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Ulrika Aschan
Emma Pettersson

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Ulrika Aschan
Emma Pettersson

Supervisor: Jonathan Stråle, Swedish University of Agricultural Sciences, Department of Economics

Examiner: Jens Rommel, Swedish University of Agricultural Sciences, Department of Economics

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Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

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Abstract

Global warming is becoming an increasing issue on the agenda for the world's policy makers. One way of solving the issues is to reduce the emissions; another is to compensate for them through equally climate positive projects, such as planting trees to sequester carbon. We want to know more about the level of sustainability of climate compensation through tree planting. We perform a cost-benefit analysis to put monetary values on two different aspects of the compensation; the social and the economical. Three different scenarios of land use for climate compensation on 10 hectares in South West Uganda are considered in the analysis. The first scenario is baseline, where the land is left as today, the second scenario is monoculture forestry, where trees are planted on the land, and the third is agroforestry where the planted trees are intercropped with maize. We evaluate the costs and benefits connected to each scenario, and our results show the highest Net Present Value is reached for monoculture forestry. However, the results are not robust, since they are very dependent on what price of carbon equivalents that is used, and what rate of discount. Our sensitivity analysis shows that agroforestry may be equally favourable, depending on what perspective is applied.

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1. Introduction

Greenhouse gases contribute to a thicker ozone layer which warms our planet above normal. CO_2 Emitted into the atmosphere is pointed out as one of the largest contributor to the greenhouse effect and emissions are becoming an increasing problem to the global climate. A company whose production is completely reliant on greenhouse gas emissions can today call themselves climate neutral. Through so called climate compensation they can neutralize their negative impact on climate changes by investing in a project which is equally climate positive. It has also become popular for private persons to compensate for their consumptions in an equal manner.

A common method for compensation of greenhouse gas emissions is to plant trees, often in developing countries. Both the United Nations and the World Bank have initiated global projects in the purpose of transferring money from the western world to preserve and plant new forests in developing countries. The *Clean Development Mechanism* (CDM), is an example of such a global project, and it is developed by the participating countries of the Kyoto Protocol and the UN.

The mechanisms collaborate with global green companies and governmental funds to promote sustainable forestry investments. One partner country within these projects is Uganda. 15 % of Uganda's land area consists of forest, but this area diminishes on average by 88000 ha per year (Chamchama, 2011). Investment projects financed from for example the CDM can lead Uganda towards a more sustainable forest management, but the question is what economic and social incentives there are for local population in Uganda considering these types of externally financed projects, and how the projects are carried through.

We investigate the functionality and options for climate compensation via tree planting in Uganda. Is this type of climate compensation the salvation of our planet, or an exhibition of a modern type of colonization?

1.1 Research Objectives

We want to find out if there is a sustainable way of compensation for CO_2 emissions. We investigate tree planting as a way of sequestering emitted CO_2 from the atmosphere. To do this we apply three different scenarios on a hypothetical case study in Uganda. The case study consists of 10 ha in South East Uganda, on which we will apply three different scenarios of land use: leaving the land as it is today (degraded grassland); planting trees in a monoculture forestry; and planting trees simultaneously with growing maize, agroforestry. The aim of the study is to perform a cost benefit analysis on the three different projects to see which method is most suitable from an economic and social aspect for climate compensation.

Our research question is:

What type of forestry is the most sustainable option for climate compensation?

We will answer this question through two stages:
1. Is it economically sustainable? What type of forestry is the most efficient considering climate compensation? What are the costs and benefits of the different types of forestry?
2. Is it socially sustainable? Who is affected by the tree planting for compensation? How are they affected? Who benefits? What are the possibilities and complications with different types of forestry as climate compensation?

We include the costs and benefits from two different perspectives; the local and the global. The global perspective is represented by policy makers and foreign investors who are interested in the value of the CO_2 equivalents for compensation, environmental services or as revenue from an investment.

The local perspective is represented by the habitants of the region where our case study is located, who might be more interested in the income from harvests, recreational values or property rights. We compute the Net Present Value for each project, and we discuss which of the three scenarios is more beneficial from the global and the local perspective.

1.2 Motivation

There are many qualitative studies about tree plantations in Uganda. This thesis contributes with a quantitative analysis, compare the impact of three different options of land use, and apply both a local and a global perspective in the same analysis.

1.3 Limitations

The subject of foreign investments in climate compensation in developing countries is a very complex matter. There are many things that this thesis does not cover. For example, this is not an analysis on the economic profits of an investment; this is an attempt to valuation of different social and environmental values connected to climate compensation. That means that we have not included things such as revenues a foreign investor might expect, or the payments carbon farmers might get from climate compensation mechanisms for planting the trees.

We have not made a real case study in this thesis, which means we have entirely depended on other scientific articles for data. The thesis is therefore limited to the data that we have been able to find within the time limit. Things that we have not been able to find monetary values for are for example the difference in biodiversity between monoculture forestry and agroforestry, a factor of economic growth, or the level of political instability.

1.4 Disposition

The thesis will start with a short description of the background of the subject. The background will treat subjects that are of relevance to the hypothetical case study and that will be mentioned in later sections of the text. It will then continue with a description of the underlying theories behind our research questions. This will be followed by a description of the method used, and then it will continue with a description of the hypothetical case study. After that comes a section which describes all the data used and where we found the data. That is continued with the results and discussion, an analysis of our results and finally a conclusion of the thesis.

2. Literature review

The issue of climate compensation is frequently debated in scientific circles. Especially the matter of carbon sinks and plantation of trees have arisen as one of the most important solutions to global warming (Lal, 2004; Bellassen & Luyssaert, 2014; Powlson et al, 2011). However, the method of climate compensation through plantation of trees can be divided into two perspectives; the global and the local.

2.1 The global perspective

Human emissions of carbon dioxide into the atmosphere are a negative externality. Rezai et al (2012) describes a situation where political efforts to reduce CO_2 emissions have not affected individual producers is a market failure and an inefficient allocation of resources. There is an over- accumulation in global capital and an under- investment in mitigation. Correcting this market failure would lead to a pareto improvement, where the current generation invest less, so that future generations may enjoy higher output combined with lower CO_2 emissions. Changes of our lifestyle and the technology used under this scenario are significant, but the mitigation costs to return to pre-industrial carbon dioxide levels are relatively small with their peak at around 2% of world product, according to simulations in this article.

Phan et al (2014) write that avoiding afforestation in developing countries is relatively cheap compared to abatement actions in other economic sectors. No new technology is needed and the opportunity cost is relatively low, which makes forestry in developing countries a competitive alternative for climate compensation. Besides reducing carbon emissions, avoided deforestation also contributes to other benefits, such as conservation of biodiversity, watershed and soil quality protection. This article is a meta-analysis of 32 studies, calculating the unit cost of avoiding deforestation. The study concludes that such projects are cheaper in Africa compared to Asia and Latin America.

Many studies have been made on the social impact of governmental payments for climate services. Engel and Muller (2016) wrote an article about the effects of payments for environmental services (PES) for climate smart agriculture in developing countries. These payments can be a suitable approach where sustainable practices might be obstructed by high discount rates and risk aversion, where property rights are secure, the implementing agency has sufficient administrative, monitoring and enforcement capacity, and incentives for sustainable management are low.

Thomas et al (2010) wrote that out of the more than 1600 Clean Development Mechanism (CDM) projects that are currently registered with the United Nations Framework Convention on Climate Change (UNFCCC), only four are afforestation or reforestation projects. They wonder how this could be given the many economic, social and environmental benefits that such activities potentially offer. The conclusion is that it cannot only be the condition of carbon sequestration that can be optimized in such projects. There has to be other incentives for local population, government and investors.

2.2 The local Perspective

Chamshama (2011) has written a report that presents the current status, challenges, opportunities and options for developing, as well as ensuring better management of, existing forest plantations and woodlots in Burundi, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. One of the main environmental challenges in this area is deforestation, a growing population leads to increased demand in timber and fuelwood, and poor governmental management to an unsustainable extraction of native forests. According to Chamshama increased incentives through secure land tenancy and a cash flow from international financiers might subside deforestation in the area.

Place and Otsuka (2010) investigate the productivity of trees per hectare given different conditions for landowners in Uganda. Their hypothesis was that the more access tenants and landowners have to their land, the more trees would be planted and give a productive payoff. Place and Otsuka show that more trees per hectare were planted on parcels where individual rights to plant were found. Thus, tree planting is less common in systems with relatively less secure individual rights. This supports the theory that if the farmer´s tree plantations are not threatened by eviction, but rather protected from it, more land will be allocated for carbon forestry.

Lyons and Westoby (2014) did a case study on Green Resources, the largest forestry plantation operator in Africa. Green resources have two plantations in Uganda and they are only one of many private investors from foreign countries investing in “green” development projects. The problem, according to Lyons and Westoby, is that this foreign private investment contributes to a modern kind of colonization. Their findings show that foreign investors such as green resources benefit from the privatization of public land earmarked for carbon offset plantations, while local population are evicted and faced with a constraint to access to land and resources, leading to loss of income and food.

However, Fisher et al (2016) argue that the consequences livelihoods have suffered in plantations in Uganda are not necessarily because of the Green Resources investments. Their research suggests that there have been conflicts between local livelihoods and foreign private investors, but that the investors are trying to take measures to restore relationships and that they are actually appreciated in some regions by the local population. There is no consensus as to whether private investment plantations are good or bad for local population, but it can be argued that it is a source of conflict between different interests.

One of the reasons local population might obstruct large monoculture forests is that a large area of land is made unavailable for any other income than the yield after 20 years of wood and carbon forestry. Discount rates in this region of Africa range between 10-30% (Wiskerke et al, 2010; Kiyingi et al, 2016; De Jong et al, 2004; Kimaro et al 2011). This points towards a lower valuation of future income compared to today. An alternative method that would make income available more frequently is to plant trees within an agroforestry. Both shorter rotation of the trees and a possibility for grazing and agriculture can yield income to local population at shorter intervals.

2.3 Agroforestry

Many studies have been carried through on agroforestry in the East African region. To evaluate different costs and benefits with agroforestry Ajayi et al (2009) did a study in Zambia that compares production of maize without fertilizing, with fertilizing and with an agroforestry system. To compare these three ways of agriculture they have measured the total quantity of labour and the soil quality to get the financial profitability. The conclusion of this paper is that maize production in an agroforestry system is around 50% more profitable than regular agriculture with no fertilizers but it is 61% less profitable than fertilized maize production. The lower profit compared to fertilized maize is because of a subsidy that exist in Zambia, without this subsidy the profit of fertilized maize is only 13% higher than maize production in an agroforestry system. An important factor that this article discusses is that agroforestry has a higher return per unit cost of investment than agriculture with and without fertilizers. When it comes to rural areas agroforestry will probably have even higher profitability than fertilized maize since the transportation costs of the fertilizers are high because of poor infrastructure.

Franzel (2004) review the possibilities of increased milk production for cows in Kenya. The main issue according to Franzel is the lack of protein in their fodder. Around 80% of the households in central Kenya own nearly 2 cows per family to use in agriculture and to get dairy products for self-supply. In this study it is shown that fodder shrubs could grow among other crops in an agroforestry system and be harvested to give the cows an additional protein source in the fodder. Another positive thing with the fodder shrubs is that it helps the irrigation of the land and prevents soil erosion. With the higher protein content in the fodder the milk production could increase around 12%. The protein could also come from dairy meal but growing fodder shrubs on the farm the farmer can save the cost of buying and transporting the dairy meal.

3. Background

3.1 Forestry in Uganda

Uganda has a total of 4,9 million hectares of forests and woodlands. 1,9 million ha are *Central Forest Reserves*, land reserved by the government of Uganda to preserve forests and the environmental services that forests provide.

Climate in Uganda is sub- tropical, with an average rainfall of about 1500 mm per year and average temperatures around 25-30 degrees. Conditions for forestry are most favourable in the southern part of the country due to more rainfall. Tropical high forests are found around the Eastern and Western borders and in the south around Lake Victoria.

Uganda's forest and woodland cover has dropped from 4,9 million hectares (20% of Uganda's land area) in 1990 to 3,6 million (14%) in 2005. This represents a 1,9% deforestation rate. On private lands, nearly 1,3 million hectares have been lost over the last 15 years while 91,000 ha have been lost in forest reserves, confirming that forests on private lands are fast disappearing. The main reasons for deforestation in Uganda are the conversion to agricultural land and an increased domestic demand for forest products. These products include furniture, construction material, charcoal, poles and firewood. The human population growth in Uganda is at 3,4%, resulting in an increased settlement on forest land and private uncontrolled cuttings and grazings (Obua et al 2010).

3.2 Ownership conditions

To discuss the social aspect of sustainable forestry in Uganda it is important to look at the ownership conditions of land. To begin with, Uganda has several legal constitutions: state, customary, religious, project and local, all of which can imply legal rights to a property (Doss et al 2012). In Uganda 14140 ha of forest plantations are owned by the state, while 48090 ha are owned privately (Chamshama, 2011). Uganda has a Land Act constituted in 1998, where three different land- tenure systems are recognized: Mailo, Freehold, Leasehold and Customary. Under Mailo tenure, land is held with ownership of a title certificate, granting tenure permanently as well as the right to sell, mortgage or donate it. Often landowners hold big areas of land that are occupied by many tenants (Bibanja holders) who are expected to pay rent to the land owners. The land can also be occupied by so called squatters, who settle on the land and may eventually claim the rights to it. The Land Act grants the squatters rights to the land after 10 years of occupancy. Mailo is the predominant ownership in the study area (Doss et al 2012).

Although there is a legal system in place since 1998, following the peace after many years of internal war, there is a gap between the law itself and the enforcement of it. Many people have claims to the same strip of land, following the legal system of their tradition rather than that of the state. This leads to insecurity in private ownership and tenancy, and may remove incentives for long term investments in agriculture and forestry (Place and Otsuka, 2002). There is also an issue of local leaders administering the legal systems, and they may rule in favour of male ownership. This excludes females from owning land and enforces gender inequality. Secure access to land is one of the keys to unlock equality issues, since agriculture is the main economic activity (Doss et al 2012).

Our example plantations are located on land which has been reserved by the Ugandan government for plantation forestry; Central Forest Reserves (CFR). The state has not managed to maintain viable plantations in the CFRs and recent changes in forest legislation and policy have therefore opened the way for private investments in forestry. These investments are often made by international companies who trade in carbon equivalents (Fischer et al 2012).

3.3 What is climate compensation?

The idea of climate compensation is that the person who causes emissions can pay for the corresponding amount of emissions to decrease elsewhere. This can be done by purchasing emission allowances so that they cannot be used by anyone else. The compensation can also be based on providing money for, for example, tree planting or expansion of renewable energy.

It is hard to define what climate compensation is, and there is no consensus on how a reasonable compensation for emissions can be calculated, but there are some factors that are important to consider for the climate compensation to generate a real climate benefit.

Additionality

It can be ensured that the project would not have gone off without the money from selling the climate compensation

Verifiability

The alleged emission reductions have been quantified and verified by an independent third party.

Traceability

An emission reduction must be traceable so that it can be ensured that it has not been sold, or in the future can be sold, several times to other customers.

Persistence

The emission reduction that is financed should be long-term, not temporary.

Contribution to sustainable development

In addition to the actual climate benefit, it is often important to know that climate compensation also contributes to sustainable development in other ways. Although this is not the basic purpose of climate compensation, this can be a decisive factor in the choice of climate compensation measures that are equivalent from a climate point of view. Criteria for sustainable development can be if the project improves everyday life for people in the immediate area, by creating jobs, combating poverty, improving health, economic security, better access to energy resources, and other environmental values such as biodiversity conservation (Tricorona, 2018).

3.4 The concept of carbon sequestration

Trees work as carbon sinks. All growing things bind carbon dioxide through the process of photosynthesis, and trees, which grow in the same place for a long time, have very good abilities to store carbon. A grown tree sequesters between 400-2000 kg CO_2, depending on tree species and surrounding conditions. The best conditions for photosynthesis in forests are in a humid condition and a temperature between 15-20 degrees. The ability of carbon sequestration is dependent on what stage of development the trees are in. Directly after logging and in the early stages after planting the forest emit carbon dioxide, whereas under the condition when the net production is the biggest in the forest, is also when it sequester carbon dioxide most efficiently. How much carbon a tree can sequester can be calculated based on its height, weight and circumference (Bergh, J. et al, 2000)

3.5 Clean Development Mechanism

Clean Development Mechanism is an initiative developed as a result of the Kyoto Protocol and is run by the United Nations Framework Convention Climate Change (UNFCC). The Mechanism works as a link between investing countries and the countries where investments takes place. The investments are individual projects with the purpose of mitigating climate change and can be anything from waste handling to energy efficiency measures, sustainable development and renewable resources, and planting trees. There are two reforestation CDM projects in Uganda; *Nile Basin Reforestation Project No. 3* and the *Nile Basin Reforestation Project No 5*. Both projects have the purpose of planting trees in Central Forest Reserves in Uganda (UNFCC, 2019).

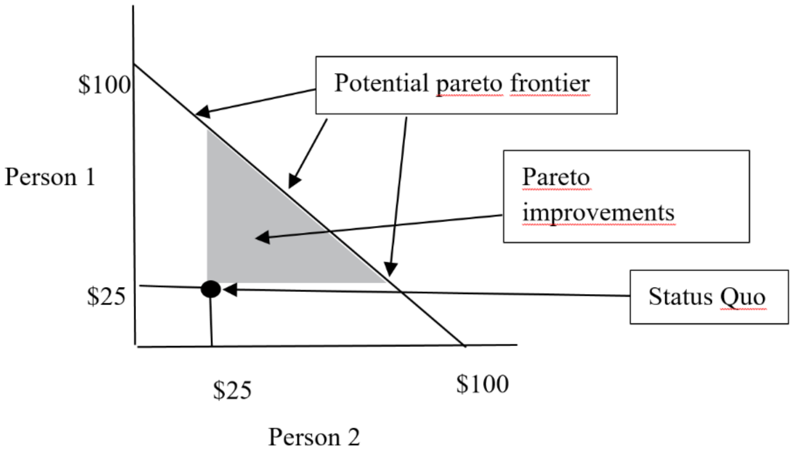
4. Theory

In this section the theory behind the objectives of the thesis is presented.

4.1 Pareto Improvement

*An allocation of goods is Pareto efficient if no alternative allocation can make at least one person better off without making anyone else worse off. (*Boardman et al, 2014).

Figure 1: pareto improvement



Own illustration based on Boardman et al (2014)

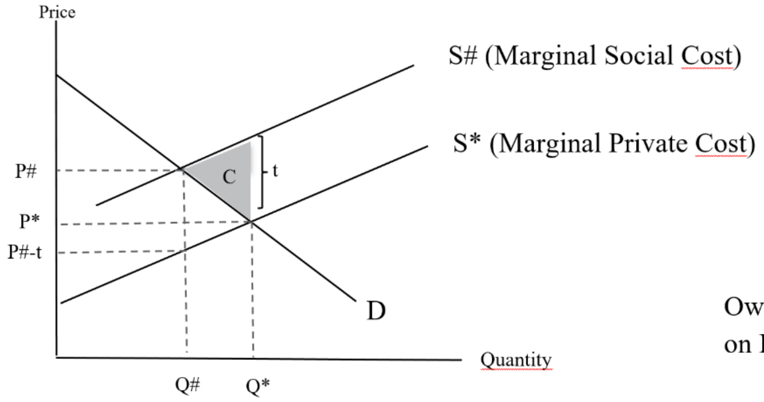
Figure 1 shows possible allocations of a fixed amount of money between two persons; person 1 and person 2. If the two people cannot agree on how to allocate the money, they each get 25 US$ which is status quo. If they do agree they can split any amount of money up to 100 US$ in total. The potential Pareto frontier represents all the feasible allocations of the optimal amount of 100 US$. Allocations represented within the shaded triangle are slightly less than the optimal 100 US$, but still a Pareto improvement from the point at which the two persons do not agree at all (Boardman et al, 2014)

If the CO_2 market of the world were to be analysed from this model, person 1 would be the western world, and person 2 would be developing countries such as Uganda. The Cost Benefit Analysis is made to see what possible Pareto improvements there are in the concept of international investors planting trees in Uganda. The question to be asked is if the western world could benefit more from CO_2 sequestration without making developing countries worse off.

4.2 Externalities

An externality is an effect that production or consumption has on third parties-people not involved in the production or the consumption of the good. (Boardman et al, 2014)

Figure 2: externalities



Own Illustrations based on Boardman et al (2014)

Figure 2 shows how a negative externality of a good might affect the supply of that good. If the actual cost of the negative externality was to be incorporated in the private cost, in the example in shape of a tax on producers (t), the production price of the good would increase and the supply would decrease (S#). As a result of this, the price of the good on the market would increase, and the quantity demanded decrease (P#). This would result in a net benefit for society consisting of C.

If the CO_2 market of the world would be analysed from this model then the externality would be the CO_2. The producers would be corporations whose operations result in a CO_2 emission, for example airlines. The t in this example would be the cost for the airline companies to compensate for their travels. As a result consumers would travel less due to more expensive airline tickets. The C in this case would be the net benefit of subsided climate change caused by CO_2-emissions.

5. Methodology

This section explains the method used in the thesis.

5.1 Cost-benefit analysis

To compare agroforestry, monoculture forestry and baseline we do a cost benefit analysis. A cost benefit analysis is used to make social decision making more rational. A value is set to different non-monetary benefits and costs to get a net social benefit result. This is done to make it possible for decision makers to see if the different ways of climate compensation are justifiable or if it would be better to not climate compensate at all. The benefits should include all the indirect and direct revenues, intangible benefits such as increase in social wealth and possible economic growth. The costs have to include both direct and indirect cost, opportunity cost, intangible cost and potential risk cost. We find the different values in previous studies (Boardman et al. 2014).

A cost benefit analysis is done, according to Boardman, through 9 major steps;

1. Specify the set of alternative projects

When a cost benefit analysis is performed all the different projects that will be analysed needs to be specified. In our study we compare agroforestry, monoculture forestry and a baseline case to see which one is the most favourable for climate compensation.

2. Decide whose benefits and costs count

When deciding whose benefits and costs that should be accounted for it is important to think about and write down who are affected, both from a global and a local perspective. We decide to take the cost and benefits for the citizens of Uganda that are affected by the forestry and will work within that sector, and the global benefits of removing carbon dioxide from the atmosphere.

3. Identify the impact categories, catalogue them, and select measurement indicators

In this step the effects on individual utility is measured, along with the impact the different projects have. Even though a lot of the impacts do not have a monetary value, we put a common measurement indicator to all the benefits and costs.

4. Predict the impacts quantitatively over the life of the project

To predict future benefits and costs it is important to analyse different risks of the project, this could be hard if the projects occurs under a long period of time. With the different projects we investigate we have to estimate what will happen in 20 years which makes the values estimated unstable.

5. Monetize all impacts

To be able to compare the different costs and benefits they need to be monetized into the same value. We put a US-dollar value to all the different costs and benefits that we have found in previous studies.

6. Discount benefits and costs to obtain present values

To be able to make a relevant analysis of the costs and benefits of a project over a long period of time the values are converted into present values. This is made with a discount rate that varies between countries and project types. We are using a discount rate of 5% since a low discount rate is motivated when it comes to environmental projects because climate benefits are preferred to occur today, not tomorrow (Rosén et al, 2006).

Figure 3: converting costs and benefits to present values

PV(B)= $\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}$ PV(C)= $\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$

7. Compute the net present value of each alternative

After the benefits and costs have been discounted the net present value is computed. The net present value is the difference between the discounted benefits and the discounted costs. If the discounted benefits exceed the discounted costs, the climate compensation is motivated. Since we compare more than one type of forestry against a baseline scenario we know that more than one of the forestry projects could be positive.

Figure 4: computing the net present value

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

8. Perform sensitivity analysis

A sensitivity analysis is done so that changes in different parameters are accounted for. This is to see what would happen if other values and discount rates would be used and how much the net present values of the different scenarios would change. Since we have doubts if the benefits and costs are estimated into monetary values correctly it is favourable to do a sensitivity analysis.

9. Make a recommendation

Generally, the project with the highest net present value should be recommended as the best alternative. However, in our study we have to take the benefits and costs that we failed finding a monetary value to into consideration in our final discussion. It could be that the scenario with the highest net present value is not necessarily the best alternative for climate compensation in all aspects.

5.2 Limitations of a Cost Benefit analysis

In a cost benefit analysis the costs and benefits are required to be in monetary values. The problem is that many of the aspects that are important are in non-monetary values and to be able to use these aspects in the cost benefit analysis everything needs to be converted in to comparable values. It is challenging to transform non-monetary values into monetary values.

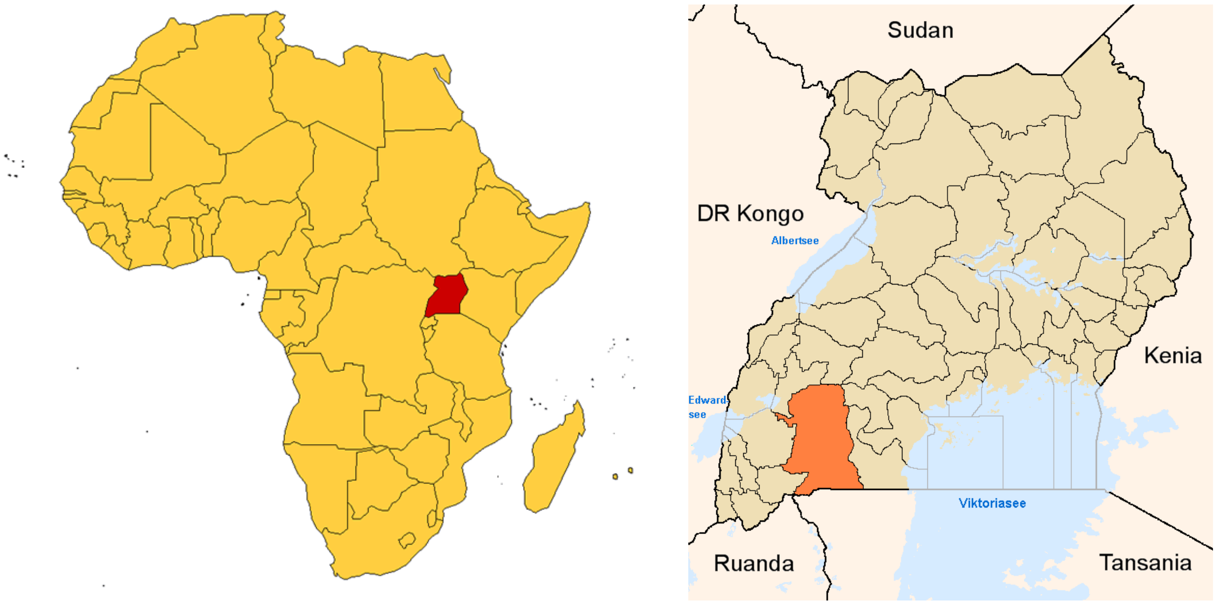
Another problem is that there are a lot of uncertainties about how to assess the future. When discounting the costs and benefits into current value it is hard to determine which discount factor to use. This differs between countries and individuals (Hansjürgens 2004). For example, a very underprivileged individual probably has a high discount rate since he or she is in a need of money today. A very wealthy person would probably have a lower discount rate since they don’t need money right now. In our study this could apply to investing in forestry with high revenues after 20 years or not investing and getting smaller revenues from maize harvest today. With different discount rates it will be a big difference in the net present value which is why it is important to do a sensitivity analysis that will take this into account.

Another important thing to notice is that other factors than efficiency may be of importance to policymakers. These factors might be equality of opportunity, equality of outcome, expenditure constraints, political feasibility or national security. When goals in addition to efficiency are relevant, the outcome of the cost benefit analysis might point in the wrong direction (Boardman et al, 2014).

6. Hypothetical Case Study: Mbarara, Uganda

Our case study is based on 10 hectares of land in the South-Eastern part of Uganda, near the city of Mbarara. The location is currently a forestry reserve owned by the state of Uganda. It is picked because plantations in the purpose of carbon sequestration under the Clean Development Mechanism are already conducted in the area (UNFCC 2013). The case study is based on three different scenarios. The first scenario is when no carbon forestry is conducted at all, and will consist of 10 ha of degraded grassland. The second where the 10 ha are planted in a monoculture with Caribbean Pine, and the third where the land is cultivated in the practice of alley cropping; rows of Acacia are simultaneously planted with rows of maize and grazing for milk cows in an agroforestry system. We use already practiced valuation methods to include all possible costs and benefits with each scenario. Both social values and economic values are estimated. All calculations are estimated on a project timeline of 20 years.

Figure 5: location of the case study



6.1 The Baseline Scenario

The concept of the baseline example is what would have been done with the land without the money input from climate compensation investments. In the *Uganda Nile Basin Reforestation Project No 3* it is stated that all plantations are made on degraded grasslands (UNFCC 2013). This is what our baseline example is based on. If no Clean Development Initiative was taken in this area the alternative could in theory be to restore the grassland. What we include in the calculations for this example are the costs of degraded grassland, and the benefits that could come to local population from it, but also how much carbon that can be stored in the 10 ha of grassland in Africa.

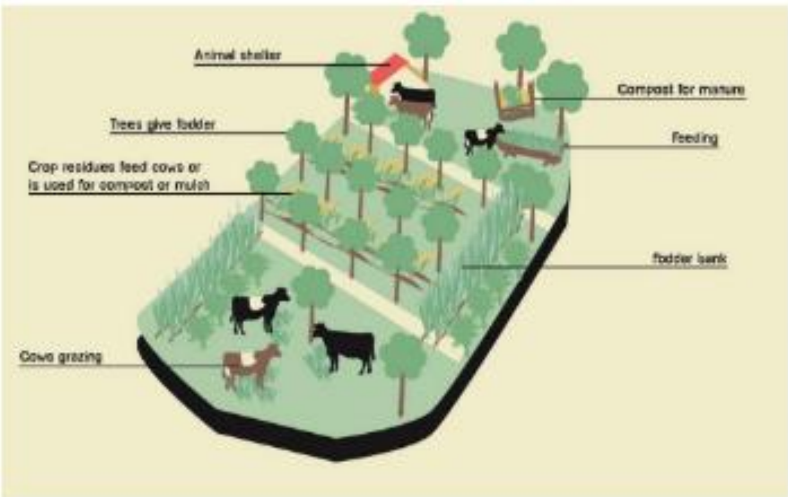
6.2 The Monoculture forestry scenario

In monoculture forestry management focus lies on the survival of one species. The purpose is to have the highest growth rate per hectare and year and the production in Uganda is mostly firewood, poles or timber. The most common species are Eucalyptus Grandis and Pinus Caribea, both fast growing and efficient on carbon sequestration (Oballa, 2010). Our example is, like the CDM project already conducted in the area, based on 10 hectares planted with Pinus Caribea. Our calculations based on Orwa et al (2009) show that up to 25 000 pines can be successfully grown on these 10 hectares in 20 years. The positive aspects with monoculture forestry are the efficiency of the carbon sequestration, but also soil quality improvement. However, the land cannot be disposed for any other purposes than the growing of trees for twenty years.

6.3 The Agroforestry Scenario

Agroforestry is both a rural development and a climate compensation system. It is a method for creating a better environment and reducing poverty. The method is to let trees grow among crops and livestock, so that all parties can benefit from each other. The trees provide, among other things, shade, animal feed, compost material and moisture in the soil. Agroforestry helps to recreate a natural ecosystem. The intended result is greater harvests, a more pleasant climate and increased resilience to the effects of climate change. Another impact however is that the choice of tree species cannot be based on only the effectiveness of the tree, and trees need to be planted with greater spacing (Agroforestry Network and Vi- Skogen, 2018).

Figure 6: Agroforestry in practice



(Agroforestry Network 2010)

There are many different methods of agroforestry. Our example builds on the concept of rotational woodlots. The 10 hectares are planted with rows of Acacia Mangium, a drought resilient, fast growing legume, suitable for agroforestry because of its multipurpose use (wood and fodder) and because of its shape (a large protecting canopy) (Mercado et al 2006). Between the rows of Acacia plants maize is grown and harvested for 2 years. After this the shade of the Acacia crowns will affect the yield of the harvest negatively. Year 3 the soil between the rows is left fallow for cows grazing. Year 5 the trees are cut and maize is again grown between stumps. Coppice shoots are left for new stems to grow. In 20 years there are 4 rotations of Acacia, 4 times 2 years of maize harvests and 4 times 3 years of grazing for the cows (Wiskerke et al 2010).

7. A cost benefit analysis of three different scenarios

While conservationists value tropical forests for their diversity, nutrient cycling, water quality improvement, and role in regulating climate, these factors are rarely of the same value to local land owners and tenants. Rather, the short- term financial return from converting tropical forest land to agriculture or ranching are often greater than the returns from maintaining the forest cover, increasing the individual farmer's incentives to deforestation. In our valuation we try to take into account both perspectives on the imagined projects. We compare the three projects under an equally long time, 20 years, and with a discount rate of 5%. All results have been converted into US$ using exchange rates from Bloomberg's (2019). The price of CO_2 eqivalents is set at 139 US$/ t which is the Swedish carbon tax price, according to The World Bank (2018). The costs and benefits accounted for in each project are listed in figures 7, 8 and 9:

Figure 7: Baseline grassland

Benefits	**Costs**	**Indirect Benefits**
-Grazing for cows -Hunting for local population -CO_2 Sequestration		-Biodiversity

Figure 8: Monoculture Pine Plantation

Benefits	**Costs**	**Indirect benefits**
-Income from Pine harvest -CO_2 sequestration Pine trees	-Pine Seedlings -Labour costs -Slashing, pruning and thinning	-Improved soil and water quality

Figure 9: Agroforestry rotational woodlot

Benefits	**Costs**	**Indirect Benefits**
-Increased production from Fodder pods from acacia -Income from maize harvest -Income from Acacia wood production -CO_2 sequestration of acacia trees -CO_2 sequestration of Maize crops	-Acacia Seedlings -Training for practitioners -Cost of establishing maize -Labour costs -Slashing	-Sustainable livelihoods for families -Increased Biodiversity -Improved soil and water quality -Land reclamation for local population

(Own illustrations based on Wiskereke et al 2010)

7.1 Limitations

We do not include the cost of land, because our assumptions are that this cost will be the same for all three examples since they are based on the same strip of land. We also choose to exclude the payments for carbon equivalents that carbon farmers get from the UN among others, since we want to see the actual costs and benefits irrespective of which carbon sequestration program that initiated the projects. The analysis is generally limited by the data we have been able to find. When data on Uganda specifically has not been located we have used exemplifying data from the closest region possible. Some posts have been left out due to lack of data.

7.2 Baseline scenario

In the baseline scenario it is assumed that the land remains untouched. We therefore also assume that this comes at a cost of nearly zero. However, according to Nagendo et al (2002), there are some benefits of the grassland to the local populatin and environment; grazing, hunting, and a greater biodiversity than in forestry.

Benefits

Carbon sequestration

In the *Uganda Nile Basin Reforestation Project No3* an assessment on dry biomass and carbon storage before the project start was made. They conclude that the total stock of carbon per hectare in the area is 3,05 CO_2 equivalents (UNFCC, 2013). The price of the CO_2 equivalent differs between countries and we use the Swedish price of 139 US$ /ton CO_2 equivalents in our cost benefit analysis. We include this as a one-time benefit of 4239,5 US$ in year one since the 3,05 CO_2 equivalents- figure is a stock which is stored in the grassland before any measures of planting is taken (UNFCC, 2013).

Hunting

Mukadasi (2010) interviewed 120 respondents living in the Mt. Elgon forest reserve in Uganda on their valuation of non-wood products, where hunting is classified as one. We use the average of his results on the respondent's valuation of hunting. Average yearly value for hunting per person is estimated 35467 UGX which is 9,4 US$. According to Nationalencyklopedin (2018) 187 people live in each km^2, so we assume 19 people have access to 10 ha of hunting in the area and that gives a total benefit of 178,6 US$ per year.

Biodiversity

Biodiversity is in this scenario estimated to a value of 0,02 US$ per ha/ year. This figure is based on the willingness to pay for biodiversity in grasslands in South Africa which was estimated in an article by Turpie (2003).

7.3 Monoculture Forestry- Pine Plantation scenario

Benefits

Carbon sequestration

In the *Uganda Nile Basin Reforestation Project No 5* estimations are made on how much Green House Gases will be sequestered every year for the first 20 years of the project. The plantation is spread over 487 ha, so we assume the same potential in our own project but only over 10 ha. The monetary value is based on the Swedish carbon price of 139 US$ /ton CO_2 equivalent. The values used are shown in figure 10.

Figure 10: carbon sequestration abilities of monoculture forestry

Year	tCO_2/ 487 ha	tCO_2/ 10 ha	US$
1	-207	-4	-591
2	3456	71	9864
3	3276	67	9350
4	4788	98	13666
5	9449	194	26969
6	6557	135	18715
7	4238	87	12096
8	9474	195	27041
9	11266	231	32156
10	6474	133	18478
11	1876	39	5354
12	6461	133	18441
13	11832	243	33771
14	2359	48	6733
15	540	11	1541
16	4722	97	13478
17	9139	188	26085
18	497	10	1419
19	8825	181	25188
20	901	19	2572

Wood harvest

The thinning is made in year 5 and 13 but only gives a benefit at year 13 at a value of 10023 US$ (NFA/ SPGS 2018). Trees for timber after thinning grow optimally at a spacing of 4 m^2. Given our reference surface of 10 ha and a life cycle of 20 years, 25000 stems are grown at the end of the project (Orwa et al 2009). We calculate the benefits from harvesting the wood based on a final harvest of 279 m^3ub/ 10 ha (Kyingi et al 2016) and a price per m^3 of 160 US$ (FAO/ SPGS3, 2018) which gives a total benefit of 44640 US$ in the end of the 20-year period.

Costs

Costs of planting

The cost for establishing commercial pine plantations in Uganda has been estimated by the SPGS (Sawlog Production Grant Scheme) to be around 1,2 million UGX/ha which equals 3180,6 US$/ 10 ha: this is an average cost across a range of sites in Uganda and includes cost of seedlings and nursery, clearing of the site, plantation of pine and monitoring in the early stages. This is only a one-time cost in year one of the plantation.

Weeding, Pruning and Thinning

In order to maintain a good quality of timber production a management plan is followed. This includes weed control the first 3 years. Weed control is done by spraying glyphosate, 4 l/ ha is needed and 1 l costs 10000 UGX which is 2,65 US$ and gives a total cost of 106 US$ for 10 ha. In year 5, 7 and 9 pruning of the stems is needed in order to make clear, straight wood and enable management of the plantation rows. Pruning is made at a cost of 300 US$ per ha. Finally 2 thinnings are made to maximize annual growth. The first thinning will be in year 5 and cost 300 US$/ha. The second thinning will be in year 13 and cost 250 US$/ha (SPGS 2018).

7.4 Agroforestry rotational woodlot scenario

Benefits

Income from maize harvest

The benefits of maize harvest are shown during the first 2 years after the trees establishment for every rotation. Since the project lifetime is 20 years and the rotation of tree planting is 5 years there is a total of 4 rotations which makes it possible to harvest maize for a total of 8 years. The benefits from harvesting maize in 1 hectare are different between the years. The income for year 1 is 368,7 US$ and for year 2 the income is 229,8 US$ for 10 hectares(Ramadani et al 2002). We make an assumption that the income from maize harvest is the same for all the 4 rotations.

Income from Acacia wood production

The wood production has a two stage income, one is from pruning and one is from the final harvest. The pruning takes place during year 2 for every rotation and gives revenue of 14000 Tanzanian shillings per hectare which equals 60,9 US$ for 10 hectares. In year 5 in every rotation the final harvest gives revenue of 479936 Tanzanian shillings per hectare which is 2086,7 US$ for 10 hectares (Ramadani et al 2002).

Fodder pods from acacia increasing milk production

When using Calliandra as a fodder substitute for dairy meal in milk production for one cow the farmer saves 129,72 US$ in dairy meal costs and 4,02 US$ in transportation of dairy meal. The costs for planting Calliandra as a substitute for dairy meal is 10,03 US$ when including both labour and seedling cost. This gives a net benefit of 123,71 US$ for using Calliandra as a protein high fodder instead of buying dairy meal (Franzel 2004). We apply this to our rotational woodlot scenario since Acacia is a legume that is high in protein and could therefore be used as fodder (Maasdorp et al 1999).

Sequestration of Agroforestry systems

Carbon sequestered per hectare and year in the rotational woodlot system is 3,77 tons of CO^2. The values on carbon stored per hectare and year are gathered from an article on Carbon Pools in Tree Biomass and Soils Under Rotational Woodlot Systems in Eastern Tanzania (Kimaro et al 2011). We assume that the sequestration potential in Ugandan agroforestry will be similar and we apply the average value per hectare and year on all of the 20 years in the project which will give a benefit of 5240,3 US$ for 10 hectares in every rotation based on the Swedish carbon price of 139 US$ /ton CO_2 equivalent.

Costs

Training for practitioners

A case study from southern Mexico handles the different costs of agroforestry projects under a Plan Vivo certification. According to figures from Plan Vivo a three days long education for the farmers in tree planting and maintenance of the forest by a professional technician is one of the most important actions to make the forestry successful. This technician needs lodging, transportation and a salary, the cost for this lies between 400-500 US$. The plan is that at a minimum of ten farmers should take part in this education which makes every Plan Vivo project cost around 50 US$ (De Jong et al 2004) we assume that regardless of which certification the project has this should be included as a cost.

Costs of establishing maize

The price of maize seeds is approximately 2500 Tanzanian shillings per hectare for year 1 and 2 in every rotation which is 10,9 US$ (Wiskerke 2010). The maize needs fertilizers which cost for every rotation 48000 Tanzanian shillings year 1 and 38400 year 2 which is 208,7 respectively 167 in US$ for 10 hectares.

Costs of establishing Acacia

What's included in establishment costs are land preparation, cost for seedlings, planting of seedlings, weeding, fertilizing, harvesting, threshing, gapping, pruning and wood harvesting. The total labour cost of these different chores per hectare are in Tanzanian shillings 22686 in year 1, 20608 in year 2 and 55417 in year 5 for every rotation (Ramadani et al 2002). This equals 98,6 US$ in year 1, 89,6 US$ in year 2 and 240,9 US$ in year 5 for 10 hectares in every rotation.

8. Results and Discussion

The results are based on values found in previous studies and the primary results are discounted with a level of 5%. The carbon price used is based on the Swedish tax level of carbon which is 139 US$ /ton CO_2 equivalent (World Bank, 2018).

Figure 11: Primary Results

	Baseline	Monoculture forestry	Agroforestry
Net benefits	$ 6266	$ 218693	$ 134310
Net costs	$ 0	$ 13410	$ 2162
Net Present Value	$ 6266	$ 205282	$ 132149

The results show that the net present value of the monoculture forestry is considerably higher than agroforestry. They also show that the net present value of planting trees is significantly higher than the baseline scenario of leaving the land for grazing. The results depend mostly on two variables; the rate of discount and the price of carbon. Both of these variables are a product of a global perspective on the matter of tree planting. From the global perspective low discount rates and high carbon prices are motivated with mitigation of climate change.

The results are also highly dependent on tangible costs, because intangible values are harder to monetize. It is likely that the values for baseline and agroforestry would increase if we could put a monetary value on biodiversity, sustainable livelihoods for rural families, increased soil and water quality, and land reclamation to local population.

The matter of the size of our example may also affect the results. 10 hectares for a rotational woodlot is very big, average size of landholding in Uganda is 2,6 ha (Kakuru et al, 2014) but a plantation as small as 10 ha in monoculture is rarely profitable in practice (Wiskerke et al, 2010).

Figure 12: Sensitivity analysis

	Baseline	Monoculture	Agroforestry
Base net present value	$6 266	$205 282	$132 149
50% increase wood yield	$6 266	$216 352	$134 518
50% decrease wood yield	$6 266	$194 212	$129 716

50% increase maize yield	$6 266	$205 282	$163 779
50% decrease maize yield	$6 266	$205 282	$100 519
50% increase wage	$6 266	$200 415	$131 624
50% decrease wage	$6 266	$210 150	$132 673
15% discount rate	$4 806	$84 606	$48 899
30% discount rate	$3 854	$33 975	$20 144
FR carbon price 55 US$/tCO2	$3 826	$86 502	$92 683
Chile carbon price 5 US$/tCO2	$2 374	$15 799	$69 192
Chile carbon price and 30% discount	$710	$-3 148	$3 393
Chile carbon price and 15% discount	$1 252	$-833	$17 279

Figure 13: Sensitivity analysis, different discount rates

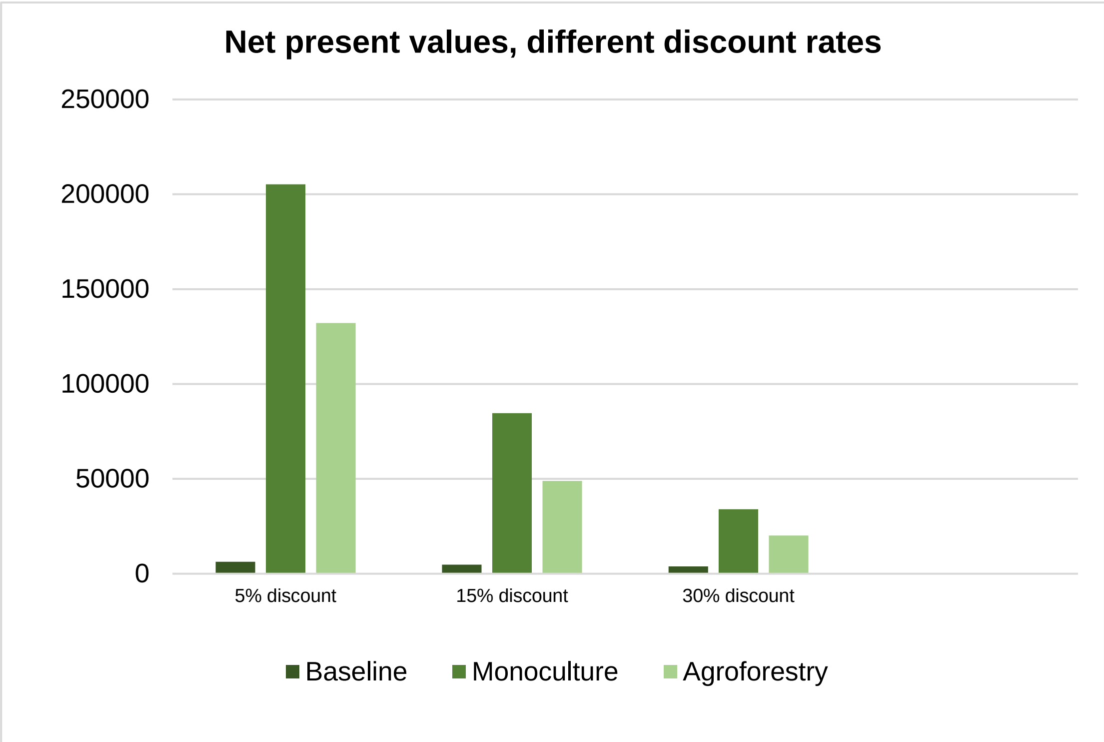
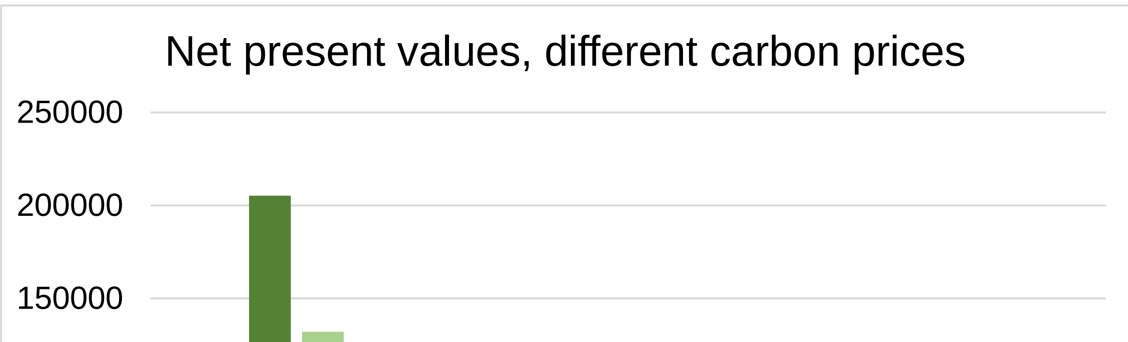


Figure 12: Sensitivity analysis, different carbon prices



8.1 Sensitivity analysis

We want to take changes in wage, maize yield and wood yield into account in our sensitivity analysis. That is why we test to increase and decrease wage, maize yield and wood yield with 50% separately. This doesn't change the net present values much and it is still monoculture forestry that has the highest net present value.

When doing the cost benefit analysis we use Sweden's price for carbon which is 37% higher than the countries with the second highest price which is Switzerland and Liechtenstein. This could mean that Sweden don't have the most representative carbon price. That is why we do a sensitivity analysis where we use France's carbon price which is 55 US$/tCO2e and Chile's carbon price which is 5 US$/tCO2e (World Bank 2018).

We think that France's carbon price is interesting since they have a similar economy as Sweden and Chile's carbon price is used since they have one of the lowest prices of carbon. Monoculture forestry is the scenario that has the highest carbon sequestration and with a carbon price as high as Sweden's it is the scenario with the significantly highest net present value. Already at France's carbon price the agroforestry scenario gets a higher net present value than the monoculture forestry. This is since agroforestry has more other benefits than only carbon sequestration.

We also wanted to see what happened to the net present values when altering the discount rate. In various articles (for example Wiskerke et al 2010) about forestry in developing countries a discount rate around 20% is used. In environmental projects a lower discount rate between 1%- 5% is motivated (Rosén et al 2006). In our cost benefit analysis we have used a discount rate of 5% and since monoculture forestry has a high benefit in the end of the 20 year period they have a considerably higher net present value than agroforestry. When doing our sensitivity analysis, we use discount rates of 15% and 30%. None of the new discount rates gives agroforestry a higher net present value than monoculture forestry but the difference is not as big. But when we use Chile's carbon price at the same time as we change the discount rate to 15% and 30% the monoculture forestry scenario has a negative net present value. The net present value of the agroforestry scenario stays positive, even the baseline scenario has a higher net present value than the monoculture forestry. This is since agroforestry has more continuous benefits and the benefits are not only from carbon sequestration.

The recommendation we make from our cost benefit analysis is seen from a Swedish point of view, where the main purpose of the project is carbon sequestration, where taxes on carbon dioxide are high and discount rates used in environmental projects are very low. Our sensitivity analysis however, offers different interpretations when altering the perspectives, showing that our results are volatile and not general.

9. Analysis

It is important to point the simplifications of the world that we have made in order for us to get any results. This thesis was completed in little less than two months and there were several things that would affect real projects like this that we have left out. Examples of these things might be political stability, economic growth, biodiversity, ethnicity and culture, and so on and so on. We, the authors of this thesis have never visited Uganda so it is in reality difficult for us to say what those affected by this project prefers and how they value different environmental measures. What we have aimed to do however, is to present a scientific way of looking at climate compensation. The results give no answer as to whether climate compensation is a good or a bad thing, but they do show the complexity of the problem; when changing only a few parameters the results can vary a lot.

9.1 The Data

The project we have investigated does not exist in reality, and figures used are collected from similar projects in other regions, which is why our own calculations are to be looked upon with scepticism. The data we found on the Acacia Mangium is limited. There is not much research done on the growth rate of these trees, and to draw a reliable conclusion about the optimal length of the rotational cycle of the trees in the agro forestry system we would have needed more data. In other reports on agro forestry the rotational cycle is most often 5-10 years. The figures on Willingness to Pay for biodiversity are from a project in South Africa which is far away from Uganda. The data on revenues from harvests in monoculture are the revenues from a finished product, and not the actual revenue for the farmers, which can be expected to be lower. Our main data on agroforestry is from a project conducted in Tanzania, which is close, but can still differ from Uganda. In conclusion the data needed for a realistic analysis is hard to find and define, and results we have calculated ourselves are to be looked upon as exemplifying material on how calculations could be conducted.

9.2 The Valuation of CO2

The question of how to set a value to the carbon equivalents is the core of this analysis. The prices we have used are from the World Bank and they are based on the domestic carbon tax in the countries respectively. This is why the prices can differ so much from each other. However, the domestic tax of a country is one way to look at the value of carbon. The world price is another. In the end the climate compensation boils down to who pays for what. The National forestry Autority annual report of financial year 12/13(2013) state that the major carbon partner is The World Bank. The World Bank pays US$ 4.15/ t CO_2 equivalent to the Ugandan state (NFA 2013). This is lower than our lowest price in the analysis, and it emphasizes the complexity of the valuation of Carbon dioxide.

It is important to note the difference between different calculations on the carbon sequestration abilities of trees. The numbers we have taken on sequestration are from the IPCC and it is possible that they have shown high estimations on the sequestration possibilities of African trees to make their own projects look more successful. The difference between a growth maximizing managed forestry and small scale forestry with integrated agriculture are big, and the possibilities of sequestration are bigger with the species and the management methods used in large scale forestry. However, from the literature we have read, large scale forestry is not realistic in many regions of Africa. Many people´s livelihoods are based on the small scale farms, and in regions with instability land owners do not want to make investments that will render revenues only after 20 years.

This is why we think that the two different forestry scenarios answer our research question in different aspects; monoculture forestry in the economical way since it is the forestry with the highest carbon sequestration which gives the highest net present value and agroforestry are better from a perspective of social sustainability since it benefits the local population more.

9.3 What Happens after

Our hypothetical case study stretches over 20 years which, in a carbon sequestration point of view, is not very long. We have chosen to focus on the costs and benefits during the duration of the project, but we have not provided data that analyzes the impact after the project. For example, a lot of trees in Uganda are harvested for fuel wood, which means they are burned. This action emits carbon in the atmosphere again, which makes it a core question on whether climate compensation through tree planting does or does not have a positive impact on the climate. For further research this point should be included.

9.4 Possible Policy making

Policy makers in Sweden are currently discussing a tax on aviation on governmental level. This paper aims to make awareness of implications and limitations of tree planting as climate compensation. Today, climate compensation for private persons is optional, but it could be incorporated in an aviation tax.

Consumers know very little about the different impacts of different methods of climate compensation. It could be investigated whether, through taxes and subsidies, policymakers could favour more sustainable methods for climate compensation in front of others.

10. Conclusion

We wanted to know more about the level of sustainability of climate compensation through tree planting. We performed a cost- benefit analysis to put monetary values on two different aspects of the compensation; the social and the economical. We applied the Cost- benefit analysis on a hypothetical case study of three different types of land use of 10 hectares in South Western Uganda. Our initial results show that monoculture forestry is the most beneficial. The difference in Net Present Value between monoculture and agroforestry is 73134 US$. Our results also show that it is better to plant trees in any kind of system than to do nothing at all with the land.

However, the results depend very much on what price of carbon equivalents that is used and what rate of discount. In “The Swedish model”, where discount rates are low and carbon prices are high, monoculture forestry is the most favourable. But in “The Ugandan model” where we used discount rates more similar to the ones in Africa, and a carbon price the same as in Chile, the

Net present value of the monoculture forestry is negative, and the most favourable alternative is agroforestry.

In conclusion tree planting seems like a good method for climate compensation, but in order for it to compensate our extensive emissions in the world it would take a lot of trees and a vast area of land, and it would risk reinstating the western world´s colonization of developing countries. While, in theory, planting trees could completely neutralize our emissions of CO_2 that assumption is made without regard to the human rights of local population in developing countries, and without regard to the moral obligations of the western world. According to our results the most sustainable way of climate compensation with regard to local population in developing countries is agroforestry.

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