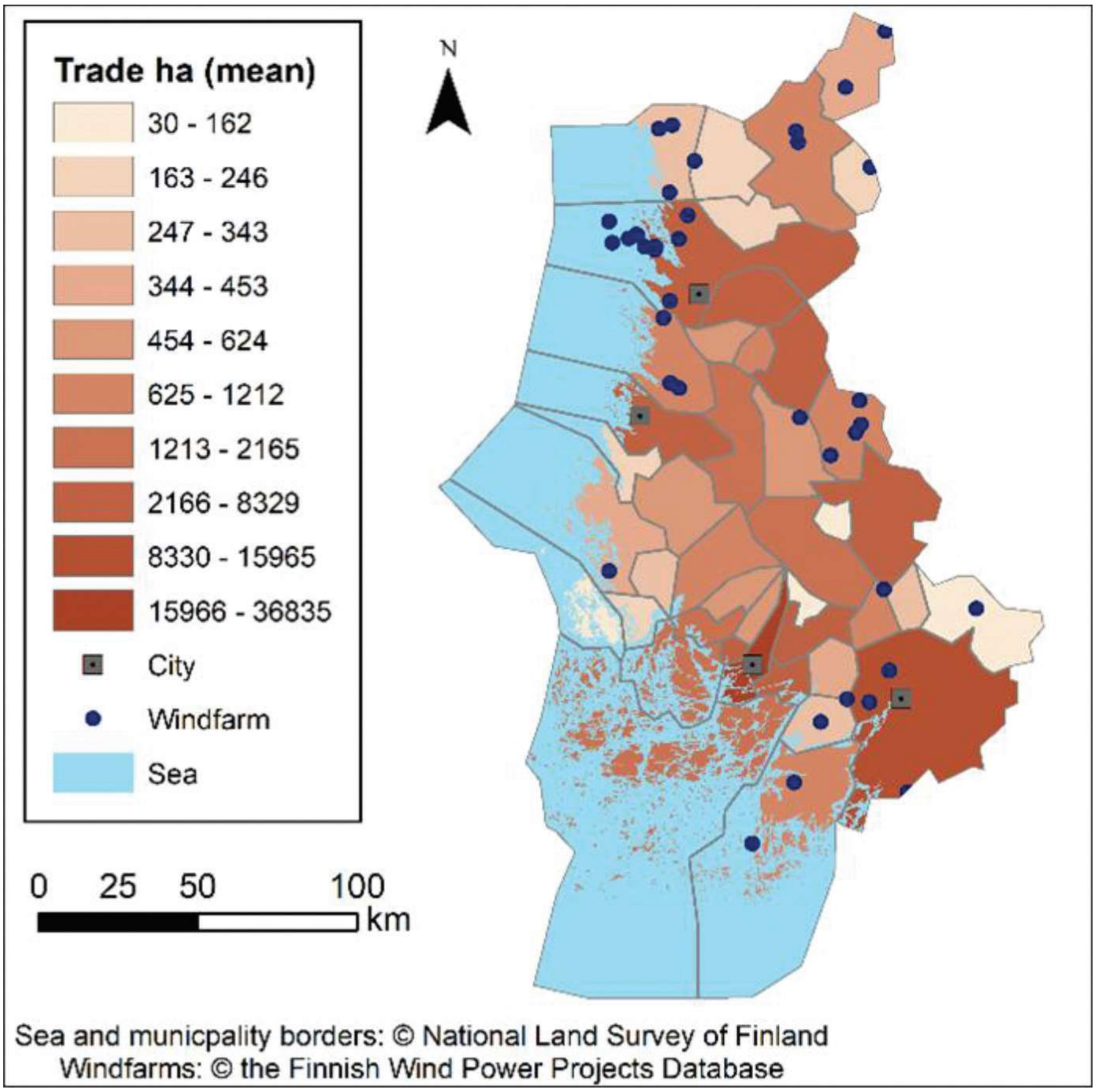

Figure 3: Number of possible contract hectares in an LVT mechanism for separate municipalities in the research area of Satakunta and Varsinais-Suomi.

Taking into account the number of households having a shield (127), the household size (1.7), and the participation rate (0.82), the average annual WTP per hectare was € 78.0 and the total annual WTP per wind farm € 1013.0. Using corresponding figures for the supply side, the annual average WTA per hectare was € 498.0 and the total annual WTA per wind farm € 3730.0. Thus, the total WTA per wind farm exceeded the total WTP per wind farm, the difference being -€ 2716.0. When comparing WTP and WTA with each other for wind farms on a case-by-case basis, we found that the probability of agreements, i.e., total WTP being higher than total WTA, was only 2.0%. This means that if the total WTP was spent on trading the most important hectares with the average WTA, the trades would only include 2.0 hectares of forest.

Table 5: Feasibility of LVT at the wind farm level ($N = 50$).

	Statistics over wind farms
Per wind farm:	
Number of landscape shields against a wind farm*	127
Landscape shield hectares	9.7
Demand	
Number of households having a shield, mean	127
Household size	1.76
Participation rate, mean	0.82
Average WTP/ ha, mean €	78.0
Total WTP per wind farm, €	1,013.0
Supply	
Number of forest owners in shield areas**, mean	69
Participation rate of forest owners, mean	0.69
WTA/ ha, mean €	498.0
Total WTA per wind farm, €	3,730.0
Opportunity for trade	
Total WTP per wind farm - total WTA per wind farm, €	−2,716.0
Proportion of possible trades (total WTP >total WTA)	0.02
Traded hectares if WTP targeted at the same number of hectares	2.0

Note: * Classified as separate farms if located in several municipalities
** Estimated as forest lots.

5.4 Shield Level

Finally, we analyzed the feasibility of LVT at the landscape shield level with simulated data for 10,000 shields using the survey and GIS information on the shield characteristics (Table 6). On the demand side, using information related to the number of households per shield (2.0), the household size (1.76), the participation rate (0.83), and annual WTP per shield (€ 5.4), the simulation produced a total WTP of € 16.2 per shield. On the supply side, the corresponding WTA figure was € 15.2. According to a comparison of the total amounts per shield, on average, WTP exceeds WTA by € 1.0, leading to the conclusion that an LVT agreement could be reached for 41% of the shields.

Comparing the means for simulated variables between shields with a possibility of trade (total WTP >total WTA) and with no possibility of trade (total

Table 6: Feasibility of LVT at the landscape shield level. Simulated landscape shields (10,000).

	Statistics over landscape shields
Landscape shield hectares /shield	0.077
Demand	
Number of households per shield	2.0
Household size	1.76
Participation rate	0.83
Annual WTP per shield, €	5.4
Total WTP per shield, €	16.2
Supply	
Participation rate of forest owners, mean	0.74
WTA per shield, €	20.5
Total WTA per shield (participation*WTA), €	15.2
Opportunity for trade	
Total WTP - Total WTA, €	1.0
Proportion of possible of trades (total WTP > total WTA)	0.41

WTP <total WTA), we found several significant differences, emphasizing the importance of both demand and supply variables (Table 7). The effect size column indicates how strong the difference between the groups is. The shields with a possibility of trade especially differed regarding individual WTP and WTA per shield. However, the participation rates differed significantly, as well as numbers of households and household sizes.

6 Discussion and Conclusions

To find solutions for the acceptability challenges of wind power, this study evaluated the feasibility of LVT in addressing the harmful visual landscape effects of wind turbines at four spatial levels: two counties, the municipalities of the counties, operating and planned wind farms, and possible landscape shields in the research area.

The evaluation at the first level revealed that the total WTP exceeded the total WTA in both counties in terms both of median and mean figures. Taking into account the monetary valuations based on means, for example,

Table 7: How shields with a higher possibility of trade (total WTP >total WTA) differ from those with a lower possibility of trade (total WTP <total WTA).

		No trade	Trade			
		Mean		*t*-test	*p*-value	Effect size*
Demand	Number of households per shield	1.9	2.3	−12.65	< 0.001	0.14
	Household size	1.7	1.8	−8.77	< 0.001	0.65
	Participation rate of residents	0.83	0.84	−2.09	0.04	0.14
	Individual annual WTP per shield, €	2.08	10.14	−31.99	< 0.001	10.51
	Total WTP per shield, €	4.16	33.62	−25.44	< 0.001	47.58
Supply	Participation rate of forest owners	0.75	0.72	6.98	< 0.001	0.19
	Individual annual WTA per shield, €	28.99	8.38	73.30	< 0.001	14.04
	Total annual WTA per shield, €	21.75	5.79	72.13	< 0.001	11.37

Note: *Cohen's *d* standardized

LVT agreements could be made for an area as large as 17,698 hectares in the county of Satakunta, 59,766 hectares in the county of Varsinais-Suomi, and 82,199 hectares in both counties combined. These results appear to convey a message that it would be possible to implement LVT and to sign agreements for landscape shields in abundance in the study area. However, this conclusion might be premature, as the harmful visual effects of turbines are not county but site specific, in which case the demand for and supply of the PES mechanism should be separately met at each location. However, while regional councils define suitable areas, they could act as such initiators and mediators in LVT and as a body supporting an independent foundation or trust targeting the LVT activities in the area.

At the municipal level, we found that the total WTP was not sufficient to cover the total WTA if the calculation was based on the median but was sufficient based on the mean. We presented both, as the mean WTP is the conventional measure of benefit in benefit–cost analysis and reflects efficiency (Bateman *et al.*, 2002). However, the median is informative, as it reflects the majority voting rule (Bateman *et al.*, 2002). Based on average figures, WTP was sufficient for the agreement of 82,297 hectares if forest owners were paid compensation according to the mean WTA of forest owners. Since the calculations were performed as an average per inhabitant, the consequence was that the more people were living in a municipality, the higher was the total WTP of the municipality. This could pose challenges to the implementation of LVT. Because the total WTP is highest in population centers, but wind turbines are often located in sparsely populated regions, where WTP and WTA do not meet at the same sites, agreements may not be concluded very often. However, in the future, as the pressure for wind power increases, our results encourage urban municipalities, which issue permits for the construction of turbines and have the best knowledge and decision-making power regarding land use in their area, to include landscape shields as one of their land use planning instruments and possibly support a platform for agreements on the urban fringe.

At the wind farm level, we used GIS information to define potential landscape shields and found that the total WTA substantially exceeded the total WTP. The case-by-case comparison of WTPs and WTAs for wind farms demonstrated that agreements are very seldom feasible, for only 2.0% of wind farms. In addition, if WTPs were targeted at the same hectares as WTAs, agreements would only include 2.0 hectares of forest. These results highlight the same challenges in organizing LVT as the analysis at the municipal level. Those who are willing to pay to reduce the landscape effects of wind turbines do not necessarily live in areas where turbines have been built or are going to be built. Thus, the number of people actually affected by a visual disturbance and their WTP may not be sufficient to cover the WTA of a local forest owner and lead to an agreement to preserve a landscape shield.

Using simulated data, we conducted the final analysis for the feasibility of LVT at the level of landscape shields. According to the analysis, on average, the total WTP exceeds the total WTA per shield by € 1.0, leading to the conclusion that an LVT agreement could be reached. A shield-specific calculation indicated that this would be possible for 41.0% of all shields, which was a relatively large proportion. Furthermore, we found that the possibility of trade was particularly dependent on the WTP and WTA figures, and less on the participation interest.

If we consider LVT as an environmental policy instrument at the most precise spatial levels, i.e., the wind farm and landscape shield level, our results can reveal both locations where it is likely to be implemented and those that are close to implementation. Furthermore, the results provide benchmarks for compensation levels that can be used as a starting point for potential contract negotiations. If residents' WTP in a certain location is not quite sufficient to cover the forest owners' compensation claims, based on the results of this type of study, support for communication can be directed to this community with the aim to avoid the cancellation of the project or a conflict arising from its implementation. In some areas, residents' WTP exceeds forest owners' WTA, implying a Coasean bargaining solution, i.e., private actors internalizing negative externalities voluntarily could be expected. This would require low transaction costs, including the costs of reaching an agreement. In the case of LVT, many factors suggest that these costs are unlikely to be low. The situation could be, for example, one forest owner and several residents, who must act in a coordinated manner to reach an effective voluntary agreement. Therefore, a broker operator may help to create markets and negotiate contracts. As shown by Mäntymaa *et al.* (2023), the interaction between parties can enhance the positive attitudes for trade and reduce the probability of free riding (Grammatikopoulou *et al.*, 2013).

The results of this study revealed that the feasibility of a PES mechanism depends on how the demand for and supply of the service meet at the narrowest geographical level if the object of trade is a local ecosystem service. In this respect, this study differs from those of both Barr and Mourato (2009) and Xuan and Sandorf (2020), who analyzed PES markets for spatially relatively homogeneous ecosystem services produced by marine ecosystems in coastal areas. The situation in our study is more similar to the case of Mäntymaa *et al.* (2018) and Tyrväinen *et al.* (2021), in which the supply of an ecosystem service, i.e., a scenic landscape, in a nature tourism area depends on the forest management practices of individual forest owners in each forest stand. Both in their case and in our present case, the stand location was found to be important. If, in the case reported by Mäntymaa *et al.* (2018) and Tyrväinen *et al.* (2021), a forest owner holds a scenically beautiful forest lot near a tourist center or along a hiking trail, for example, it can be an important object for a PES contract. However, if the stand is not visible to tourists, it is of no use in terms of the PES mechanism. This is also analogous to our results. Consequently, if an ecosystem service is strongly local, it is difficult to create a common PES market for a larger geographical area. Thus, people willing to pay must be found in the place where the service is located and where it is produced.

We also found a significant association between the participation rate on the demand side and the probability of an agreement. Since the rate of participation at least partially depends on people's attitudes, they can be influenced by being provided facts about LVT and the possibilities of preventing or mitigating the harmful visual landscape effects of wind turbines. Thus, as also found by Mäntymaa *et al.* (2021) and Mäntymaa *et al.* (2023), the possibilities of implementing LVT can be influenced by open communication among the people who live or spend time in potential wind power areas. If attitudes towards LVT could be made more positive, WTP for reducing the effect may increase, more agreements on landscape shields could be concluded, and the disadvantages of wind turbines could be mitigated (Mäntymaa *et al.*, 2023). This, in turn, would give space to build new wind farms and produce additional renewable, emission-free energy, which current society and the climate would need.

As a possible weakness of this study, we identified the rough spatial accuracy of our data. Although we aimed at a spatially detailed analysis with a map survey and GIS analysis of the wind parks, compromises were needed. For example, we did not include the analysis of actual viewscapes or measures based on distance decay, which would, in our rocky terrain and forested landscapes, have demanded more detailed analysis and more complex definitions of landscape shields. The survey data sets did not offer full spatial coverage, either. If shield level analysis could be conducted with full coverage of residents and landowners, an interesting approach for future studies would be action research where researchers would participate in the actual negotiations on an LVT agreement.

The basic question regarding the credibility of the results of this study is whether the WTP and WTA data used in the study are reliable. It is difficult to prove the reliability of WTP, but it is easier to assess the magnitude of WTA. One possibility is to compare it with forestry operating profit, which describes the difference between forestry income and costs (Natural Resources Institute of Finland, 2023). According to the Official Statistics of Finland (2023), the operating profit of non-industrial private forestry in the counties of the study area varied between € 129 and € 198 per hectare in 2015–2019. Since, according to our results, the average WTA per hectare was € 445 in Satakunta and € 491 in Varsinais-Suomi (medians € 250 and € 350, respectively), WTA considerably exceeds the operating profit. These are also relatively large amounts of money compared to the actual average compensation (€ 176/h/year) in the 10-year voluntary contracts of the Finnish Biodiversity Conservation Program (METSO) (Juutinen *et al.*, 2008). On the other hand, the respondents may have included transaction costs, such as the effort of making a contract, in the compensation claims, which might have increased WTA. However, as Nape *et al.* (2003) concluded, in reality, individuals appear to accept less money as compensation than in a hypothetical situation. Therefore, the actual compensation amounts can be assumed to be lower than the results in this study. This could be good news for the implementation of LVT, as the WTP of residents would then be enough to cover the WTA of forest owners in more cases.

With a good reason, asking residents their WTP to finance a landscape shield can be criticized for the fact that there is generally a perception that "polluters" should pay for the harm they have caused. Thus, would it in this case be considered that wind farm companies should pay for shields or participate in LVT? To control for this, Mäntymaa *et al.* (2023) asked in a follow-up question from those who answered "zero" or "don't know" in the WTP question to explain their answer. Of the alternative responses, "A wind power company is responsible for paying for the landscape shield" received the most mentions, i.e., 20.5% of all respondents. This indicated that a clear majority of the respondents accepted a WTP-type question, and only those who did were included in the data set used in the modeling.

Although in the surveys related to data collection in this study the respondents were asked to state their WTP and WTA specifically in relation to landscape shields covering wind turbines, the respondents may also have taken into account other environmental benefits that less economically efficient forest management practices such as continuous cover forestry or extended rotation periods may increase. These side benefits might include benefits for recreational use, carbon sequestration, or biodiversity protection, for example. If this is the case, residents may be willing to pay something even if they do not perceive a benefit from landscape protection, or they may be willing to pay more than just for a landscape shield. These factors, of course, may lead to an overestimation of WTP related to landscape shields. On the other hand, LVT could in practice be combined with other programs related to environmental protection, because it obviously increases the supply of other ecosystem services as well.

In this study, we analyzed the feasibility of LVT from an aggregate to a spatially detailed level, but mostly only by comparing WTP and WTA in different geographical areas. However, to fully assess the feasibility of the proposed LVT system, several other requirements for a functioning contract mechanism remain to be explored. For example, the costs incurred by forest owners need to be opened up and clearly articulated to them. These costs may include the direct and alternative costs of increasing landscape values, i.e., the loss of income caused by reduced wood harvesting, as well as the additional costs caused by special felling and regeneration methods. Furthermore, an important aspect is the evaluation of the costs of the mechanism itself. This includes the costs of collecting residents' payments and transaction costs between residents and forest owners. Finally, the functioning of the mechanism depends on whether some kind of intermediary body would be needed to help convert the stated WTP of residents into actual cash flows to pay compensation. This institution should also help the parties to agree on various contract details, such as the size of the forest shield, the appropriate management practice, and the amount of compensation at each site. However, the results of this study may help decision-makers to understand how the PES mechanism could be applied and implemented at various spatial levels.

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