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Moving (back) to greener pastures? Social benefits and costs of climate forest planting in Norway

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ABSTRACT

Norway is considering a national afforestation program for greenhouse gas sequestration on recently abandoned semi-natural pastureland. However, the program may have negative impacts on landscape aesthetics and biodiversity. We conducted a nation-wide choice experiment survey to estimate non-market values, combined with secondary data on program costs and other impacts, to derive the social net return on land use scenarios. Our results indicate that the scenarios where either half of the abandoned pastures are recovered, or half of the pastures are recovered, and a quarter are designated to the climate forest program, yields the highest net present value. The net present value of all land use scenarios remains positive when limiting the aggregation of willingness to pay to rural households, and when allowing for potential hypothetical bias in benefit estimates and cost increases. Results indicate that landscape and biodiversity values are substantial and should be considered when designing agricultural and climate policies.

1. Introduction

Norway has ratified the Paris Agreement to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial level. Norway committed to cut emissions of greenhouse gases by 40 per cent by 2030, while the Norwegian Climate Act target an 80–95 per cent reduction by 2050 compared to the 1990 level. Afforestation and forest management measures to increase carbon storage are becoming an important means of reaching the targets. However, these measures may come at the expense of other ecosystem services (ES) provided, and the question is how to make the right trade-offs from a societal perspective (Burrascano et al. 2016; Luyssaert et al., 2018).

The Norwegian government is considering implementing a national Climate Forest Programme (CFP) consisting of planting forest for the sequestration of greenhouse gases on former semi-natural pastures, that otherwise would be revegetated by natural forest. Semi-natural pastures (hereafter pastures) has been maintained by grazing and the ecosystem depends on grazing (or mechanical mowing) to maintain its characteristic biodiversity. In addition, the pastures provide provisioning and cultural ES such as landscape aesthetics, but probably also sense of identity and place, as pastures have been an important component of traditional farming and rural lifestyles. Pastures previously covered large areas but have been considerably reduced across Europe due to land use changes (Jepsen et al., 2015). An official report identified 9800 km^2 of abandoned pastures, of which 1350 km^2 have quite recently been abandoned and have not yet become forested (Norwegian Environment Agency, 2013).

When abandoned, the pastures slowly grow into natural forests consisting of tree species like birch (*Betula pubescens*), Scots pine (*Pinus sylvestris*) and in some regions of Norway, spruce (*Picea abies*). Compared to natural reforestation, spruce climate forests are relatively densely planted, grows faster and can thus contribute to climate mitigation by two processes: faster sequestering of carbon while growing, and timber and biomass substituting other materials that are carbon intensive in use or production (Taeroe et al., 2017). There is public debate on the planting of climate forests, since such land use reduces biodiversity (Henriksen and Hilmo, 2015b), and many people see the presence of climate forests as an impairment of landscape aesthetics (Grimsrud et al., 2019). The CFP requires avoiding the planting of climate forests on land areas that are important for recreation and of high value for biodiversity preservation (Norwegian Environment Agency, 2013). The CFP may not cause immediate extinction of any species, but

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planting monocultures of spruce will infringe on the land areas inhabited by species dependent on a landscape kept open by grazing. Over time, the loss of habitat requiring human maintenance may increase the risk of extinction, in the same way as the risk of extinction is increased by the loss of available natural habitat (Tilman et al., 1994). While several species, including some that are red listed, may expand their current habitats because of reforestation (Henriksen and Hilmo, 2015a), several red listed species are endemic to pastures (Henriksen and Hilmo, 2015b), due to the long-term management of grazing and/or mowing. The loss of pasture to any type of forest represents a loss of associated ES. Hence, an alternative to natural reforesting of abandoned pastures and the CFP would be to reverse reforestation and restore the recently abandoned pastures.

The CFP commenced with a three-year pilot starting in 2015 in the three counties of Nordland, Nord-Trøndelag and Rogaland. The decision of whether to scale up the programme should depend on an assessment of the costs and benefits of the different land uses. We consider the costs and benefits of combinations of land use options compared to the status quo situation. An official evaluation of the pilot program was recently released without a full economic assessment of costs and benefits (Norwegian Environment Agency, 2019). Our focus on land not yet reforested differs from studies of the Norwegian Environment Agency (2019) and Søgaard et al. (2019), which consider the effect of climate forest planting in already reforested abandoned pastures. In addition, we expand their analyses by also estimating the non-market benefits elicited from people's preferences for different land use options. We conducted a nationally representative choice experiment (CE) internet survey to assess the benefits of different land use options, including landscape aesthetics and greenhouse gas sequestration and biodiversity, and derive welfare estimates based on future scenarios. We use secondary sources to estimate the costs and market benefits of the land use options of CFP and recovering pastures by grazing animals, and compare them with the benefits, within a cost-benefit analysis (CBA) framework.

The main objective of the paper is, therefore, to estimate the welfare effects of land use options in a situation where there are trade-offs between the different ES provided. There is a relatively large related stated preference (SP) literature on assessment of different land uses, including national assessments of landscape aesthetics (e.g. Hynes et al., 2011; Campbell et al., 2008; Scarpa et al. 2007; Dallimer et al., 2015; Huber and Finger, 2019), forest ES such as biodiversity and recreation (Mönkkönen et al., 2014), forest management alternatives targeted to enhance recreational benefits (Mäntymaa et al., 2018), and carbon sequestration (Mogas et al., 2005; Varela et al., 2017).

This study contributes to, and expands on, this literature by integrating the values from the choice experiments (CE) into a full CBA of the Norwegian carbon forest program, pasture recovery and natural reforestation of abandoned pasture. We find that all our considered land use scenarios are preferable over the status quo of no management and natural reforesting.

The paper is structured as follows: The next section briefly presents the analytical framework of the CBA in terms of social cost and benefit components, and how they are defined and measured. Section three explains the underlying data for estimating costs and benefits and discusses the assumptions for the policy scenarios. Section four estimates and compares costs and benefits over time in terms of net present value and conducts sensitivity analyses of restricting the extent of the market. We conclude and discuss the implications of the results in the final section.

2. Analytical framework

The pastures in Norway have been the home of numerous vascular plants, including herbs, and pollinators and other insects that depend on meadows and pastures for their survival as a species. As of 2015, 635 species distinctive for pastures were threatened. Of course, afforestation of abandoned farms as well as modern farming practices on pastures which involves the use of more fertiliser is identified as causes (Henriksen and Hilmo, 2015a). Natural reforestation of abandoned pastures will allow species thriving in landscapes with more woody vegetation to increase their populations. Planted spruce for climate forests is a vegetation monoculture and has the lowest biodiversity of the analysed land uses (Aarrestad et al., 2013).

Landscapes sequester carbon at different rates. According to the Norwegian Environment Agency (2013), planted spruce forests sequester carbon in the above ground biomass faster than any other vegetation in Norway. If the chosen policy is to recover pastures, we will miss out on the sequestration associated with natural reforesting or spruce forests. The soil also stores carbon, and soil carbon storage is substantial for boreal forests (IPCC, 2000). There are knowledge gaps regarding the carbon sequestration potential of the soil of pasture (Dahlberg et al., 2013). At the time of this study we did not have adequate knowledge on soil organic carbon levels for Norwegian climatic conditions for the two other land uses. We, therefore, choose to focus only on carbon storage in vegetation above ground.

Benefits of planted spruce includes the timber value. The CFP requires that the spruce trees must first be felled after 60 years. Although the discounted value of net profits from forestry are relatively small, we account for these future incomes from forestry. According to several studies (see e.g. Greaker et al., 2005; Brunstad et al., 2005), Norway would, in a free-trade equilibrium with no subsidies, in theory produce no agricultural food. Since the recovery of pastures is dependent on government subsidies covering costs and toll barriers protecting the home market, we do not include farmer incomes of recovered pastures in this analysis. Thereby we implicitly assume the subsidies to cover the income.

2.1. Cost-benefit analysis, the decision rule and policy options considered

CBA is a method for ranking of policy options and finding whether policies are socially beneficial taking account of both the benefits and costs of the options as compared with a situation without policy intervention ("status quo" or "baseline situation"). The social welfare function summarises social preferences over allocations of resources and represents a preference ordering of individual utilities in CBA.

CBA ranks policy options based on a monetary criterion, which distinguishes CBA from other decision-making assessments such as for instance multicriteria analysis. As pointed out by for example Boadway (2006), the decision rule in an intertemporal context is the net present value (NPV) criterion. In our case, this criterion implies that the policy-maker should choose land uses for the abandoned pastures that maximise welfare in terms of the NPV of the future (change in the) flow of net benefits, as given in Eq. (1):

$$Max\,NPV = \left\{ \sum_{t=1}^{T} \frac{\Delta B_t^A - \Delta C_t^A}{(1 + r_t)^t} \right\} \tag{1}$$

where ΔB is the change in social benefit flow of the ES of land use and biodiversity following the combination of land uses, A, considered. Similarly, ΔC is the associated change in the social cost flow, r is the social discount rate (which may vary with time), T is the time period of the policy.

The status quo scenario is to let abandoned pastures naturally reforest as mixed forest, causing a reduction in the number of species threatened by extinction to only 550 species (Henriksen and Hilmo, 2015b). We investigate eight land-use scenarios to the status quo in our CBA (cf. Table 1); two scenarios where either half or a quarter of the abandoned pasture is recovered through agricultural production in the form of grazing (scenarios P1 and P2), two scenarios where either half or a quarter of the abandoned pastures are afforested through the climate forest program (CPF) (scenarios F1 and F2) and, finally, four scenarios combining afforestation and pastures (scenarios PF1 to PF4).

Table 1
The land use scenarios and the associated biodiversity attribute levels in the scenarios.

Scenarios	Biodiversity (species under threat)
Status quo	550
P1 Pasture - 50% of abandoned land	400
P2 Pasture - 25% of abandoned land	475
F1 Climate forest - 50% of abandoned land	700
F2 Climate forest - 25% of abandoned land	625
PF1 Pasture and climate forest (50%/50%)	550
PF2 Pasture and climate forest (50%/25%)	475
PF3 Pasture and climate forest (25%/50%)	625
PF4 Pasture and climate forest (25%/25%)	550

Land use will affect landscape aesthetics, CO_2 sequestration and other values, and the associated species under threat range from 400 to 700 species in the different scenarios. Our simple set up implies linear relations between the land-use and the associated values. Thereby we disregard that spatial distribution of land-use may affect aesthetics and other values. We also assume an increase in pasture land use and a correspondent decrease in the CFP land use are equivalent in terms of impacts on biodiversity. We apply a seventy year horizon in our cost-benefit comparisons. We return to our assumptions for key parameters below.

2.2. Benefits

The total economic value of an environmental good produced by a policy measure equals the sum of all benefits/values of the change in the ES flow related to changes in land use. In our case this is the sum of the value attached to landscape aesthetics (a type of cultural service), carbon sequestration (a regulating service) and biodiversity (regarded as underpinning both ecosystem processes and a final cultural ES; see e.g. Mace et al., 2012).

The total economic value includes the benefits individuals derive from using the good (use values) and the value they place on the good even if they do not use it (non-use values). Landscape aesthetics affect both non-use and use values. Landscapes provide existence and bequest values through people's feelings towards how and for what purpose different types of land are managed and their sense of place, and use values through visual perceptions, such as observing landscapes while travelling or walking from home/cabin. The ability of landscapes to sequester carbon is a global public good, and the marginal benefit of carbon sequestration for individuals themselves approaches zero. Biodiversity is also a global public good (IPBES, 2019), in terms of biodiversity as basis for ES and future food security. Although the value of biodiversity is often attributed to containing a large part of existence value (non-use value), people also appreciate the experience of nature, enjoying flowers, birds and butterflies (use value). The value of carbon sequestration is more related to future generations' use values, i.e. bequest values. Thus, while it is currently a non-use value, it may, by time, turn into a use value for future generations enjoying a beneficial climate.

The economic value of the overall stream of social benefits can be defined by the compensating surplus (CS), which is measured by the beneficiaries' willingness to pay (WTP) for the benefits. This relationship is defined by the underlying conditional indirect utility function, where the maximum WTP for the policy measure described in scenario A, WTP^A, is defined as the reduction in income which makes the beneficiary indifferent between a situation with and without the policy measure (e.g. Bergstrom and Taylor, 2006) in Eq. (2):

$$\mathrm{V}(P^A, Y - WTP^A; Q^A, QUAL^A, I) = V(P^0, Y; Q^0, QUAL^0, I) \quad (2)$$

Here P is a vector of prices for market goods, which may differ between the status quo/reference case, 0, and the land use scenario A. Y is the aggregated household incomes, Q is a measure of the quantity of land (in the status quo/reference case, 0, or for land use scenario A), as a percentage of abandoned pastures, QUAL a measure of land quality (in the status quo/reference case, 0, or for land use scenario A), for instance biodiversity associated with land use, and finally I is a measure of information available. Solving this equation for WTP^A the annual change in benefits from conducting policy measure A, as compared to a situation with no policy interventions, provides an estimate for the benefits in Eq. (3):

$$\Delta B^A \equiv WTP^A = f(P^A - P^0, Q^A - Q^0, QUAL^A - QUAL^0, I) \quad (3)$$

Eq. (3) defines WTP^A as the amount that can be subtracted from the household's incomes so that the population is indifferent with respect to natural reforestation in the status quo as opposed to an scenario land use. We define the market for land use scenarios (i.e. the population that could potentially gain utility from the chosen policies for land use) as the population of Norway, as these pastures and forests affect carbon sequestration and biodiversity, mainly non-use values, which means that any household in Norway in principle could derive utility.

2.3. Costs

Total social costs given in Eq. (1) can be broken down as follows in Eq. (4):

$$\Delta C^A = \Delta C_P^A + \Delta C_M^A \quad (4)$$

where ΔC_P^A is the annual program cost of implementing policy scenario A and ΔC_M^A is the change in marginal costs of public funds of implementing scenario A.

2.3.1. The cost of the Climate Forest Programme

The CFP aims to incentivise landowners to plant spruce on abandoned pastures to increase the uptake of CO_2 in standing biomass. The Norwegian Environment Agency examined possible organizational models, environmental aspects, costs and future benefits associated with the programme in 2013 and started several pilot projects in three counties to test the forest planting policy. The agency proposed that the CFP should produce 10 million spruce plants and plant 50 million square meters of abandoned pastures a year. The government will cover expenses, including production of plants, administration of the program, the planting and the first years of maintenance by the landowner. We include all these costs, annualised, in our calculations.

2.3.2. The cost of recovering pastures programme

Pastureland can be categorised into different types, such as cultivated and uncultivated pastures, and the different types are grazed by different animals, first and foremost sheep, which graze both cultivated and uncultivated pastures during spring, summer and autumn. There are also cattle, which graze mostly on cultivated pastures, and on mountain pastures during summer farming, and goats, which graze mostly on uncultivated pastures. The areas of focus for this study is abandoned semi-natural pastures, meaning these pastures are not cultivated or fertilised, and they need not be fenced.[1]

The long-term trend has been a reduction in pastures, investments, relative wages and number of farmers, which complicates the calculation of the costs associated with increase in pastures. We assume linear cost of recovering pastures, meaning more recovery cost the same per unit recovered.

2.3.3. The marginal costs of public funds

The distortionary effects of the taxation and tariffs necessary to raise

[1] Except for within the relatively small designated management area for wolves, where sheep must be protected by fences. The designated area streches along the border to Sweden in the most southern part of Norway.

revenue for pastures and climate forests (marginal cost of public funds) are an additional cost in all scenarios. Given that taxes are distortional to the economy, i.e. it is costly in efficiency terms to collect them (Sandmo, 1998), a substantial increase in governmental funding will, *ceteris paribus*, increase the marginal cost of public funds required to compensate farmers. To account for this, we apply a standardised net distortionary factor.

3. Measuring costs and benefits: Methods, data and assumptions

In this section we describe the methods used to estimate benefits and costs of the various land use options. There is no market information that could approximate the value of the ES benefits of land use and biodiversity. We decided to elicit people's preferences for these two ES benefits using the CE method. Thus, benefit estimates are based on data collected specifically for this purpose.

3.1. The Choice experiment survey and benefit estimation approach

3.1.1. Survey development

We held on one focus group to receive feedback on our prototype questionnaire design. After adjusting the questionnaire based on the feedback from the first focus group, we held a second focus group where we conducted one-to-one interviews to perform a final test of the questionnaire before sending out the survey to the Internet panel.

3.1.2. Survey design

The questionnaire contained an introductory section with questions about people's preferences for environmental policy objectives, the CE survey contained text explaining the main topic of the survey, starting by describing the baseline situation of areas in Norway that were previously used for farming and grazing. The policy problem was defined as whether to restore these areas to pastures, set aside and utilise some areas for climate forest planting (of Norway spruce) for a sixty year period, or let them naturally reforest as mixed forest (status quo option). The policy alternatives were defined as various combinations of these three land uses, compared to an alternative representing the status quo situation of natural reforestation (see explanation below). Any active management choice would entail a cost, while leaving the areas for natural reforestation would be free. Based on focus group testing and a qualitative study conducted by means of Q-methodology (see Grimsrud et al., 2019), two main attributes for the CE, in addition to the cost, were identified: combinations of land-use and biodiversity. These attributes were in turn explained in the survey using photos and icons for illustrations (see examples in the Appendix A). For land use, examples of open, grazed pasture, mixed, natural reforestation and climate forest were shown using photos from three representative areas in the three counties of Nordland, Nord-Trøndelag and Rogaland in respectively Northern, Central and Western Norway. In the CE, land use were statistically designed as three different attributes (see Table 2), but graphically, it appeared as a single attribute consisting of combinations of them (see Fig. A4).

The survey then explained how biodiversity in terms of vascular plants such as flowers, herbs and grasses, as well as the occurance of insect species, are the highest in pastures and the lowest in climate forest (Aarrestad et al., 2013). The planted spruce by our design could never occupy more than 50 per cent of the total land area considered (see below for details), and consequently biodiversity levels were permitted to vary independently of the spruce attribute in the CE. The argument for permitting this variation in biodiversity levels was that the impact of planted forest on biodiversity is reduced if one is more careful when determining where to plant. This information was presented to the respondents before they were given the choice sets.

Table 2
– Attributes and levels in the CEs. The status quo level is marked in bold.

Attribute	Specifics	Level vector
Land use	Climate forest	0%, 25%, 50%
	Pasture	0%, 25%, 50%
	Natural reforestation	0, 25%, 50%, 75%, 100%
Biodiversity	Species under threat	400, 550, 700 species
Cost	Additional earmarked income tax per person p.a.	NOK 0, 300, 600, 900, 1200, 1500, 1800

Note: Reforestation is the residual of the land use Climate Forest and Pasture (so the percentages sum to 100 per cent).

Finally, the survey explained above-ground carbon sequestration in the three land use types, from low (pasture) to high (climate forest). The amount of carbon sequestered was derived directly from the proportion of each type of land use in the alternatives in order for the different choices to be realistic – i.e. the highest level of carbon sequestration in the vegetation combined with land use that is all pastures would not appear credible to the respondent, violating content validity. Thus, while we represent carbon sequestration and storage graphically to the respondents as an attribute, statistically they are not, but are rather a specification of the characteristics of the land use attribute. Hence, the combinations of land uses give trade-offs between land use and biodiversity. As we ask for people's preferences, we are looking at changes in a given level, and we assume that these changes can result in the ES provision mentioned in the CE. The areas relevant for the CFP are generally not very accessible and most likely not much used for recreational purposes. Thus, to make sure that all the attributes were relevant, we omitted recreation from the CE. Instead, we chose to ask about recreation in separate questions.

The attribute levels were based on parameters from the initial report on the CFP. This report identifies the total amount of land that could potentially be planted with spruce (Norwegian Environment Agency, 2013). We set the maximum amount of planted spruce or pasture as 50 per cent of the total potential area. In addition, these land uses had levels of 25 per cent and 0 per cent. The amount of the landscape left to naturally reforest was derived as the residual area when the other land uses varied freely. As a result, natural reforestaton has five levels as shown in Table 2. Although the land use options vary by percentage in the choice cards, the respondents are given the exact land area size in the introductory information in the CE. An early estimate of the number of species under threat of extinction in Norway due to abandonment of pastureland was 550 (Henriksen and Hilmo, 2015b). Two other biodiversity levels were added in based on advice from biologists, an increase and a decrease of 150, or about 30 per cent of 550, in the number of species under threat of extinction. The levels of carbon sequestration were estimated on the basis of the CFP report for planted spruce and reforestation (Norwegian Environment Agency, 2013). For pasture we made the assumption that this vegetation can store one third of the carbon stored by planted spruce (Norwegian Environment Agency, 2013). Cost levels were based on feedback from the focus group and one-to-one interviews with respondents.

After receiving information about the impacts of the various land uses, respondents were introduced to the choice sets. They were informed that anything other than status quo would require active management that has a cost that would have to be paid for by an *annual* earmarked income tax levied on all Norwegian households. The CFP, and agricultural policy, is paid for by everyone, so this was not expected to generate much protest.

The CE design was found using SAS and uses the methods and procedures described in Kuhfeld (2009). A full factorial design would have $3 \times 3 \times 3 \times 6 = 162$ profiles and 81 choice sets. We chose to use a fractional factorial design with 18 choice sets based on the output from the MktRuns-procedure. The profiles used in the choice sets were then chosen using the MktEx-procedure with constraints. The design was constrained to prevent the lowest level of red listed species to occur together with the highest levels of area allocated to spruce planting. The status quo alternative was added to the final output of the MktEx-procedure. The ChoiceEff-procedure (Kuhfeld, 2009) optimised the combination of profiles into choice sets. The 18 choice-sets were blocked using the Mktblock-procedure.

Each respondent received either 6 or 12 sets of choices[2] and were asked to choose between two policy options ("Management option A and B") in addition to the status quo ("No management"). The order of the choice sets was randomised between individuals. The choice sets were followed by standard follow-up questions regarding which attribute (if any) they thought was the most important and whether it was difficult to answer. The survey then had a series of questions about recreational use and whether there are areas (counties) people prefer no climate forest planting, before concluding with socio-economic background questions.

3.1.3. Data collection

The data were collected from an Internet survey panel maintained by the survey company NORSTAT, as part of a large nation-wide, representative survey. Internet stated preference surveys have been shown to give reasonable response quality compared to more traditional survey modes such as personal interviews, mail or telephone (Lindhjem and Navrud, 2011a, b). The survey was conducted on a representative sample of the Norwegian adult population in April-May 2018, obtained through their panel. We obtained 977 completed surveys, using a median of 12 min to complete.

3.1.4. Econometric analysis and estimation of WTP for the scenarios

The CE and the corresponding results and welfare measures are based on the random utility model (RUM). RUM assumes that individual utility can be separated into a deterministic part and a stochastic part, as given in Eq. (5) (McFadden, 1974):

$$V_{ij} = v_{ij} + \varepsilon_{ij} \tag{5}$$

where V_{ij} is the indirect utility derived from choice *j* by individual *i*, v_{ij} is the deterministic part and ε_{ij} is the stochastic part of the utility.

The individual faces a choice among three alternatives in each choice situation and is assumed to choose the alternative giving the highest utility. In the survey, the respondent chooses among bundles of attributes; different land uses, biodiversity levels and costs. We use the random parameters logit model (RPL) to estimate of the attributes' effect on respondent choice and the marginal rate of substitution (MRS) between different attributes. The RPL model lets coefficients vary over respondents following an assumed density function of parameters in the survey population. The researcher specifies a distribution for the coefficients and estimates the parameters of that distribution through simulation. The utility of alternative *j* for individual *i* is given by Eq. (6):

$$V_{ij} = x'_{ij}\beta_i + u_{ij} + \varepsilon_{ij} \tag{6}$$

where u_{ij} is a random term with zero mean and whose distribution over individuals and alternatives depends on underlying parameters related to alternative *j* and individual *i*. Further, $x'_{ij}$is a vector of observed attributes, with the estimated corresponding parameters given by β_i while ε_{ij} is an unobserved error term (Hensher and Green, 2003). In most applications, the distribution of u_{ij} is assumed to be normal or lognormal (Train, 2009). We let all the nonmonetary attributes be specified as normally distributed, while the cost parameter is kept fixed, and we allow for correlation between the parameters. Dividing the attribute estimates by the cost parameter gives the estimate of marginal willingness to pay (MWTP) (Train, 2009), as given in Eq. (7):

$$MWTP = \frac{\frac{\partial V}{\partial X_1}}{\frac{\partial V}{\partial C}} = \frac{\beta_1}{-\beta_C} \tag{7}$$

where $-\beta_C$ is the negative coefficient of the cost attribute and reflect the marginal utility of income, while β_1 is the coefficient of a non-monetary attribute. When estimating WTP for the options in our CBA, we must estimate the combined welfare change represented by the corresponding bundles of attributes in each scenario. Deriving a welfare measure consistent with RUM requires calculating the Hicksian Compensating Surplus (CS) measure (Lancsar and Louviere, 2008).

Respondents are asked to evaluate each choice set independently, assuming that only one alternative can be realised. Thus, the CE is a so-called state-of-the-world experiment where a respondent values the changes in the attributes in the scenarios compared to the reference level (Holmes et al., 2017). The CS is given by Eq. (8):

$$CS^A = WTP^A = \frac{1}{-\beta_C}[V^A - V^0] \tag{8}$$

where V^A are the values of the indirect utility function for scenario *A* after the quantity change and V^0 is the status quo option where the abandoned pastures are naturally reforested (Holmes et al., 2017). The estimated parameters are bundled into the land use scenarios in accordance to Table 1. Eq. (9) exemplifies of how WTP for scenario P2 is calculated.

$$\begin{aligned} WTP_{P2} &= -\frac{\beta_1 \Delta x_1 + \beta_2 \Delta x_2}{\beta_C} \\ &= -\frac{Constant + \beta_{Pasture-25\%} * 1 + \beta_{\text{Biodiv}-150\,\text{sp. no long. end.}} * 0.5}{\beta_C} \end{aligned} \tag{9}$$

The estimated parameters for non-monetary attributes are capturing changes in utility when departing from status quo, $V^A - V^0$ in Eq. (8).

3.2. Other benefits and costs

3.2.1. Benefits and cost of the climate forest programme

In 2013, the program was estimated to cost slightly less than NOK 100 million a year throughout a twenty-five year period (Norwegian Environment Agency, 2013), a total of NOK 2.4 billion in 2018 prices. When the government hand out afforestation grants to individual farmers, the farmers agree not to extract timber for the next sixty years. After sixty years the farmers are permitted to utilise the forestry resources. The survey respondents were explained that the farmers were assumed to harvest the trees after 60–80 years. We assume the CFP is implemented within 10 years, and that the costs are about NOK 190 million a year in 2018 prices, totalling NOK 1.9 billion NOK in the 50 per cent afforestation scenarios. The government will cover all expenses, including production of plants, administration of the program, and the planting and management of the climate forests by the forest owners.

In addition to sequestering carbon, planting of climate forests represents future forestry incomes. We assume a single rotation situation, meaning that once trees are harvested, the area may be used for something else, which is consistent across the three alternatives. It also reflects how land use is going to change in the future with climate change and expected changed demand for food and fibre products is highly uncertain, thus assuming a repetition of rotations into perpetuity would not be appropriate for the current analysis. We account for the future harvest incomes of the first rotation and assume that the trees are felled and sold when the trees are 60 years old, meaning that the first trees to be planted in 2022 are cut down in 2082 while the last three to be planted in 2028 are cut down in 2088. The estimated volume of timber in that future point in time is 55 cubic meters per thousand square meters, and we assume that future prices correspond to current prices.[3] We are only to include the net profits in our net benefits calculations, excluding the alternative use of labour and capital, and we assume a 25 per cent profit margin on the value of timber. The calculations are in accordance with valuation assumptions made by The Land Consolidation Courts of

[2] This variation was introduced for another experimental test not reported here. The datasets of respondents who received 6 and 12 choice sets were merged here, to improve efficiency of the estimates.

[3] We assume 70 percent sawlogs and 30 percent pulpwood at a price of NOK 490 per cubic meter of sawlogs and NOK 240 per cubic meter of pulpwood.

Norway (2013) and our resulting estimates are in line with an alternative estimation made by Søgaard et al. (2019).

3.2.2. Costs of recovering pastures

There are several studies investigating the costs of recovering pastures in Norway. Ebbesvik et al. (2017) investigate the cost of incorporating abandoned pastures when farms have excess capacity among labourers, in barns and outbuildings. They find that incorporating abandoned pastures cost about NOK 250 a year per thousand square meters. Small increases in the use of pasture, incorporating abandoned pastures into a farm with excess capacity, will be a lot less costly than a large scale increase in the use of pastures at national level. In our analysis, we investigate situations where the government decides to increase pastures by 337 or 675 square kilometres, more than 2.5 and 5 per cent of the total agricultural land in Norway. Such policies will necessitate both investment and stronger economic incentives for farmers to utilise the pastures. A cost analysis by Fjellhammer and Hillestad (2013) finds that investing in outbuildings and farm equipment reduces sheep farmers' profitability by NOK 1500–2300 per thousand square meters as an annual average. We therefore expect the cost of recovering pastures to be NOK 500 per thousand square meters on average, both when the use of pastures is increased by 337 square kilometres and when the use of pastures is increased by 675 square kilometres. At present, about 65 per cent of the farmers' income stems from governmental subsidies (Fjellhammer and Hillestad, 2013), and since the protection of the consumer markets from outside competition is an additional de facto subsidy, we expect this policy to be covered by governmental taxes and tariffs.

3.2.3. Transaction costs and marginal costs of public funds

In estimating the marginal cost of raising public funds, we follow the guideline of the Norwegian Ministry of Finance (2014), which recommends assuming a cost of NOK 0.2 to raise NOK 1 for a public project or policy. This means in practice that we add 20 per cent to the opportunity and transaction costs of the programs.

3.2.4. List of cost-benefit analysis assumptions

Further assumptions are provided in Table 3. We apply a time period of 70 years, from 2018 to 2088, including a ten-year implementation period and 60 years of climate forest conservation through the program. Regarding the other CBA assumptions, the Norwegian Ministry of Finance presented a White Paper making predictions for Norway until the 2060s in 2013, and a White Paper recommending assumptions for CBA in 2014. We adopt assumptions on number of households, real price growth and discount rates from these government documents, and use the recommended risk-adjusted discount rates of 4 per cent per annum for the first 40 years, and 3 per cent per annum for the years thereafter (Norwegian Ministry of Finance, 2014).

4. Analysis and results

4.1. Estimation of annual benefits

The response rate for the CE survey was 16 per cent, and the completion rate was 82 per cent. The sample shows fairly good representativeness of the Norwegian population along the dimensions of gender, age distribution and education.[4]

Attribute levels for pastures, climate forest and biodiversity are dummy coded with the status quo of natural reforesting as the reference level. We include an alternative specific constant term coded as a dummy equal to one on the alternative scenarios, capturing respondent's unobserved preference for moving away from the status quo. Table 4 presents the RPL model estimated on CE data.

[4] Respondents with solely primary school is underrepresented in our data.

The coefficients of pastures, climate forest, biodiversity and income tax all have the expected signs. The coefficients for biodiversity show, as expected, a higher marginal value of a loss than of a gain of the same size.

The parameter coefficients indicate that respondent's value recovered pastures significantly higher than planted spruce. Respondents value pasture higher than natural reforestation (status quo). The two pasture coefficients are significantly different from each other but close in value; respondents' value 25 per cent pasture recovery almost at as much as 50 per cent pasture recovery. The coefficients for planted spruce are not significantly different from each other and only the 25 per cent level is different from the status quo at 90 per cent significance level.

All the standard deviation parameters are statistically significant and large relative to the mean coefficients, implying large heterogeneity among the respondents. The coefficients for s_{11} to s_{66} are the lower triangular Cholesky decomposition of the variance-covariance matrix. Twelve of these eighteen coefficients are significant, indicating substantial correlation between the parameters. The variance-covariance matrix and the correlation matrix are included in Table B1 in Appendix B. We find large correlation coefficients between the different levels of attributes. We have also run a model with independent parameters, not reported here, resulting in larger and significant parameters for planted spruce and a smaller significant constant parameter.[5]

We calculate the WTP for changes in non-monetary attributes relative to the base case, according to Eq. (9), following Holmes et al. (2017). We calculate standard errors and confidence intervals using the delta method. The results are presented in Table 5.

The scenarios involving some recovery of pastures yield higher WTP, reflecting both higher valued land use and increased biodiversity compared to status quo, F1, and F2. The scenarios involving solely the CFP (F1 and F2) are less popular, although the land-use is valued positively, this is severely dampened by the negative effects of the biodiversity reduction. Notice, the only reason this scenario has a positive WTP at all, is due to the constant term indicating a willingness to pay to move away from status quo regardless of the policy.

The highest WTP is obtained from the P1 pasture recovery of half of the abandoned land scenario and the PF2 scenario, which is not significantly different from each other, but significantly higher than the other scenarios.

We calculate the population's annual WTP for land uses by multiplying household WTP by the number of households in Norway in 2018 (see Table 5)[6] . We assume that planting of climate forests and recovering of pastures will be implemented during a ten year period, so that the population WTP figures will increase stepwise from zero to the levels presented in Table 5 during implementation of policies.

4.2. Estimation of other annual costs and benefits

4.2.1. Benefits and cost of the CFP

We consider an introduction of the scheme initiated in 2018 and completed within ten years. We assume the production of the spruce plants starts in 2020. In 2022 the planting starts, and as of this year, the total costs will be approximately NOK 230 million a year (see Table 6). We base our cost estimation on the Norwegian Environment Agency's

[5] Results available upon request.

[6] The survey text introducing the annual earmarked income tax was somewhat ambiguous, both asking for individuals' WTP and stressing household budget constraints. Since we ask people to value public goods where for most respondents it may be natural to think about their household members, we chose the conservative approach to aggregate WTP by households rather than individuals. The literature is generally not clear on which unit to choose in SP surveys (Johnston et al., 2017; Lindhjem and Navrud, 2009), and it is hard to think of a tax or other payment vehicle that is measured out and paid by the household.

Table 3
Assumptions applied in the cost-benefit calculations.

	Assumed	Source/Source of guideline
Start / end of analysis	2018 / 2088	
Year of assembly	2018	
Years of analysis	70	Norwegian Ministry of Finance
Years to full program implementation	10 years	
Benefits estimated from CE		
Included net profits from forestry in benefits		
Programs publicly financed		
Additional cost of public financing	20%	Norwegian Ministry of Finance
Discount rate	4% (2018–2057)/3% (2057–2088)	Norwegian Ministry of Finance
Real price growth	0.8 %	Norwegian Ministry of Finance
Number of households 2018	2 409 257	Statistics Norway
Number of households in 2060	2 959 136	Statistics Norway

program cost estimates, a recent report on the effect of planting on natural reforesting areas (Søgaard et al. 2019) and a recent evaluation of the CFP (Norwegian Environment Agency, 2019). We assume linear cost between 50 per cent and 25 per cent programs, except for administrative costs, which is higher in the 25 per cent scenarios.

In addition, we calculate the incomes from future forestry of the climate forest. We expect that on good site quality three quarters of the climate forest provides financially profitable forestry in the future, and thus a ten year of forestry incomes towards the end of our period of analysis. Given today's timber prices minus operating costs (25 per cent profit margin), we calculate the present value of future incomes at about NOK 30 million a year from 2078 to 2088 in scenarios where half of the abandoned pastures are afforested with spruce, and NOK 15 million when a quarter the abandoned pastures are afforested with spruce. From 2088 we allow land use to be changed – or continued. Thus, we look at a single rotation situation.

4.2.2. Costs of recovering pastures

To simplify, we assume that both the 50 per cent and the 25 per cent scenarios of recovering abandoned pasture, through the reintroduction of grazing animals, are implemented stepwise over a ten-year period. This implies that pastures gradually recover from 2019 and are fully recovered, according to the land use specified in the respective scenarios, in 2029.

In the 50 per cent scenarios, we assume linearly rising cost from 2019 until 2029, where additional NOK 34 million NOK is funnelled to farmers in 2019, rising to NOK 337 million per year from 2029 and onwards throughout the time period analysed (see Table 7).

In the 25 per cent scenarios, we also assume linearly rising costs from 2019 until 2029, where additional NOK 17 million is funnelled to farmers in 2019, rising to about NOK 169 million per year from 2029 onwards.

4.3. Cost-benefit comparisons

The net present values of the population's willingness to pay and program costs calculated using the standard CBA assumptions listed above, are provided in Table 8. Our main result is that active use of the abandoned pastures, whether through pasture recovery, planting spruce forest in the CFP or a combination of these policies, is preferable to the status quo option of natural reforestation. When comparing our scenarios, we see that the 50 per cent and 25 per cent pasture scenarios

Table 4
Results of random parameters logit model discrete CE, correlated parameters simulated through 600 Halton draws. *** $p < 0.01$ ** $p < 0.05$ *$p < 0.10$.

Mean		Coefficient	Standard error
Pasture recovery: 25% of abandoned land	Mean	1.148***	0.11
	Std.dev.	2.646***	0.15
Pasture recovery: 50% of abandoned land	Mean	1.209***	0.13
	Std.dev.	3.271***	0.15
Climate forest program: 25% of abandoned land	Mean	0.167**	0.08
	Std.dev.	1.827***	0.10
Climate forest program: 50% of abandoned land	Mean	0.094	0.09
	Std.dev.	2.236***	0.12
Biodiversity: 150 species no longer endangered	Mean	0.346***	0.06
	Std.dev.	0.988***	0.09
Biodiversity: 150 additional endangered species	Mean	−0.477***	0.07
	Std.dev.	0.746***	0.10
Income tax (per 1000 krone) (fixed)		−0.971002***	0.00
Alternative specific constant		1.300***	0.10
s_{11}		2.65***	0.13
s_{21}		3.22***	0.15
s_{31}		1.41***	0.11
s_{41}		1.60***	0.13
s_{51}		0.37***	0.10
s_{61}		0.07	0.11
s_{22}		0.59***	0.12
s_{32}		−0.05	0.23
s_{42}		0.27	0.23
s_{52}		0.22	0.15
s_{62}		0.26	0.16
s_{33}		1.16***	0.09
s_{43}		1.49***	0.10
s_{53}		−0.06	0.11
s_{63}		0.32***	0.11
s_{44}		−0.40***	0.11
s_{54}		−0.89***	0.08
s_{64}		0.58***	0.12
s_{55}		0.01	0.34
s_{65}		−0.17	0.32
s_{66}		−0.12	0.32
Number of repondents/choice sets	977/8214		
Pseudo - R^2	0.277		
Log likelihood	−6,011.4		
LR $\chi^2(21)$	4621.3		

Note: 1 2018-NOK = 0104 EURO. The population's yearly WTP given in billion Norwegian 2018-kroner.

Table 5
Willingness to pay (compensating variation) per household per year for land use scenarios (2018 NOK).

Scenarios	WTP per household	Standard error	CI 95% - LB	CI 95% - UB	The population's yearly WTP
P1 Pasture - 50% of abandoned land	2939	178	2591	3289	7.1
P2 Pasture - 25% of abandoned land	2699	143	2418	2981	5.6
F1 Climate forest - 50% of abandoned land	944	127	695	1193	2.3
F2 Climate forest - 25% of abandoned land	1265	109	1052	1478	3.0
PF1 Pasture and climate forest (50%/50%)	2680	200	2288	30573	6.5
PF2 Pasture and climate forest (50%/25%)	2933	202	2539	3329	7.1
PF3 Pasture and climate forest (25%/50%)	2373	175	2029	2716	5.7
PF4 Pasture and climate forest (25%/25%)	2685	170	2351	3018	6.5

(P1 and P2) yield larger net benefits than the 50 per cent and 25 per cent climate forest scenarios (F1 and F2).

The households' WTP for policy measures other than the status quo of natural reforestation of the abandoned pastures yield net benefits between NOK 51 and 158 billion, implying that any of the policies considered would be highly efficient use of public resources. According to our respondents' choices and the subsequent cost-benefit comparisons, our results indicate that the scenario P1 where half of the abandoned pastures are recovered yields the highest net present value. This scenario provides the largest household WTP together with the PF2 Pasture and climate forest (50 per cent/25 per cent) scenario but is a less extensive program and thus cheaper to implement than PF2. In conclusion, the difference in aggregated welfare between pure pasture and the combined policies with 25 per cent CFP land use are not large, indicating that the loss in aesthetic values of establishing climate forest may be compensated by carbon sequestration. Notice that the value of carbon sequestration, and potential substitution effects in future use of the wood is elicited through respondents' value hereof seen together with the land-use attributes.

4.4. Sensitivity considerations

Stated preference methods have been under scrutiny for estimating exaggerated welfare estimates, especially non-use values (Johnston et al., 2017). Murphy et al. (2005) found that among 28 stated preference valuation studies, 83 observations had a median ratio of hypothetical to actual value of 1.35. All our scenarios remain positive even if we cut the willingness to pay figures by half, meaning net present benefits are positive at a 100 per cent hypothetical bias level, while the scenario with the highest net present value change to the P2 Pasture (25 per cent/0 per cent) scenario.

Our cost estimates are uncertain. Although the costs could be underestimated, the scenarios considered yield benefit-cost ratios ranging from 16 to 35, suggesting that cost is unlikely to overturn total benefits. We test whether changing the estimated costs change the ranking of scenarios and find that the P1 Pasture (50 per cent/0 per cent) scenario remains the most beneficial scenario when multiplying costs by factors of 0.5, 1.5 and 2.

A central issue in CBA is defining the extent of the market (Loomis, 2000; Johnston et al., 2017). Should all households in the country count equally, or should the preferences of households closer to the abandoned pastures be given a higher weight than households further away? One can argue that households in the larger cities are likely to be less informed and affected by the ongoing abandonment of agricultural land and that the aesthetics related to landscapes are more relevant to households living in the affected areas. We check whether our results remain stable when restricting the analysis to rural households.

Unfortunately, we lack detailed geographical information on the abandoned pastures, thus we cannot easily determine which and how many households are close to abandoned pastures. As a second-best solution we use urban-rural dimension as an instrument. Although the urban-rural dimension is unrelated to landscapes and pastures, it should coincide with the approximate geographical location of abandoned

Table 6
Estimated annual costs of the CFP. Million Norwegian 2018-kroner.

Levels	1st Year	2nd Year	3rd Year	4th to 10th Year
50 % of abandoned pastures	61	111	181	230
25 % of abandoned pastures	61	86	121	146

pastures, which one is relatively more likely to encounter in rural areas where agricultural production is costlier due to difficult terrains and long distances. When running the model presented above and restricting the analysis to the 323 500 most rural households[7], rather than the whole Norwegian population, we find that all the scenarios retain the positive net benefits result. The P1 and P2 scenarios are the most efficient due to higher WTP for pasture recovery among rural households, revealing spatial heterogeneity of pasture ES values. Economic theory motivates several explanations for spatial welfare patterns, such as distance decay of use values, substitutes and complements distributed across space, and spatial dimensions of scope and diminishing marginal utility (Glenk et al., 2019). Shorter distance to use values of pastures and biodiversity such as visual perception of landscape, experiences of nature, flowers, birds and butterflies, might explain the higher WTP among rural households. See results in Appendix C.

5. Discussion and conclusion

Our CE and corresponding CBA indicate that recovery of abandoned pastures would be efficient use of land. Climate forests may be an efficient measure to meet the 80–95 per cent carbon dioxide emission reduction target in 2050, but other societal demands require land use management measures to recover semi-natural pastures as well, both because of landscape values and biodiversity benefits. Apart from the effect on the landscape itself, the result is driven by a strong preference for biodiversity conservation. From an economic point of view, any of the policy measures considered are highly beneficial compared to the status quo of natural reforesting. Recovering half of the abandoned pastures is the most preferred scenario, and while setting aside land area for climate forests for sixty years is slightly preferred over natural reforestation, respondents do have strong preference for departing from the status quo scenario of no management. Our results lend some support to the favourable assessment of the pilot program made by Søgaard et al. (2019) and Norwegian Environment Agency (2019). These studies conclude that recently abandoned pastures with high site quality should not be used for climate forests due to biodiversity concerns, while already reforested pastures, not considered in our study, are more suitable for the CFP.

Respondents were not scope sensitive to the area coverage. While this could be an indication of low validity of the survey, an alternative explanation is that people find that *some* traditional land use is important to keep, somewhat independently of specific size. The ranking

[7] According to index number 5 and 6 in Statistics Norway's centrality index (Statistics Norway, 2017).

Table 7
Estimated annual costs of the recovering pastures policy. Million Norwegian 2018-kroner.

Levels	1st Year	2nd Year	3rd Year	…	After 10th Year
50 % of abandoned pastures	34	68	101	…	337
25 % of abandoned pastures	17	34	51	…	169

Table 8
Summary of present value (PV) benefits, costs and net benefit compared to status quo in billion Norwegian 2018-kroner.

Scenarios	Household WTP (aesthetics, carbon sequestration and biodiversity)	Program net costs (incl. forestry incomes and cost of public financing)	PV Net benefits
P1 Pasture - 50% of abandoned land	167	−10	158
P2 Pasture - 25% of abandoned land	154	−5	149
F1 Climate forest - 50% of abandoned land	54	−3	51
F2 Climate forest - 25% of abandoned land	72	−2	70
PF1 Pasture and climate forest (50%/50%)	153	−13	140
PF2 Pasture and climate forest (50%/25%)	167	−12	155
PF3 Pasture and climate forest (25%/50%)	135	−8	127
PF4 Pasture and climate forest (25%/25%)	153	−7	147

of scenarios holds when increasing the costs, while when allowing for substantial hypothetical bias the scenario where a quarter of the abandoned pastures are recovered as pastures is most efficient.

There are some examples of similar, but not directly comparable studies. Hynes et al. (2011) find a compensating surplus of EURO 22 per person per year for a sustainable rural environment in Ireland, implying the same area of pastures as status quo and improved conservation of species and stone walls. This would amount to about NOK 600 per household in 2018 prices and is roughly similar to our WTP estimates for enhanced biodiversity. Huber and Finger (2019) find in a recent meta-analysis of monetary valuation studies of cultural ES aesthetics, thus including e.g. landscape aesthetics values but not carbon sequestration values, a willingness to pay by EURO 53 per person per year for an increase in grasslands in less-intensive land-use in mountain regions, about NOK 1300 per household in 2018 prices. In another study from Ireland, Campbell et al. (2008) find a WTP for safeguarding *some* pastures as EURO 190, and a WTP for safeguarding of *a lot* of pastures as EURO 210 per individual per year, which is higher but comparable with our results.

Designing public policies targeting a large geographical area, like an entire country, faces the problem that people may care less about the extent – but more about the process and where benefits are distributed. If this is a problem, it also carries over to similar surveys. Interestingly, similar to our findings, Campbell et al. (2008), as noted above, find a similar low scope sensitivity.

In the analyses we have excluded recreational values which is in line with the lack of geographical specificity as it would require people to link national policies to where they specifically recreate. We have addressed this by telling respondents that climate forests will not be established in areas of importance for recreation. If they have ignored this, they could potentially have factored it in.

Further, aggregation of household level welfare estimates becomes an important issue in CBA, especially as the study is on a national scale. Many studies find unrealistically high welfare estimates when mean WTP estimates are aggregated over a national population (e.g. Sanchirico et al., 2013; Lindhjem et al., 2015). Recent guidance on the use of SP methods mentions that determining the extent of the market “remains a challenge for which research is warranted” (Johnston et al., 2017; p341-2). This issue is also closely related to non-use or existence values, as, for example in our case, only a small part of the population will experience or use the areas for which afforestation is considered. Hence, the extent of the market for non-use values may be difficult to assess and “distance decay” approaches may not be appropriate for high non-use value goods (Zimmer et al., 2012; Johnston and Ramachandran, 2014; Johnston et al., 2015). When we restrict the extent of the market to most rural households, we find net benefits to remain positive across scenarios, while scenario P1 and P2 become most efficient, due to higher WTP for pasture recovery among rural households. An interesting extension would be to go further into the distribution of values across geography.

We rely on general calculations of cost and income of recovering pastures and planting climate forests. A further enhancement of the CBA would be to add more detailed figures on the costs and income possibilities related to different production scenarios. The estimated WTP for pastures, climate forests and biodiversity could be applied in agro-economic modelling, as Norwegian studies using such models have long called for values based on stated preference studies. Brunstad et al. (19992005), for example, adopt the Norwegian JORDMOD model, used by the government for agricultural policy planning purposes, to consider the values of public goods stemming from agricultural production. Brunstad et al. (19992005) had to resort to a crude transfer of values from an old Swedish study (Drake, 1992), since local values were non-existent. The inclusion of our results in agro-economic models could give a better knowledge of the total economic significance of the agricultural and food sector and how policy measures and framework conditions can best be designed. Our results indicate substantial positive externalities stemming from agricultural production.

In our analysis we estimate the value of carbon sequestration through people’s perception hereof through the land use. Thus, we do not explicitly put an estimate on the carbon sequestration, but we do inform people of the carbon sequestration levels of the alternatives. This information is based on the climate sequestration from the pastures and forests and do not include the emissions caused by grazing animals (i.e. methane), thereby implicitly assuming that the meat produced would cause as much emission if produced under other circumstances. Pastures can be maintained both through different production methods associated with different emissions, such as harvesting grass for the purpose of landscape preservation, or by grazing sheep, goats and cattle. We do neither include the potential climate mitigation through future materials substitution due to increased forestry. Natural extensions of our analysis would therefore be to include the cost of emissions of methane gas associated with grazing animals in our CBA, include the effect of materials substitution due to increased forestry and explore the importance of albedo, increased by maintaining the open pastureland. Had we included such values, we would have come up with larger climate policy benefits of the scenarios. However, the difference in estimates of our scenarios is likely small, as carbon sequestration is only a part of the land use attribute evaluated.

Rather than having respondents valuing carbon sequestration indirectly through land-use alternatives, a possibility would be to calculate the value of carbon sequestration explicitly, using a unit price on carbon. Norway's national climate policy has in isolation no effect on the global climate, and therefore inclusion in (national) welfare economic analyses is best done from a cost-effectiveness approach, given the international commitment Norway has made (through the Paris agreement). It is in this light the current paper should be seen – a CBA of a policy to fulfill the overall climate policy through the use of land use changes. Expanding the analysis to let people make tradeoffs between different ways to obtain the goal would be a different approach that we leave for future research.

CRediT authorship contribution statement

Endre Kildal Iversen: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Henrik Lindhjem:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Validation, Writing - original draft, Writing - review & editing. **Jette Bredahl Jacobsen:** Conceptualization, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. **Kristine Grimsrud:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Writing - original draft, Writing - review & editing.

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Appendix A. Example of information set and choice

Figs. A1–A3: The information provided about the CE attributes.

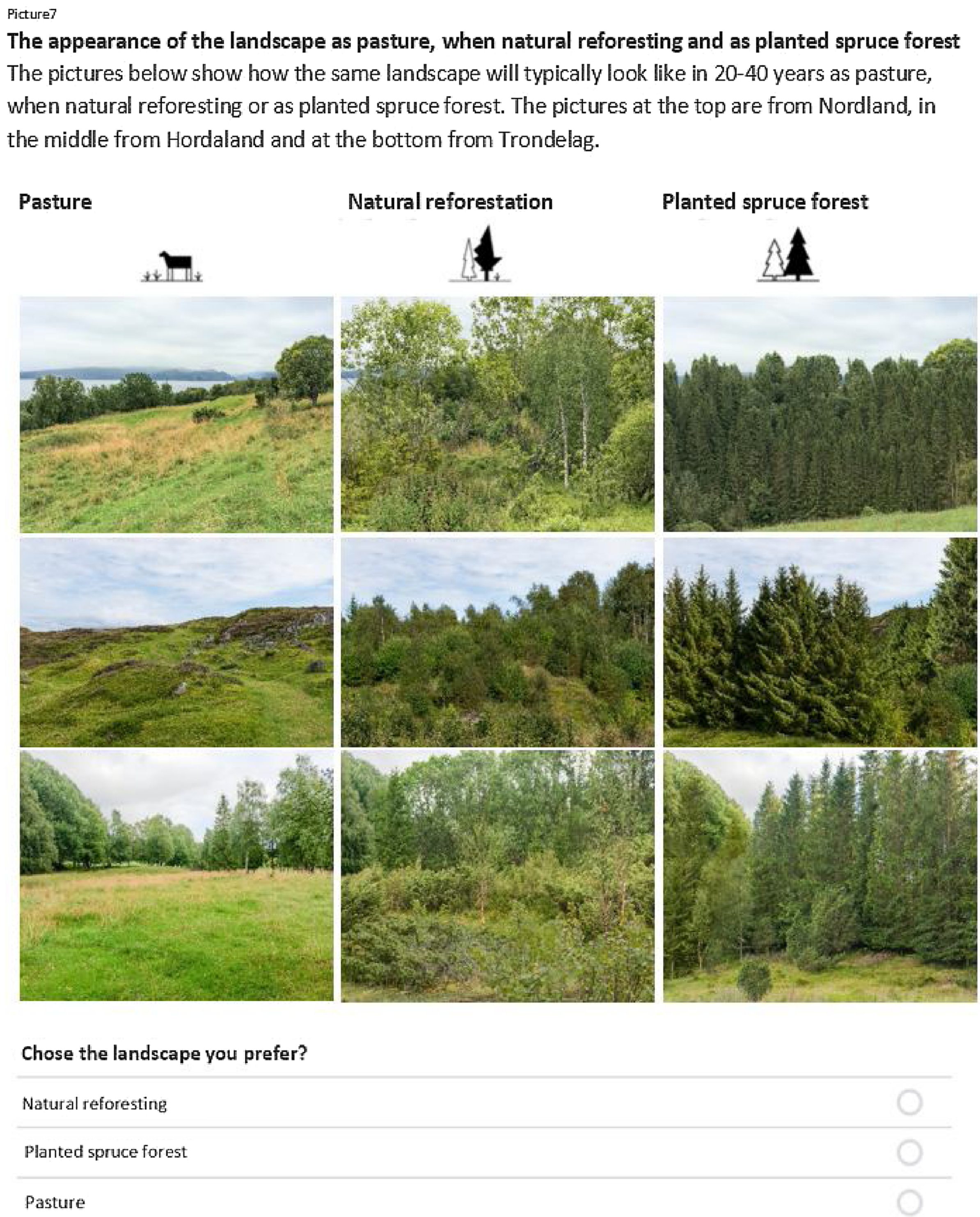


Fig. A1. Information regarding the land use attribute.

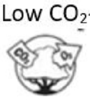
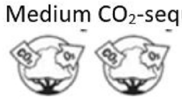
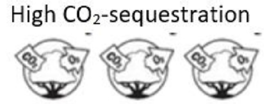
Picture9

Sequestration of greenhouse gases in the vegetation

The densely planted Norwegian spruce probably sequestrate and stores more greenhouse gases (CO_2) than pastures and natural reforesting areas.

It has been estimated that planting of 1,000 km^2 forests will take up 1.45 million tonnes of CO_2 a year over a period of 80 years. This corresponds to about 2.7 per cent of the total Norwegian emissions of approximately 53 million tonnes. Naturally reforesting areas stores about one-third as much CO_2 per km^2 as planted forest.

NOTE: In a given landscape one can influence the consequences for greenhouse gas sequestration in several ways. The greenhouse gas sequestration in forests can be increased by fertilization, denser planting and by other forest care.

Pasture	**Natural reforestation**	**Planted spruce forest**
		
Low CO_2-sequestration  Pastures sequestrate relatively less CO_2.	Medium CO_2-sequestration  Natural reforested areas may sequestrate a significant amount of CO_2, but lower than planted forests because the trees are less dense.	High CO_2-sequestration  The densely planted spruce forest has a high sequestration of CO_2 in the stem, branches and roots below the ground.

Did you know before you received the information above that planted forests take up and store more greenhouse gases than pastures and naturally reforesting areas?

- Yes
- No
- I don't know

Fig. A2. Information regarding the GHG sequestration attribute.

Picture8

What the land use implies for plant and animal life

Most endangered species in Norway are mammals, birds, vascular plants, lichen, butterflies or wasps. Butterflies and vascular plants (herbs and grass) are particularly dependent on pastures to thrive.

The table below shows that there are fewer habitats for endangered grass, herbs and butterfly species when moving from traditional operated pastures to planted spruce forests. The areas in natural reforesting will house species other than grazing land and planted spruce forest.

NOTE: In a given landscape one can influence the consequences for endangered species in several ways. Through careful mapping of plant and animal life, one can make sure that the most important habitats for endangered species are kept in traditional operation and are not planted with forests or grow back again.

Pasture	**Natural reforestation**	**Planted spruce forest**
		
High species richness On these areas, endangered grass, herbs and butterfly species live. Due to reforesting and modern farming operations, one third of these species are threatened.	**Medium species richness** These areas have fewer endangered grass, herb and butterfly species than pastures but will house some other species.	**Low species richness** Dense, planted spruce has few grass and herbs and rarely shelter endangered grass, herbs and butterfly species.

Did you know before you received the information above that traditional operated pastures have more endangered species than planted spruce forest?

- Yes ○
- No ○
- I don't know ○

Fig. A3. Information regarding the biodiversity attribute.

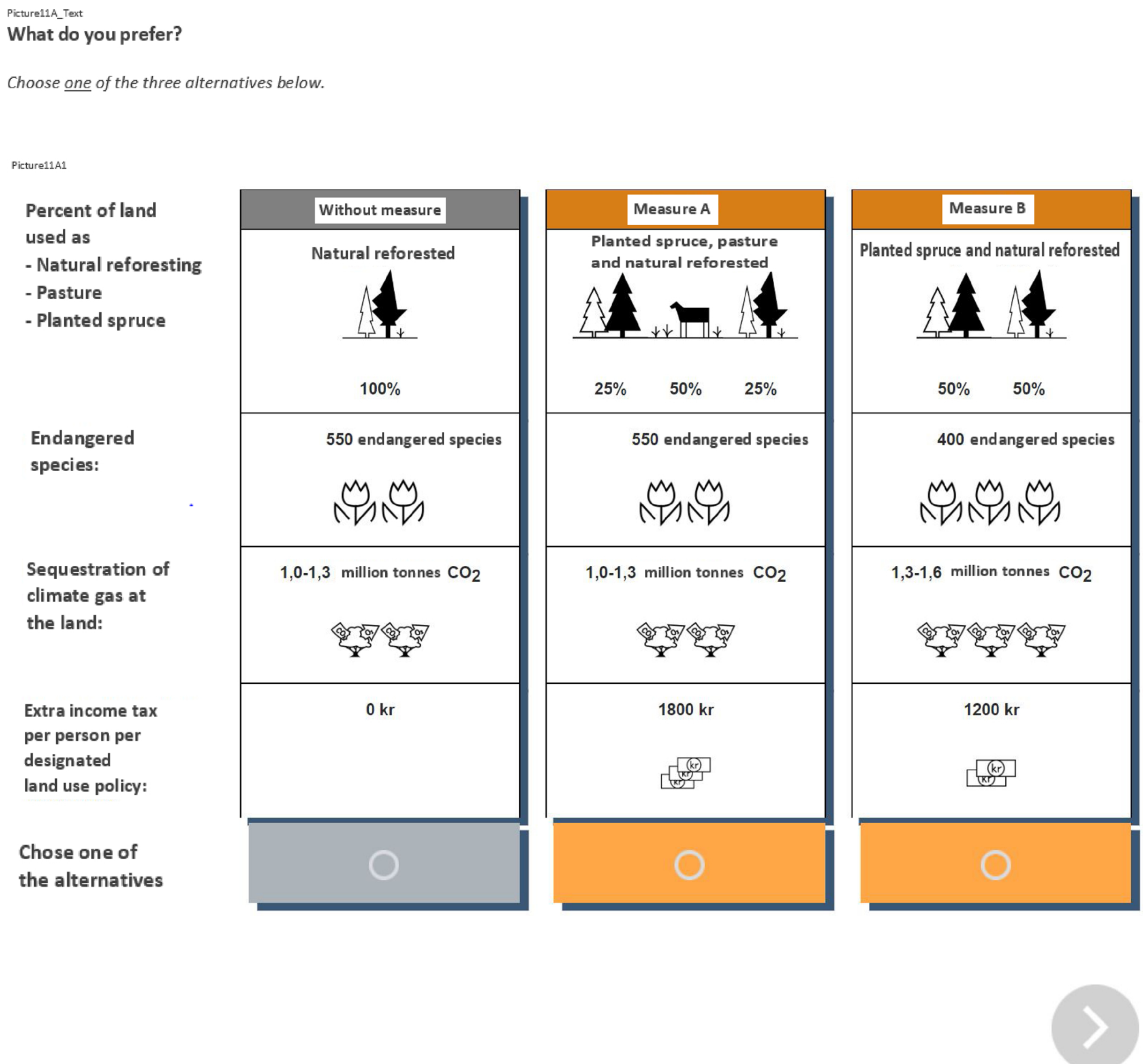


Fig. A4. Choice set example.

Appendix B. Variance-covariance and correlation

Table B1
Variance (diagonal), covariance (lower triangular) and correlation (upper triangular, grey area).

		Pasture recovery		Climate forest program		Biodiversity	
		25% of abandoned land	50% of abandoned land	25% of abandoned land	50% of abandoned land	150 species no longer endangered	150 additional endangered species
Pasture recovery	25% of abandoned land	7.00	*0.98*	*0.77*	*0.71*	*0.37*	*0.10*
	50% of abandoned land	8.51	10.70	*0.76*	*0.72*	*0.40*	*0.16*
CFP	25% of abandoned land	3.74	4.51	3.34	*0.97*	*0.24*	*0.34*
	50% of abandoned land	4.22	5.29	3.97	5.00	*0.41*	*0.26*
Bio-diversity	150 species no longer endangered	0.97	1.30	0.43	0.90	0.98	*−0.62*
	150 additional endangered species	0.19	0.39	0.46	0.44	−0.46	0.56

Appendix C. Rural analysis

Tables C1–C3

Table C1
Results of random parameters model discrete CE, correlated parameters simulated through 600 Halton draws. Most rural households. *** $p < 0.01$ ** $p < 0.05$ *$p < 0.10$.

Mean		Coefficient	Standard error
Pasture recovery: 25% of abandoned land	Mean	1.28***	0.39
	Std.dev.	2.76***	0.42
Pasture recovery: 50% of abandoned land	Mean	1.44***	0.45
	Std.dev.	3.35***	0.47
Climate forest program: 25% of abandoned land	Mean	−0.02	0.25
	Std.dev.	1.62***	0.33
Climate forest program: 50% of abandoned land	Mean	−0.25	0.28
	Std.dev.	1.91***	0.37
Biodiversity: 150 species no longer endangered	Mean	0.08	0.22
	Std.dev.	1.07***	0.31
Biodiversity: 150 additional endangered species	Mean	−0.49**	0.19
	Std.dev.	0.76***	0.28
Income tax (per krone) (fixed)		−0.00***	0.00
Constant		1.27***	0.33
s_{11}		2.76***	0.42
s_{21}		3.24***	0.47
s_{31}		1.21***	0.34
s_{41}		1.42***	0.36
s_{51}		0.64*	0.34
s_{61}		0.47	0.29
s_{22}		0.87***	0.31
s_{32}		0.40	0.43
s_{42}		0.57	0.53
s_{52}		−0.28	0.37
s_{62}		−0.17	0.31
s_{33}		1.01***	0.27
s_{43}		1.14***	0.29
s_{53}		−0.01	0.36
s_{63}		0.54**	0.28
s_{44}		−0.07	0.29
s_{54}		−0.74*	0.41
s_{64}		0.12	0.31
s_{55}		−0.37	0.45
s_{65}		0.11	0.36
s_{66}		−0.02	0.36
Number of respondents/choice sets	95/804		
Pseudo - R^2	0.274		
Log likelihood	−596.4		
LR $\chi^2(21)$	451.7		

Table C2
Willingness to pay (compensating variation) per household per year for land use scenarios (2018 NOK).

Scenarios	WTP per household	Standard error	CI 95% - LB	CI 95% - UB
P1 Pasture - 50% of abandoned land	6,454	2,223	2,096	10,812
P2 Pasture - 25% of abandoned land	5,996	1,927	2,219	9,773
F1 Climate forest - 50% of abandoned land	1,233	924	−578	3,044
F2 Climate forest - 25% of abandoned land	2,328	898	568	4,088
PF1 Pasture and climate forest (50%/50%)	5,702	2,123	1,540	9,864
PF2 Pasture and climate forest (50%/25%)	6,318	2,283	1,845	10,792
PF3 Pasture and climate forest (25%/50%)	4,765	1,783	1,270	8,260
PF4 Pasture and climate forest (25%/25%)	5,860	1,985	1,969	9,752

Note: 1 2018-NOK = 0,104 EURO.

Table C3
Summary of present value (PV) benefits, costs and net benefit compared to status quo in billion Norwegian 2018-kroner. Most rural households.

Scenarios	Household WTP (aesthetics, carbon sequestration and biodiversity)	Program net costs (incl. forestry incomes and cost of public financing)	PV Net benefits
P1 Pasture - 50% of abandoned land	49	−10	40
P2 Pasture - 25% of abandoned land	46	−5	41
F1 Climate forest - 50% of abandoned land	9	−3	7
F2 Climate forest - 25% of abandoned land	18	−2	16
PF1 Pasture and climate forest (50%/50%)	44	−13	31
PF2 Pasture and climate forest (50%/25%)	48	−12	37
PF3 Pasture and climate forest (25%/50%)	36	−8	29
PF4 Pasture and climate forest (25%/25%)	45	−7	38

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