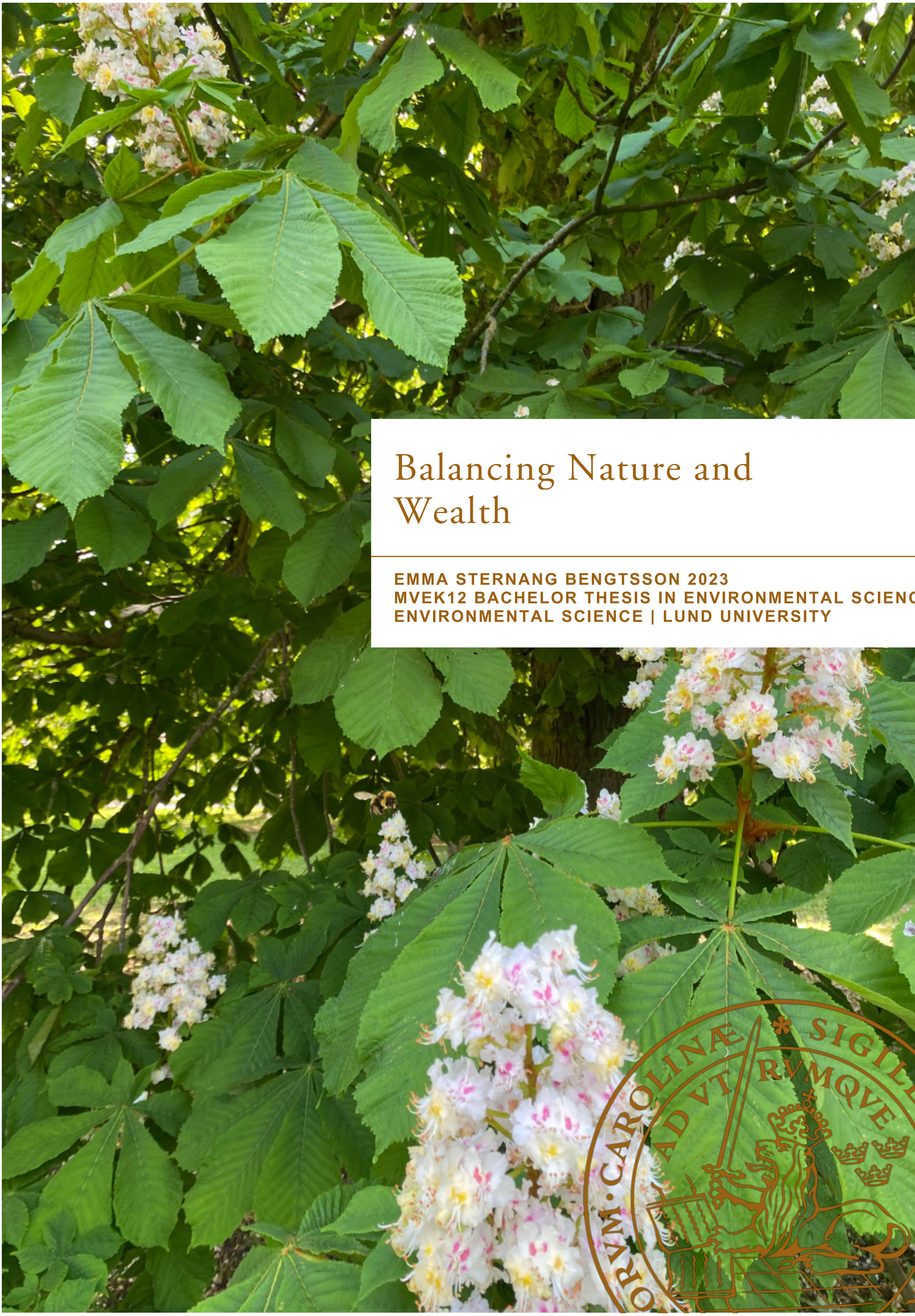

Balancing Nature and Wealth

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Balancing Nature and Wealth

A Socioeconomic Analysis of the Costs and Benefits
Associated with Reduced Logging in Swedish Forestry

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Abstract

The forest contributes multiple services, among others renewable materials, carbon sequestration, and recreational value. This thesis studied the effects on forestry stemming from the revised Land Use, Land Use Change, and Forestry regulation. The question is how reduced logging, which is in line with the new regulation, affects social welfare when incorporating the benefits of ecosystem services. This thesis carried out a socio-economic analysis of decreased logging by estimating the monetary value of lost income as well as carbon storage, recreation, water, and non-wood products. The results showed a long-term positive effect from decreased logging. This was mainly due to the tree's long-term carbon-storing possibility. However, the first twenty-five years show a negative social benefit, and to benefit from the positive effects trees must be set aside for a minimum of twenty years. The thesis looked at a short period of decreased logging and compared it to the long-term benefits. Continuing to set aside forests for nature conservation will motivate further costs which will alter the result of the analysis. Forestry is a big industry in Sweden, and this means that it affects much more than just national income. In conclusion, forestry is a sensitive subject with an ocean of different opinions and stakeholders. It is therefore important to explore all affected parties to come to a final conclusion. Time perspective is here a great question and motivator in decision-making regarding the environment. Both the question concerning how long we have until it's 'too late' and how long we are willing to wait before an investment pays off.

Populärvetenskaplig sammanfattning

Kärt barn har många värden, eller vad är det man brukar säga? Skogen är älskad och brukad av oss året om och i alla delar av landet. Det är förståeligt att det framkallar stora debatter och delade åsikter. Likaså gör EU om man kollar på vilken nyhetskälla som helst. Hur blir det då när EU ska komma in och bestämma över Sveriges skog. Kaos antagligen. En av EU:s förordningar är den så kallade 'Land Use, Land Use Change and Forestry' förordningen som ansvarar för en hållbar skog- och markanvändning. En revidering av förordningen som genomfördes i början av 2023 innebär att Sverige måste öka sin kolsänka med drygt fem miljoner ton till och med år 2030. Som det kanske går att utläsa mellan raderna kommer det här att påverka Sverige skogsbruk och våra avverkningsnivåer. Som en av Sveriges större industrier kommer det här ha stor effekt på ekonomin. Men vad händer om vi också ser värdet av de positiva effekter minskad avverkning har på övriga ekosystemtjänster i skogen?

Genom att genomföra en socioekonomisk analys av minskad avverkning har förlorad inkomst jämförts med värdet av ökad kolinlagring och de positiva effekterna på biodiversitet, rekreation, vatten och icke-träprodukter från skogen. Två scenarion har utvärderats där det första är en minskad avverkning med 15% och det andra en minskning med 30%. Under den sjuårsperiod som studerats innebär de två scenariona en inkomstförlust på 46,58 respektive 93,56 miljarder kronor. Genom att inkludera värdet av koldioxidsänkan, med hjälp av metoden social cost of carbon, samt World Bank's national wealth accounts som ett mått på biodiversitet har den stora förlusten jämförts med de positiva effekter omställningen kommer ha på skogen. Det stora ekonomiska värdet av kol och biodiversitet ger omställningen till lägre avverkningsnivåer en positiv samhällsnytta, på lång sikt. Resultatet blir, efter att ha inkluderat kolinlagringen de kommande tjugo åren, en ekonomisk vinst på 2,44 respektive 4,53 miljarder kronor. Men det är först efter, ganska exakt, cirka tjugo år efter det att avverkningen gått tillbaka till det normala, som en positiv samhällsnytta syns. Utöver det här är skogsindustrin en av Sveriges större industrier och påverkar mycket mer än bara samhällsekonomin. Resultatet förutsätter även en minskad avverkning i enbart sju år. Om avverkningen fortsätter att vara reducerad kommer det att initiera ytterligare kostnader. För att få hela bilden av hur minskad avverkning påverkar samhället är det viktigt att inkludera de som påverkas privat i form av sysselsättning tillsammans med inverkan på samhället. Som tidigare nämndes är det här en investering som eventuellt kan löna sig på lång tid. Att göra satsningar som inte skapar nytta inom den närmsta framtiden är svårt för människan. Ännu svårare blir det när kan tänkas skapa nytta för kommande generationer, men det här är svårigheterna med allt hållbarhetsarbete. Nytta för oss idag och nytta för kommande generationer ses ofta som olika saker och det hela handlar om att prioritera.

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1. Introduction

The EU has implemented multiple legislations, policies, and strategies to try and mitigate climate change and the current key mission is to become climate neutral by the year 2050 (European Commission, n.d.-a). The European Green Deal is a package to ensure the sustainable development and preservation of Europe's environment and climate (European Commission, n.d.-b). The package, proposed in July 2021, planned to revise multiple existing legislation. One of many is the Land Use, Land Use Change, and Forestry Regulation.

The Land Use, Land Use Change and Forestry Regulation (LULUCF) is a legal action under the EU that regulates the use of soil, trees, timber, plants, and biomass to contribute to a strong and reliable climate policy (European Commission, n.d.-c). The EU adopted the regulation in October 2014 to ensure all member-states contribute to sustainable forestry and land use. The regulation focuses on land use and forestry as a method to remove greenhouse gas emissions through carbon sinks (*Fit for 55*, 2023). In March 2023 the regulation was revised to increase the EU's carbon removal target to contribute to the long-term goal of climate neutrality (*Fit for 55*, 2023). The overall goal of the revision is to increase the total carbon sink for all EU member states to a capacity of 310 tons of carbon dioxide equivalents by the year 2030. The main effects of the revision would be in the forestry sector, particularly the volume of harvest (Regeringskansliet, 2021). The national target for Sweden will be a carbon sink of 47,3 million tons of CO_2-equivalents by 2030 (COM(2021) 554, 2021).

The greenhouse effect is essential to life on Earth and is a balanced system that controls the temperature on our planet (Surampalli et al., 2013). Anthropogenic behavior has affected Earth, and further, has affected the greenhouse effect by introducing and increasing greenhouse gasses (GHG) in the atmosphere and thereby causing a heat-trapping system that raises the temperature (Surampalli et al., 2013). To reduce the effects of global warming and climate change, environmental mitigation actions must be taken. One climate mitigation practice to reduce GHG emissions from the air is the use of carbon sinks. IPBES (2021) glossary defines carbon sequestration as long-term storage of carbon in living biomass such as soil, plants, the ocean, and geological formations. Forests are a major contributor to the world's global carbon cycle and provide multiple services, including carbon sequestration (Pan et al., 2011). Increasing the rotation length of tree stands can increase the ability of the forest to store carbon (Liski et al., 2001). An increase in rotation length by thirty years, from 90 to 120 years, has been shown to have a massive effect on carbon sequestration in trees (Liski et al., 2001). According to the Swedish University of Agricultural Science, (2022), the mean age for final feeling in Sweden is 100 years, but the trend is a declining mean age. A declining trend in mean age for final felling differs from the scientific studies done saying that longer rotation length is positive for carbon sequestration in trees. Therefore, the trees that are set aside in scenarios 1 and 2 could be left standing for a longer period before being logged to positively affect Sweden's carbon sink.

The Swedish land surface is 41 million hectares (ha). Of these 41 million ha 27,9 million ha are woodlands (SCB, 2023). Furthermore, out of these 27,9 million hectares, 89 percent are suitable for forestry. Today in Sweden, clear-cutting is the most common type of forestry (Lundqvist, Cedergren, et al., 2014). When clear-cutting, all or almost all of the trees are felled which leaves very little to no vegetation left at the site (Ram et al., 2020). This is then followed by replanting trees or in some cases natural regeneration of the trees (Ram et al., 2020).

For Sweden to be able to reach the goal set out by the EU and increase its total carbon sink there are a few different approaches that could be considered. You can say that there are three main ways that forests can contribute to carbon storage, 1)through carbon storage in living trees, 2) an increase in carbon storage in harvested wood products, and 3) by substituting fossil fuel with bioenergy (Seidl et al., 2007). The approach that is analyzed in this thesis is the first one mentioned, increasing the storage in living trees. However, there are multiple approaches to increasing the abundance of trees and thereby increasing carbon storage. One way is simply to decrease the amount that is being felled. Another way is to change the foundation of forestry, in other words, change the way we manage our forests and do it in a way where fewer trees are logged. Clearcutting contributes to greater alteration of forests compared to other methods, like selective logging and continuous cover forestry (Potapov et al., 2017). This alteration of intact forests has been shown to directly affect multiple ecosystem services, including carbon storage (Potapov et al., 2017).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services defines ecosystem services as the services or benefits people retrieve from nature, or more precisely from ecosystems (IPBES, 2017). Essentially, increased disturbance and changes in our ecosystem services stem from a loss in biodiversity (Millennium Ecosystem Assessment, 2005). A more diverse forest landscape, with different species as well as a greater abundance, has positive effects on plant species richness as well as habitat quality (Pedro et al., 2015). It also improves the resilience of the forest and creates a greater buffer against negative impacts from disturbances (Pedro et al., 2015). Further, trees dominate a lot of landscapes and therefore have a large impact on biodiversity as well as cultural and regulating ecosystem services (Freer-Smith & Webber, 2017).

Loss of biodiversity and its ecosystem services is not a matter of the number of species in an ecosystem, but a matter of resilience and key processes (Folke et al., 1996). When this is disturbed, it composes a threat to our ecosystem services. Folke et al.,

(1996) continue by saying that it is not necessarily a nature reserve or a designated protected area that is the main solution here, but to make the conservation of biodiversity a private as well as social interest in politics and decision-making. Biodiversity is important for functioning ecosystems and thus to the ecosystem services they provide (Hanley & Perrings, 2019). Ecosystem services later provide benefits to us humans, both market-valued ones such as crops, and non-market values such as recreation. Preventing further biodiversity loss has shown other positive effects, including on the forest's ability to store and take up carbon. Greater diversity in tree species has been shown to dampen the effects of disturbance on carbon net uptake (Pedro et al., 2015). Pedro et al., (2015) study further implies a positive relationship between diversity and resilience in forests. Changes that occur in biodiversity can be linked to changes in economic values and output, and it is, therefore, important to find the links between these (Hanley & Perrings, 2019).

For Sweden to be able to reach the goal of a larger carbon sink, changes will have to be made in the forestry sector. This thesis will analyze how the LULUCF regulation can affect harvest levels and look at the socioeconomic consequences in Sweden. The enhancement of Sweden's carbon sink is given an economic value to be able to compare it to the loss of harvest. Further, an increase in the volume of trees can have positive effects on the ecosystem services of the forests. Therefore, the socio-economic analysis will include the value of biodiversity, water, recreation, and non-wood products as a social benefit.

A big part of this thesis is the monetary valuation of life. Both the life of humans, animals, and vegetation. By putting a price on biodiversity, we implicitly say what we think an animal is worth to us. There is no way of correctly estimating the value of life. Carbon sequestration could be seen as the price we think clean air is worth. This means that we put a monetary worth on human health regarding clean air.

To handle this ethical dilemma as unbiased and professionally as possible the thesis will be based on previous research from different sources and scientists. However, it is important to see the benefits that can occur from monetarily valuing such things. By putting a monetary value on biodiversity, we can create an understanding of its value and show society and politicians that it has a worth. This can help prioritize differently in decision- and policymaking.

Environmental science studies the relationship between nature, the environment, and humans. The forest contributes multiple services including ecosystem services, employment, and income. To combat many of the challenges of climate change, we need to find a way to sustainably exploit this resource to please all parts. There will never be a fully right or wrong way but hopefully, this thesis can contribute with some valuable points of view to help understand the value of nature and its importance for a sustainable future.

1.1 Aim of Thesis and Research Question

The thesis aims to find the links between economic and ecological worth and explore the social consequences of decreased logging in terms of the Land Use, Land Use Change, and Forestry regulation in Sweden. The thesis will evaluate the cost of lost timber as well as the monetary value of increased carbon storage and its effects on other ecosystem services in monetary terms. This results in the question:

i) Will the monetary value of the forest's ecosystem services alter the results of a socio-economic analysis on decreased logging?

2. Methodology

A socio-economic analysis is composed by comparing the potential social cost with the potential social benefits. This type of analysis is a helpful tool to analyze the advantages and disadvantages for society when changing welfare systems, integrating new climate change measures, or investing in new infrastructure. This analysis will be comparing the costs and benefits of changed forestry following the LULUCF regulation.

The analysis compared two scenarios. Scenario one (1) implies a decrease in logging by 15% until 2030. This scenario is based on facts from Swedish foresters and what they imply is necessary to reach the goal of a larger carbon sink. The second scenario (2) is based on a decrease in logging by 30% until the year 2030. This scenario is hypothetical and constructed to understand the effects of an even further decrease in logging on Sweden's welfare. Two assumptions were made to simplify the calculations. They were that the Swedish forest area, as well as the area of production forest, are constant and unchanged during the period examined.

2.1 Decreased Logging

The two scenarios 1 and 2 were the base for calculating the expected loss in harvest as well as the increase in the carbon sink. To carry out the calculations Excel was used.

Firstly, an average of carbon uptake per hectare of forest was calculated. This was done by dividing the UNFCC, (2022) estimate of net emissions in Sweden by the total amount of ha forest. Net emissions from Sweden varied between -45 million tons of CO_2 equivalents to -39 million tons of CO_2 equivalents according to the UNFCCC net emissions report. There was no distinct pattern, as a yearly increase or decrease, so therefore an average was calculated for the years 2013 – 2020.

$$\frac{Estimated\ Net\ Carbon\ Flow\ (ton\ CO_2\ eq)}{Forestland\ (ha)}$$

After this, an average percentage increase in logging each year was estimated by observing logging levels from the year 2000 until 2022. This estimated increase in logging was then multiplied by each year's harvest level (2023-2030). This created the BAU scenario. A BAU scenario is necessary to reference the two hypothetical scenarios of reduced logging. I then calculated how many m^3forest (m^3f) of the forest will be set aside until 2030 by multiplying the BAU scenario each year by 0,85 and 0,7 for scenarios 1 and 2 respectively.

Table 1. How the volume of harvest is calculated for Scenario 1

Year	2023	2024	2025	2026	2027	2028	2029	2030
Logging after decrease of 15%	Original volume of harvest	Volume of harvest BAU x 0,85	Volume of harvest BAU x 0,85	Volume of harvest BAU x 0,85	Volume of harvest BAU x 0,85	Volume of harvest BAU x 0,85	Volume of harvest BAU x 0,85	Volume of harvest BAU x 0,85

Table 2. How the volume of harvest is calculated for Scenario 2

Year	2023	2024	2025	2026	2027	2028	2029	2030
Logging after decrease of 30%	Original volume of harvest	Volume of harvest BAU x 0,7	Volume of harvest BAU x 0,7	Volume of harvest BAU x 0,7	Volume of harvest BAU x 0,7	Volume of harvest BAU x 0,7	Volume of harvest BAU x 0,7	Volume of harvest BAU x 0,7

After this, the total was calculated by summing up the volume of harvest for each year to get a total for the years 2023-2030 for each respective scenario: BAU, 1, and 2.

The statistics were taken from the Swedish Forest Agency statistics database. The logging levels had the unit forest cubic meter (m^3f). This then had to be converted into ha since the unit of carbon net flow is per ha. This was done by multiplying m^3f by 257 since there are on average 257 m^3f for each ha (Swedish Forest Agency, 2022a).

2.2 Value of Timber

In this analysis, the average price of timber is based on the price that the forest owner sells their timber to four different forest organizations. The average market price for timber in Sweden depends on where the trees are being logged and sold. Further, the timber price varies depending on the quality of the trees as well as their height. To estimate a value that is as unbiased as possible, an average was calculated using different buyers, harvest areas, and tree heights. This analysis used the timber stock price of sawlogs from Scots Pine and Norway spruce as well as the price of pulpwood. The price of other byproducts of forestry was not included. The analysis does not take into regard variations in demand or cost of logging.

The estimated average price was calculated by looking at the prices from four different forestry organizations: *Södra Cell, Svea Skog, Norra Skog,* and

Skogsstyrelsen. On each website, there were prices for each tree class, graded from one to four, and for the different tree heights. The price is in the unit SEK per m^3 solid over bark (sob). Solid over bark refers to the volume of the tree trunk without bark (Lundqvist, Lindroos, et al., 2014). The prices were then added to Excel and an average was calculated for Scots pine timber classes 1,2,3 and 4 as well as Norway spruce timber classes 1 and 2 for each of the organizations. The different tree heights in each class were combined in the mean. Here class 1 is the best quality tree and has the highest value, and 4 is the least good quality. After this, a mean for Scots pine timber class 1 from all organizations was calculated, as well as for classes 2-3, and 4. The same was done to Norway spruce timber classes 1 and 2. Scots pine classes 2 and 3 were combined since they often had the same price or were already combined on the organizations' price lists. A national average for Scots pine and Norway spruce was calculated using the means from each organization and each tree classification, and then lastly a national average of the timber price for Scots pine and Norway spruce together.

The average price of pulpwood was calculated using primarily the same method. First, the price of pulpwood from each organization was added to Excel. After this, an average for each respective organization was calculated. Then a national average was calculated by adding the four different averages and dividing by four. This was then added to the average price of Scots pine and Norway spruce and divided by three, to get a national average for the price of timber (including pulpwood).

$$\frac{Scots\ pine\ (SEK) +\ Norway\ Spruce(SEK) + Pulpwood\ (SEK)}{3}$$
$$= Average\ price\ of\ timber\ and\ pulpwood\ (SEK^{2023}\ per\ m^3 sob)$$

The cost of logging was taken from the Swedish Forest Agency statistics database and subtracted from the market price of timber:

$$market\ price\ per\ m^3 sob\ - cost\ of\ harvesting\ per\ m^3 sob$$

The price of timber was in the unit m^3sob and decreased harvest in m^3f or ha. Skogforsk, who is a central unit in forest research in Sweden, estimated the conversation factor from m^3sob to m^3f to 1,188 (Skogforsk, 2022). The prices, currently in the unit m^3sob, were multiplied by 1,188 to acquire the unit m^3f. To estimate the economic loss from decreased logging, harvest loss for each year was multiplied by the market value of timber.

$$timber\ loss\ (m^3 f) \times market\ price\ per\ m^3 f\ timber$$

The prices were taken from the websites of these organizations:

Table 3. The different forest organizations and in what region they are active.

Region	Organization
Southern, Middle	Södra
All of Sweden	Svea Skog
All of Sweden	Skogsstyrelsen
Northern	Norra Skog

The price was calculated using 2023 years pricelists and prices in units other than SEK^{2023} were revalued into the correct monetary value using Statistics Sweden price converter (n.d.).

2.3 Carbon Sequestration

To estimate the value of carbon sequestration, the method called the social cost of carbon (SCC) was used. SCC is a widely used method to estimate the value of carbon and imply the economic damages from one extra ton of carbon dioxide (CO_2) or carbon dioxide equivalents emissions (Ricke et al., 2018). They further explain that SCC can be understood as an economic valuation of the marginal impacts associated with climate change and that it can be a global estimate or a country-specific estimate.

Ricke et al., (2018) method is based on a model that uses five different socio-economic scenarios, called socio-economic pathways, alongside twelve discounting schemes. Ricke et al., (2018) model follows the classic integrated assessment models but also uses climate projections taken from climate simulation data along with country-level economic damage relationships from microeconomic analysis, rather than the standard way of building reduced-form models of the economy and climate. For this thesis, a global average SSC of US$ 175 per ton of CO_2 was used from Ricke et al., (2018) study. The value was then transferred into SEK^{2023} with an exchange rate of 10,17 SEK per US dollar.

To estimate how much the increased carbon sink will benefit Sweden, the extra net carbon uptake calculated in section 1 was used. The extra net carbon uptake for each year from scenarios 1 and 2 was multiplied by the SCC values. The year 2023 is year zero and no change will therefore be made this year.

The decrease in logging can be seen as a set-aside and the trees that are left standing will continue to take up carbon. So, it is also necessary to understand how much they will continue to contribute to carbon sequestration over a longer period. As previously mentioned, an increase in rotation length to 120 years has a great positive impact on the total carbon sink (Liski et al., 2001). Therefore, the thesis also includes a long-term segment where the trees that are set aside each year are expected to be standing for an additional twenty years to continue to contribute to Sweden's carbon sink. This was done by accumulating the costs for the first seven years, as well as the SCC and the worth of biodiversity, recreation, water, and non-wood forest products, then continuing to add on the SCC each year for a total of twenty years.

2.4 Recreation, Water, Non-Wood Forest Products and Biodiversity

To measure the value of a few of the ecosystem services provided by the forest a method from Hanley & Perrings (2019) was used based on the World Bank's wealth accounts data. The World Bank provides national wealth accounts for countries around the world. These national accounts are developed on the concept of adjusted net savings and are a way to inspect whether a country is investing enough capital to sustain the value of the capital stock when changes in natural capital are considered (Hamilton & Clemens, 1999). The World Bank has multiple natural capital accounts and the ones used in this thesis are 1) Natural Capital, forest: ecosystem services, 2) Natural Capital, Agricultural Land, and 3) Natural Capital, Protected Areas. Hanley & Perrings, (2019) method for valuing biodiversity is the sum of the natural capital accounts related to land use. Using the value of agricultural land may not seem related to this thesis. However, what is interesting here is the value of biodiversity. To obtain a more correct estimate of the value of biodiversity, this account must be included since it contributes to the overall function of biodiversity and ecosystem services. In the account Natural Capital, forests: ecosystem services the three services included are water, recreation, and non-wood forest products (The World Bank, n.d.). When mentioning 'the ecosystem services' further in the method and the results, these are the ones being referred to. The World Bank's accounts are based on methods of the System of National Accounts (SNA) (The World Bank, n.d.). The total wealth is the sum of estimates of natural capital, human capital, net foreign assets as well as produced capital (The World Bank, n.d.).

This value of the accounts has the unit $US\$^{2018}$, this had to be converted into SEK^{2023}. This was done by using the exchange rate of US$ to SEK for 2018 and then the SCB price converter from SEK^{2018} to SEK^{2023}. This value of the forest's ecosystem services was divided by the ha of forest in Sweden. The value of biodiversity was divided by the total amount of ha in Sweden. This was mainly done because there is no specification of where protected areas are and exactly what the account includes. This may be an underestimation of the value of biodiversity but because of time limits, limitations had to be made. This resulted in an estimated average of the worth of biodiversity as well as the three ecosystem services water, recreation, and non-wood products per ha forest in Sweden.

After this, the average per ha was multiplied by the difference in logging for BAU and scenarios 1 and 2 respectively.

$$Value\ of\ Biodiversity\ and\ the\ Ecosystem\ Servies \\ \times\ Set\ Aside\ Ha\ of\ Forest$$

2.5 Discounting

There have been many studies done regarding the correct discount rate. In a study from 2018 concerning the correct long-term social discount rate (SDR), most experts agreed that an SDR between 1 – 3% is acceptable and around 2% is the most correct (Drupp et al., 2018). The higher the risk of the investment, the higher the rent, and therefore the discount rate must be (Drupp et al., 2018). Valuing non-market values is risky and there is no way of knowing if they are valued at the correct price. Therefore, the 'investment' that the LULUCF regulation is, can be seen as a risky one. In this thesis, the discount rate used is 3%. It is slightly higher than 2% since this type of valuation and investment comes with a risk. All monetary values in this thesis have been discounted using a 3% discount rate. Below is the formula used to calculate the net present value, which is the cash value after being discounted.

$$NPV = \frac{R_t}{(1+r)^t}$$

R = Cash flow at time t
t = time of cash flow (years from year zero)
r = discount rate

2.6 Socio-Economic Analysis

The socio-economic analysis is conducted by comparing the loss of income, which is seen as a cost, and the value of carbon, biodiversity, and the ecosystem services. The sum is the net present value of the discounted costs and benefits calculated in the previous sections. A positive result implies a socio-economic benefit and a negative result a socio-economic cost.

3. Results

Below are the results of the calculations performed to answer the question regarding how ecosystem services affect a socio-economic analysis. Sections 3.1 – 3.5 are the preoperative calculations to be able to execute the socio-economic analysis.

3.1 Decreased Logging

The table presents the volume of harvest for a BAU scenario as well as scenarios 1 and 2. The unit is million m^3forest (m^3f). The year 2023 is seen as a year zero, no decrease is therefore made during this year.

Table 4. Decrease in harvest for the BAU scenario and the hypothetical scenarios 1 and 2 in million m^3f.

Year	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*
BAU (Million m^3f)	97,62	99,27	100,95	102,66	104,39	106,16	107,95	109,78	828,78
Scenario 1 –15% (Million m^3f)	97,62	84,38	85,81	87,26	88,73	90,23	91,76	93,31	719,11
Scenario 2 –30% (Million m^3f)	97,62	69,49	70,67	71,86	73,07	74,31	75,57	76,84	609,43

3.2 The Economic Value of Timber

In the table below are the prices calculated for each class of Scotts Pine and Norway Spruce, as well as for pulpwood, the cost of logging, and the average price of timber used in the analysis. The cost of harvesting was transferred from the Swedish Forest Agency statistics database. The estimated cost of harvesting was in the year 2021 133 SEK per m^3sob (Swedish Forest Agency, 2022b). This was revalued into SEK^{2023} which gave the result 154,27 SEK.

Table 5. Average prices for pine, spruce, and pulpwood in SEK per m^{3}sob.

Average price for Scots pine class 1	785,94 SEK per m^{3}sob
Average price for Scots pine class 2-3	634,25 SEK per m^{3}sob
Average price for Scots pine class 4	512,27 SEK per m^{3}sob
Average price for Norway spruce class 1	668,70 SEK per m^{3}sob
Average price for Norway spruce class 2	603,90 SEK per m^{3}sob
Average price for Scots pine (total)	659,86 SEK per m^{3}sob
Average price for Norway spruce (total)	617,17 SEK per m^{3}sob
Average price for pulpwood	398,32 per m^{3}sob
Cost of logging for forester	154,27 SEK per m^{3}sob
Average price of timber (Scots pine and Norway spruce) and pulpwood	404,18 SEK per m^{3}sob

3.3 Loss of Income

Below are the results from calculating the loss of income. This comes from multiplying the difference in harvest between a BAU scenario and scenarios 1 and 2 by the price of timber.

Table 6. The difference in logging between the BAU scenario and scenario 1 and the result of loss of income in billion SEK.

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
BAU (Million m^{3}f)	97,62	99,27	100,95	102,66	104,39	106,16	107,95	109,78	828,78
-15% (Million m^{3}f)	97,62	84,38	85,81	87,26	88,73	90,23	91,76	93,31	719,11
Difference (Million m^{3}f)	0	14,89	15,14	15,40	15,66	15,92	16,19	16,45	109,67
Value (Billion SEK)	0	7,15	7,27	7,39	7,52	7,65	7,78	7,91	52,66
Discounted Value, 3% (Billion SEK)	0	6,94	6,85	6,78	6,68	6,60	6,51	6,43	46,78

Table 7. The difference in logging between the BAU scenario and scenario 2 and the result of loss of income in billion SEK.

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
BAU (Million m^3f)	97,62	99,27	100,95	102,66	104,39	106,16	107,95	109,78	828,78
-30% (Million m^3f)	97,62	69,49	70,67	71,86	73,07	74,31	75,57	76,84	609,43
Difference (Million m^3f)	0	29,78	30,29	31,80	31,32	31,8	32,39	32,93	219,35
Value (Billion SEK)	0	14,30	14,54	14,79	15,04	15,29	15,55	15,81	105,32
Discounted Value, 3% (Billion SEK)	0	13,88	13,71	13,53	13,36	13,19	13,02	12,86	93,56

3.4 Carbon Net Uptake and Social Cost of Carbon

The average net emissions in Sweden were -42 197 997 tons of CO_2 equivalents per year. The total amount of forestland in Sweden is 27,9 million ha. These two divided by each other gave the average of -1,512 tons of CO_2 equivalents per ha forest. This means that one ha forest takes up around 1,512 tons of CO_2 equivalents.

$$\frac{42\ 197\ 997\ t\ CO_2}{27\ 900\ 000\ ha} = 1{,}512\ {}^{ton\ CO_2}/_{ha\ forest}$$

The difference in harvest between a BAU scenario and scenarios 1 and 2 was converted from m^3f to ha by dividing the value in m^3f by 257. The uptake of CO_2 per ha forest (1,512) was multiplied by the difference to obtain how many tons of CO_2 the set-aside forest will take up. The total carbon uptake was multiplied by the SCC value. In the table below a SCC value of 1780,37 SEK^{2023} was used (US$175).

Table 8. The difference in harvest between the BAU scenario and scenario 1 converted into ha and the result from SCC for scenario 1. The SCC value is 1780 SEK per ton of CO_2.

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
Difference in Ha (Thousand Ha)	0	57,94	58,92	59,91	60,93	61,96	63,01	64,07	426,75
Total Carbon Uptake (k ton CO_2)	0	87,63	89,12	90,62	92,15	93,71	95,30	96,91	645,44
SCC (Million SEK)	0	156,02	158,66	161,34	164,07	166,84	169,66	172,53	1149,13
Discounted Value of SCC, 3% (Million SEK)	0	151,48	149,55	147,65	145,77	143,92	142,09	140,28	1020,74

Table 9. The difference in harvest between the BAU scenario and scenario 2 converted into ha and the result from SCC for scenario 1. The SCC value is 1780 SEK per ton of CO_2.

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
Difference in Ha (Thousand Ha)	0	115,88	117,84	119,83	121,86	123,92	126,01	128,14	853,49
Total Carbon Uptake (k ton CO_2)	0	175,27	178,23	181,24	184,31	187,42	190,59	193,81	1290,88
SCC – 1780 SEK/t CO2 (Million SEK)	0	312,04	317,32	322,68	328,14	333,68	339,32	345,06	2298,25
Discounted Value of SCC, 3% (Million SEK)	0	305,03	303,21	301,40	299,61	297,28	296,05	294,28	2097,40

The estimated value of carbon sequestration for the coming 20 years (after 2030) is illustrated in the table below. A SCC value of 1780,37 SEK per ton of CO_2 was used and the values were discounted using a 3% discount rate.

Table 10. Value of long-term carbon sequestration from the set-asides for scenarios 1 and 2

	SCC of set-aside forest for the year 2031 – 2081
Scenario 1 – 15%	16,21 billion SEK^{2023}
Scenario 2 – 30%	32,41 billion SEK^{2023}

3.5 Recreation, Water, Non-Wood Forest Products and Biodiversity

Table 11. Names of the World Bank's account and their worth in US$.

Account Name	**Value in $US\$^{2018}$**
Natural Capital, forest: Ecosystem Services	165 172 372 179,2
Natural Capital, Agricultural land	21 762 415 428,3
Natural Capital, Protected Areas	17 243 359 118,6

The worth of ecosystem services divided by the total amount of ha forest (27 900 000 Ha) was 5920,16 $US\$^{2018}$ per ha. The worth of biodiversity and the three ecosystem services; recreation, water, and non-wood products were divided by 41 000 000 ha which is the area of Sweden. That was 951,4 $US\$^{2018}$ per ha. The sum of the two is 6871,5 $US\$^{2018}$ per ha.

The monetary rate at the time of the calculations from $US\$^{2018}$ to $US\$^{2023}$ was 1,2$US\$^{2023}$ per 1$US\$^{2018}$. So, 6871,5 $US\$^{2018}$ multiplied by 1,2 is 8245,8 $US\$^{2023}$. Transferred into SEK with an exchange rate of 10,17 SEK per US$ gave us the value of 83 860,0 SEK per ha forest. Below is the difference in logged ha between a BAU scenario and scenarios 1 and 2 respectively multiplied by the value of biodiversity and the three ecosystem services.

Table 12. Result from the value of biodiversity and the three ecosystem services water, recreation, and non-wood forest products for Scenario 1

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
Difference in Ha (Thousand Ha)	0	57,94	58,92	59,91	60,93	61,96	63,01	64,07	426,75
Value of Biodiversity and Ecosystem Services (Billion SEK)	0	4,86	4,94	5,02	5,11	5,20	5,28	5,37	35,79
Discounted Value, 3% (Billion SEK)	0	4,72	4,66	4,60	4,54	4,48	4,43	4,37	31,79

Table 13. Result from the value of biodiversity and the three ecosystem services water, recreation, and non-wood forest products for Scenario 2.

Year	2023	2024	2025	2026	2027	2028	2029	2030	Total
Difference in Ha (Thousand Ha)	0	115,88	117,84	119,83	121,86	123,92	126,01	128,14	853,49
Value of Biodiversity and Ecosystem Services (Billion SEK)	0	9,71	9,88	10,05	10,22	10,39	10,57	10,75	71,57
Discounted Value, 3% (Billion SEK)	0	9,43	9,31	9,20	9,08	8,96	8,85	8,74	63,58

3.6 Socio-Economic Analysis

The socio-economic analysis is conducted of the net present values from each of the previous calculations; loss of income, the social cost of carbon, and biodiversity and ecosystem services.

Table 14. Socio-economic analysis of the costs and benefits associated with reduced logging. Divided into two parts describing the first seven years and then the additional twenty years (long-term) that the trees are set aside.

	Scenario 1 (-15%)		Scenario 2 (-30%)	
	Cost	Benefit	Cost	Benefit
Loss of income (Billion SEK)	-46,58		-93,56	
Biodiversity and the Ecosystem Services (Billion SEK)		31,79		63,58
Social Cost of Carbon (Billion SEK)		1,02		2,10
Analysis of reduces logging after seven years	-13,77 billion SEK		-27,88 billion SEK	
Long-term Social Cost of Carbon (Billion SEK)		16,21		32,41
Total including Long-term SCC (Billion SEK)	-46,58	49,02	-93,56	98,09
Analysis of reduced logging long-term	2,44 billion SEK		4,53 billion SEK	

4. Discussion

4.1 Analysis of Results

The results show a positive long-term result for both scenarios 1 and 2 which implies that reducing the amount that is being harvested each year for a seven-year period results in a total social benefit. However, this is the result when including the long-term social cost of carbon. Looking at only the seven years, it results in a cost of 13,77 billion SEK for scenario 1 and 27,88 billion SEK for scenario 2. This type of investment would have a positive effect in the long run. Nonetheless, there are a few things to be recognized before saying that this is a positive long-term investment. Firstly, there is a major economic loss from decreased logging for the first seven years. In total, Sweden would lose 46,58 and 93,56 billion SEK respectively. The thesis does not consider how this vast economic loss would affect Sweden and if it is manageable. The analysis does not include a decrease in logging beyond these seven years and implicitly implies that logging goes back to normal after this. If the implementation were to continue there would be a greater economic loss. The analysis does not consider how employment is affected and if that would result in a greater economic loss. For example, if the decrease in logging would lead to unemployment. Secondly, the positive economic effects of reduced logging are not visible until around 25 years after the legislation was implemented. This does not mean that it shouldn't be included in the analysis but is important to point out. Not to forget is of course that the positive environmental effects are immediate and just as important and should not be overlooked because of the vast economic investment. It is because of the environmental benefits that this type of investment could lead to a positive return on investment. The analysis shows that including the monetary value of ecosystem services considerably alters the results of the socio-economic analysis.

Understanding that consequences for ecological values and the environment can have an economic effect is important to create both economically and ecologically sustainable decision-making processes. Changing the current praxis from most often only including purely economic costs and benefits to also including the value of the environment will probably be a long process. However, it is important to be able to understand the full picture of an investment. In this thesis, the environmental effects are positive, but it can just as well show the negative effects of a welfare investment on the environment and thus not make it economically beneficial.

4.2 The Time Perspective

An interesting factor with this type of implementation is the time perspective. As discussed above, a positive economic return on investment is visible after 25 years, if ever, depending on if the decreased logging would continue or not. Delayed gratification, as it is often called, is a phenomenon that determines many of the decisions we make in our everyday life, as well as how we approach political decision-making (Christensen & Rapeli, 2020). Policies that present positive effects within a time horizon of 20 to 30 years are less favorable than those that show positive effects immediately or within 2 years (Christensen & Rapeli, 2020). However, here is where there once again needs to be a shift in the paradigm and more precisely how we perceive positive effects. The positive effects on the environment are immediate and should be treated equally to the economic effects. To add to this discussion, it is also important to include how employment would be affected. Understandably, income and occupation go before environmental profit for the individual. On a societal level, on the other hand, there should be incentives to promote both individual safety and the environment's future.

4.3 Alternative Approaches and Critiques

This thesis studied the new legislation's effects on forestry and based it on the solution of reduced logging. However, there is nothing in the LULUCF regulation that specifies the details of the execution. Already back in 1977, Schlesinger W.H, found that soil is the largest terrestrial carbon sink. It would therefore be important to look at the effects of harvesting on soil carbon storage and the possibility of using the soil to increase Sweden's carbon sink. Soil carbon storage is an area full of potential and previous research. Jörgensen et al., (2022) for example concluded that carbon sequestration, as well as biomass production, are promoted by nitrogen fertilization. Other studies, such as Forsmark et al., (2021), suggest that roots and root-productivity contribute to an increased carbon stock after fertilization, mainly due to increased carbon use and production efficiency. Soil is and can act as a great carbon sink and it would be interesting to further explore the possibilities of enlarging its possibilities.

Many different forestry practices besides clear-cutting could be enforced in Sweden to gradually implement a more sustainable forestry sector and work towards a sustainable future. Continuous cover forestry for example is a well-debated method that implies that there is no clear-cutting and the density of trees is maintained to enable the natural regeneration of the forest (Seidl et al., 2007). This method of forestry and the research behind it originates from (Adams & Ek, 1974). However, considering the almost 50 years since the research began, and even further since the method was implemented, it might be a difficult task to try and change the way Sweden manages their forests in the timeframe given by the EU. This type of change is important to consider when developing forestry long-term.

Among others, Swedish Foresters has presented concerns regarding the fact that logging will have to be reduced and says that it will interfere with the potential of switching from fossil fuel to biofuel as well as using more sustainable materials (Swedish Forest Industries, 2021). This is a very relevant argument and if the volume of timber decreases, there is a potential that there will be a shortage of renewable and bio-based materials. Once again, this shows the importance of evaluating other actions to improve our carbon sink as well as integrating this into the economic analysis. Forestry is a subject that affects many parties with different views and opinions. We cannot forget the importance it has for Swedish industry and employment and how these would be affected.

Another thing that has not been discussed excessively in this thesis is the storage of carbon in harvested wood products. To completely understand how reducing harvest levels will affect carbon storage, it is of course important to understand how carbon transports from living biomass to harvested wood products and how they store carbon. There is a list of factors that would be of great interest to examine and that would contribute to the thesis, making it more realistic and reliable.

4.4 Methodology Assessment and Credibility

A few things should be mentioned regarding the valuation of biodiversity and the social cost of carbon. The social cost of carbon is, as mentioned, an established method to monetarize carbon dioxide and carbon dioxide equivalents and in this thesis, a global average of US$175 was used. In Ricke et al., (2018) study they concluded that northern Europe, Canada, and Russia have a negative SCC. This is because the temperature is under the economic optimum and the country's welfare would benefit from an increase in carbon dioxide emissions (Ricke et al., 2018). In other words, an increase in temperature, that the enhanced emissions would contribute to, would benefit the country. However, the negative value which would be the country-specific social cost of carbon for Sweden was not used in this thesis. GHG do not care about borders and Sweden, as a country dependent on both the import and export of goods, should include the effects of emissions in other countries in this type of analysis. Therefore, a global average was used to include environmental effects on a global level.

Biodiversity does not have an established method and there is no way of saying if the calculations are correct or representative. In this thesis, a method by Hanley & Perrings, (2019) was used. To get an even better estimate, multiple different methods should be compared to receive an average on the worth of biodiversity. To develop the calculations a sensitivity analysis should be conducted. This is to test the results and see which factors primarily affect the results.

The results from this thesis are a broad overview of how environmental non-market values can alter the results of a socio-economic analysis. They do not in-depth show what biodiversity is worth or the exact cost of carbon sequestration. The important key finding to take away from the results of this thesis is the importance and impact of ecological and environmental values. Benefit transfers should not be made from this thesis.

4.5 Wider Implementations, Improvements, and Future Studies

This thesis can be used to understand the significance of valuing our nature. To be able to implement welfare investments that are sustainable for both society and the environment, all parts must be included in the economic analysis. Future studies should focus on improving the methodology and exploring how more or different ecosystem services can change the economic value of an investment. In the future, understanding how to communicate these types of results to decision-makers is fundamental to implementing a sustainable decision-making process and should also be studied further.

5.Conclusion

This thesis aimed to understand how ecological and environmental non-market values can affect a socio-economic analysis of reduced logging. In conclusion, it positively affects the socio-economic analysis and reduces costs immensely. From a long-term perspective, it even shows a positive result. However, there are great costs associated with this type of investment and it affects much more than national income. This, alongside the fact that a positive return is visible after thirty years, suggests that this type of investment should be evaluated thoroughly before being finalized. To fully understand the effect of decreased logging or any similar investment it is also important to include all affected parties.

Involving the value of nature in political decision-making is important to be able to prioritize a sustainable use of resources and for our future. This is thus interesting since it could potentially, in the long term, contribute to a shift in the paradigm where environmental benefits are recognized as highly as economic benefits. However, the thesis has also shown that there is a need for further development regarding the valuation of ecosystem services. Before this shift can become a reality, it is necessaire to find established and reliable methods to evaluate nature's services.

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