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Do they get what they want?

An analysis of cost and biodiversity effectiveness of voluntary versus government initiated forest conservation in Norway 2005-2013

Får de det de vil ha?

En analyse av kostnads- og biodiversitets-effektivitet av frivillig versus statsinitiert skogvern i Norge 2005 - 2013

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Abstract

The study analyzes cost and utility-cost effective use of government funds for voluntary conservation and government initiated conservation of forest in Norway from 2005 to 2013, to better understand bias in voluntary conservation when compared to government initiated conservation of forested areas. This is accomplished by estimating a mean opportunity cost for a decare of productive forest for the counties included in the analysis, and to compute solutions to a optimization problem, where the different criteria of effectiveness were chosen, to 1) evaluate if and how the two conservation policies differ, and 2) determine the bias of the effectiveness criteria, using cost effective criteria, and three utility-cost effectiveness criteria, targeting: old-growth forest, areas under harvesting pressure, and areas with old-growth forest not under pressure from harvest. Using contemporary available data for: prices, forest and forest distribution, and conservation.

The results indicate that counties where there is perceived availability of forest for harvesting, that for different reasons does not come under pressure for harvesting, were not included in the voluntary conservation scheme. And, an indication that voluntary conservation does not include counties with higher ratio of old-forest. While showing no specific bias towards any of the cost- or utility-cost effectiveness criteria, for either form of conservation.

Sammendrag

Denne studien analyserer effektiviteten av kostnad og biodiversitets-effektivitet for frivillig vern og statsinitiert skogvern i Norge, i perioden 2005 - 2013, for å bidra til å forstå skjevheter i det frivillige skogvern, sammenlignet med statsinitiert vern av skogområder. Dette er gjort ved å estimere gjennomsnittlig alternativ kostnad for en dekar produktiv skog, for de fylker som er inkludert i analysen, deretter så å løse optimerings problem, hvor forskjellige kriterier for kostnad- og biodiversitets-effektivitet er benyttet, for å 1) evaluere om det er forskjeller mellom de to vernemetodene, og 2) undersøke systematiske skjevheter for de forskjellige kriteriene: kostnadseffektivitet, og tre kriterier for biodiversitets-effektivitet bestående av: antatt tilgjengelighet til gammel skog, avvirknings trykk, og gammel skog antatt unnlatt fra avvirkning. Ved bruk av tilgjengelig data for: tømmerpriser, skog og skogfordeling, og vern.

Resultatene indikerer at fylker, hvor det er antatt tilgjengelig gammel skog for avvirkning, som av ulike grunner ikke blir utsatt for hogsttrykk, ikke blir inkludert i det frivillige skogvern. Samt en indikasjon for at frivillig vern til dels ikke inkluderer fylker med større andel gammel skog. Mens det ikke ble funnet indikasjon for at noen av effektivitetskriteriene blir vektlagt, verken for frivillig eller statsinitiert vern.

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1 Introduction

From the start of 2005 until the end of 2013, Norway has increased the conservation of productive forest[1], from 1.71% (1 286.73 km^2) to 2.97% (2 234.18 km^2) (Miljødirektoratet 2014, Skog og Landskap 2014) (summary found in the appendix, table 7). Of this increase of 948.45 km^2, about 320.72 km^2 (34%) has been conserved through the voluntary forest conservation scheme (Norwegian Environment Agency 2013*a*), while the rest has been conserved through different forms of government initiated conservation of productive forest areas [2]. Conservation of productive forest is part of Norway's goal to stop the loss of biodiversity by 2020 (Myhre 2012).

The two main aims of this study is: 1) To compare the effectiveness of using government funds for voluntary conservation versus government-initiated conservation of forested areas, using four different criteria: cost-effectiveness, and three different utility-cost measures for the amount of biodiversity conserved per unit cost. The three proxy measures for utility in terms of the level of biodiversity are i) old forest: as a measure of the higher perceived biodiversity of old forests, ii) harvest pressure: as areas of economic interest from forestry is evaluated as a negative effect on forest dwelling species of the Norwegian red list, iii) old-growth forest with lower harvesting pressure: as a measure of areas that to a lesser extent have economic interest, and because of this could provide areas with potentially greater biodiversity with lower compensations. These utility measures are the same as the governance targets specified by Miljøverndepartementet (2003)[3]

2) To evaluate the bias of the cost- and utility-cost effectiveness criteria for both voluntary conservation and government initiated conservation of forested areas, for the same four measures of effectiveness, measuring to what extent the proxies can explain the conservation bundle.

[1] Productive forests, forests with a growth greater than $0.12m^3$ per decare per year.

[2] Cannot be described as government initiated forest conservation, due to limitations in the observed dataset for total forest conservation. However, it is still productive forest under some form conservation

[3] Klima- og miljødepartementet since January 2014

This is done by creating an optimization environment and evaluating the corner solutions with regards to observed conservation, for different goals of conservation and effectiveness criteria, for both voluntary conservation and government initiated conservation of forested areas for the period 2005 - 2013 for all counties in Norway, except Troms and Finnmark. The solutions to the optimization problem were evaluated with regards to the observed conservation bundle.

The rest of the paper is organized as follows. In section 1.1 I give a brief introduction to the policy context of forest conservation. In section 1.2 I formalize the two main hypotheses of the paper. Section 2 presents the methods for estimating opportunity cost (section 2.1), and derive the optimization problem (section 2.2). Section 3 presents the results (section 3.1) with a sensitivity analysis, discuss the policy implications (section 3.2) and limitations of the analysis (section 3.3). Finally, section 4 concludes.

1.1 Policy Context

In 1993 Norway ratified the Convention on Biological Diversity (CBD), where the goal were to stop the loss biodiversity by 2010 (Myhre 2012). This goal was not reached, and in October 2010 new negotiations were held in Nagoya (CBD COP 10) (Myhre 2012). At the meeting, a new binding goal towards 2020 were ratified, where Norway committed to stop the loss of biodiversity in Norway by 2020 (the so called Aichi goals) (Myhre 2012). As an essential part of this goal, forest conservation is a major part of Norway's strategy to reach these targets, as roughly 50% of species on the Norwegian red list are fully or partially in forest habitats (Kålås et al. 2010).

A analysis of forest conservation in Norway conducted in 2002, found a highly uneven distribution of the conserved areas, with regard to: geography, natural conditions and forest type (Framstad et al. 2002). Further, the evaluation found that there is a lack in the conservation of continuous old-growth forests, and several specific ecosystems in forests (Framstad et al. 2002). At the time only 1% of the productive forest were conserved, while 4.5% were deemed necessary to reach the 2010 goal (Framstad et al.

2002).

The updated Aichi biodiversity targets from 2010 (Goal C, target 11 (CBD 2012)) specify that ”By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape.” This goal was proposed, by the nature conservation organizations, divided into different measures, 10% strict forest conservation through the Nature Diversity Act (Myhre 2012), while the residual 7% should be protected through other area-based conservation measures, such as certifications, prioritized species, and selected habitats (Myhre 2012).

During the 90s there were at times disputes between the forest owners association and environmental authorities', and the situation was perceived as untenable, for both sides (Skjeggedal et al. 2010). The results of these conflicts was the launch of the voluntary conservation scheme by the Norwegian Forest Owners' Association in 2000 and had wide political support (Skjeggedal et al. 2010). The main differences between government initiated conservation and voluntary conservation on private land is to what degree the forest owner can influence the process (Skjeggedal et al. 2010). In voluntary conservation the forest owner is the proposer, and is included in all parts of the planning of the nature reserve (Skjeggedal et al. 2010). While government initiated conservation, the forest owner is not included in the planning process, and would to a lesser extent be able to influence the results (Skjeggedal et al. 2010). However, both voluntary conservation and government initiated conservation follow the same process for estimating compensation for nature reserves, under the Nature Diversity Act (Skjeggedal et al. 2010). These compensations should, in principle, reflect the opportunity cost of choice to forgo harvest for the current and all future harvesting opportunities (Skjeggedal et al. 2010). Although, government initiated conservation

has been attributed higher transaction costs, in the form of negotiations, legal costs, and increase use of time (Skjeggedal et al. 2010).

From 2003 nearly all new processes to conserve forest on private land were conserved by voluntary conservation (Skjeggedal et al. 2010). However, as stated in the start of the introduction, voluntary conservation amounts to 34% of the total conservation of productive forest areas, in the period 2005 - 2013. The remaining areas are either: government initiated conservation of forested areas in the form of regular forest conservation or conservation with other goals than forest conservation, areas which had processes start before the wide spread implementation of voluntary conservation (due to conflicts), or areas wholly owned by the government[4], all situated in productive forests.

According to Sørgård et al. (2012) "There exist several area-based measures to negate negative environmental impacts on forests apart from forest conservation. Sustainable forest management is ensured through legal instruments, such as: the Forestry Act, the nature diversity act, and the Outdoor Recreation Act. And most of Norwegian Forestry is also certified, the certification requirements are based on the Living Forest Standard". With this certification there exists compensation up to a fixed amount for one forest owner, that can be obtained from the authorities for forest set aside and excluded from harvesting (Sverdrup-Thygeson et al. 2009), which is not a part of the voluntary conservation scheme. However, the nature conservation organizations have little faith that these measures represent enough security that areas with high conservation value will be excluded from harvest, and are convinced that there is a need for government initiated forest conservation (Skjeggedal et al. 2010).

[4]Statskog and Opplysningsvesenets fonds skogarealer

1.2 Formalizing the hypothesis

The two hypothesis are expressed in table 1, all hypothesis are tested for the cost- and utility-cost effectiveness criteria.

Table 1: Description of hypothesis, and formalization of their interpretation

	Description	H_0	H_1	H_2
Hypothesis: 1	Cost and utility-cost effectiveness of Voluntary conservation does not differ from government initiated conservation of forested areas.	$Vol = Gov$	$Vol < Gov$	$Vol > Gov$
Hypothesis: 2	There exists no bias of the different forms of conservation of forest w.r.t cost and utility-cost effectiveness.	$Vol = 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol > 0.5$ $Gov > 0.5$

Describing the hypothesis tested in the analysis. Vol is voluntary conservation, and Gov is government initiated conservation of forested areas. The 0.5 measure in hypothesis 2, is represents a unbiased conservation bundle, if its greater than 0.5 there is a bias toward either cost effectiveness, or utility-cost effectiveness, if it is less than 0.5 there is a inverse bias, meaning that the conservation bundle does not tend to cost or utility-cost effectiveness.

2 Methods and data

2.1 Opportunity cost

The opportunity cost for the forest-owner to forgo harvesting of areas with a large amount of restrictions is measured as the net present timber value (NPV) of harvesting the timber without restrictions, for all future harvesting opportunities.

And a general representation of the NPV would take the form of equation 1.

$$NPV_t = f(P_{ts}, C, Q_s, r) \tag{1}$$

Where the net present timber value NPV for one decare can be derived as a function of price P_{ts}, the costs (C) connected to forest management, silviculture, and harvesting, and cubic mass (Q) of timber for one decare, for a specific forest species s, and a discount factor r, for each county. The discount factor r is set to 4%, which corresponds with practice used when finding the net present value for the forest as grounds for compensation (Myrbakken 2011). This NPV cannot be directly observed, thus a mean net present timber-value was derived($\widehat{NPV}$), by obtaining mean cubic mass of timber, and mean price for each county.

Mean cubic mass: The National Forest Inventory(NFI) has an established framework for surveying forests in Norway using a grid of surveyed plots, where they survey: forest type, biodiversity, terrain, vegetation and information about the given tree. Since 1919 the NFI has gathered information about forest growth and development, and published their findings in rapports for each county. These rapports vary greatly in time from the first to the last rapport, and as forests are dynamic entities, this information will only be an approximation of the true forest values.

These rapports contain data for the main conifer species (Norway spruce (*Picea abies*), and Scots pine (*Pinus sylvestris*)), and deciduous forests. Data containing information regarding area distribution and cubic mass for the forest over site quality and

development class, were extracted for each main species, for all counties except Troms and Finnmark[5], references for the NFI are found in table 6 of the appendix.

The reported cubic mass for each specified development class, soil quality, and species are assumed to be directly connected with the reported areas specified in the same division, and thus the average per unit ($\bar{m}_{sij}$) area unit (decare) were estimated.

The estimated opportunity cost does not include any fixed costs that would influence the opportunity cost, so to discount for all future time periods, the mean per decare cubic mass were discounted for future harvesting opportunities, equation 2.

$$s(d)_{sj} = \sum_{n=0}^{N} \frac{1}{(1+r)^{Y_{sj}n}} \tag{2}$$

Where $s(d)_{sj}$ is the discount factor for specified species s and the defined soil quality j, Y is the amount of years until, on average, specified species and soil quality will have reached maturity based on the mass principle, obtained from Skog og landskap (2015)[6]. n is the number of rotation periods, cut of for these periods was set when the sub-problem for all species and soil qualities were arbitrarily close to 0, which on average is 7 periods (roughly 700 years).

Myrbakken (2011) states that "the government does not see it probable that a area subject to conservation will have all been cut in year zero, thus the harvest periods is set to 10 years. This is done to have a realistic time horizon for when the forest would have been harvested if there were no environmental significant interests for the government to conserve the forest."

Since this factor follows the same assumptions as discounting for rotation periods, the scalar in equation 3 were created.

$$s(t) = \frac{\sum_{t=0}^{T-1} \frac{1}{(1+r)^t}}{T} \tag{3}$$

[5]These counties was excluded due to lack in price data(Troms) and surveys done by NFI (Finnmark). However, Finnmark is fairly close to the 17% goal of conservation of productive forest(appendix table 7), and would not influence the results of this paper.

[6]Decidious areas was attributed the rotation of Birch.

Which for a discount factor of 4% and $T = 10$ the factor $s(t) \approx 0.84$

The discounted $\bar{m}_{sij}$ for all specified species, development class, and soil quality was obtained, equation 4

$$\hat{m}_{sij} = s(t)s(d)_{sj}\bar{m}_{sij} \tag{4}$$

Assuming that, on average, the conservation distribution follows the same distribution as the county over species, soil quality and development class, a conditional probability can be constructed. $Pr(X_{sij}|DC_n)$, equation 5, express that a unit area of X is located within a specific forest species (s), development class (i), and site quality (j), subject to the subset (DC_n) of development classes defined in table 2.

$$\Upsilon_{sij} = Pr(X_{sij}|DC_n) = \frac{X_{sij|DC_n} \sum_{ij} X_{sij}}{\sum_{ij|DC_n} X_{ij} \sum_{sij} X_{sij}} \tag{5}$$

Table 2: Sets of Development Classes

DC_n	index	Definition	Percentage of productive forest in Norway
DC_{1-5}	$i = \{1, 2, 3, 4, 5\}$	D.C. I - V	100%
DC_{2-5}	$i = \{2, 3, 4, 5\}$	D.C. II - V	97%
DC_{3-5}	$i = \{3, 4, 5\}$	D.C. III - V	76%
DC_{4-5}	$i = \{4, 5\}$	D.C. IV - V	56%
DC_5	$i = \{5\}$	D.C. V	34%

Defining the subsets of different development classes DC_n, where $DC_{1-5} \supset DC_{2-5} \supset DC_{3-5} \supset DC_{4-5} \supset DC_5$. These subsets represent all forests within subsets of development classes, and will decrease when fewer subsets are included. A measure of the amount of productive forest in each subset is described as a percentage, the index describes the subsets included in different solutions to the conditional probability (equation 5)

The sum of these conditional probabilities, s.t. DC_n, shown in equation 6, equals 1. This is a criteria for the conditional probability of a unit area X will be distributed across the main species s, development class i, and soil quality j.

$$\sum_{sij} Pr(X_{sij}|DC_n) = 1 \quad \forall DC_n \tag{6}$$

Estimating the weighted arithmetic mean, equation 7, using jackknife re-sampling to obtain variance coming from a unknown distribution, using a small sample.

$$\hat{Q} = \sum_{sij} \hat{m}_{sij} \Upsilon_{sij} \tag{7}$$

Creating weights for the distribution of the species used for calculating the price, was obtained by equation 8.

$$\hat{Q}_s = \sum_{ij} \hat{m}_{sij} \Upsilon_{sij} \tag{8}$$

the weights are represented in equation 9

$$w_s = \frac{\hat{Q}_s}{\sum_s \hat{Q}_s} \tag{9}$$

$\hat{Q}$ and w_s were obtained for all counties included in the analysis.

Price: Spatiotemporal data-series for prices (Statistics Norway 2014*b*) and quantities (Statistics Norway 2014*a*) were obtained for the period 1996-2013, and all prices were CPI-adjusted to 2013NOK. The prices were reported in yearly averages, for each species and each product for the period 1996 - 2013.

Myrbakken (2011) states that, "..old forest will be harvested within a relatively short time frame, however predicting timber prices for the future is not easily done, thus a reference year prior to the forest conservation within a short time frame is chosen, usually within 1-4 years." To negate the issue with finding reference years for each year (2005 - 2013), a moving average were taken over the 4 prior years.

Combining this with weights for quantity q and species s and product p, to negate a bias in price, as pure average of price does not reflect the actual average price. These

weights are found for all species products and time periods, equation 10

$$w_{q_{spt}} = \frac{q_{spt}}{\sum_{spt} q_{spt}} \tag{10}$$

Using weights for: the forest w_s representing species distribution in a county, the time weights $w_t = \frac{1}{4}$, and $w_{q_{spt}}$, to estimate the weighted moving average price, equation 11 for all counties and time-periods.

$$\hat{P}_t = \sum_{t=1}^{4} w_s w_t w_{q_{spt-t}} P_{spt-t} \tag{11}$$

$\hat{P}_t$ was estimated for all counties where price information existed, using jackknife re-sampling due to uncertainties about the distribution, and its corresponding variance, and constructing 95% confidence intervals.

Costs: According to Myrbakken (2011) "..10% of the gross cubic mass is deducted from the total, as top, roots, rot, and waste. Another 5% is deducted for environment, as specific trees are withheld from harvesting, used for natural reseeding, as specified in the Living Forest Criteria."

Damvad (2014) found, ".. based on their data, the harvesting costs accumulates to 47% of the timber value. This includes costs connected different aspects of harvesting including, distance to the loading site, number of timber assortment, clearing before logging, operation size, rig costs (transport/moving to start-up) and planning."

Another 10% is attributed to silviculture, as a mean cost of silviculture in 2013 for private agricultural forests (NILF 2013), this factor is fairly uncertain, as it reflects the forest owners effort in increasing timber value, and will vary.

Combining these percentages into a scalar of the form $C = (1 - 0.47) * (1 - 0.1) * (1 - 0.1) * (1 - 0.05) \approx 0.407$, to obtain net opportunity cost.

The mean net present timber value, for one decare of forest, now takes the form of equation 12

$$\widehat{OC_t} = \widehat{NPV_t} = \hat{P}_t \hat{Q} C \tag{12}$$

And is evaluated at the mean price for one decare, the upper bound confidence interval, and the lower bound confidence interval for price or quantity, found for all counties and time-periods.

Evaluating the estimated opportunity cost and observed compensation: Information regarding the voluntary conservation has been obtained through Norwegian Environment Agency, as a unpublished manuscript (Norwegian Environment Agency 2013*a*), this data represent time of conservation, the paid compensation, the names of the nature reserves. This data was combined with the environmental agency database of conservation areas "Naturbase"(Norwegian Environment Agency 2015) to allocate the specific area to a county. Where nature reserves crossed county lines, the area was attributed to the county where the county governments office had conservation authority.

The observed voluntary conservation X_{it}^{vol}, is evaluated in regard to estimates of $\hat{OC}_{it}$, and compared to the different subsets of DC_n[7], for county i and time-period t, equation 13.

$$\widehat{OC}_{DC_n}^{vol} = \sum_{t=1}^{T} \widehat{OC}_{it} X_{it|DC_n}^{vol} \tag{13}$$

A comparison of $\widehat{OC}_{DC_n}^{vol}$ versus the compensation, CPI-adjusted to 2013 NOK, can be seen in figure 1, including the confidence intervals for cubic mass or price.

Using a paired t-test comparing $\widehat{OC}_{it}^{vol}$, and compensation for i and t, found that DC_{4-5} fails to reject the null hypothesis of no difference at the mean against the alternative. This is on par with the statements from Norwegian Environment Agency (2013*b*) "For a forest owner considering voluntary conservation, it is not attractive to

[7]Only DC_{3-5}, DC_{4-5}, and DC_5 were in range of the compensation, thus DC_{1-5} and DC_{2-5} were excluded from further analysis

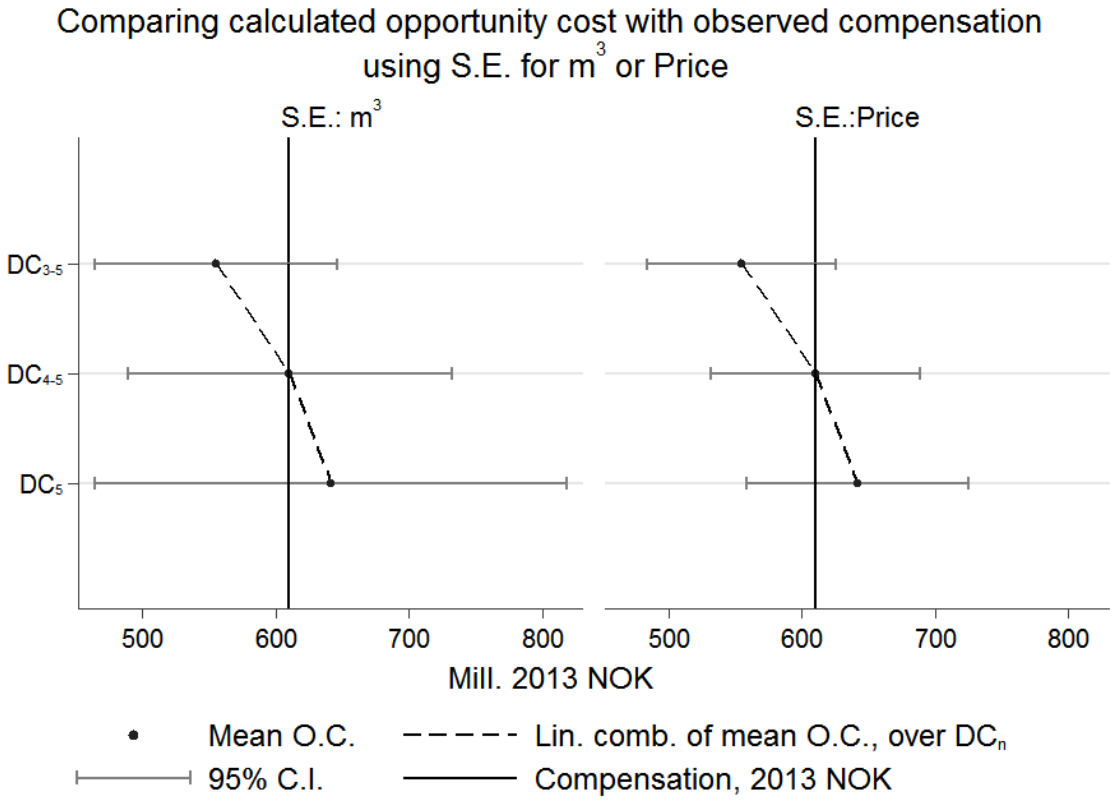

Figure 1: Comparing the cumulative estimated opportunity cost of voluntary conservation ($\sum \widehat{OC}_{it}^{vol}$) for different subsets of DC_n within range of observed compensation in the period 2005 - 2013, using either confidence intervals for cubic mass (m^3) or price

offer young forests, or forest with a development class lower than 4, as compensation for these areas will be much lower when the harvest is further away than 20 years, thus young forests are paid comparatively little compared to mature forests. However, some areas of lower quality are included to create a natural demarcation of the forest reserve."

Thus, the opportunity cost for one decare of forest in each county, and time period, was attributed a mean distribution within development class 4 and 5, and using the confidence intervals for price, as they are consistent across development classes, and due to the small sample size for the mean cubic mass. A presentation of the opportunity cost for one decare can be found in table 8 of the appendix.

2.2 Optimization problem

The mathematical optimization problem is divided into subsets describing linear optimization problems, obtaining vector solutions, for all included counties (c), for maximization (X_t^{max}) and minimization (X_t^{min}), where X is a measure of area size(decare), for all time periods(t). The general form of the sub-problem for one time period is expressed as the linear program:

$$\min \setminus \max(Z) = \sum_{i=1}^{n} E_c X_{ct} \tag{14}$$

$$s.t.$$

$$\sum_{i=1}^{n} \widehat{OC}_{ct} X_{ct} \leq B_t \tag{15}$$

$$X_{ct} \leq X_c^{UB} - \sum_{p=1}^{\infty} X_{ct-p} \tag{16}$$

$$X_{ct}, B_t, \widehat{OC}_{ct}, X_{ct}^{UB}, Z \geq 0 \quad \forall c, t \tag{17}$$

Where the objective function (equation 14), is optimized w.r.t. to efficiency criteria E_c, a predefined efficiency target, and X_{ct}, the vector that optimizes Z. Equation 15 defines that the summed cost at optimum can only be less then or equal to the budget constraint. This is a necessary construct of the linear optimization problem; the optimum solution will be at the margin of the budget constraint, as long as no other constraints are met.

The budget constraint B_t is the sum of estimated opportunity cost for voluntary or government initiated conservation of forested areas, for a given time period.

In the evaluation of the opportunity cost, the DC_{4-5} quantity option was found to fit the compensation. Thus the budget constraint in a given period (B_t^{Vol}) for voluntary conservation was obtained by finding the linear combination of conserved areas of voluntary conservation and mean opportunity cost.

Equation 16 describes the per county possible conservation, expressed as percentage

goals of productive forest, this constraint is per county upper bound, for all perceived goals of conservation, described in table 7 in the appendix, subtracted conservation in the county prior to the evaluated period, and the solution vector obtained for the prior optimization period.

This optimization is done for all 9 periods (2005 - 2013), where the opportunity cost vector for each year, and the conservation constraint change as long as the budget is larger than zero.

This linear program can be solved using the dual-simplex algorithm[8] due to the assumptions in 17.

The resulting corner solution matrix (including all counties and time periods) for voluntary conservation , is evaluated as a ratio equation 18.

$$\Delta Vol = \frac{E'(X_{Vol}^{obs} - X_{Vol}^{min})v'}{E'(X_{Vol}^{max} - X_{Vol}^{min})v'} \tag{18}$$

X^{obs} is the observed conservation matrix, X^{min} and X^{max} is the corner solution for the problem at the given constraints, E is the effective criteria the optimization problem was evaluated for, v is a vector consisting of ones [9]

For government initiated conservation of forested areas, the total conservation of productive forest was obtained by combining two maps, AR50 and Protected areas.

The AR50 (Area resource map - Precision: 1:20 000 - 1:100 000) has several uses: overhead planning, as a basis for impact assessment, natural resource management, and as a reference map (Skog og Landskap 2007). Mapped resource in the form of shape files[10](Skog og Landskap 2014), ArcGIS were used to extract numerical area(m^2) information of forested areas for each county. This information is divided into several different themes and can be used to find specific information using selection criteria. The extracted information in this analysis is limited to the distribution of productive for-

[8]Matlab has been used to do this linear optimization, as it provides a suitable framework for conducting solving linear programs of this type

[9]Can represent time-weights, which have not been used, as the effectiveness criteria is non-changing over time.

[10]Shape files are used in several GIS software.

est, even though the mapped resource also divides the information into site quality and forest types, it was found that there were great differences from this information and the information provided in the NFI. Mapped information about Protected areas was obtained from map catalog for the Norwegian Environment Agency (Miljødirektoratet 2014). This map gives vectordata(Polygon) information of protected areas in Norway (precision: 1:5 000 - 1:50 000), and time of implementation for given protected area. This information is used in combination with the AR50 mapped resource to obtain spatiotemporal information regarding forest conservation in Norway for each county in the period 2005 - 2013, a summary can be seen in table 7 in the appendix. However, information about voluntary conservation cannot be directly linked to this dataset, neither with time, nor area. This is due to difference in definition in either dataset, or missing information.

The budget constraint for government initiated conservation of forested areas (B_t^{Gov}), was obtained by finding the linear combination of total conservation and mean opportunity cost in a given time period, and subtracted the budget constraint for voluntary conservation in the same period.

The government initiated forest conservation was evaluated as the total conservation of productive forests, subtracted the voluntary conservation. And was evaluated as a ratio equation 19.

$$\Delta Gov = \frac{E'(X_{tot}^{obs} - X_{Vol}^{obs} - X_{Gov}^{min})v'}{E'(X_{Gov}^{max} - X_{Gov}^{min})v'} \tag{19}$$

Since X_{Gov}^{obs}, is unobserved, and does not reflect strict government initiated forest conservation, the assumption was made that it represent a conservation bundle for productive forest as it would have been without the voluntary conservation scheme.

Solutions were computed for constructing the confidence intervals for the analysis, the upper and lower bound opportunity cost were obtained and the optimization problem was solved for both ends, while holding the budget constraint fixed.

Cost and utility-cost proxies: E in the linear program can be changed to reflect some utility proxies for the different counties, the cost and utility-cost effectiveness criteria are expressed in table 3.

Table 3: Description of the environmental proxies

E_n	Description
E_1	The cost effective criteria, E is a vector of 1. Targeting areas of low cost of conservation.
E_2	The amount of forest in development class 5 (old growth forest), as a ratio of the total in Norway. Targeting areas where there is perceivable more old growth forest. Created using data from NFI (table 6 in the appendix)
E_3	The cumulative harvested timber 2005 - 2013 for each county, as a ratio of the total harvested timber in Norway, for the same period. Targeting areas where the forest is under pressure of economic interest. Created using data of harvested roundwood in Norway (Statistics Norway 2015)
E_4	The the amount of standing timber in development class 5, as ratio of harvested timber in the period 2005 - 2015 for each county. Targeting areas of old growth forest not susceptible to harvesting.

A representation of the different criteria tested. E_n is the vector representation of the effectiveness criteria, including a description of the vector. E_1 is the cost effectiveness, while $E_2 - E_4$ are the different utility-cost criteria.

3 Results, policy implications and limitations

3.1 Results

The results from comparing observed conservation to the corner-solutions of the optimization problem are expressed in table 4, and evaluated in table 5 with regard to the specified hypothesis (table 1 in the introduction).

Table 4: Results - Evaluation of the optimization problem

Type of conservation	E_n	Conservation constraint 4.5%	10%	17%
Voluntary	E_1	0.27 (0.12 - 0.42)	0.20 (0.10 - 0.29)	0.16 (0.08 - 0.24)
	E_2	0.43 (0.37 - 0.49)	0.37 (0.33 - 0.41)	0.33 (0.28 - 0.38)
	E_3	0.39 (0.34 - 0.45)	0.40 (0.34 - 0.45)	0.40 (0.34 - 0.45)
	E_4	0.09 (0.08 - 0.10)	0.06 (0.05 - 0.07)	0.05 (0.04 - 0.06)
Government	E_1	0.45 (0.21 - 0.65)	0.37 (0.22 - 0.50)	0.29 (0.19 - 0.38)
	E_2	0.52 (0.44 - 0.59)	0.48 (0.42 - 0.54)	0.43 (0.39 - 0.47)
	E_3	0.34 (0.30 - 0.39)	0.35 (0.30 - 0.39)	0.35 (0.30 - 0.39)
	E_4	0.38 (0.35 - 0.41)	0.24 (0.23 - 0.26)	0.19 (0.18 - 0.20)

Results evaluating different cost- or utility-cost effectiveness criteria, for voluntary conservation and government initiated conservation of forested areas, evaluated from zero to one, where one is the maximum, and zero the minimum obtainable subject to the budget and conservation constraint. Using jackknife re-sampling to obtain the mean price, and its corresponding variance, constructing confidence intervals for lower bound and upper bound price, subject to a scalar representing conditionally weighted jackknife re-sampled average of mean cubic mass per decare for a specific county. E_1 cost effective criteria, E_2 distribution of development class 5 ("old forest"), E_3 distribution of harvested timber from 2005 - 2013, E_4 the ratio of development class 5 over harvested timber as a representation of old forest not under pressure of harvesting. Evaluated over the three different conservation constraints (4.5%, 10% and 17%).

There are three main results of interest:

First, the results indicate that at higher conservation constraints, voluntary conservation is less effective than government initiated conservation of forested areas at targeting counties with a higher ratio of old forests.

Second, Voluntary conservation is less effective than government initiated conservation of forest areas at targeting counties where there is a perceived higher ratio old forest not susceptible to harvesting pressure, for all conservation constraints.

Third, none of the cost- or utility-cost effectiveness criteria were found to show a bias toward being of specific interest in either voluntary conservation or government initiated conservation of forested areas.

Table 5: Results - Hypothesis

Hypothesis	E_n	Conservation constraint 4.5%	10%	17%
Hypothesis 1:	E_1	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_2	$Vol = Gov$	$Vol < Gov$	$Vol < Gov$
	E_3	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_4	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
Hypothesis 2:	E_1	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_2	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_3	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_4	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$

A representation of the evaluation of the hypothesis presented in table 1, for all hypothesis, measured effective criteria, and conservation constraints. Vol is the voluntary conservation, Gov is the government initiated conservation of forested areas, E_1 is the cost effective criteria, E_2 is the utility-cost criteria for targeting forest in development class 5 (old-growth forest), and E_4 represent the old growth forest not susceptible to harvest.

Sensitivity analysis: Two different types of sensitivity analysis were done to check how robust the analysis is to change.

Type 1 error: Assuming that the price alone can reflect the price change could lead to a type 1 error, as the confidence intervals for quantity are greater when scaled with price, compared to the confidence intervals scaled by quantity (as shown in figure 1 in section 2.1). There is a concern that estimating the joint confidence intervals will lead to Type 2 errors, due to a joint variance, as price is an indirect measure of quantity per area, and quantity per area will affect price. To investigate type 1 errors, the solutions were found using the confidence intervals for quantity, as the assumed "true" joint confidence intervals should lie between that of price, and that of quantity, given larger samples for quantity. Table 9 and table 10 in the appendix, shows the evaluated observed conservation in the optimization problem, and the results from the hypothesis, respectively. For hypothesis 1, the results change so that for E_1, E_2 and E_3 all fail to reject the null of no difference between voluntary and government initiated conservation. But, for E_4 the results are unchanged. Underlining a difference between voluntary conservation and government initiated conservation of areas of old growth forest not susceptible to harvest. The measures change, but there is still no evidence that the cost- or utility-cost effectiveness criteria show bias toward being of specific interest in either voluntary conservation or government initiated conservation of forested areas.

Excluding counties: Looking at subsets of different counties to include, with regard to their influence on the results.

First Nordland was removed, as it has the lowest opportunity cost (connected to cost effective criteria E_1), and highest utility for old growth forest not susceptible to harvest (connected to utility-cost criteria E_4). The results, table 11, and hypothesis evaluation, table 12, can be found in the appendix. Show that, by excluding Nord-

land, voluntary conservation is not different than government initiated conservation of forested areas for all cost- and utility-cost effectiveness criteria, except for targeting counties with higher ratio of old forest not susceptible to harvest. It also shows a bias towards cost effective conservation bundle for voluntary conservation, at the 10% and 17% conservation constraint.

Second, both Nordland and Hordaland were removed, as Hordaland has the next greatest utility for old growth forest not susceptible to harvest (connected to utility-cost criteria E_4). The results, table 13, and hypothesis evaluation, table 14, can be found in the appendix. Show that by excluding both Nordland and Hordaland, all criteria for cost and utility-cost effectivity, fails to reject the null hypothesis of voluntary conservation and government initiated conservation being equal. While the bias towards effectivity, change for the cost effectivity criteria for all levels of conservation for voluntary conservation, and for government initiated conservation of forested areas show bias toward effectivity, for 10% and 17% conservation constraint.

Third, Hedmark was removed, as it has the highest ratio of old growth forest(connected to utility-cost criteria E_2), and harvesting pressure (connected to utility-cost criteria E_3). The results, table 15, and the hypothesis evaluation, 15, can be found in the appendix. Show that, by excluding Hedmark, voluntary conservation becomes less effective than government initiated conservation of forested areas for criteria E_1, E_2, and E_4, while for E_3 they are equal. A bias towards cost effective conservation for government initiated conservation of forested areas for the 4.5% conservation constraint is observed.

Fourth, both Hedmark and Oppland were removed, as Oppland has the next greatest ratio of old growth forest, and harvesting pressure. The results, table 17, and the hypothesis evaluation, 17, can be found in the appendix. Show that, by excluding Hedmark and Oppland, voluntary conservation becomes more effective at targeting areas with higher harvesting pressure, then government initiated conservation of forested areas, for 10% and 17% conservation constraint. While were worse at targeting areas

with higher ratio of old forest, and areas with old forest not susceptible to harvest for all conservation constraints. And, where found to be worse for cost-effectiveness, for 10% and 17% conservation constraints While no criteria show bias towards cost or utility-cost effectiveness.

3.2 Discussion & Policy implications

The results indicate that government initiated conservation of productive forest have greater utility-cost effectiveness, without showing bias toward effective use of government funds, for conservation of old growth forest when evaluating the higher conservation constraints. This observation could be the result of lags in the information criteria for the conservation goals, as it is non-different at 4.5% forest conservation. When controlling for type 1 error, the results also change so that voluntary and government initiated conservation are not different. And only a indication can be drawn from the results.

There is however, a strong indication that voluntary conservation does not target counties with old forest not susceptible to harvest, when compared to the government initiated conservation of productive forests. While neither conservation scheme show a bias towards conservation in counties with old forest not susceptible to harvest, only the utility-cost effectiveness bias for voluntary conservation of old forest not susceptible to harvest had a bias below 0.1. Indicating exclusion of these counties in the voluntary conservation scheme.

This result support the claim by the conservation organizations, that voluntary conservation does not necessarily target all forests of interests, this can be a result of higher production costs in these counties due to topological difficulties, and could have a considerable amount of ”zero-areas”, that would in it self be conserved due to no economic interest of harvest. But, if technologies were to be developed in the future that lower harvesting costs, or an increase in the construction of forest roads occurred, these areas would become economically viable to harvest. If these areas were found to have several

large environmental restrictions, would end up being offered as part of the voluntary conservation scheme, as long as the scheme is in place.

Reaching the Aichi goal to stop the loss of biodiversity in Norway by 2020, with ”areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures” (CBD 2012). Measures will need to be implemented so that these counties are included.

Since the scheme of government initiated forest conservation, is attributed a high level of controversy, and increased costs, incentives to the forest owner to offer the forest to voluntary conservation could be considered. These incentives could take the form of decreasing the perceived cost for harvesting inaccessible areas, assuming either forest roads, or decreased costs due to assumed technological advances. Otherwise, government initiated conservation will have to be used.

3.3 Limitations

There are several fundamental limitations to the analysis conducted in this paper, due to limitations of the data. First of all, there is a perceived difference between voluntary conservation, and government initiated conservation of forested areas. The voluntary conservation scheme specifically targets forest conservation, while the government initiated conservation of forested areas, is quite ambiguous as to what the specific goal of the conservation is.

When conducting this analysis, discrepancies were found for the dataset containing voluntary conservation, as not all areas were defined strictly as conservation of forest, but rather some other form of habitat, when investigating the areas in the ”Naturbase”. This could affect the results of the analysis, as the quantity measured would vary greatly. This is however negated somewhat by the assumption of ceteris paribus, everything else equal, and the results are still quite sound.

Another aspect found was that, the data-sets differ greatly when it comes to their in-

herent structure, and being quite coarse grained. The National Forest Survey, specifies three main groups of species, two being conifers, and one being deciduous. The conifers being the main interest when harvesting round-wood, and were divided into their respective price groups, while the deciduous forest were a relatively narrow dataset for price, and does not vary across the deciduous species. Areas with large amount of specific deciduous trees would not be attributed their correct value, but are deemed to have lower opportunity cost than the conifers.

When comparing the fine grain data from the (Skog og Landskap 2014) to the rapports of the National forest survey, there were a great shift in distribution of the conifers, deciduous, and mixed forest, across subsets of soil quality. Making it impossible to implement a more fine grained analysis of the data, within counties, as there would be no way of finding the distribution of the conservation.

Data-sets of greater detail, would increase the precision of the analysis conducted in this paper, there is currently half finished maps, containing forest distribution of species, development class, soil quality and species, and a distribution of environmental indicators. When these maps are completed, this analysis could be done at the within county level, or even the municipality level, and would increase the accuracy of the analysis.

4 Conclusion

The main results found in this analysis indicate 1) that voluntary conservation express less effective use of government funds versus government initiated conservation of forested areas for: conservation in counties with old forest with lower harvesting pressure, and to a lesser extent counties with a higher ratio of old forests. 2) No strong bias towards any of the cost- or utility-cost effectiveness criteria were found, which is interpreted that no single criteria is weighted higher than the rest, for either form of conservation. However, the bias for voluntary conservation regarding counties with old

forest with lower harvesting pressure is significantly lower than the rest.

The implications of voluntary conservation not including counties with old forest with lower harvesting pressure, could be due to difficulties in harvesting, due to terrain and technology limitations. A technological shift or an increase in forest road construction, both measures reducing harvesting costs, would open these areas up to harvest. And as the areas become of economic interest, could be found to have several large environmental restrictions, which would create incentive for the forest owner to implement voluntary conservation.

To answer the title question ”Do they get what they want?”, the short answer is ”It depends”. The goal is to stop the loss of biodiversity by 2020, and if the areas with lower economic interest can be implemented as they become viable for conservation through the voluntary conservation scheme, there is no need for any specific measures to target these counties. But, if the goal is to be reached via measures of conservation before 2020, incentives in these counties would have to be considered for them to be implemented via the voluntary conservation scheme, otherwise government initiated forest conservation would have to be used to supplement the conservation. Either way, they would have to pay to get what they want, i.e. reaching the goal of stopping the loss of biodiversity by 2020.

Appendix

Table 6: Summary of sources for The National Forest Inventory

		Table number		
County	Period	Quantity (m^3)	Area (ha)	Reference
Østfold	1995-99	53, 54, 55	14	Tomter & Eriksen (2001*b*)
Akershus & Oslo	1995-99	53, 54, 55	14	Tomter et al. (2002*a*)
Hedmark	2000-04	52, 53, 54	13	Eriksen et al. (2006*b*)
Oppland	2000-04	52, 53, 54	13	Eriksen et al. (2006*c*)
Buskerud	2000-04	52, 53, 54	13	Eriksen et al. (2006*a*)
Vestfold	2000-04	52, 53, 54	13	Eriksen et al. (2006*e*)
Telemark	2000-04	52, 53, 54	13	Eriksen et al. (2006*d*)
Aust-Agder	1995-99	53, 54, 55	14	Tomter et al. (2001)
Vest-Agder	1995-99	53, 54, 55	14	Tomter & Eriksen (2001*a*)
Rogaland	2005-09	51, 52, 53	13	Andreassen et al. (2013*b*)
Hordaland	2005-09	51, 52, 53	13	Andreassen et al. (2013*a*)
Sogn og Fjordane	2005-09	51, 52, 53	13	Andreassen et al. (2012)
Møre og Romsdal	2000-04	52, 53, 54	13	Eriksen et al. (2006*f*)
Sør-Trøndelag	2000-04	52, 53, 54	13	Eriksen et al. (2006*g*)
Nord-Trøndelag	1995-99	53, 54, 55	14	Tomter et al. (2002*b*)
Nordland	2005-09	51, 52, 53	13	Andreassen et al. (2011)

A presentation of the sources for individual counties from the The National Forest Inventory, surveyed is the period the county were surveyed, table number in the rapports connected to either quantity or area, and a direct reference to the rapport.

Table 7: Summary of key numbers for Norwegian forest conservation

Region	Productive forest	Conservation prior to 2005		Conserved forest prior to 2014		Conservation goals (km^2)		
	km^2	km^2	%*	km^2	%*	4.5%	10%	17%
Østfold	2 466.22	12.74	0.52 %	70.89	2.87 %	110.98	246.62	419.26
Akershus & Oslo	3 436.08	79.42	2.25 %	115.20	3.26 %	343.61	343.61	584.13
Hedmark	13 012.98	129.33	0.99 %	297.87	2.29 %	585.58	1 301.30	2 212.21
Oppland	6 846.01	121.44	1.77 %	228.17	3.33 %	308.07	684.60	1 163.82
Buskerud	5 830.88	78.24	1.34 %	171.81	2.95 %	262.39	583.09	991.25
Vestfold	1 368.72	10.39	0.76 %	23.16	1.69 %	61.59	136.87	232.68
Telemark	5 542.83	30.61	0.55 %	98.59	1.78 %	249.43	554.28	942.28
Aust-Agder	3 809.87	39.21	1.03 %	74.18	1.95 %	171.44	380.99	647.68
Vest-Agder	2 815.49	38.43	1.36 %	54.74	1.94 %	126.70	281.55	478.63
Rogaland	1 656.15	36.67	2.21 %	38.16	2.30 %	74.53	165.62	281.55
Hordaland	3 114.89	42.22	1.36 %	56.83	1.82 %	140.17	311.49	529.53
Sogn og Fjordane	3 167.13	107.12	3.38 %	150.67	4.76 %	142.52	316.71	538.41
Møre og Romsdal	3 138.87	88.41	2.82 %	124.11	3.95 %	141.25	313.89	533.61
Sør-Trøndelag	4 079.18	46.30	1.13 %	96.21	2.36 %	183.56	407.92	693.46
Nord-Trøndelag	6 521.41	171.48	2.63 %	281.43	4.32 %	293.46	652.14	1 108.64
Nordland	4 927.67	124.12	2.52 %	209.80	4.26 %	221.75	492.77	837.70
Troms	2 907.63	19.08	0.66 %	30.92	1.06 %	130.84	290.76	494.30
Finnmark	685.24	110.53	16.13 %	111.45	16.26 %	30.84	68.52	116.49
Norway	75 327.22	1 285.73	1.71 %	2 234.18	2.97 %	3 389.72	7 532.72	12 805.63

Summary of key numbers for conservation in Norway from, specified as amount of productive forest (areas with growth greater than 0.12 m^3 per decare per year), conservation prior to 2005 in km^2 and, conservation prior to 2014 in km^2, and the different conservation goals specified as km^2. *Percentage conservation of productive forest. Obtained by combining mapped resource for productive forest (Skog og Landskap 2014) and protected areas (Miljødirektoratet 2014)

Table 8: Estimated opportunity cost for one decare of productive forest

Region	Year 2005	2006	2007	2008	2009	2010	2011	2012	2013
Østfold	2441 (2723 - 2159)	2397 (2665 - 2130)	2366 (2631 - 2102)	2459 (2767 - 2152)	2507 (2816 - 2199)	2420 (2729 - 2112)	2452 (2758 - 2146)	2380 (2628 - 2131)	2278 (2508 - 2049)
Akershus & Oslo	2624 (2930 - 2318)	2558 (2846 - 2270)	2522 (2818 - 2227)	2582 (2917 - 2247)	2657 (2992 - 2321)	2575 (2910 - 2240)	2590 (2924 - 2256)	2525 (2802 - 2247)	2401 (2669 - 2133)
Hedmark	1938 (2157 - 1719)	1899 (2108 - 1689)	1904 (2125 - 1684)	1997 (2262 - 1732)	2047 (2317 - 1777)	1996 (2268 - 1724)	2013 (2287 - 1739)	1960 (2190 - 1731)	1899 (2117 - 1680)
Oppland	2087 (2327 - 1847)	2028 (2260 - 1797)	2007 (2252 - 1762)	2081 (2375 - 1787)	2120 (2417 - 1823)	2059 (2361 - 1757)	2057 (2361 - 1752)	1991 (2245 - 1736)	1906 (2145 - 1666)
Buskerud	2086 (2304 - 1867)	2029 (2235 - 1822)	2026 (2243 - 1810)	2106 (2364 - 1848)	2144 (2402 - 1887)	2079 (2339 - 1819)	2097 (2361 - 1833)	2034 (2255 - 1814)	1935 (2141 - 1729)
Vestfold	2490 (2858 - 2123)	2448 (2802 - 2094)	2431 (2790 - 2072)	2468 (2906 - 2031)	2498 (2948 - 2049)	2439 (2876 - 2002)	2463 (2904 - 2023)	2419 (2781 - 2058)	2336 (2667 - 2005)
Telemark	1774 (1959 - 1589)	1716 (1888 - 1545)	1688 (1869 - 1508)	1747 (1973 - 1520)	1786 (2016 - 1557)	1739 (1974 - 1504)	1757 (1993 - 1521)	1702 (1893 - 1510)	1618 (1803 - 1434)
Aust-Agder	1784 (1992 - 1576)	1747 (1948 - 1546)	1740 (1940 - 1541)	1806 (2034 - 1578)	1831 (2055 - 1606)	1778 (2000 - 1556)	1809 (2028 - 1590)	1753 (1927 - 1579)	1683 (1851 - 1515)
Vest-Agder	1880 (2078 - 1681)	1819 (2021 - 1618)	1816 (2016 - 1617)	1871 (2091 - 1651)	1883 (2094 - 1672)	1866 (2067 - 1664)	1889 (2088 - 1689)	1826 (2000 - 1652)	1749 (1917 - 1581)
Rogaland	2447 (2821 - 2074)	2395 (2774 - 2017)	2194 (2397 - 1991)	2221 (2442 - 2000)	2161 (2375 - 1948)	2030 (2233 - 1827)	2000 (2197 - 1803)	1800 (2037 - 1563)	1748 (2039 - 1456)
Hordaland	2212 (2426 - 1998)	2113 (2363 - 1864)	2058 (2291 - 1824)	2050 (2303 - 1796)	2014 (2266 - 1763)	2005 (2236 - 1775)	1957 (2178 - 1737)	1903 (2096 - 1710)	1860 (2036 - 1684)
Sogn og Fjordane	2137 (2324 - 1949)	2066 (2280 - 1852)	1971 (2205 - 1738)	1964 (2205 - 1722)	1907 (2122 - 1693)	1871 (2063 - 1679)	1898 (2086 - 1711)	1686 (1947 - 1425)	1569 (1838 - 1300)
Møre og Romsdal	1788 (1958 - 1618)	1755 (1931 - 1578)	1755 (1946 - 1563)	1815 (2044 - 1585)	1824 (2076 - 1572)	1782 (2035 - 1529)	1725 (1994 - 1456)	1648 (1891 - 1406)	1555 (1785 - 1325)
Sør-Trøndelag	1588 (1757 - 1419)	1567 (1743 - 1391)	1548 (1737 - 1358)	1588 (1809 - 1367)	1589 (1815 - 1363)	1543 (1765 - 1321)	1499 (1720 - 1278)	1432 (1610 - 1253)	1362 (1525 - 1199)

Region	Year 2005	2006	2007	2008	2009	2010	2011	2012	2013
Nord-Trøndelag	1458 (1637 - 1279)	1414 (1600 - 1227)	1406 (1612 - 1200)	1480 (1734 - 1227)	1506 (1763 - 1248)	1473 (1727 - 1219)	1447 (1698 - 1196)	1378 (1568 - 1188)	1319 (1484 - 1153)
Nordland	905 (965 - 845)	887 (953 - 821)	879 (954 - 805)	899 (991 - 806)	886 (989 - 783)	845 (958 - 731)	818 (933 - 702)	770 (867 - 673)	727 (812 - 642)

Estimated mean opportunity cost for one decare of productive forest, for forest in development class 4 and 5, which includes a conditional distribution of the forest over development class IV and V. Using weighted moving average m^3, weighted with regard to distribution of species, site quality and development class. Combined with the quantity and species weighted moving average of price, using 4 prior periods, discounted with 4% discount rate given 10 years of harvesting of the timber, and the discounted future value of the timber with regard to rotation periods. Subtracted costs connected to, silviculture, harvesting, waste products, and environmental costs. 95% confidence intervals obtained from the weighted mean of price

Table 9: Sensitivity analysis - Results: Using confidence intervals for cubic mass

Type of conservation	E_n	Conservation constraint 4.5%	10%	17%
Voluntary	E_1	0.27 (0.04 - 0.52)	0.20 (0.06 - 0.35)	0.16 (0.05 - 0.32)
	E_2	0.43 (0.31 - 0.55)	0.37 (0.28 - 0.46)	0.33 (0.24 - 0.44)
	E_3	0.39 (0.29 - 0.49)	0.40 (0.29 - 0.49)	0.40 (0.30 - 0.49)
	E_4	0.09 (0.07 - 0.11)	0.06 (0.05 - 0.08)	0.05 (0.04 - 0.07)
Government	E_1	0.45 (0.08 - 0.80)	0.37 (0.14 - 0.62)	0.29 (0.13 - 0.47)
	E_2	0.52 (0.35 - 0.66)	0.48 (0.35 - 0.61)	0.43 (0.32 - 0.53)
	E_3	0.34 (0.26 - 0.43)	0.35 (0.25 - 0.43)	0.35 (0.26 - 0.43)
	E_4	0.38 (0.30 - 0.46)	0.24 (0.20 - 0.29)	0.19 (0.15 - 0.22)

Results, using confidence intervals for cubic mass, evaluating different cost- or utility-cost effectiveness criteria, for voluntary conservation and government initiated conservation of forested areas, evaluated from zero to one, where one is the maximum, and zero the minimum obtainable subject to the budget and conservation constraint. Using jackknife re-sampling to obtain the mean price, subject to a scalar representing conditionally weighted jackknife re-sampled average of mean, and its corresponding variance, constructing confidence intervals for lower bound and upper bound cubic mass per decare for a specific county. E_1 cost effective criteria, E_2 distribution of development class 5 ("old forest"), E_3 distribution of harvested timber from 2005 - 2013, E_4 the ratio of development class 5 over harvested timber as a representation of old forest not under pressure of harvesting. Evaluated over the three different conservation constraints (4.5%, 10% and 17%).

Table 10: Sensitivity analysis - Hypothesis: Using confidence intervals for cubic mass

Hypothesis	E_n	Conservation constraint 4.5%	10%	17%
Hypothesis 1	E_1	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_2	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_3	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_4	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
Hypothesis 2	E_1	$Vol = 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_2	$Vol = 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$
	E_3	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_4	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$

A representation of the evaluation of the hypothesis presented in table 1, using confidence intervals for cubic mass, for all hypothesis, measured effective criteria, and conservation constraints. Vol is the voluntary conservation, Gov is the government initiated conservation of forested areas, E_1 is the cost effective criteria, E_2 is the utility-cost criteria for targeting forest in development class 5 (old-growth forest), and E_4 represent the old growth forest not susceptible to harvest.

Table 11: Sensitivity analysis - Results: Excluding Nordland

Type of conservation	E_n	Conservation constraint 4.5%	10%	17%
Voluntary	E_1	0.59 (0.39 - 0.79)	0.69 (0.52 - 0.84)	0.74 (0.62 - 0.87)
	E_2	0.53 (0.45 - 0.62)	0.56 (0.48 - 0.64)	0.57 (0.49 - 0.64)
	E_3	0.40 (0.34 - 0.46)	0.41 (0.35 - 0.46)	0.41 (0.36 - 0.47)
	E_4	0.18 (0.16 - 0.21)	0.16 (0.14 - 0.18)	0.16 (0.14 - 0.18)
Government	E_1	0.50 (0.26 - 0.72)	0.56 (0.39 - 0.73)	0.64 (0.49 - 0.79)
	E_2	0.47 (0.39 - 0.55)	0.50 (0.42 - 0.57)	0.52 (0.45 - 0.59)
	E_3	0.34 (0.30 - 0.38)	0.34 (0.30 - 0.39)	0.35 (0.30 - 0.40)
	E_4	0.35 (0.31 - 0.40)	0.29 (0.26 - 0.32)	0.25 (0.23 - 0.28)

Results, excluding Nordland, evaluating different cost- or utility-cost effectiveness criteria, for voluntary conservation and government initiated conservation of forested areas, evaluated from zero to one, where one is the maximum, and zero the minimum obtainable subject to the budget and conservation constraint. Using jackknife re-sampling to obtain the mean price, and its corresponding variance, constructing confidence intervals for lower bound and upper bound price, subject to a scalar representing conditionally weighted jackknife re-sampled average of mean cubic mass per decare for a specific county. E_1 cost effective criteria, E_2 distribution of development class 5 ("old forest"), E_3 distribution of harvested timber from 2005 - 2013, E_4 the ratio of development class 5 over harvested timber as a representation of old forest not under pressure of harvesting. Evaluated over the three different conservation constraints (4.5%, 10% and 17%).

Table 12: Sensitivity analysis - Hypothesis: Excluding Nordland

Hypothesis	E_n	Conservation constraint 4.5%	10%	17%
Hypothesis 1	E_1	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_2	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_3	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_4	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
Hypothesis 2	E_1	$Vol = 0.5$ $Gov = 0.5$	$Vol > 0.5$ $Gov = 0.5$	$Vol > 0.5$ $Gov = 0.5$
	E_2	$Vol = 0.5$ $Gov = 0.5$	$Vol = 0.5$ $Gov = 0.5$	$Vol = 0.5$ $Gov = 0.5$
	E_3	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_4	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$

A representation of the evaluation of the hypothesis presented in table 1, excluding Nordland, for all hypothesis, measured effective criteria, and conservation constraints. Vol is the voluntary conservation, Gov is the government initiated conservation of forested areas, E_1 is the cost effective criteria, E_2 is the utility-cost criteria for targeting forest in development class 5 (old-growth forest), and E_4 represent the old growth forest not susceptible to harvest.

Table 13: Sensitivity analysis - Results: Excluding Nordland and Hordaland

Type of conservation	E_n	Conservation constraint 4.5%	10%	17%
Voluntary	E_1	0.70 (0.55 - 0.85)	0.74 (0.61 - 0.86)	0.74 (0.61 - 0.86)
	E_2	0.56 (0.48 - 0.64)	0.57 (0.49 - 0.64)	0.57 (0.49 - 0.64)
	E_3	0.41 (0.35 - 0.46)	0.41 (0.36 - 0.47)	0.41 (0.36 - 0.47)
	E_4	0.29 (0.25 - 0.32)	0.28 (0.25 - 0.32)	0.28 (0.24 - 0.32)
Government	E_1	0.55 (0.39 - 0.70)	0.64 (0.52 - 0.75)	0.65 (0.55 - 0.75)
	E_2	0.47 (0.40 - 0.54)	0.50 (0.43 - 0.57)	0.50 (0.44 - 0.57)
	E_3	0.34 (0.30 - 0.39)	0.35 (0.31 - 0.40)	0.35 (0.31 - 0.40)
	E_4	0.33 (0.28 - 0.38)	0.32 (0.28 - 0.36)	0.31 (0.28 - 0.35)

Results, excluding Nordland & Hordaland, evaluating different cost- or utility-cost effectiveness criteria, for voluntary conservation and government initiated conservation of forested areas, evaluated from zero to one, where one is the maximum, and zero the minimum obtainable subject to the budget and conservation constraint. Using jackknife re-sampling to obtain the mean price, and its corresponding variance, constructing confidence intervals for lower bound and upper bound price, subject to a scalar representing conditionally weighted jackknife re-sampled average of mean cubic mass per decare for a specific county. E_1 cost effective criteria, E_2 distribution of development class 5 ("old forest"), E_3 distribution of harvested timber from 2005 - 2013, E_4 the ratio of development class 5 over harvested timber as a representation of old forest not under pressure of harvesting. Evaluated over the three different conservation constraints (4.5%, 10% and 17%).

Table 14: Sensitivity analysis - Hypothesis: Excluding Nordland and Hordaland

Hypothesis	E_n	Conservation constraint 4.5%	10%	17%
Hypothesis 1	E_1	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_2	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_3	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_4	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
Hypothesis 2	E_1	$Vol > 0.5$ $Gov = 0.5$	$Vol > 0.5$ $Gov > 0.5$	$Vol > 0.5$ $Gov > 0.5$
	E_2	$Vol = 0.5$ $Gov = 0.5$	$Vol = 0.5$ $Gov = 0.5$	$Vol = 0.5$ $Gov = 0.5$
	E_3	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_4	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$

A representation of the evaluation of the hypothesis presented in table 1, excluding Nordland & Hordaland, for all hypothesis, measured effective criteria, and conservation constraints. Vol is the voluntary conservation, Gov is the government initiated conservation of forested areas, E_1 is the cost effective criteria, E_2 is the utility-cost criteria for targeting forest in development class 5 (old-growth forest), and E_4 represent the old growth forest not susceptible to harvest.

Table 15: Sensitivity analysis - Results: Excluding Hedmark

Type of conservation	E_n	Conservation constraint 4.5%	10%	17%
Voluntary	E_1	0.48 (0.43 - 0.54)	0.40 (0.36 - 0.43)	0.34 (0.30 - 0.38)
	E_2	0.33 (0.30 - 0.36)	0.26 (0.24 - 0.28)	0.22 (0.19 - 0.24)
	E_3	0.44 (0.38 - 0.50)	0.44 (0.38 - 0.50)	0.44 (0.38 - 0.50)
	E_4	0.11 (0.11 - 0.12)	0.08 (0.07 - 0.08)	0.06 (0.05 - 0.07)
Government	E_1	0.64 (0.55 - 0.71)	0.55 (0.49 - 0.61)	0.48 (0.44 - 0.51)
	E_2	0.52 (0.47 - 0.57)	0.41 (0.37 - 0.45)	0.35 (0.32 - 0.37)
	E_3	0.47 (0.41 - 0.52)	0.44 (0.38 - 0.50)	0.44 (0.38 - 0.50)
	E_4	0.41 (0.38 - 0.43)	0.26 (0.25 - 0.27)	0.20 (0.19 - 0.21)

Results, excluding Hedmark, evaluating different cost- or utility-cost effectiveness criteria, for voluntary conservation and government initiated conservation of forested areas, evaluated from zero to one, where one is the maximum, and zero the minimum obtainable subject to the budget and conservation constraint. Using jackknife re-sampling to obtain the mean price, and its corresponding variance, constructing confidence intervals for lower bound and upper bound price, subject to a scalar representing conditionally weighted jackknife re-sampled average of mean cubic mass per decare for a specific county. E_1 cost effective criteria, E_2 distribution of development class 5 ("old forest"), E_3 distribution of harvested timber from 2005 - 2013, E_4 the ratio of development class 5 over harvested timber as a representation of old forest not under pressure of harvesting. Evaluated over the three different conservation constraints (4.5%, 10% and 17%).

Table 16: Sensitivity analysis - Hypothesis: Excluding Hedmark

Hypothesis	E_n	Conservation constraint 4.5%	10%	17%
Hypothesis 1	E_1	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
	E_2	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
	E_3	$Vol = Gov$	$Vol = Gov$	$Vol = Gov$
	E_4	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
Hypothesis 2	E_1	$Vol = 0.5$ $Gov > 0.5$	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$
	E_2	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_3	$Vol = 0.5$ $Gov = 0.5$	$Vol = 0.5$ $Gov = 0.5$	$Vol = 0.5$ $Gov = 0.5$
	E_4	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$

A representation of the evaluation of the hypothesis presented in table 1, excluding Hedmark, for all hypothesis, measured effective criteria, and conservation constraints. Vol is the voluntary conservation, Gov is the government initiated conservation of forested areas, E_1 is the cost effective criteria, E_2 is the utility-cost criteria for targeting forest in development class 5 (old-growth forest), and E_4 represent the old growth forest not susceptible to harvest.

Table 17: Sensitivity analysis - Results: Excluding Hedmark and Oppland

Type of conservation	E_n	Conservation constraint 4.5%	10%	17%
Voluntary	E_1	0.44 (0.39 - 0.49)	0.36 (0.33 - 0.39)	0.31 (0.27 - 0.34)
	E_2	0.28 (0.26 - 0.31)	0.22 (0.21 - 0.24)	0.19 (0.16 - 0.21)
	E_3	0.44 (0.40 - 0.48)	0.42 (0.37 - 0.47)	0.42 (0.37 - 0.47)
	E_4	0.11 (0.10 - 0.11)	0.07 (0.07 - 0.07)	0.06 (0.05 - 0.06)
Government	E_1	0.53 (0.47 - 0.59)	0.46 (0.41 - 0.51)	0.40 (0.37 - 0.43)
	E_2	0.42 (0.38 - 0.45)	0.32 (0.29 - 0.35)	0.27 (0.25 - 0.29)
	E_3	0.38 (0.34 - 0.41)	0.32 (0.29 - 0.36)	0.32 (0.29 - 0.36)
	E_4	0.39 (0.37 - 0.41)	0.25 (0.24 - 0.26)	0.19 (0.18 - 0.20)

Results, excluding Hedmark & Oppland, evaluating different cost- or utility-cost effectiveness criteria, for voluntary conservation and government initiated conservation of forested areas, evaluated from zero to one, where one is the maximum, and zero the minimum obtainable subject to the budget and conservation constraint. Using jackknife re-sampling to obtain the mean price, and its corresponding variance, constructing confidence intervals for lower bound and upper bound price, subject to a scalar representing conditionally weighted jackknife re-sampled average of mean cubic mass per decare for a specific county. E_1 cost effective criteria, E_2 distribution of development class 5 ("old forest"), E_3 distribution of harvested timber from 2005 - 2013, E_4 the ratio of development class 5 over harvested timber as a representation of old forest not under pressure of harvesting. Evaluated over the three different conservation constraints (4.5%, 10% and 17%).

Table 18: Sensitivity analysis - Hypothesis: Excluding Hedmark and Oppland

Hypothesis	E_n	Conservation constraint 4.5%	10%	17%
Hypothesis 1	E_1	$Vol = Gov$	$Vol < Gov$	$Vol < Gov$
	E_2	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
	E_3	$Vol = Gov$	$Vol > Gov$	$Vol > Gov$
	E_4	$Vol < Gov$	$Vol < Gov$	$Vol < Gov$
Hypothesis 2	E_1	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov = 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_2	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_3	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$
	E_4	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$	$Vol < 0.5$ $Gov < 0.5$

A representation of the evaluation of the hypothesis presented in table 1, excluding Hedmark & Oppland, for all hypothesis, measured effective criteria, and conservation constraints. Vol is the voluntary conservation, Gov is the government initiated conservation of forested areas, E_1 is the cost effective criteria, E_2 is the utility-cost criteria for targeting forest in development class 5 (old-growth forest), and E_4 represent the old growth forest not susceptible to harvest.

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