CHARLES UNIVERSITY IN PRAGUE
FACULTY OF SOCIAL SCIENCES
INSTITUTE OF ECONOMIC STUDIES

Bachelor Thesis

Combining carbon sequestration and biodiversity conservation: Possible way to protect rain forests

Tomáš Baďura

Consultant

Ing. Jan Melichar

2009/2010

Acknowledgments

I would like to thank my consultant for helpful remarks and useful recommendations. Moreover, I am grateful to Mr Tim Taylor and to prof. Anil Markandya from University of Bath, UK, for being the first ones who gave me the very first information on the subject. Lastly, I am especially grateful to my girlfriend for being patient listener and being able to withstand my enthusiasm about the topic.

Prohlášení

Prohlašuji, že jsem bakalářskou práci vypracoval samostatně a použil pouze uvedené prameny a literaturu.

In Prague / V Praze dne

20. 5. 2010

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Student

Abstract

Despite the fact that forests and rain forests in particular are known for being a source of various goods and services tropical deforestation, mostly happening in developing countries, is still way over the sustainable rate. Nevertheless, due to the massive potential in reducing carbon emissions from deforestation and its importance in biodiversity conservation, rain forest are increasingly expected to play an important role in both conservation and climate change mitigation activities. Moreover, it might be possible to combine both these ecosystems services together in a synergistic way which would benefit each other. This paper will examine these issues, especially from the biodiversity conservation perspective.

Abstrakt

Přestože lesy a speciálně deštné pralesy jsou známy bohatstvím služeb a produktů které poskytují, odlesňování tropických pralesů, jež je nejvíce závažné v rozvojových zemích, pokračuje v neudržitelném tempu. Nicméně díky velikému potenciálu ve snižování „odlesňovacích“ emisí a jejich významu z hlediska konzervace biodiverzity, je čím dál tím více očekáváno, že deštné pralesy budou hrát významnou roli v boji s globálním oteplováním. Co víc, zdá se možné skombinovat tyto dvě funkce deštných pralesů dohromady tak, že se budou obě navzájem podporovat. Tato práce se bude věnovat této tématice, obzvláště z pohledu konzervace biodiverzity.

Table of contents

1. Introduction

Despite the historically low perception of its importance, biodiversity has been influencing human wellbeing on many levels. As a result of evolutionary processes over several billion years, the current diversity of species is carrying a stock of information of enormous value and importance, information which has its use for both medical and agricultural research. Moreover, as a key factor for functioning of world's ecosystems, biodiversity allows mankind to rely on vast numbers of goods and services ecosystems are providing, varying from watershed function to climate regulation. Most of these complex ecosystem services do not have any substitutes, and if lost, it might take several million years of evolutionary processes to replace the species which were lost and on which the existence of these ecosystem relies.

World's diminishing forests and tropical forests in particular, are one of the richest sources of this biological diversity. In the current environment debate the profile of forests' significance in biodiversity conservation, which is the essential part of forests' sole existence, is gaining its unique prominence between all the forests' benefits, stemming the international debate in this way. Moreover, the important role forests might play in world's fight against climate change is being acknowledged. The increased attention on the relation between biodiversity and climate change implies that climate change is being recognized as a serious threat to biological diversity and because both have become main international policy goals, more synergistic and cost-effective approach combining climate change mitigation and biodiversity conservation is being undertaken. Especially the so-called Reduced Emissions from Deforestation and forest Degradation (REDD) have become one of the most debated issues in the climate change negotiations. Moreover, recent studies suggest that biodiversity considerations might play an essential role in maximizing the long term carbon sequestration and thus should receive significantly more attention in climate change context.

Therefore, I would like to concentrate in my bachelor thesis on forests' and particularly rain forests' goods and services, focusing mainly on their importance in conservation of biological diversity and its role in the climate change mitigation activities. In order to do so, I have divided the thesis to four main chapters. In the first chapter, this paper set the international policy context, explain the main forests' functions and outline the theory of externalities in this context. In the second chapter, the problem of continuous deforestation and forest degradation will be outlined and the main causes will be described, consequently showing the complexity of deforestation process at two studies. In the third chapter, we will look at two particular services forests are providing and which are important in the climate change context: biodiversity protection and carbon sequestration and storage, focusing mainly on the biodiversity. We will show the importance of biodiversity, the values biodiversity is embodying and point out the recent research concentrating on the relation with carbon sequestration. And finally in the last chapter, we will describe the REDD mechanisms, show both the main pro and against arguments concerning it and outline its relevance for biodiversity conservation.

1.1. Climate Change

We would like to very briefly comment on the issue of climate change mainly because the current debate concerning this topic. This paper is not aspiring or willing to make any normative or positive judgment about the issue of climate change nor is in any case willing to contribute to this topic due to mainly lack of expertise and knowledge in this field. We regard the prevalent scientific opinion that the climate change is (at least by substantial part) driven by the human activity as ours only to some extend, bearing in mind that the issue is not completely backed by enough data and researchers consensus. (Climate science: Spin, science and climate chase, 2010.) Nevertheless, this paper (and most of the academia) takes the climate warming as a dangerous threat to human well-being which needs to be taken into consideration and against which precautious/preventive measures needs to be taken in order to avoid any such outcome. Therefore, we take climate change as the underlying assumption for any following discussion on emission reduction and carbon sequestration. As explained then, we will not go into this issue any further and we advice any interested reader to follow more rigorous research at institutions such as IPCC, OECD or World Bank.

2. Forests and rain forests: The set up

2.1. Outline

In the first chapter, we will look at the forest as a source of numerous goods and services. Initially, we will briefly outline the most influential matters for forest management in the international politics. We will then shortly describe the main forest goods and services, discuss the different sources of values which might arise from forest and indicate why we have chose the rainforests as a focus of this paper. Lastly, we will briefly outline the theory of externalities in the context of forest management and show possible solutions to forest external effects.

2.2. International policy set up

In order to set our discussion in the political context, this paper will firstly very briefly outline the important developments in the international policy negotiations, which has been directly influencing the issue of deforestation, especially in the context of international climate change negotiations.

The first important point for our discussion is the signing of Kyoto protocol, in 1997, which has been agreed upon in order to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system", which in fact meant the reduction of the GHGs emission below 1990 levels. (UN, 1994) To achieve such a goal, Kyoto provides "flexible mechanisms" such as international emissions trading (IET), Joint Implementation (JI) or Clean Development mechanism (CDM). It is the CDM which could (and still can) provide several ways how to halt diminishing amount of tree cover. In UN's words "the CDM allows emission-reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol." (http://cdm.unfccc.int/about/index.html) Doing so can, for instance, mean financially supporting adoption and development of "clean" energy sources in these countries, e.g. solar, wind or biomass power. For our context more importantly, CDM might take form of various afforestation and reforestation projects, which are (if properly done) in fact reducing global emissions due to these "new" trees' ability to sequester and store the carbon from the atmosphere.

However, the CDMs don't include reducing emissions from deforestation which are according to some sources (see in later sections) amounting to around 17% of world emissions. In fact, deforestation is most rapidly happening in developing countries and is causing diminishing of indigenous forests, forests which are providing very stable and long-lasting carbon stock and which are additionally supporting wide range of ecosystem services, as will be showed later. Nevertheless, this situation has been changing in last couple of years and Reduced Emissions from Deforestation and forest Degradation, shortly known as REDD, has become one of the major issues in the field of international climate change negotiations. Even though last year's 2009 United Nations Climate Change Conference in Conference has been prevalently perceived as more of a failure than success on the grounds of climate change mitigation commitments (Better than nothing, 2009), it was on the grounds of REDD where some advancements have been done. In the so called 'Copenhagen Accord', "crucial role of reducing emission from deforestation and forest degradation" has been recognized. In the same document REDD+, which implicitly includes forests protection and biodiversity conservation, is mentioned as a way to do such reductions.

2.3. Forests and rain forests, basic information

World’s forests are providing many benefits to not only species living inside of them, but as well to the whole humanity and to the planet itself. Through provision of various goods and services, forest are delivering ecosystem services which are so complex and unique, it is unlikely they could be substitutable. Forests function as a climate regulator helps to maintain planet’s cycles running. Moreover, they are harbouring most of the land-situated species, making especially rainforests one of the most biologically diverse places on Earth. That carries with it many additional benefits, from possible source for medical or agricultural research to ’just’ providing different food-forms. We might continue to name forests benefits, but that is not the purpose of this paper. We will then briefly describe the main functions of forest and point out the problems facing any effort to conserve the remaining forested areas.

2.3.1. Forests' goods and services: An overview of a problem

Forests are in general a source of wide range of goods and services, many of which are complexly tied together. Probably the oldest use of forests comprised of being a source of various food forms (i.e. fruit and meat) and a source of fuel. More recently (in the view of humankind as a whole) timber extraction has become one of the major uses of forests. Whereas as a source of food forests are currently used mainly by the forest dwellers and native inhabitants, i.e. a minority of the world population, the use of wood from forests has increased substantially throughout the history of a mankind. Extraction of wood for fuel wood and conversion to charcoal is according to FAO estimated around 1,5 billion m^3 per year by the end of 1990s (FAO 2001). This is dominantly the case of developing countries, due to relative local poverty and consequent need for cheap fuel, of which forest is a rich source. In fact, the fuel wood is an important contribution to income for poorer countries. That can be seen in Pearce and

Pearce (2001) who point to paper by Shyamsundar and Kramer, who show on the case of Madagascar that the value for household per annum for collected fuel wood was around 14% of households' income. Another source of wood extraction is commercial use of forest, which has grown significantly in the last century. As Pearce shows, according to FAO and Barbier et al., the world industrial round wood production expanded from around 1 billion m^3 by the 1960s to around 1,5 m^3 by the late of 1990s, where the tropical forests accounts for around 40% of total round wood production.(Pearce and Pearce, 2001) Currently, the unsustainable logging and land conversion to agriculturally usable land are being one of the biggest contributors to the loss of forest cover.

Non-timber forest products (NTFP) are another big category of forests goods, which in some cases substantially constitutes to local communities' income. This support, such as taking wild animals as food, extracting plant material, using tree products like cocoa, gum etc., can be in some cases extremely important for local communities, but is in reality very complicated to evaluate. What has been more of a recent topic of interests of both practicians and academics are the goods and services which are not being used directly. These include services such as watershed protection (i.e. regulation of hydrological flows), carbon sequestration (withdrawing carbon from the atmosphere and consequently storing it in the trees and soil) or biodiversity conservation. Most of these services are not being marketed and hence the existence and, more importantly, the value of these services are not incorporated into market decisions about the use of particular forested areas, creating an economic incentive to land conversion. In later section (Chapter 3), this paper will look particularly at the carbon sequestration and biodiversity conservation functions and will show the possibilities how these services are and/or might be included in these decisions, creating an incentive to conserve forests.

2.3.2. Problem of deforestation: An outline

The rate at which the forested land is being changed to mostly agriculturally usable areas is unsustainable. According to Hansen et al., the humid tropical forested areas decreased only throughout the years 2000-05 by estimated 1.39% of the total biome area, which makes up for 27.2 million hectares and 2.36% of the total area of humid tropical forests. In Brazil alone, the clearing accounts for 47.8% of overall deforestation, four times more than in the second country Indonesia, where it has been 12.8%. (Hansen et al. 2008) Such a rate of deforestation is by no means sustainable. As a consequence, especially in massively forested countries like Brazil or Indonesia the "deforestation agenda" has become one of the biggest environmental issues, recently. It has come as no surprise when at the 14th Conference of Parties (COP) Brazil announced commitment to reduce its rate of deforestation by 70% over the period 2006-2017 relative to the deforestation levels from previous ten years. (Bosetti et al. 2009) This reduction, though, was expected to be helped by participation of developed countries, through various transfer mechanisms such as clean development projects, REDD and the like.

Even though the situation has improved in the last couple of years as will be pointed out in the chapter 2, many economic incentives are still pushing deforestation forward. On one hand many governments are providing financial incentives to convert the forested areas and many forms of subsidies are encouraging inefficient logging and agricultural colonization. On the other, the missing market forces of many ecological functions provided by forests are only supporting the land conversion. Since the price of numerous goods and services listed before are due to non-existing markets equal to zero, it creates an illusion that the economic value of them is null as well. It is then rational to extract timber from the forested areas rather than conserve them, which is in comparison to logging very unprofitable and hence in the classical framework irrational. This uneven situation is even pushed further from the very bottom when forest-dwellers are changing for them unprofitable areas to agriculturally usable land or to pasture for their cattle. To add to this fact, in this land conversion process conventionally called slash-and-burn agriculture, the stored carbon in the trees is released and hence added to the overall carbon concentration in the atmosphere. As can be seen then, it comes by no surprise, then, that when faced by the choice between conservation of the forest on one hand or changing that particular area into an agriculturally usable land or simply using it as a source of timber on the other, any rational economic agent goes for the latter choice in such a framework. Moreover, even the scarce incentives to conserve the forest for the future economic purposes are in many cases swept away by such factors as insecured property rights or perverse government incentives.

2.3.3. Forest: A source of value

Thus, one of the very essential steps in order to preserve forests is to develop ways how to evaluate the economic value of the main (or more likely the most valued) goods and services forests ecosystems are providing. To do this, it is widely accepted method[1] to use consumers' Willingness to Pay (WTP) as a measure of such value. This approach aims to capture the consumer demand for a particular non-marketed good in monetary terms.

As Pearce (2001) argues, the basic and accepted distinction between the values provided by forest is into four categories: 1) Direct use values 2) Indirect use values 3) option values and 4) non-use values. Direct use values are derived from the non-consumptive and consumptive use of forest. Tourism, timber logging or genetic information used for medical research can be listed in this category. The indirect use values are not directly connected to the consumer, the use of such goods or services is not fully participated. An obvious example of

[1] But not without any controversies: as Pagiola et al.(2002) point out, some people are against comparing the market and non-market values, p.30.

this category is watershed protection function of forests, which does increase the crop yields downstream from the area, and the carbon sequestration function. Option values are derived from the possible future use of the forest and its services, even though no current use is happening. The potential use of the forest by the future generation (sometimes called the bequest value) might be taken as an option value as well. And finally non-use values are neither associated with current nor future use of the forest, they are derived from the very existence of it. For example, non-use value might arise from the people willingness to pay for biodiversity conservation. However, biodiversity might be embodying an option value too, arising from the potential but not certain future use of genetic information for the biochemical industry (Pagiola et al. 2002).

In theory, if we sum up the use values including option values and non-use values, we obtain the total economic value which indicates the total economic value lost when the forest is converted to other uses or when it is degraded. (Pearce 2001) Even though it is clear that this "total value" is, and very likely will ever be, practically impossible to obtain , many forests' goods and services values are possible to estimate and hence included in market decisions. In the course of last twenty years many valuation techniques has been developed and used to achieve such goal. It is not an intention of this paper to go into any details of valuation techniques and just the simple outline will be made.

2.3.4. Problem of valuation

Valuation of ecosystem services is one of the biggest challenges facing environmental economists. Since the topic is very complex, this paper will just very briefly comment on the topic.

Since many of the goods and services forest is providing, and in which we are interested, are without markets and the prices of services and goods cannot then show their financial values, various non-market valuation techniques are used to asses them. Whereas we use the bottom up approach, where we through aggregating the valuations of particular goods and services and then adding them up together, or the top down approach, where the valuation is made for the change of the provision of the whole forest, the value obtained might, and in many cases is, biased. To see the difficulties in determining the willingness to pay one just need look at the Contingent Valuation method (CVM), one of the most widely used technique for valuing forests' goods and services. As a stated preference method, CVM is a form of questionnaire which asks people about their willingness to pay to conserve the good, improve the quality of some service etc. Determining the truthfulness of the answer is, clearly, very hard to estimate and it is still considered as the main problem of this method. In recent years the influence of *hypothetical bias,* as this problem is commonly known, has been decreased substantially, with help of many sophisticated approaches in CV methodology. Nevertheless, we can expect that from the very nature of the problem that some sort of uncertainty will, very likely, ever persist. Yet, the valuation methods of these non-marketed services might be helpful in determining the approximate level of these values and consequently incorporating these values in the land decisions. As such, it is a very important tool in order to conserve the forest in an economically viable way.

2.3.5. Rain forest: A subject of our attention

Although all the forests could be and rightly would be taken as a subject of our attention, this paper will further consider mainly the rain forest as a focus of our discussion, in some cases referring particularly to the Amazon or other particular rainforests in order to illustrate specific problem. This decision has been done due to two factors.

Firstly, the rainforests constitutes for around 5% of the world's surface and hence are one of the main possible sources of avoided emissions. Humanity's industrial production and economic development is underlined by massive use of fossil fuels. Climate change (see section 0.9), which is very likely a consequence of an increased concentration of carbon dioxide and other green house gasses (GHGs) in atmosphere due to burning of those fuels, is expected to raise the world's temperatures and hence is threatening to negatively influence human well-being. If any such negative outcome is to be avoided or the probability of its occurrence is to be substantially decreased, the prevalent opinion is to stabilize and consequently reduce the number of carbon emissions being emitted. (see IPCC,OECD,EU etc.) The ongoing deforestation and land conversion of tropical forests and peat lands is assumed to account for approximately 17% of global emissions (OECD, 2009) and if avoided, it is considered as one of the cheapest ways to reduce a significant portion of global emissions and their possible impact on Earth's climate, also creating an incentive to conserve one of the most biologically diverse places on Earth. (*Seeing REDD in the Amazon, 2009;* Bosetti et al. 2009, Pearce, 2001) Even though any emission reductions from avoided deforestation has not been included in Kyoto protocol, there is a very high probability of this happening in any post-Kyoto agreement to be signed either this year, in Mexico, or later. Through various payment schemes like Kyoto's Clean Development mechanism (CDM) or the European Emission trading system, it is possible to reduce the rate forests are disappearing and even achieve other environmental goals (see next point). However, and despite what has been previously argued, as the last year's previously mentioned OECD_report argues, there are still many uncertainties around the number of emissions from deforestation. (OECD 2009) OECD (2009) show that the main research numbers fluctuates from around 7,3 GtCO2, or 18% of world's emissions per year to around 3,5 GtCO2 for the 1990s and 4,8 GtCO2 to 5,8 for the years after the year 2000.

We will look at particular ways of achieving emission reduction from avoided emissions in the section 3 and 4 a bit more.

Secondly, the reason why this paper will focus mainly on rainforests is the importance rainforests have in maintaining its status as a harbour of world's biodiversity. Even though the exact number is unknown, rainforests are assumed to account for around as much as half of world's biodiversity (Pearce and Pearce 2001). However, the rate at which the rainforests are being cleared has a clear negative impact on the amount of species living in the rainforests, mainly because of the loss of natural habitat. Moreover, in overall the loss of biodiversity has been accelerating in last century. According to Millenium Ecosystem Assesment (2005),human actions are fundamentally and to a significant extend irreversibly causing the loss of biodiversity on the Earth. Moreover, the change has been more rapid in the last 50 years than any other time in human history. A biodiversity loss of this extend could have an irreversible impact on the human well being. The fact that the United Nations declared the year 2010 as a year of biodiversity can only confirm such concerns and as well can explain our motives in choosing rainforests as a main focus for this paper. This paper will look at he issue of biodiversity in more detail in the section three.

2.4. Forest as a source of externalities

We have previously stressed the problem of missing markets for the ecosystem services, the fact that many of the services provided by the forest are not taken into consideration of economic agent when deciding about the future use of forested areas. This particular problem is between economists commonly known and it is underlined by the theory of externalities. Since the analysis of externalities is an issue of enormous size, it is beyond the scope and allowed space of our discussion to look at the issue thoroughly. Moreover, despite the big attention this area of economic theory has been receiving ever since Marshall or Pigou, the consensus and enough empirical coverage is still missing (Verhoef 2002).Environmental economics has in part helped in development of the recent debate in this field. Therefore, we will just briefly outline the problem of comparability and measurement in the externality context, comment on the definition of externality and use the relevant analysis of externalities only in the context of environmental problems in our discussion. Eventually, we will try to show the problem present in the forest management, outline the possible solutions and show main currently used policy prescriptions.

2.4.1. Measurement and comparability

Even despite the substantial attention externalities are being given in the welfare economics, the judgment-free welfare function which would serve as a measurement tool for choosing positively "best" solution is still not present. By the welfare function we mean real value function, one which could serve for comparing the different social states. We cannot, then, properly compare different approaches for environmental policy (such as particular tools of regulation, taxation or subsidies) and choose the best solution, because we simply don't know what will eventually be better for the whole society. From the normative point of view, we are not able and as economists not asked to evaluate such "betterness" and therefore we are looking for as much objective measurement as possible. This particular problems is nothing new for economics and it is why to evaluate outcomes of different scenarios economists employ what is most widely known as *Pareto criteria* (Verhoef 2002).

During his studies of economic efficiency Vilfredo Pareto has created a concept of comparability of effectiveness of different states. In his point of view an efficiency improvement in a situation can be made if one can be made better of without making anybody else worse off. Eventually, if these "Pareto improvements" would be continuously done until the situation when no such improvement can be made any further, the situation would end up in a Pareto efficient allocation. In such a situation, nobody can be made better of without making somebody worse off. The better off/ worse off situation is distinguished by the individual's preferences. Furthermore, Pareto criteria might be distinguished between strict and potential one. In the strict version, policy change is to be socially desirable if everyone (the strong version) or at least one person (the weak version) is made better off without making anybody else worse off. However, this criterion is not exactly the best for use in most policy measures, because both gainer and losers (i.e. the worse offs) are often involved and the criterion does not provide any basis for choice between feasible alternatives (Verhoef 2002). As then Verhoef (2002) suggests, in these situations, the option might be the use of *potential Pareto criteria* or compensation criteria based on the work of Kaldor and Hicks. In these cases, the efficiency improvement might arise even despite the fact that somebody will be worse off. In so called *Kaldor-Hicks improvement* if the better offs could, in theory, compensate those that are worse off, the situation would arrive in more efficient outcome. We might say that this is more realistic point of view, especially in the case of environmental policy. As an example, one might think of a factory’s pollution payments for degrading the environment, where even though people are worse off than in an initial situation they are compensated for their loss and both parties are eventually satisfied.

It is important to note, however, that the stress in Pareto criterion is on the allocation effectiveness, not on the equality, nor social desirability of particular policy measure. In another words Pareto efficient measure might be socially desirable but might as well not be.

Hence we are eventually able to compare the feasibility of any particular measure taken to deal with externalities in the terms of Pareto effectiveness. The question of the desirability of the resulting distribution, as Verhoef (2002) nicely puts it, “..is then often left aside as an ethical one, beyond the domain of economists.” In consequent sections, then, when we talk about the effectiveness we are referring to the sense explained above.

2.4.2. Definition of externality

Despite the long interest in the theory of externalities, economists have not come up with an universal definition of externality nor with an universal set of properties which would help to identify one. Main characteristics are but common. It can be said that the externalities are widely seen form of market failure. The existence of externalities is then a deviation from a first-best neoclassical state, in which the prices are sustaining efficient allocation of recourses (i.e. Pareto Efficiency from above). Furthermore, when externalities are present, the market prices are not fully reflecting economic costs or benefits embodied. As Baumol and Oates argues (Baumol and Oates, 1988), source of external effects are typically flaws in definition and enforcement of property rights, often linked to prohibitive high transaction costs. The concept of externality is often applied in environmental economics, as Verfhoef (2002) points out, since environmental quality is a typical good without defined property rights and hence no existing markets. Eventually, we could even say that externalities in general are one of the cause of the existence of public sector, which is supposed to be dealing with externalities and market imperfections in general.

As showed before, these characteristics are very common for environmental problems and for forests in particular. Since many forest services are not marketed and/or property rights are in many cases badly defined and enforced (as showed in the section 2), forests can qualify for being a source of externalities at least from this point of view.

Baumol and Oates (1988) are describing the externalities by using two conditions. Because their book is on the theory of environmental policy and the conditions are quite similar in many sources, we will use these two for illustration. First one is: "An externality is present whenever some individual's (say A's) utility or production relationships include real (that is, nonmonetary) variables, whose values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare." Verhoef (2002) defines the externality very similarly, only differs in the fact that in his definition the deliverer of the externality in the decision-making process does not consider the effect on others at all. The fact of not-awareness or, as in the case of Verhoef, not consideration of the effect is crucial for distinguishing the externality from other unpriced interactions such as barter, jealousy, altruism etc. As Verhoef (2002) shows Mishan goes even further in this point, when saying that, “the essential feature of an external effect produced is not a deliberate creation but an unintended or incidental by-product of some otherwise legitimate activity.”

First condition fairly fits our environmental externalities problem: one can just imagine a farmer downstream from forest, whose level of production (or his utility derived from the produced goods sold) is influenced by the decision made by the owner of forest. If owner decides to clear the area, consequent missing watershed functions of forests (the externality in this case) will decrease the yield and thus utility of the farmer.

The second condition Baumol and Oates use for defining externality is ensuring the this concept of externality has the negative impacts we are expecting from it, like various inefficiencies and market misallocations. The condition goes as follows: "The decision maker, whose activity affects others' utility levels or enters their production functions, does not receive (pay) in compensation for this activity an amount equal in value to the resulting benefits (or costs) to others." (Baumol and Oates, 1988) . If this particular compensation would be made, the externality would be internalised, i.e. "repairing" the misallocation. That is, actually, the goal for our problem and it is the outcome we want to achieve when dealing with externalities in our discussion.

What Verhoef (2002) stress further is the distinction between optimization, compensation, internalisation and regulation of an externality. In the case of optimization, the level of externality is consistent with "optimal resource allocation according to the potential Pareto criterion." Compensation, which can be both optimal or not, is when a transaction between supplier and receiver takes place and this transaction compensates the receptor's welfare effects from externality. Internalisation occurs when the external effect is removed and hence the effect itself is included in the market decisions. Lastly, regulation is a term associated with direct government intervention regarding the externality.

2.4.3. Application to rainforest's conservation

In our case, the externalities in question are various services rainforests are providing and which are not incorporated in market decisions. In order to internalize the externalities, such as watershed protection, carbon sequestration or biodiversity conservation, one of the first steps is to estimate the value added from these services. We have shortly discussed the valuation method of non-marketed goods and we will a bit more comment on the sources of value for particular services we focus on in the section three. When the value of particular service is estimated, we need to incorporate it into the land decision in order to increase the value of forest conservation.

To put it in a very simplified way, if a landowner is making a decision about the use of forested area, there is on one hand the possibility to extract the timber from the area and continue to use the place for agricultural production. If the likelihood of conservation is to be increased, the decision maker needs to have on the other hand as much other benefits from the use of forest area as possible. As some already working schemes shows, he can be paid for watershed protection from farmers downstream, compensated for the stored carbon in the trees and soil or eventually for biodiversity protection the forest is providing. Moreover, there are other sources of possible stream of income stemming from services like ecotourism, medical and agricultural research or just from sustainable production of non-timber products like honey or coffee. It is clear that the more sources of future income will be incorporated into this decision process, the more probable is the decision to conserve rather than convert the forested area. However, all these benefits are in essence marginal in the short term compared to the imminent and high profit from timber and agriculture, such as palm oil or soya beans cultivation (most common cases for Brazil’s and Indonesia’s rainforests). Thus, it is crucial to ensure the long-term permanence of the forests in order to ensure that the conservation benefits will outperform the timber and agricultural ones. To do so, however, is in many cases very complicated. Flawed institutional settings, such as insecure and badly defined property rights (see next section) might increase the likelihood of forest conversion due to high discount rates. Moreover, ‘perverse’ timber subsidies or high demand for timber is deceasing the likelihood of forest conservation.

One can see that internalizing forest’s positive externalities is not an easy task, which relies on many factors at work. Nevertheless, many projects around the world shows that this is very likely one of the few possible ways how to make the forest’s future achievable. Economic instruments are, if well used, about to play a key role in the sustainable forest management then. In the case of biodiversity protection, for instance, “economic instruments are being recommended more and more as a cost-effective means of implementing biodiversity policies” (Ring et al. 2010).

3. Deforestation

Ever since Malthus the effect of the population growth on environment is considered as in the nature degrading, this effect is caused by the increased pressure on land. The bigger need for arable land and space for ever growing population is pushing the land conversion of (not only) forests to other uses. Even though links between rapid population growth and deforestation definitely exist, these links present a very complex relationship and as Pearce and Pearce (2001) notes it is false to imply that just „population growth cause deforestation". Nevertheless, since the most of the population growth is being expected to occur in tropical countries, increased pressure on forest areas is fair to expect in the future.

Tropical deforestation is a very complex process, which is employing both natural and social sciences in order to analyse properly the causes of it. Varying from perverse government incentives and badly defined and enforced property rights, which lead economic agents to log rather than conserve forested areas, to problems in properly defining and estimating the "additional" benefits of forested areas, one can judge that to halt the deforestation process, a very rigorous and comprehensive approach needs to be taken and proper analysis for paricular areas need to be prepared. As a consequence, some of these analyses have been done and this paper will try to look at the most important ones.

Nevertheless, and as it will be pointed out later in this section, the causes of deforestation have in most cases synergic effect and the causality between different causes are in many cases hard to understand.

3.1. The state of the problem

The deforestation rates have been declining from the 16 million hectares per year for the 1990s to around 13 for the years 2000-2010(FAO 2010). Both Brazil and Indonesia, coutries with the highest deforestation rate for the 1990s, have substantionally decreased their forest loss. However, “ afforestation and natural expansion of forests in some countries and regions have reduced the net loss of forest area significantly at the global level.“ (Ibid) The net change of forest area is estimated around -5,2 million hectares per year for the years 2000-2010, which about the size of Costa Rica. For the 1990s the number was -8,3 million. (Ibid)

Even though we can see that the situation has improved, it is still considered high, especially for the indigenous forest the like of Brazil, Indonesia, Kenya or other rainforests, where the importance of harbouring numerous species is very significant. Combined with the influence of climate change, it is important that especially for these particular places meeting ‘tipping points’ should be avoided. Between one of such tipping point of the Earth system, where the situation might jump to another stable equilibrium, has been identified the climate–vegetation equilibrium in the Amazon rainforest. (Nobre and Borma, 2009) The paper identifies tipping points for the Amazon at more than 40% of deforested area and temperature change of three to four Celsius degrees.(Ibid) This is not likely to happen soon, but it might become reality, if precautious measures are not taken. Even though the current situation has substantially improved, In the case of Amazon the deforestation rates have been historically extremely dire. As paper by Araujo et al. put it shortly: “According to the Brazilian National Institute of Space Research (INPE — Instituto Nacional de Pesquisas Espaciais) by August 2007, the deforested area in the Brazilian Legal Amazon (BLA) reached 700 thousand square km, which represent 14% of its geographic area. Most of the deforestation, 570 thousand square km to be more precise, took place in the last three decades since 1977” (Araujo et al. 2009).

It is then no surprise that the international debates are concentrating especially on places like Brazil. As will be showed in the last section, the possibility to combine halting the deforestation with other international policy goals might lead toward less deforested future.

3.2. Causes of deforestation

There are many sources of deforestation, most of them tied together. We will outline the basic difference and briefly describe the main ones in order to understand the deforestation process. The basic distinction should be made between the proximate and underlying causes of deforestation.(Pearce and Pearce 2001) We will devote space to this distinction a bit further, because we would like to look at the causes from general point of view first.

As stated before, the problem of missing markets is being present in deforestation process. Many forest goods and services do not have any markets and hence there is no price signals which would tell the users of forest about the economic values embodied in these goods and services (the discussion on the values is in the first section). There is a consensus that if the sustainable use of forests is to be made competitive, 'encashing' of other services needs to be made. The most potential service in this context seems carbon sequestration, watershed functions and biodiversity conservation. The question of discount rate needs to be raised here. Since the decision on land use is completely dependent on comparison of present benefit versus future income flows, the discussion on discount rate is justified to address very briefly. Higher discount rates favours early exploitation of land. The discount rates in developing countries are in our context considered higher due to the lower security and institutional qualities and hence are favouring the unsustainable use of land. However, the question arises why they are high and that is in many cases connected to property rights security (see the discussion on property rights below). Lastly, this paper would like to point out that in many countries perverse incentive for both legal and illegal logging and deforestation in general are present. For such an example see the description of deforestation process in Brazil, later in this section.

3.2.1. Proximate causes of deforestation

Geist and Lambin (2002) in the study of 152 sub national case studies throughout the years 1880-1996 were trying to find proximate and underlying forces behind tropical deforestation. They describe the proximate causes of deforestation as "..human activities or immediate actions at the local level, such as agricultural expansion, that originates from intended land use and directly impact forest cover." As the paper consequently argues, at the proximity level, deforestation is best explained by variety of regionally-changing factors working together, highlighting agricultural expansion, wood extraction and infrastructural expansion as the main ones, having all other factors in one category. As could be expected, agricultural expansion is the most common proximate cause of deforestation, being present at 96% of cases. In the case of South America, it is strikingly mainly caused by the pasture creation for cattle ranching. Second most common cause of deforestation is the infrastructure expansion in 72% cases, being followed by the wood extraction in 67% cases.

Agriculturally driven land conversion is indeed considered as one of the main factors driving deforestation forward (FAO 2010). Even though it has significantly slowed down during the last decade from around 16 million hectares in the 1990s to around 13million hectares in the last decade (Ibid), the current rate is still being too high. Moreover, this improvement has been mainly caused by the large scale afforestation and natural expansion of forests in some countries. The conversion to agriculturally usable land is dominantly done in developing countries and due to the technological “backwardness” in the area of agriculture intensification many countries are converting more land than would be needed. The study of economic factors underlying agricultural land expansion and tropical deforestation in developing countries is looked at in more detail by Barbier (2004).

3.2.2. Underlying causes of deforestation

In the same study as cited before Geist and Lambin (2002) refers to underlying causes as “fundamental social processes, such as human population dynamics or agricultural policies, that underpin the proximate causes and either operate at the local level or have an indirect impact from the national or global level.” These include population pressure, landownership and income distribution, national and regional development strategies, agricultural research and technological change.

What the paper finds out is that at the level of underlying causes of deforestation, Economic forces are the prominent cause, being in overall present in 81% of all cases. Such a high occurrence is highly surprising due to the nature of problem, in most cases commercialization and growth of timber markets and market failure being the main drivers of tropical deforestation. Institutional factors such as government policies or property rights were reported to affect deforestation in 78% cases and technological factors such as agricultural and logging techniques in 70%, followed by socio-political factors(66%) and lastly demographic factors(61%).

Some empirical research has been done in the field of distribution policy relevance towards tropical deforestation. Koop and Tole made an empirical analysis of the development countries distribution policy and its impact on deforestation(Koop and Tole 2001). Taking tropical forested countries as a subject of their attention, they found out "..that distributional profile is a significant determinant of whether economic development will have either a positive or a negative effect on the rate of forest depletion." Where the inequality is high, the deforestation will be exacerbated by the development and on the opposite where the more egalitarian system works, the less deforestation could be expected.

3.2.3. Property rights

Despite the fact that the previously cited paper by Geist and Lambin (2002) does not consider it as the main influence in their study, in many sources the insecurity and bad enforcement of property rights is being considered as one of the main sources of deforestation and that is why we will devote more space to this topic. Furthermore, we will show the deforestation process at work in two studies. As Pearce and Pearce (2001) point out, it is widely accepted that actually "..the existence of complete, exclusive, enforced and transferable property rights is a prerequisite for the efficient management of natural resources." Whereas the completion and exclusivity ensures no disputes over boundaries and access, transferability satisfy land allocation to its best use. And enforcement of property rights is a key to avoid rights being usurped. If these conditions are not met, there is not enough incentives to conserve the forests and to sustainably use it.

Furthermore, forest is being considered as a natural capital that will generate future streams of output and income (Araujo et al., 2009). Accumulation of such capital is being conditioned to institutional quality and especially on rules protecting property rights. The flawed property rights frameworks is, however, often the case of most of the developing countries where getting a formal title for a land is very difficult and in many cases the system does not protect owners from expropriation from government or evictions from individuals (Ibid). It can be even said that in many cases the settled land is not legally owned, then. In sum, in words of Araujo et al.(2009), numerous empirical studies point out that the weakness of institutions in developing countries favours forest and other natural resources depletion.

This paper looks at two studies on property rights in Amazon rainforests, one being more broadly taken, second more specific. Both of them argue, to some extent, that insecurity of property rights has a positive impact on deforestation. In the first study, carried out by Araujo et al. (2009), the paper "focuses on the consequences of ownership insecurity on deforestation in the Brazilian Amazon. The econometric analysis has been done on the nine states which encompass the Brazilian Legal Amazon, time frame being years 1988-2000. Using an instrumental variable for property rights insecurity and consequently a two stage least squared model, paper comes in all four equations used to a same effect of unsecured property rights on deforestation. This effect is, as expected, that the insecurity of property rights drives deforestation, even though this effect cannot be considered as a simple positive correlation due to the technique employed. As the paper argues, since the owners of forest areas are facing a high level of insecurity of their ownership rights, the discount rate rises, making the potential future flows of income from other use of forests lower. Hence the turn towards timber extraction, agricultural land conversion or cattle ranching, all of which generate immediate profits, seems reasonable in such framework. Moreover, since the forest areas are practically considered unproductive in the Brazilian legal framework (and hence a possible subject to land reform), conversion to agriculturally usable land makes the area more likely to be protected by landowners against the invasion of land by squatters(see next case study). It can be clearly seen that conversion might be regarded, then, practically as a form of risk management strategy.

In the second study written by Jose Antonio Puppim de Oliveira (2007) the focus is on the Maranhao State in the Easter Amazon, throughout approximately the years 1980-2000. On this in-depth study of area around the town of Buriticup, which was chosen because of the highest number of land invasions (21), we would like to briefly illustrate the complexity of deforestation process. The paper considers four main factors determining the occurrence of a high number of land invasion and agrarian conflicts in the area. Firstly, the government's too ambitious and subsidy-laden colonization plans, which were not at all met (only a fragment of planned both firms and citizens settlements actually happened), resulted in vast areas of apparently unproductive land properties. This project has been partly based on the region development due to the huge Carajas Iron project in the state of Para, which was in turn the source of infrastructure development in the area of study. Secondly, the colonization plans attracted an enormous amount of people expecting to get work, land etc. This population growth in the region was, however, accompanied by the uneven distribution of land which left most of the families landless and created first tensions between the landowners and the landless peasants. Thirdly, the development in the area was associated with the rise in the number of rural labour unions. Eventually, this high level of organization of rural and landless people was a catalyst in the process of claiming the rights over land invaded or got from agrarian reforms. Lastly, there is the influence of institutional framework at which will be looked more in detail.

The conflicting prescriptions of two governmental companies, The National Institute for Colonization and Agrarian Reform (INCRA) and Brazilian Institute for the Environment and Renewable Resources (IBAMA), has created a conflicting situation in which one could not decide whether to save 50% of forested areas as IBAMA ordered to, or be at risk of being expropriated because of having this forested area(which was under INCRA being considered as unproductive land). The slowness and expensiveness of acquiring the title over land and INCRA’s lack of capacity resulted in high number of landless people and consequently has created a environment of high property rights insecurity over land. Because the landless peasants’ increasingly more successful land invasions were receiving more media and thus political cover even the landowners could not be sure about their lands. With as little as 80 field inspectors and high level of corruption, IBAMA was completely unable to secure the timber extraction despite the fact that it was entitled to do so. Therefore the rights over timber were de facto attached to rights over land and the situation of insecurity of property resulted in enhanced extraction of timber. Moreover, increased accessibility of a region and ever growing demand for timber brought many loggers into the area. In short, all this gave people the incentives to exploit the areas under control as quickly as possible. As landless people become organized, local leaders prepared an enthusiastic plan to go forward with land reform and submitted it to the president. Nevertheless, as the plan did not get any response from officials, landless people become frustrated and some started to invade large properties from the plan, eventually resulting in organized land invasions. In these invasions ever increasing number of solitary lumbermen started to join in and consequently established a kind of relationship with the movement. These madereiros, as they are called, were giving peasants logistic support, food supply and most importantly were buying the logging “rights” from the invaders. Since the peasants wanted just land and needed cash for subsistence, they did sell the timber from invaded properties for probably low price. Increased accessibility of the region and relative scarcity of timber in other regions caused an increased number of sawmills coming to the region. This unsecure setting, landowners we faced with, had created two perverse incentives. First, as IBAMA was not present and land invasion very likely was, it was rational to log as much timber as possible before land would be invaded. Second, since INCRA regarded pasture land as more valuable than forest, landowners were cutting down the trees in order to make the land pasture and to get more money as a compensation after invasion by landless people took place. Moreover, as the price of land were declining all around the area, some landowners made an agreement with invaders to have their land (already logged and to pasture transformed) invaded, a form of an exit strategy from the land ownership.

One might see that the synergic effect of social, political, agrarian and institutional influences described above increased the rate of deforestation and led to a massive unsustainable agricultural practice. What can be seen as well is that the deforestation process is a one of many causes complexly tied together and to avoid it, cautious policy measures needs to be considered.

All in all, tropical deforestation is caused by many different problems, combination of which varies according to particular area, country or part of the world. Nevertheless, some causes are being considered as the main driving forces: economical forces, institutional settings or agrarian expansion being between the most frequent ones. Moreover, the fact that the benefits stemming from the forest conservation such as watershed protection of biodiversity conservation are in most of the cases not present at land decisions, is decreasing the chances of forest being conserved. We will therefore look at two of these services in more detail in the next section, in order to properly understand benefits arising from them and problems connected to possible incorporation of their values in market decisions.

4. Carbon sequestration and biodiversity protection

Even though forests and rainforest in particular are sources of various goods and services, we have restricted our focus only to the two services: carbon sequestration and biodiversity conservation. Carbon sequestration has been chosen due to its very likely high importance in climate change mitigation, biodiversity conservation for its sole importance and particularly for its potential to synergize with carbon sequestration initiatives. That is to say, that the combination of the two might even unite different interest groups, e.g. conversationalists and various firms with duty to offset emissions.

4.1. Carbon sequestration and storage, emissions from deforestation

Due to the climate change mitigation activities carbon sequestration and storage have received great attention and this trend will very likely continue. Since the main purpose of this section is to look at biodiversity itself and its possible synergy with carbon sequestration and due to the writer's lack of chemical and biological knowledge needed for proper discussion of this service, we will just outline the main attributes of carbon sequestration and show corresponding relation to emissions of carbon.

Since the global warming mitigation activities are presently an essential part of global politics, the possibility to use forests as a way to reduce global emissions has greatly increased the likelihood of conservation of forests in an economically viable way. It is widely accepted that ongoing deforestation and forest degradation is massively increasing the concentration of carbon dioxide in atmosphere. This effect of deforestation is actually additive, to some extent. Firstly, the area cleared from the forest is not anymore sequestering and storing the carbon. Secondly, since the clearing is in many places occurring through slash-and-burn process in order to convert forest to agriculturally usable land, most of the carbon, which was previously being stored in the trees, is released through burning and therefore increasing the carbon concentration in the atmosphere.

Numerous studies measuring the amount of carbon stored in different types of forest has been done. The distinction between soil and biomass sequestration and their different carbon storage rates needs to be noted here. To put it simply, according to Lal (2005), the ratio of soil:vegetation C density increases with latitude.

As FAO (2010) reports, the world's forests are storing 289 gigatones in their biomass alone, and as older FAO report argues (FAO, 2005), "the carbon stored in forest biomass, dead wood, litter and soil together is more than the amount of carbon in the atmosphere." For the world as a whole, amount of forests biomass carbon stock has decreased by 1,1Gt per annum for the years 1990-2005 (Ibid). For some benchmark number, according to The Guardian USA's emissions for the year 2007 has been around 6 Gt of CO_2.[2]

From measuring the amount of carbon stored the way towards emission estimation should be short. However, the overall amount of emissions arising from deforestation is still proving hard to estimate and the clear consensus is lacking. As noted before, recent OECD report argues (OECD, 2009) that the range goes from as much as 7,3Gt to as low as 2,1Gt emissions of CO_2 per year. The IPCC takes 5,9Gt as their estimate (but within very wide range) and most recent papers put annual emissions around 5-6gigatones. Despite the lack of consensus in this issue, the mitigation of climate change through avoided deforestation is widely accepted as one of the least-costly way to do so and it is expected that as such, it will very likely be included in any post-Kyoto climate deal.

[2] http://www.guardian.co.uk/environment/datablog/2009/dec/07/copenhagen-climate-change-summit-carbon-emissions-data-country-world

For illustration of rainforests numbers, we will briefly look at concrete study of particular area. In study carried out by Julia Glenday(2006) it was looked at Kakamega National Forest of western Kenya and its potential for carbon storage and emission offset potential. The study estimated indigenous forest carbon concentration of the whole ecosystem at 330 ± 65 Mg C/ha and for above biomass at 200±36 Mg C/ha.

For the practical matters, Pearce and Pearce (2001) are estimating benchmarks for carbon stored in tropical forest in Table 1. In this table, the resulting changes in carbon balance are shown and that is done in relevance to different land change occurring. For instance, the conversion of a closed[3] primary forest[4] to pasture releases approximately 220 tones of carbon.

For evaluating the value of carbon stock we need to take the benchmark values and the price of carbon. That, practically speaking, might be obtained from the carbon markets, which are already in use. These prices vary because of the different regulation practices, but one can for instance use the value from voluntary carbon markets, which might give a fair estimate of value of carbon stored in the trees.

Table 1: Changes in carbon with land use conversion: tropical forests tC/ha

		Shifting agriculture	**Permanent agriculture**	**Pasture**
	Original carbon	79 (53 soil, 25 biomass)	63 (mainly soil)	63 (mainly soil)
Closed primary forest	283 (116 soil/167 biomass)	-204	-220	-220
Closed secondary forest	194 (84 soil/110 biomass)	-106	-152	-122
Open forest	115	-36	-52	-52

[3] Closed & open characteristics refer to the percentage of crown cover, ie how dense the forest is.
[4] Primary forest refers to the "forests with no – or no visible – indications of past or present human activity" (FAO, 2005).

Source: Pearce and Pearce (2001).

In overall, the potential in forest carbon sinks is very promising and will be very likely employed in any future Kyoto successor climate deal.

4.2. Biodiversity conservation

Human development has been extraordinary fast during last century. The population more than doubled in the last fifty years and significant measures of human wellbeing such as average life expectancy or human health has improved dramatically. The amount of economic activity has approximately quadrupled during the same period according to some sources (see Polasky et al. 2005). However, this development has been accompanied by a rapid fall in the number of species living on planet Earth, mostly due to the expansion of agriculturally usable land and consequent rapid diminishing of natural habitats all around the world. “Though evidence is fragmentary”, Polasky et al. notes (Ibid), “current rates of species extinction are estimated to be several orders of magnitude above background or natural extinction rates.”

Forests are known of being a great harbour of world’s biodiversity and it is hardly surprising that the loss of it is in many places closely aligned with ongoing deforestation and forest degradation. We will look at the issue of biodiversity more closely, show the main problems connected with it and lastly show the not-that-apparent connection to carbon sequestration.

Even though the loss of world’s biodiversity might be taken as a problem on its own it does have a negative impact on human wellbeing too. Human depend on natural ecosystems and their ecosystem’s goods and services, in the case of forest varying from being a source of food to medical research information, water purification or climate regulation. The loss of biodiversity deteriorates the level of those services for individuals whose wellbeing consequently decreases. In prevalent cases, those affected individuals are not compensated for such inconvenience. Therefore, we might say that the loss of biodiversity might be considered an externality as a result of our previous discussion (see section 1.3) and as such should be dealt with corresponding policy-measures.

In the context of rainforest, when looking for a way to “internalise” biodiversity into market decisions an option on offer is to include a value of biodiversity into income stream coming from the forest area. Probably the easiest way to do so is to somehow incorporate such value into already set carbon markets. There are, however, two problems facing efforts to this approach to conservation of biodiversity. The first is more economical one: question of measuring or more likely estimating *the value of biodiversity* in order to make biodiversity present at market decisions. Second is more of a pragmatic one, the problem of measurement and definition of biodiversity itself in order to find the location of most biologically diversified places on Earth for efficient use of conversationalists’ ever scarce resources. (Myers et al. 2000)

4.2.1. Measurement and definition of biodiversity

The term of biodiversity has been defined in many ways, but we can use the definition of FAO from the year 1998:

‘Biological diversity’ encompasses the variety of existing life forms, the ecological roles they perform and the genetic diversity they contain (FAO, 1998).

As one can see from the definition, the term of biodiversity is very broad due to the complexity the biological diversity encompasses. As it is in most of the times, however, the resources for conservation are mostly very limited and hence there is a need to develop a measure of biodiversity which would give us a fair estimate where the conservation is “most needed”.

There are two main types of measures of biodiversity, one based on relative abundance and the other based on joint dissimilarity of species.

As for the first one, measure based on relative abundance of species within one community is probably the most often employed and is defined as the proportion of individual organism in the community that belong to that species (Polaski et al. 2005). One of the possible explanations of low diversity of species after disturbance is the conflict between so-called *r*- and *K-strategists*. Whereas the re-colonization after disturbance is led by the former, more fertile species, in the long term the latter, less fertile but longer-lived species, are able to compete and hence make the environment more diverse. Nevertheless, this qualitative measure cannot be a subject to proper analysis and that is why other ways to quantitatively asses the diversity are being developed. Polaski et al.(2005) cites the contribution of Patil and Tailie who defined the diversity community as $\sum_{j=1}^{s} r_j \pi_j{}^j$, where π is vector of relative abundance and r_j is a vector of relative rarity of a species *j*, which is clearly a more applicable view than the qualitative analysis.

The second type of measure, which is based on the joint dissimilarity of a collection of species, is mostly used to evaluate policies aimed at preventing the extinction of particular species. As such, these measures should be, as Polaski et al. notes, sensitive to extinction rates (or probabilities) and not to ecological changes such as population size. (Polaski et al. 2005) The measuring function in question should have three formal conditions to satisfy, according to Weitzman, cited by Polaski et al. (2005). Let us assume a non-negative, real value function of diversity, set of species and a dissimilarity function between any two species for these conditions. Firstly, the addition of species to a set of species should not reduce the diversity. Secondly, the diversity should not be increased by the addition of species which are already in the set. And lastly, diversity should not decrease with an increase in dissimilarities between species.

Polaski et al. (2005) then discuss feasibility of some chosen approaches but eventually concedes that for actual conservation decision-making the main drawback to most of the diversity measures is the information requirements which are, apart from some exceptions, too unrealistic. In another words, the decision-makers are dealing with large and in most cases unknown number of species and unknown dissimilarities between them and hence measures mentioned before are mostly to not much of a practical use.

Quite naturally, then, the current activities on conservation of biodiversity are often concentrated into so called ‘hotspots’. According to Myers et al (2000) “as many as 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth.” Consequently, in order to use conservation funds efficiently, i.e. to preserve as much species for as low costs as possible, the conservation priorities lie at “biodiversity hotspots” which are under biggest pressure of habitat and species loss.

In defining such world’s hotspots Myers et al. (2000) focused on areas “featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat. ” Not surprisingly, in prevalent cases those hotspots identified were tropical forests, being present in 15 out of 25 cases. This finding is_therefore partly explaining our focus on rainforests as a source of biodiversity and deforestation as one of the most significant causes of biodiversity loss.

4.2.2. Estimating the value of biodiversity

This paper holds the view of Polaski et al. (2005) that “biodiversity is a broad term encompassing everything from genes to species to ecosystems, ” and hence that the “value from biodiversity can arise at any of these levels.” (Ibid) Therefore we will look at only for our purpose selected values arising from rainforests conservation.

In effect, there are two sources of values embodied in biological diversity: the value of *information* and the value of *insurance*. Firstly, we will comment on the latter.

There is a stock of information in existing living species regarding evolutionary processes happening over several billions of years. Besides, Pearce (2001) argues, "..the diversity of living species also embodies characteristics that make them resilient to further 'natural' change (but not human intervention)." Biodiversity thus exists in order "..to protect entire range of goods and services, including information, provided by the diverse system." (Ibid) From this perspective, the insurance value is the WTP to avoid all those goods and services being lost, i.e. in our case payments to conserve rainforest. Interestingly, one of the most recent empirical study by Baranzini et al. (2010) gives very encouraging news from this perspective. This study, conducted in Geneva in Switzerland, was trying to analyze responses from a public survey of attitudes and preferences on the issue of tropical deforestation. Using the method of contingent valuation (see first section), the study found out that the Willingness to Pay to conserve rainforest is strongly linked to biodiversity, compared to other services forests are providing. They eventually estimated the mean WTP as "174 CHF/year[5] at the mean of the distribution, while the median as 151CHF/year" (Ibid).[6]

Second source of biodiversity's value is the value of information which mainly arises from its potential use for drug development and crop breeding, but for both cases findings are still being debated. In general, it must be considered that the complexity of biological diversity is still not fully understood. In the words of Swanson, cited by Pearce and Pearce (2001), the information embodied in current species might be liken to "a huge library on chemically active ingredients, a library that has rarely been accessed."(Pearce and Pearce 2001). From this perspective, it is this aspect of biodiversity (ie information) that

[5] That is approximately 3094 CZK/year and 2685 CZK/year in current exchange rate.

[6] However, "not all economists agree that the contingent valuation method can 'provide meaningful estimates' of value for conserving species," as Polaski et al. (2005) point out. They cite a study in which after aggregating the estimated WTP from different study, very likely too high values were obtained. Nonetheless, this study regards the technique used by Baranzini et al.(2010) as a different case, since the WTP is estimated indirectly and on the global basis (ie conservation of whole biodiversity), not for particular species.

embodies the option (and hence bequest) value, such as explained before (section 1), due to the stock of known and unknown information which might be useful in the future.

We might say that even though both medical and agriculturally substitutes to "indigenous germplasm" exist, the existence of wild germplasm might be key for sustaining current crops and therefore would be very risky to be lost. Nevertheless, the current stock of forest is still large enough to drive conservation initiated by medical or agricultural biological research activities, in most of the cases. The areas with this value high are mostly situated in biological 'hotspots'. To illustrate the high "fluctuation" of the monetary conservation incentives, one just needs to look at the table 2 from Pearce and Pearce 2001, where the values obtained vary from several hundred dollars per hectare for most of the areas to maybe several thousands of dollars for selected ones.

Table 2: Estimates of the pharmaceutical value of 'hot spot' land areas ($ per hectare)

Area	Simpson *et al.* (1994) WTP of pharmaceutical companies.	Simpson & Craft (1996) 'Social value' of genetic material per ha.	Rausser & Small (1998a) WTP of pharmaceutical companies
Western Ecuador	20.6	2,888	9,177
Southwestern Sri Lanka	16.8	2,357	7,463
New Caledonia	12.4	1,739	5,473
Madagascar	6.9	961	2,961
Western Ghats of India	4.8	668	2,026
Philippines	4.7	652	1,973
Atlantic Coast Brazil	4.4	619	1,867
Uplands of western Amazonia	2.6	363	1,043
Tanzania	2.1	290	811
Cape Floristic Province, S. Africa	1.7	233	632
Peninsular Malaysia	1.5	206	539
Southwestern Australia	1.2	171	435
Ivory Coast	1.1	160	394
Northern Borneo	1.0	138	332
Eastern Himalayas	1.0	137	332
Colombian Choco	0.8	106	231
Central Chile	0.7	104	231
California Floristic Province	0.2	29	0

Source: Simpson *et al.*, 1996; Simpson and Craft, 1996; Rausser and Small, 1998a. From Pierce and Pierce (2001)

Another approach to valuing biodiversity is to value the ecosystem as a whole, not by values stemming from particular goods and services. However, this approach is facing three main problems, as Polaski et al. (2005) argues. Firstly, the state of ecological knowledge of complex relations ecosystems consist from is still not sufficient enough to properly understand the "production functions" of forests. Secondly, the economical methods might have not developed enough to yield much sensible results. That is partly connected to the last problem of valuation of ecosystem as whole and that is the need for more integrated research between economists, ecologists and other relevant scientist.

Another question, which has received attention, is whether the more diverse ecosystems are more productive. Results from different studies such link showed, i.e. that increased number of species in the system makes the system more productive.[7]

Nevertheless, as Pearce (2001) nicely puts it: "the total value of biodiversity is clearly unbounded: without biodiversity, there would be no human life, and hence, no economic value." He consequently points out that it is then meaningless to try to estimate the global value of ecosystem services, a view this paper shares with him.

4.2.3. Biodiversity and carbon sequestration

During recent years, a shift in international negotiations on climate change towards reduction of emissions from deforestation and forest degradation (REDD) has indirectly helped to increase the profile of biodiversity conservation.

The low level of attention biodiversity has been receiving can be seen, for instance, in Kyoto protocol where the issue of biodiversity conservation has been merely present. Nevertheless, in recent years this view has been changing and both CDM (already in practice) and previously mentioned REDD initiatives

[7] For further details, see Polaski et at. (2005).

(very soon to be introduced) should be compatible with biodiversity preservation. However, biodiversity is still being seen rather as a side benefit of carbon sequestration than anything else. This view might be, not that correct as some recent research suggests.

There has been increased attention on the relation between biodiversity and climate change. In fact, climate change mitigation and biodiversity share many common attributes, as David O'Connor argues in his paper (O'Connor, 2008). Both relies on actions of sovereign states to regulate the supply of these public goods. Moreover, climate change is being recognized as a serious threat to biological diversity and because both have become main international policy goals, more synergistic and cost-effective approach combining climate change mitigation and biodiversity conservation is being undertaken (Ring et al. 2010). Besides, recent studies suggest that biodiversity considerations might play an essential role in maximizing the long term carbon sequestration and thus should receive significantly more attention in climate change context. (Díaz et al. 2009)

One of the ways to combat climate change is to enhance and sustain biosphere's carbon stock. The importance lies at increasing the net carbon sequestration, or in another words increase soil and biomass carbon sequestration in the long term. In the recent paper by Díaz et al. (2009) following points has been made regarding the relationship between biodiversity and carbon sequestration:

- There is a need for deeper understanding of how different components of biodiversity are influencing carbon sequestration and how to maintain carbon stocks in long term.
- The velocity of carbon sequestering might be in contrast to permanence of carbon stored and hence this should be considered.
- The social context which influences the creation and protection of carbon initiatives needs to be looked at in order to maximize the long term persistence of carbon stocks.

- The simultaneous maximization of multiple provisions of different ecosystem services should be the objective. However, the carbon sequestration initiatives cannot ultimately increase provisions of all other ecosystem services at the same time and hence some trade-off needs to be expected.

All in all, the policies aimed at mitigating climate change should be addressing biodiversity loss as well, not only due to cost-effectiveness of such approach but as well due to the possible synergistic potential. Additionally, if we recall the research previously mentioned by Baranzini et al. (2010),the results of their contigent valuation analysis of preferences and attitudes towards tropical deforestation suggest that "..the support for climate change mitigation activities through 'avoided deforestation' could be largely driven by biodiversity-related concerns." Despite the fact that these results need to be further validated, they show the positive attitude towards biodiversity and suggest that this type of rainforests conservation might be successful. As we will show in the final section, some pilot projects combining biodiversity conservation and carbon sequestration has already been put into practice and are giving promising results in this respect.

5. Reduced emissions from deforestation and forest degradation: A possible solution?

This paper has gradually showed the significance of forests for human wellbeing, pointed out the externalities problem, comment on the values arising from the forest conservation and outlined the main benefits and problems connected to biodiversity and carbon sequestration. Furthermore, we have discussed the main causes of deforestation and the state of forests in present times. The aim of the last section is to connect all the previous sections together and show the main possibilities in rainforests conservation policy. Lastly, we will briefly illustrate these policies in practice.

In the last section, then, we will outline the current measures aimed at tropical deforestation in the context of climate change, particularly Reduced Emissions from Deforestation and forest Degradation. This specific set of policy measures has raised its profile in recent years' climate talks, due to its relative low-cost potential, and eventually REDD was key agenda item discussed during the December 2009 COP meeting in Copenhagen(Ghazoul et al. 2010). Numerous economic analyses and projections of including REDD credits into global carbon markets has been prepared and first pilot REDD and REDD+ projects are being put into demonstration phase in order to prepare potential incorporation of REDD in any post-Kyoto climate deal. However, potential including of carbon credits from REDD in carbon markets did raised some controversies and we will comment on those in the latter part of this section. As have been suggested, the best potential mix should be more or less a combination of climate change mitigation and biodiversity conservation policies, such as REDD+ initiatives. Therefore, lastly, we would like to briefly discuss it and list some of the first REDD and REDD+ initiatives recently put into practice.

5.1. Emissions from deforestation

It is assumed that any least-cost post-Kyoto set of policy measures to combat climate change will very likely include specific mechanisms to Reduce Emissions from Deforestation and forest Degradation (OECD, 2009). Even despite already mentioned debates on the exact number, it is assumed that deforestation emissions account for around 17% of world's total emissions of green house gases (GHG) (IPCC 2007, OECD 2009). Most of the land-change related emissions (around 80%) are in fact concentrated in relatively small number of countries, situated mostly in South America and Asia. These countries includes: Indonesia, Brazil, the Democratic Republic of Congo, Bolivia, Cameroon, Ghana, Malaysia and Papua New Guinea (Eliash,2008). Humid tropical forests are disappearing due to the land-change at an average rate of 2,5% annually (Hansen et al. 2008). Or as Eliash review (2008) puts is differently: "in the tropics, it is estimated that an area of forest the size of England is cleared every year, and current annual emissions from deforestation are comparable to the total annual CO2 emissions of the US or China."

Even though it is argued that these high emissions are slowly declining and are projected to be during the second half of next century close to zero, the cumulative amount of emissions released through this period is dangerously large (OECD, 2009). Moreover, according to Eliasch (2008) not tackling of forest loss might lead to a situation when we will be unable to stabilize the GHGs concentration in the atmosphere at the level, when the worst projected effects of climate change are avoided.

5.2. Arguments in favour of REDD

In summary, inclusion of REDD credits in well-designed carbon trading system can help to achieve following objectives:

Firstly, allowing trading with forest credits can significantly reduce the cost of climate change mitigation. Including forestry sector in global carbon markets can then allow countries to adopt more stringent global emission targets - Tavoni et al. (2007) estimate that if the forestry credits are included, the target of 550 ppm[8] can be achieved for the cost of 600 ppm without forestry sector. Or in another way to put it, emission reductions from forestry can save around "$2 trillions, which could finance an estimated additional 0,25C° les of warming by the end of the century at no added cost, compared to energy-sector only reductions." (Bosetti et al. 2009)

Secondly, inclusion of REDD into global markets would create a strong incentive for tropical forest conservation. As has been argued, most of the tropical deforestation is happening in developing countries and hence REDD might both help to conserve the forests and alleviate the (financial) weight of emission reduction in there. As the increased concentration of GHGs has been, by far, caused by the developing countries, the REDD credits might in a way help to bridge the gap between developed and developing countries in the context of climate change mitigation: forested developing countries will be (rightly) beneficiaries in this system, since most of the funding for forest conservation will come from developed countries.

Thirdly, REDD will, if properly designed, at the same help to conserve biodiversity and other ecosystem services provided by the forest (Bosetti et al. 2009**,** Eliasch, 2008), even though no all ecosystem services are compatible with carbon sequestration, as Díaz et al. notes.(2009). Economic instruments, such as REDD credits, are increasingly being recognized as a cost-effective way to conservation, as "they effectively address the negative externalities of land development and internalise the positive externalities of conservation measures and protected areas" (Ring I, et al. , 2010). On international level, the negotiations shifted towards REDD+ mechanism, which explicitly includes

[8] Parts per million.

biodiversity conservation, and on which we will comment before the end of this chapter. Moreover, as has been previously showed there is an increased attention to biodiversity in the climate change context and the importance of biodiversity as a way to increase long term carbon stock is being more understood. Additionally, the willingness to pay for tropical conservation might actually increase if biodiversity loss concerns are included in the climate mitigation activities (see previous section, last part). As we will show in later section, initiatives combining more ecosystem services have already been put into practice.

Last but definitely not least, if properly designed, REDD might help to rural development and poverty reduction, especially in the developing countries.(Bosetti et al. 2009**,** Eliasch 2008). Eliasch(2008) points out, though , that for poverty alleviation the shift towards sustainable forest management and consequent local communities involvement would be needed.

5.3. Arguments against

On the other hand, there are some arguments raised against wide implementation of REDD credits, some of which are already being researched upon.

Firstly, there are concerns about measuring and monitoring of deforestation rates, closely followed by the problematic of setting the 'baseline' for crediting deforestation. Two sets of data are needed for proper monitoring: 1) data on land use change and 2) data on the corresponding carbon stock change. For that, combination of bottom-up (statistical processing of on-the-ground sampling and surveys) and top-down (satellite images, photographs and remote sensing data) methods is used. According Mollicone et al. and DeFries et al. cited by OECD(2009) that can be accomplished in foreseeable future, but the countries' current capacities differs.

Moreover, there is a need for appropriate baselines against which the offsetting will be done, in order to discourage countries overstating the deforestation rates (as they would gain more credits). Conversely, the design must regard forested countries with low rates of deforestation. Moreover, the baselines should not be based on recent rates of deforestation if ‘perverse incentives’ to speed up deforestation should be avoided.

Secondly, carbon ‘leakage’ should be avoided. The coverage of the system must be wide in order to discourage leaking emissions from covered to non-covered countries by the system.

Thirdly, the concern surrounds the fact that using REDD might happen to just offset rather than reduce emissions in industrialized countries and in energy sector and therefore it might hamper the development of clean technologies. In another words, these REDD credits would ‘flood’ the carbon market with cheap credits, not pressing the subjected companies/nations to reduce their own emissions. These issues were amongst others addressed by the paper written by Bosetti et. al (2009). Using WITCH model[9] for different policy scenarios to analyze linking REDD to global carbon markets, they arrived at following conclusions:

1) “integrating REDD into global carbon market can provide powerful incentives for the preservation of tropical forests while lowering the costs of global climate change protection and potentially enabling agreement on more stringent targets, ” (Ibid)
2) inclusion of REDD in carbon markets is to decrease forestry emissions by estimated 28% if only Brazil is included and 89% if all forested countries are,
3) REDD could enable another 50ppm reductions ‘for free’ (550 target),

[9] “The WITCH model is a climate-energy-economy model designed to assist in the stidz of socio-economic dimension of climate change. It is structured to provide information on the oprimal responses of world economies to climate damages and to identifz impacts of climate policy on hlobal and regional economic systems.” (Bosetti et al., **REFFF**)

4) the price of carbon would be decreased by 8-22%, only “modestly reducing the portfolio of investments for research and development of new energy technologies.” (Ibid)

Results from Bosetti et al. are broadly in line with other projections, such as Eliash (2008) or Dixon et al. (2009).

This particular problem of REDD being ‘too cheap’ to force countries to reduce their emissions was one of the main arguments why REDD credits were rejected to be included in EU ETS at least till the year 2020, even though this decision might be reconsidered in the case of important global agreement (Bosetti et. al, 2009).

And lastly, there are the concerns about the “right” institutional settings of REDD/REDD+ mechanisms and the wider socio-economic implication of its implementation. REDD mechanism needs to be properly designed to benefit the local community in order to make the preservation of forest viable- in the words of Blom et al.: ” the experiences of ICDPs[10] show that the design, context and implementation of projects at the local-level are extremely important for determining ultimate project success” (Blom et al. 2010). The wrong design of property rights too might have dangerous consequences, as has been showed in the second section. Furthermore, some points out that all socio-economic costs of wide implementing of REDD/REDD+ are still not properly recognized and analysed. Very recent paper from Ghazoul et al. (2010) is trying to point out to these. Between the main potential problems associated with implementation of these mechanisms Ghazoul et. al (2010) lists:

- Social costs arising from the loss of direct and indirect employment from forestry due to the conservation activities. This might lead to decrease in the development in areas in question. For instance, the production of palm oil industry indirect costs might be difficult to estimate. As the paper notes: “The governments of Indonesia and Malaysia explicitly recognize

[10] Integrated conservation and development projects.

that forestry and palm oil play a major role in regional development benefiting both district governments and local communities" (Ibid).

- Demographic changes these measures might cause. Since many of the areas in question were being populated due to the local development, as could be seen in the case study from Brazil in the section 2, the population pressures in already over-populated areas might increase.
- Global population growth. By 2050 population is expected to rise by a third and consequent pressure on land-conversion is about to increase.
- Potential changes in international connections based on trade, stemming from the consumer-supplier relationship. As the investments in developing world is largely accompanied by the natural resource exploitation, the REDD implementation might change not-only direct trade but to some extend whole political relations between nations.

The paper then argues that there is need for a comprehensive trade-off model which would allow broader evaluation of direct and indirect cost and benefits REDD/REDD+ measures bring and which would eventually increase the information available to land-decisions.

In sum, the implementation of REDD/REDD+ credits into global markets is very likely to be a major part of climate change mitigation, although more comprehensive analyses will be needed and technical issues needs to be solved in order to achieve various goals, which otherwise REDD/REDD+ have potential to achieve.

5.4. REDD and biodiversity conservation

As have been noted before, the conservation of biological diversity is not an explicit goal of REDD. Nevertheless, increased attention to the importance of biodiversity from most national bodies has led towards REDD+ concept, which "goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks" (http://www.un-redd.org/AboutREDD/tabid/582/language/en-US/Default.aspx). Apart from the biodiversity conservation, REDD+ would in effect, due to the sustainable use of forest decrease the agricultural commodity production and processing, but on the other hand it would help to secure the wood production over the long term. Moreover, REDD+ might be generating other benefits from sustainable forest use ranging from ecotourism to non-timber products.

Even though it would be safer for biodiversity to include climate change mitigation policies to wider biodiversity protection schemes, Ring et. Al (2010) point out, it is much easier to apply economic reasoning to climate policies, since climate is rather homogenous good compared to biodiversity. All in all, it might be said that as it seems, the outlook is that "forest protection and biodiversity conservation are now inextricably linked with climate mitigation" (Ibid).

As of today, numerous REDD/REDD+ projects are taking place all around the world. Some, has been eve put into demonstration phase, like *Sumatra Forest Carbon Partnership*[11], one of the world's first community-based REDD+ projects in Oddar Meanchey Province, Cambodia[12], or The Madre de Dios Amazon REDD Project[13] which was awarded with Gold Standard (the highest level of Climate, Community and Biodiversity Standards).

[11] http://www.redd-plus.com/drupal/country-network/indonesia/sumatra-forest-carbon-partnership-launched
[12] http://www.forestcarbonportal.com/project/oddar-meanchey-forest-carbon-project
[13] http://www.forestcarbonportal.com/project/madre-de-dios-amazon-redd-project

6. Conclusions

This paper has apart from the directly used goods and services provided by the forests showed the prominent importance forests are having in both climate change mitigation and biodiversity conservation context.

Growing attention to Reduced Emissions from Deforestation and forest Degradation is motivating forest protection as a cost-effective way how to significantly decrease global carbon emissions.

Meanwhile, the concern which accompanies enormous biodiversity loss the world is witnessing, due to the rapid land-change related deforestation in developing countries, is pushing for rain forests conservation in order to protect the most biologically diverse places on Earth. Moreover, as very recent studies suggest the importance of biological diversity might eventually be even bigger than previously considered: it might be a key factor in determining the forests' ability to sequester and consequently store the carbon from atmosphere in long-term perspective, which is an essential prerequisite for any emission reduction in the forestry sector.

Biodiversity related carbon sequestration projects are being implemented and first ones are currently being put into demonstration phase. Even though implementing mechanisms such as REDD or REDD+ into global carbon markets and creating functioning infrastructure for measuring and monitoring raises many difficulties, it is very likely that they will be included in any successor to Kyoto protocol. As such, these mechanisms do have potential to change the way forests are managed and, if properly designed, they might eventually lead to more synergistic approach to both biodiversity conservation and climate change mitigation.

UNIVERSITAS CAROLINA PRAGENSIS
založena 1348

Univerzita Karlova v Praze
Fakulta sociálních věd
Institut ekonomických studií

Opletalova 26
110 00 Praha 1
TEL: 222 112 330,305
TEL/FAX:222 112 304
E-mail: ies@mbox.fsv.cuni.cz
http://ies.fsv.cuni.cz

Akademický rok 2008/2009

TEZE BAKALÁŘSKÉ PRÁCE

Student:	Tomáš Baďura
Obor:	Ekonomie
Konzultant:	Ing. Jan Melichar

Garant studijního programu Vám dle zákona č. 111/1998 Sb. o vysokých školách a Studijního a zkušebního řádu UK v Praze určuje následující bakalářskou práci

Předpokládaný název BP:

Rainforests as a source of biodiversity and as a carbon capture tool: their economical usage and problems raised by ongoing deforestation

Charakteristika tématu, současný stav poznání, případné zvláštní metody zpracování tématu:

As a source of the greatest part of world's biodiversity, rainforests present an essential and unsubstitutable part of the world's natural wealth. Moreover, they generate numerous positive externalities from being a source for a medical research to being the driving factor for the high amount of rainfall in amazon area and hence generating higher agricultural returns.

Furthermore, rainforests absorb an enormous amount of carbon and deforestation is causing around 20% of world's emission of greehouse gases. Prevention of future deforestation should be by far the cheapest way to balance the world’s greenhouse gas emissions.

To do so, however, is not an easy task as can be seen from the present situation in Brazil. Badly defined property rights, inefficient regulation and corruption are some of the main factors behind the failure to create economic incentives to preserve the rainforest.

It is therefore the main aim of my bachelor thesis to look at some of those problems, describe the main environmental services which rainforests provide and look at some economical tools with which it is possible to stop or at least slow down deforestation and bring the benefits of conservation to the very people living in the rainforests.

Struktura BP:

1. Rainforests as a source of environmental services. Theoretical overview.
2. The problem of deforestation.
3. Countering deforestation - property rights and carbon capture function.
4. Conclusions.

Seznam základních pramenů a odborné literatury:

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Nature.

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Journal of Forest Economics.

Land Economics.

Forest Ecology and Management.

Datum zadání:	červen 2009
Termín odevzdání:	červen 2010

Podpisy konzultanta a studenta:

V Praze dne

7. Bibliography

Due to the interdisciplinary nature of this topic, I have used various sources only to get oriented in the topic. Therefore, I am including not only the sources from which I have directly cited, but as well some influential papers I have looked at in the process of writing this thesis.

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