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Trade-offs between carbon sequestration, landscape aesthetics and biodiversity in a cost-benefit analysis of land use options in Norway

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Abstract:
Norway is considering a national afforestation program for greenhouse gas (GHG) sequestration on recently abandoned semi-natural pastureland. However, the program may have negative impacts on landscape aesthetics and biodiversity. We conducted a national choice experiment survey to estimate non-market benefits of the afforestation program, compared to an alternative program of recovering pastures and the status quo of natural reforestation. Combining the preference data with secondary data on costs, we derive the social net return on land use alternatives. We find that restoring half of the abandoned pastures for grazing yields the highest net present value. Rural households closer to abandoned pastures are the largest beneficiaries of this policy due to the value they place on pastures and their disutility of natural reforestation. Their willingness to pay (WTP) for recovering pastures is more than three times that of urban households, while non-use values derived from carbon sequestration and biodiversity seem more constant across space. The net present value of all land use alternatives are still positive when limiting the aggregation of WTP to rural households, and when allowing for the presence of substantial hypothetical bias in benefit estimates and for cost increases. Results indicate that landscape and biodiversity values are substantial and should be considered when designing agricultural and climate policies.

Keywords: Climate forest, biodiversity, pastures, discrete choice experiment, nonuse values, cost-benefit analysis.

JEL classification: Q18, Q15, Q51, Q54, Q57

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Sammendrag

Norske myndigheter vurderer et nasjonalt skogplantningsprogram for klimagassopptak på semi-naturlige beitearealer som ikke lenger er i bruk og er i tidlig gjengroingsfase. I tilegg til virkninger på klimagassopptak, vil programmet påvirke landskapsestetikk og biologisk mangfold. Vi har gjennomført en nasjonal spørreundersøkelse hvor vi benytter et valgeksperiment til å estimere ikke-markedsverdier av ulik arealbruk. Vi sammenstiller resultat fra undersøkelsen med sekundærdata på kostnader og utleder samfunnsøkonomiske nytten av de ulike arealbrukalternativene. Vi finner at gjeninnføring av beitedyr på halvparten av de gjengroende beitearealene gir høyest nettonåverdi. Befolkningen i utkantstrøk har størst glede av alternativet da gruppen har glede av beitelandskap og ikke ønsker at arealene gror til med skog. Rurale husholdningers betalingsvillighet for å tilbakeføre arealer i tidlig gjengroing til beitearealer er over tre ganger høyere enn urbane husholdningers betalingsvillighet. Det er liten eller ingen forskjell mellom by og land når det gjelder ikke-bruksverdiene knyttet til karbonbinding og naturmangfold. Resultatene holder seg når vi begrenser nyttesiden til kun husholdninger i utkantstrøk, tillater hypotetisk skjevhet i betalingsvillighetsundersøkelsen og øker kostnadsestimatene. Våre funn indikerer verdier knyttet til landskap og biologisk mangfold er betydelige og bør vektlegges i utforming av landbruks- og klimapolitikk.

1. Introduction

According to the Paris agreement, Norway will have to cut emissions of greenhouse gases (GHGs) by at least 80 per cent by 2050 compared to the 1990 level. Afforestation and forest management measures to increase carbon storage are becoming an important means of increasing emission reductions. However, these measures may come at the expense of other ecosystem services (ES) provided, and the question is which trade-offs are worth making from a societal perspective (Burascano et al. 2016, Luyssaert et al. 2018).

The Norwegian government is considering implementing a national Climate Forest Program (CFP) for the sequestration of GHGs on former semi-natural pastures, on both already forested land and land that in the process of being naturally revegetated by forest. Semi-natural pastures (hereafter pastures) has been maintained by grazing and the ecosystem depends on grazing (or mowing) to maintain its characteristic biodiversity. In addition, the pastures deliver provisioning ES and cultural ES such as landscape aesthetics, but probably also sense of identity and place[1], as pastures have been an important component of traditional farming. Semi-natural grasslands previously covered large areas but have been considerably reduced across Europe due to land use changes (Jepsen et al. 2015). In recent decades, 9,800 km^2 of semi-natural pastures have been abandoned in Norway, of which 1,350 km^2 have quite recently been abandoned and have not yet become forested (Norwegian Environment Agency 2013). Two reports have recently assesed the program positively, although without including full economic assessment of costs and benefits (Søgaard et al 2019; Norwegian Environment Agency 2019).

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 since many people see the presence of climate forests as an impairment of landscape aesthetics (Graesse 2016; Grimsrud et al. 2019). The loss of pastureland to any type

[1] In this case, of the cultural ES, recreation is not very important in the areas considered for the CFP.

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 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 program or not was to 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 on semi-natural pastureland not yet reforested, compared to the status quo situation. Our focus on land not yet reforested differs from Søgaard et al. (2019) and Norwegian Environment Agency (2019), which also consider the effect of climate forest planting in already reforested abandoned pastures. To estimate the non-market benefits, we elicited people's preferences for different land use options. We conducted a nationally representative choice experiment (CE) internet survey to assess the trade-offs between land uses, including landscape aesthetics and GHG 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 economic return 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), 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 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 alternatives are preferable over the status quo of no management and natural reforesting. Critics have claimed that for CBA to play a more important role in the policy process, a more explicit focus on distributional issues of who wins and who loses is needed to better understand the resulting underlying conflicts of interests (Nurmi and Ahtiainen 2018; Nyborg 2012; Krutilla 2005). Increased emphasis on equity issues has also been recommended by the Ministry of Finance in their guidelines on CBA in Norway (NOU 2012). We investigate the geographical distribution of WTP per household and identify significantly higher willingness to pay (WTP) for pasture recovery and a negative WTP for climate forests among rural households. We do not find biodiversity values to vary significantly across geographic area.

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, pp. 341-2). 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). We conduct sensitivity analysis of different market definitions and find that results are robust to our market restrictions.

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 variations of the extent of the market and geographical distribution of these values. We conclude and discuss the implications of these results in the final section.

2. Analytical framework

The semi-natural (traditional) cultural landscapes 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 were threatened by afforestation of abandoned farms as well as modern farming practises on pastures which involves the use of more fertiliser (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 therefore has the lowest biodiversity of the land uses compared to natural reforestation or maintained pastures (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 of spruce forests. The soil also stores carbon, and soil carbon storage is substantial for boreal forests (IPCC 2000). There are knowledge gaps about the carbon sequestration potential of the soil of pastures (Dahlberg et al. 2013). At the time of this study we did not have sufficient knowledge about soil organic carbon levels for Norwegian climatic conditions for the two other land uses. We therefore, chose 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 only 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 are 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.

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

Cost-benefit analysis (CBA) is a method for ranking policy options to determine whether policies are socially beneficial taking account of both the benefits and costs of the options as compared with a situation without policy interventions (“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 W in terms of the NPV of the future (change in the) flow of net benefits, as given in equation (1):

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

where ΔB is the change in social benefit flow of the ES of landscape aesthetics, carbon sequestration and biodiversity, ΔC is the change in the social cost flow, r is the social discount rate (which may vary over time), T is the time period of the policy and A is the alternative combination (mix) of land uses considered.

We investigate eight alternatives to the status quo in our CBA (cf. Table 1); two alternatives where either half or a quarter of the abandoned pasture is recovered through agricultural production in the form of grazing (alternatives P1 and P2), two alternatives where either half or a quarter of the abandoned pastures are afforested through the climate forest program (CPF) (alternatives F1 and F2) and, finally, four alternatives combining afforestation and pastures (alternatives PF1 to PF4). The associated carbon sequestration ranges from 0,7 to 1,6 million tonnes CO_2 per year, while species under threat range from 400 to 700 species in the different scenarios. The time frame of the land use scenarios is not defined in time in the choice experiment, while we apply a 70 year horizon in our cost-benefit comparisons. We return to our assumptions for key parameters below.

Table 1 – The alternatives and the associated attribute levels in the scenarios.

Alternatives	**Carbon sequestration** (tonnes of CO2)	**Biodiversity** (species under threat)
Status quo	Mid (≈ 1,0-1,3 million)	550
P1 Pasture - 50% of abandoned land	Lowest (≈ 0,7 million)	400
P2 Pasture - 25% of abandoned land	Low (≈ 1,0 million)	475
F1 Climate forest - 50% of abandoned land	Highest (≈ 1,6 million)	700
F2 Climate forest - 25% of abandoned land	High (≈ 1,3 million)	625
PF1 Pasture and climate forest (50%/50%)	Mid (≈ 1,0-1,3 million)	550
PF2 Pasture and climate forest (50%/25%)	Lower mid (≈ 1,0 million)	475
PF3 Pasture and climate forest (25%/50%)	Higher mid (≈ 1,3 million)	625
PF4 Pasture and climate forest (25%/25%)	Mid (≈ 1,0-1,3 million)	550

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 ES 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[2]).

The total economic value includes the benefits individuals derive from use of the good (use values) and the values they place on the good even if they do not use it (non-use values). Landscapes 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, walking or 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, people also appreciate the experience of nature, enjoying flowers, birds and butterflies. 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, in 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 alternative 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):

$$(2) \qquad V_j\left(P_j^A, Y_j - WTP^A; Q_j^A, QUAL_j^A, I_j\right) = V_j\left(P_j^0, Y_j; Q_j^0, QUAL_j^0, I_j\right).$$

[2] We know from other Norwegian studies that biodiversity may provide substantial benefits as a cultural service (see e.g. Lindhjem et al. 2015). We focus on this benefit here and do not attempt to consider the contribution of biodiversity as basis for other services.

Here P is a vector of prices for market goods facing the individual (in the status quo/reference case, 0, or for land use alternative A), Y_j is the household income of individual *j*, Q is a measure of the quantity of land (in the status quo/reference case, 0, or for land use alternative A), as a percentage of abandoned pastures, QUAL a measure of land quality (in the status quo/reference case, 0, or for land use alternative A), for instance biodiversity associated with land use, I_j is a measure of information available to individual *j*.[3] By solving equation (2) for WTP^A, we get an estimate of the benefits in equation (1)[4], i.e. the annual change in benefits from conducting policy measure A, as compared to a situation with no policy interventions:

(3) $$\Delta B_i^A \equiv WTP^A = f(P_j^A - P_j^0, Q_j^A - Q_j^0, QUAL_j^A - QUAL_j^0, I_j)$$

Equation (3) defines WTP^A as the amount that can be subtracted from an individual's income so that she is indifferent with respect to natural reforestation in the status quo as opposed to an alternative land use. We define the market for land use alternatives (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[5].

2.3 Costs

Total social costs given in equation (1) can be broken down as follows:

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

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

[3] The information available to consumers is rarely perfect, and hence it is important to consider the amount and type of information available to individuals when valuing public goods, especially complex goods such as biodiversity (e.g. information given in a questionnaire as discussed subsequently).

[4] Bergstrom and Taylor (2006) point out that in the case of demand and/or supply uncertainty, terms capturing these effects will have to be included and the resulting WTP then measures option price.

[5] We do sensitivity checks on whether restricting the market changes the ranking of alternatives. There could also be reasons to include non-Norwegians, as some areas may be of at least Nordic or European significance (e.g. endemic species to Norway).

2.3.1 The cost of the Climate Forest Program

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 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 each 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 program

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.[6]

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 an increase in pastures. We assume an linear cost function of recovering pastures, meaning more recovery costs 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 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.

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[6] 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.

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 landscape aesthetics and biodiversity. We decided to elicit people's preferences for these two ES benefits using the Choice Experiment (CE) method. Thus, benefit estimates are based on data collected specifically for this purpose.

3.1 Choice experiment survey and benefit estimation approach

3.1.1 Survey design and administration

Following an introductory question 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 60 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; Graesse 2016), three main attributes for the CE, in addition to the cost, were identified: Landscape aesthetics, biodiversity and carbon sequestration. These attributes were in turn explained in the survey using photos and icons for illustrations (see examples in the Appendix). For landscape aesthetics, 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 Northern, Central and Western Norway, respectively. 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 forests (Aarrestad et al. 2013). 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 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 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 and the semi-natural cultural landscape (Henriksen and Hilmo 2015b), due to the long-term management of grazing and/or mowing. Since the planted spruce by our design could never occupy more that 50 per cent of the total land area considered, biodiversity levels were permitted to vary somewhat independently of the spruce attribute in the CE[7]. 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.

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 choice sets 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 various combinations of land uses give trade-offs between landscape aesthetics, carbon sequestration 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 an initial report on the CFP (Norwegian Environment Agency 2013). This report identifies the total amount of land that could potentially be planted with spruce. Since the CFP restricts planting in areas that are imporant for recreation or biodiversity, the total area would not be permitted to be planted. To allow levels to vary independently, 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

[7] The respondents were informed that by thorughly mapping the exact locations of red listed species the negative impact of the CFP on biodiversity could be reduced (i.e. allowing the biodiversity levels to vary somewhat idependently of the amount of forest planting in the CE design).

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).[8] 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. Cost levels were based on feedback from the focus group and one-to-one interviews with respondents.

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

Attribute	Specifics	Level vector
Land use	Climate forest	**0%**, 25%, 50%
	Pasture	**0%**, 25%, 50%
	Reforestation[9]	0, 25%, 50%, 75%, **100%**
Biodiversity	Species under threat	400, **550**, 700 species
Carbon sequestration[10]	Tonnes per year (derived from land use)	0,7-1,0; **1,0-1,3**; 1,3-1,6 million
Cost	Additional earmarked income tax per person p.a.	**NOK 0**, 300, 600, 900, 1200, 1500, 1800

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

After receiving information about the impacts of the various land uses, respondents were introduced to the choice sets. They were informed that anything other that 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 climate forest program, and agricultural policy, is paid for by everyone, so this was not expected to generate much protest.

[8] To elicit preference for biodiversity we simplify impacts in different ecosystems into a single one-dimentional "number of species under threat" attribute. Although this is a crude simplification, it is standard in the economics of biodiversity literature (e.g. Lindhjem et al. 2015).

[9] This is the residual of the land use Climate Forest and Pasture (so the percentages sum to 100 per cent).

[10] In choice modelling language this is not an attribute, as it is fully correlated with the land use attribute. Hence, they could be merged.

The CE design was identified using SAS and uses the methods and procedures described in Kuhfeld (2009). A full factorial design would have resulted in 3x3x3x6 = 162 profiles and 81 choice sets. We chose to use 18 choice sets based on the output from the MktRuns-procedure.[11] ¨

Each respondent received either 6 or 12 sets of choices[12] and were asked about two policy options ("Management option A and B") in addition to the status quo ("No management"). The order of the choice sets was randomised. 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 there to be no climate forest planting (to check "not in my backyard" – NIMBY-effects), before concluding with socio-economic background questions.
In addition to focus group testing, the programmed survey was tested by respondents from Oslo thinking aloud while we observed and checked their understanding, after which several improvements were made. 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 and May 2018. We obtained 977 completed surveys, which had been completed in a median of 12 minutes.

3.1.2 Econometric estimation of mean WTP for the land use combinations

The discrete choice experiment 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 equation (5), and that respondents make discrete choices between options based on their overall utility (McFadden 1974):

(5) $$U_{ij} = V_{ij} + \varepsilon_{ij}$$

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

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[11] 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.

[12] 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.

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 equation (6):

$$(6) \qquad U_{ij} = x'_{ij}\beta_i + u_{ij} + \varepsilon_{ij},$$

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 (Hensher and Green 2003). In most applications, the distribution is assumed to be normal or lognormal (Train 2009). We follow the standard assumption in the literature and let all the nonmonetary attributes be specified as normally distributed, while the cost parameter is kept fixed. 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 equation (7):

$$(7) \qquad MWTP = \frac{\frac{\partial V}{\partial X_1}}{\frac{\partial V}{\partial C}} = \frac{\beta_1}{\beta_C},$$

where C is the cost attribute and X_1 is 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). CS measures the amount of money needed to be received by or taken from a consumer after a price or quality change to leave him or her at the initial level of utility and is the WTP for securing the combined improvement in attributes for the option (Lancsar and Savage 2004).

In our study only one alternative can be realised, which means that the CE is a so-called state-of-the-world experiment where one values the changes in the attributes in the scenarios compared to the reference level (Holmes et al. 2017). The CS is given by equation (8):

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

where β_C reflect the marginal utility of income, V^A are the values of the indirect utility function for each choice alternative A before and after the quantity change and V^0 is the status quo option where the abandoned pastures are naturally reforested (Holmes et al. 2017).

3.2 Other benefits and costs

3.2.1 Benefits and cost of the Climate forest program

In 2013, the program was estimated to cost slightly under NOK 100 million a year throughout a 25 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 60 years. After 60 years the farmers are permitted to utilise the forestry resources.[13] 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 alternative. 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. This is consistent across the three alternatives. It also reflects how land use is going to change in the future with climate change and that expected changed demand for food and fibre products is highly uncertain. Assuming a repetition of rotations into perpetuity would therefore 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 at today’s markets prices when the trees are 60 years old, meaning that the first trees to be planted in 2018 are cut down in 2078 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.[14] 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

[13] The survey respondents were explained that the farmers were assumed to harvest the trees after 60 to 80 years.

[14] 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.

timber.[15] 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 and in barns and outbuildings. They find that incorporating abandoned pastures costs 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 1,500–2,300 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. [16]

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.

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[15] The calculations are in accordance with valuation assumptions made by The Land Consolidation Courts of Norway.

[16] The Norwegian agricultural sector is heavily subsidised. According to Greaker et al. (2005) and Brunstad et al. (2005) Norway would, in a free-trade equilibrium with no subsidies, essentially produce no agricultral food. For simplicity we assume that recovery of abandoned pasture must be entirely financed through government subsidies.

3.2.4 List of Cost-Benefit Analysis assumptions

Further assumptions are provided here (see 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 the number of households, the 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).

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

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 and education.[17]

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

Table 4 - Results of random parameters model discrete choice experiment, correlated parameters simulated through 600 Halton draws. *** p<0.01 ** p<0.05 * p<0.10

Mean		**Coefficient**	**Standard error**	**p-value**
Pasture recovery:	**Mean**	**1.16*** **	**0.11**	**0.00**
25% of abandoned land	Std.dev.	2.72***	0.14	0.00
Pasture recovery:	**Mean**	**1.21*** **	**0.13**	**0.00**
50% of abandoned land	Std.dev.	3.33***	0.15	0.00
Climate forest program:	**Mean**	**0.14***	**0.08**	**0.09**
25% of abandoned land	Std.dev.	1.87***	0.11	0.00
Climate forest program:	**Mean**	**0.07**	**0.09**	**0.43**
50% of abandoned land	Std.dev.	2.27***	0.12	0.00
Biodiversity:	**Mean**	**0.34*** **	**0.07**	**0.00**
150 species no longer endangered	Std.dev.	1.00***	0.09	0.00
Biodiversity:	**Mean**	**-0.48*** **	**0.07**	**0.00**
150 additional endangered species	Std.dev.	0.74***	0.10	0.00
Income tax (per krone) (fixed)		**-0.0009*** **	**0.00**	**0.00**
Constant		**1.32*** **	**0.10**	0.**00**
Number of observations	**24,642**			
Pseudo - R^2	**0.277**			
Log likelihood	**-6,011.4**			
LR $\chi^2(21)$	**4621.3**			**0.00**

Attribute levels for pasture, climate forest and biodiversity are dummy coded with the status quo of natural reforesting as the reference level. We include a constant term coded as a dummy equal to one on the alternative scenarios, capturing respondents unobserved preference for moving away from the status quo. Table 4 presents the RPL model estimated on CE data. Note that carbon sequestration is fully correlated with the land use and therefore does not enter the equation.

The coefficients all have the expected signs. The pasture and biodiversity coefficients are highly significant, while the climate forest coefficients are significantly different from zero for the 25 per cent land use change parameter, but not significant for the 50 per cent land use change parameter.

The parameter coefficients indicate that respondents value recovered pastures significantly higher than planted spruce. Respondents are not very sensitive to the magnitude of land use change, although they value pasture higher than natural reforestration (status quo). The two pasture coefficients are significantly different from each other but close in value; respondents value 25 per cent pastures 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 significantly different from the status quo.

All the standard deviation parameters are statistically significant and large relative to the mean coefficients, implying large heterogeneity among the respondents. 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.[18]

The estimated parameters are bundled into the land use scenarios portrayed in Table 1. Equation (9) exemplifies of how WTP for alternative P2 is calculated:

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

We calculate the WTP for changes in non-monetary attributes relative to the base case, following Holmes et al. (2017). The coefficient for biodiversity - 150 species no longer endangered is multiplied by 0.5 to reflect the number of endangered species in the P2 alternative. We calculate standard errors and confidence intervals using the delta method. The results are presented in Table 5.

The alternatives 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 alternatives involving solely the climate forest program (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 that 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 alternative and the PF2 pasture recovery (50 per cent) and climate forest program (25 per cent) alternative, which is not significantly different from each other, but significantly higher than the other alternatives.

We calculate the population's annual WTP for alternative land uses by multiplying household WTP by the number of households in Norway in 2018 (see Table 5).[19] We assume that the planting of climate

[18] Results available upon request.

[19] 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.

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 the implementation of the policies.

Table 5 – Willingness to pay (compensating variation) per household per year for alternative land use options (2018 NOK)

Alternatives	**WTP per household**	**Standard error**	**CI 95% - LB**	**CI 95% - UB**	**The population's yearly WTP** (billion Norwegian 2018-kroner)
P1 Pasture - 50% of abandoned land	2,944	176	2,600	3,289	7.1
P2 Pasture - 25% of abandoned land	2,718	143	2,438	2,998	5.6
F1 Climate forest - 50% of abandoned land	935	129	681	1,188	2,3
F2 Climate forest - 25% of abandoned land	1,248	109	1,034	1,463	3.0
PF1 Pasture and climate forest (50%/50%)	2,667	196	2,282	3,052	6.4
PF2 Pasture and climate forest (50%/25%)	2,911	197	2,525	3,297	7,0
PF3 Pasture and climate forest (25%/50%)	2,371	174	2,029	2,713	5,7
PF4 Pasture and climate forest (25%/25%)	2,685	170	2,351	3,018	6,5

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

4.2 Estimation of other annual costs and benefits

4.2.1 Benefits and cost of the climate forest program

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 program cost estimates, the recent report on the effect of planting on natural reforesting areas (Søgaard et al. 2019) and the recent evaluation of the climate forest program (Norwegian Environment Agency 2019). We assume equal production cost per thousand square meters in the 50 per cent and the 25 per cent versions of the program, while the administrative costs are assumed equal at both levels.

Table 6 – Estimated annual costs of the Climate forest program. Million Norwegian 2018-kroner

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

Hence, in any case, to make the choice context realistic one often have to resort to an individually based payment vehicle like we did.

25 % of abandoned pastures	61	86	121	146

In addition, we calculate the incomes from future forestry of the climate forest.[20] We expect that on good site quality, three quarters of the climate forest provides financially profitable forestry in the future, and thus 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 of 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 alternatives of recovering abandoned pasture through the reintroduction of grazing animals is 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 alternatives, in 2029.

In the 50 per cent alternatives, we assume linearly rising costs 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).

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

At the 25 per cent level, 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.

[20] We do not include the potential climate mitigation through future materials substitution.

4.3 Cost-benefit comparisons

The net present value 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 climate forest program or a combination of these policies, is preferable to the status quo option of natural reforestation. When comparing our alternatives, we see that the 50 per cent and 25 per cent pasture alternatives (P1 and P2) yield larger net benefits than the 50 per cent and 25 per cent climate forest alternatives (F1 and F2).

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

Alternatives	**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	168	-10	158
P2 Pasture - 25% of abandoned land	155	-5	150
F1 Climate forest - 50% of abandoned land	53	-3	50
F2 Climate forest - 25% of abandoned land	71	-2	69
PF1 Pasture and climate forest (50%/50%)	152	-13	139
PF2 Pasture and climate forest (50%/25%)	166	-12	154
PF3 Pasture and climate forest (25%/50%)	135	-8	127
PF4 Pasture and climate forest (25%/25%)	153	-7	146

The households' WTP for policy measures other than the status quo of natural reforestation of the abandoned pastures yield net benefits between NOK 69 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 alternative P1 where half of the abandoned pastures are recovered yields the highest net present value. This alternative provides the largest household WTP together with the PF2 (Pasture and climate forest, 50 per cent/25 per cent) alternative 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.

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

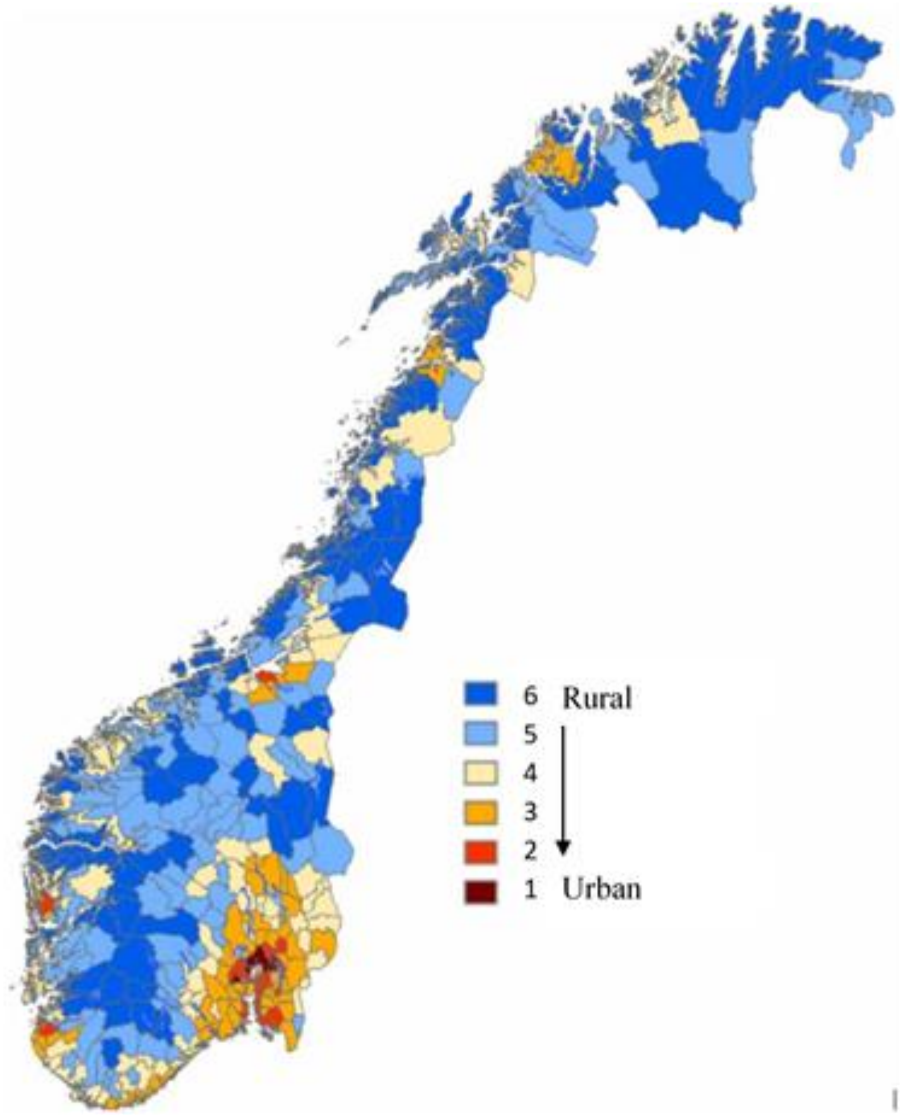
1.35. All our alternatives remain positive even if we cut the willingness to pay figures by half, meaning net present benefits are positive at a 200 per cent hypothetical bias level, while the alternative with the highest net present value change to the P2 Pasture (25 per cent/0 per cent) alternative.

Our cost estimates are uncertain. Although the costs could be underestimated, the alternatives 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 changes the ranking of the alternatives and find that the P1 Pasture (50 per cent/0 per cent) alternative remains the most beneficial alternative when multiplying costs by factors of 0.5, 1.5 and 2, respectively.

4.4 Geographical value distribution

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 those of people 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 for households living in the affected areas.

Figure 1 – Norwegian municipalities classified by centrality. Source: Statistics Norway (2017)



Unfortunately, we lack detailed geographical information about the localisation of the abandoned pastures. As such, we cannot easily determine which and how many households reside close to abandoned pastures. As a second-best solution we use centrality as an instrument (see Figure 1). Statistics Norway has created a centrality index classifying all Norwegian municipalities. The index is calculated using factors such as distance to number of services and jobs. Although the centrality concept is unrelated to landscapes and pastures, it should coincide with the approximate geographical location of abandoned pastures, which one is relatively more likely to encounter in rural areas (indices 5 and 6) where agricultural production is costlier due to difficult terrains and long distances than closer to urban areas. In the urban areas, the largest cities of Norway (indices 1 and 2), there are few pastures, and they are generally not likely to be abandoned to natural reforestation., We hypothesise that landscapes aesthetics are more relevant to households living in close proximity to affected areas, which in Norway would be households in rural areas. The same is assumed for direct appreciation of biodiversity (use value), through enjoyment of flowers, birds and butterflies. The other attributes related to the landscapes, carbon sequestration and the non-use aspect (existence value) of the value of biodiversity, are for a large part not observed in the same way, which might suggest that the values should be evenly distributed across geography.

We test the geographical distribution of the values of attributes interacting our attribute parameters with dummies on the levels of centrality (see Table 9). The urban areas, centrality level 1 and 2, are the omitted reference group, the group in between is centrality level 3 and 4, while what we define as rural households are centrality level 5 and 6. We estimate the willingness to pay dividing attribute coefficients by the cost coefficients.

Table 9 – Results of random parameters model on land use discrete choice experiment, independent parameters simulated using 200 Halton draws. Urban (ind. 1 & 2) is the omitted baseline category

	Mean	Standard error	P-value	WTP	P-value
Constant (fixed) (urban)	**-0.24***	**0.14**	**0.09**		
⁎ In between (ind. 3 & 4)	-0.21	0.22	0.33		
⁎ Rural (ind. 5 & 6)	0.22	0.35	0.54		
Pasture: 25% of abandoned land (urban)	**1.48*****	**0.14**	**0.00**	**1476*****	**0.00**
⁎ In between (ind. 3 & 4)	0.50**	0.22	0.02	511*	0.06
⁎ Rural (ind. 5 & 6)	0.46	0.36	0.20	2876*	0.09
Pasture: 50% of abandoned land (urban)	**1.57*****	**0.16**	**0.00**	**1566*****	**0.00**
⁎ In between (ind. 3 & 4)	0.88***	0.24	0.00	898***	0.00
⁎ Rural (ind. 5 & 6)	0.62	0.49	0.20	3339*	0.09
Climate forest: 25% of abandoned land (urban)	**0.45*****	**0.09**	**0.00**	**445*****	**0.00**
⁎ In between (ind. 3 & 4)	0.03	0.14	0.81	36	0.80
⁎ Rural (ind. 5 & 6)	-0.44**	0.21	0.04	-437	0.33
Climate forest: 50% of abandoned land (urban)	**0.55*****	**0.11**	**0.00**	**550*****	**0.00**
⁎ In between (ind. 3 & 4)	0.02	0.16	0.93	19	0.91
⁎ Rural (ind. 5 & 6)	-0.77***	0.25	0.00	-1041*	0.06
Biodiv: 150 species no longer endangered (urban)	**0.54*****	**0.10**	**0.00**	**541*****	**0.00**
⁎ In between (ind. 3 & 4)	0.13	0.15	0.39	138	0.41
⁎ Rural (ind. 5 & 6)	-0.14	0.26	0.59	-364	0.56
Biodiv: 150 additional endangered species (urban)	**-0.55*****	**0.11**	**0.00**	**-547*****	**0.00**
⁎ In between (ind. 3 & 4)	-0.00	0.15	0.99	6	0.97
⁎ Rural (ind. 5 & 6)	0.04	0.24	0.88	598	0.38
Income tax (per krone) (fixed)	**-.00100**	**.00007**	**0.00**		
⁎ In between (ind. 3 & 4)	.00001	.00011	0.95		
⁎ Rural (ind. 5 & 6)	.00055	.00018	0.00		

We find significant differences in attribute valuation across geography. The cost parameter is significantly lower in rural areas compared to the other areas, which elevate rural household's willingness to pay for the attributes, ceteris paribus.[21] Rural households value pastures significantly higher than urban households, supporting our hypothesis that households living closer to abandoned pastures put greater importance on use values such as landscape aesthetics than urban households. WTP for increased pastures are more than three times higher in rural areas compared to urban areas. There are no significant differences in WTP for biodiversity across geography. WTP for the climate forest program does not differ between urban households and semi-rural households (indices 3 and 4), whilst the rural households have significantly lower WTP. This could indicate that rural households place negative value on use values such as spruce forest aesthetics, while the carbon sequestration is considered equally positive across geography. We obtained WTP results within the three levels of centrality to check whether our results remain stable when restricting non-use values to rural

[21] Income levels are not significantly different across the centrality index.

households, and whether the ranking of preferable alternatives change. This is shown in more detal in Table 10.

Table 10 – Summary of present value (PV) net benefit compared to status quo in billion Norwegian 2018-kroner. Estimates from RPL with correlated parameters, 200 Halton draws

Alternative	Base case	Restricting WTP to: Rural areas (centrality index no. 3-6)	Restricting WTP to: Most rural areas (centrality index no. 5-6)
P1 Pasture - 50% of abandoned land	158	98	42
P2 Pasture - 25% of abandoned land	150	95	43
F1 Climate forest - 50% of abandoned land	50	33	6
F2 Climate forest - 25% of abandoned land	69	46	15
PF1 Pasture and climate forest (50%/50%)	139	87	35
PF2 Pasture and climate forest (50%/25%)	154	97	39
PF3 Pasture and climate forest (25%/50%)	127	82	31
PF4 Pasture and climate forest (25%/25%)	146	94	41
No. of households (2018)	2,409,257	1,347,262	323,547

All the alternatives retain the positive net benefit result due to the large significant constant term indicating a WTP to move away from status quo. Restricting WTP to the most rural areas, the P2 alternative become most efficient together with the P1 and PF4 alternatives.

5. Discussion and conclusion

Our choice experiment and corresponding cost-benefit analysis indicate that efficient land use imply recovery of abandoned pastures. Climate forests may be an efficient measure to meet the zero carbon dioxide emission target in 2050, but other societal demands require land use management measures to recover semi-natural pastures as well, because of both 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 alternative, and while setting aside land area for climate forests for 60 years is slightly preferred over natural reforestation, respondents do have strong preference for departing from the status quo alternative of no management. Our results lend some support to the favourable assessment of the pilot program made by Sørgaard et al. (2019) and Norwegian Environment Agency (2019). These studies conclude that pastures recently abandoned pastures with high site quality should be deprioritized due to biodiversity concerns, while more already reforested pastures, not considered in our study, are more suitable for the climate forest program.

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 the traditional land use is important to keep – to some extent. The ranking of alternatives holds when we increase the costs. However, when we allow for substantial hypothetical bias, the alternative where a quarter of the abandoned pastures are recovered as pastures is most efficient.

We find that net benefits associated with the policy measures considered are unevenly distributed between the rural and central parts of Norway. Rural households' WTP for recovering pastures are more than three times higher than urban households' WTP, which may be due to the value they place on landscapes' aesthetics and related local benefits. While pasture recovery is popular in rural areas, climate forests are considerably less appreciated. If we restrict the market by aggregating the WTP of only the most rural households, alternatives recovering pastures remain the most efficient. Biodiversity values does not vary across geography, indicating this attribute yields non-use values also at the national level.

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. 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. Thus, while a hypothetical bias may be present in stated preference studies, there is evidence in the literature of convergent validity between valuation methods. The uneven geographical distribution of values associated with landscape aesthetics compared to the more even distribution of carbon sequestration and biodiversity values relate to results in Dallimer et al. (2015) and Bakhtiari et al (2018). Dallimer et al. (2015) found, conducting the same choice experiment in several countries, a general WTP for ecosystem services across countries, but services with a use element (habitat conservation, landscape preservation) also attracted a patriotic premium: People were willing to pay significantly more for locally delivered services.

One potential weakness of our study is the already mentioned lack of scope sensitivity for the proportion of the abandoned land converted into pasture or climate forest. 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, Campbell et al. (2008) find that people value *some* preservation almost as much as a lot more preservation of pastures, in line with our findings.

We rely on general calculations of the cost of recovering pastures and planting climate forests without taking the possible income effects of the different programs into account. 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. (1999; 2005), for example, use 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. (1999; 2005) had to resort to very crude transfers 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 provide a better knowledge of the total economic significance of the agricultural and food sector and how policy measures and framework conditions could best be designed. Our results indicate that the externalities of landscape values and biodiversity values stemming from agricultural production is substantial.

In this analysis, we consider the climate sequestration from the pastures and forests and leave out 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. A natural extension of our analysis would be to include the cost of emissions of methane gas associated with grazing animals in our CBA and to explore the potential for methane sequestration by semi-natural grazing land, as well as exploring the importance of albedo, increased by maintaining the open pastureland. These issues remain topics for further research.

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Appendix – Example of information set and choice

Figures A1-A3 - The information provided about the choice experiment attributes

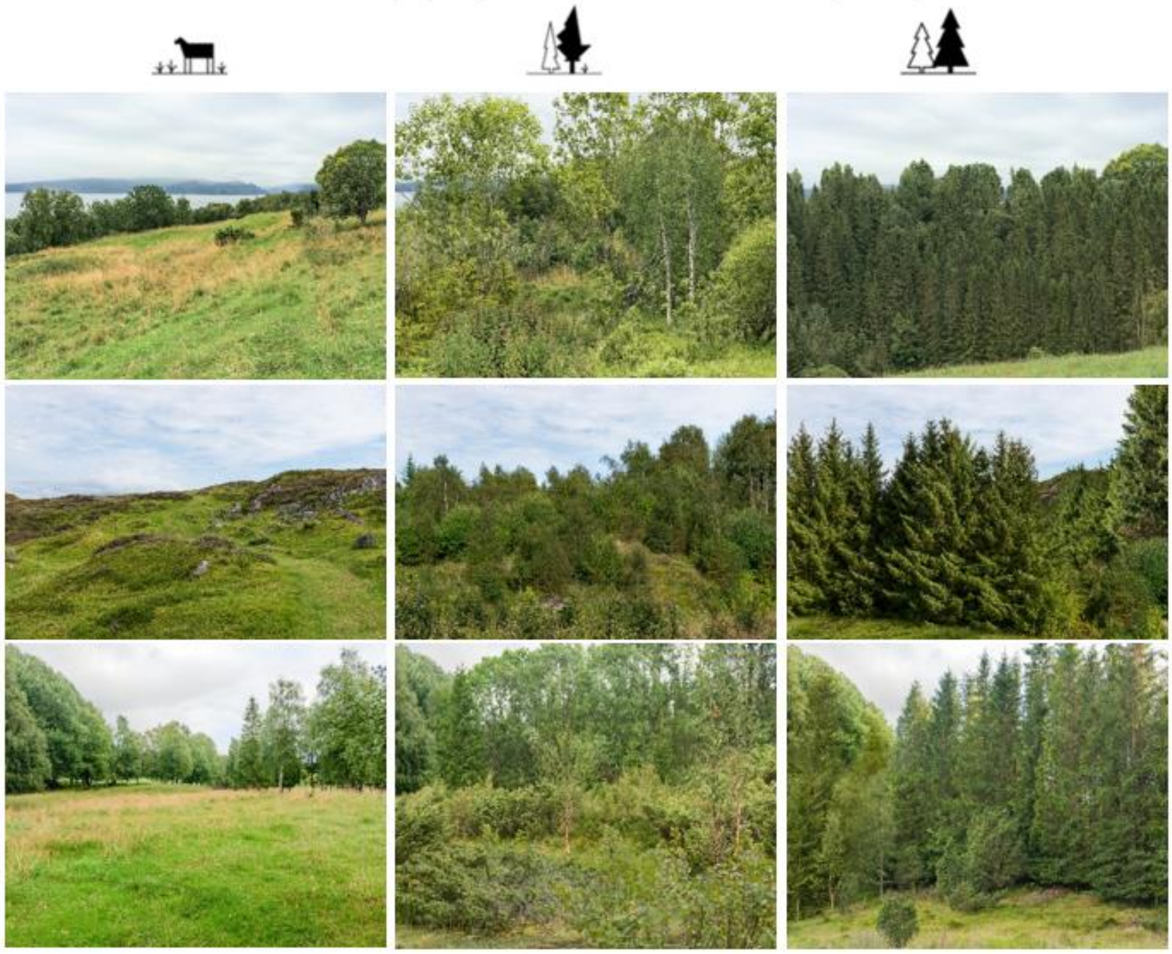
Figure A1 - Information regarding the landscape aesthetics attribute.

Picture7

The appearance of the landscape as pasture, when natural reforesting and as planted spruce forest

The pictures below show how the same landscape will typically look like in 20-40 years as pasture, when natural reforesting or as planted spruce forest. The pictures at the top are from Nordland, in the middle from Hordaland and at the bottom from Trondelag.

Pasture | **Natural reforestation** | **Planted spruce forest**



Chose the landscape you prefer?

Natural reforesting	○
Planted spruce forest	○
Pasture	○

Figure A2 - Information regarding the GHG sequestration attribute.

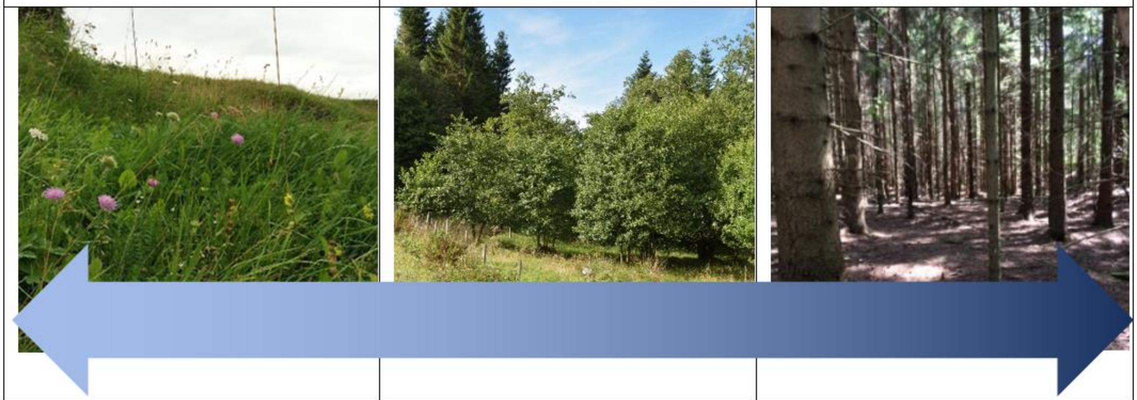
Picture9

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 ○

Figure A3 - Information regarding the biodiversity 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 ○

Figure A4 - Choice set example.