Could carbon payments be a solution to deforestation? Empirical evidence from Indonesia

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Abstract— **Up to 25 percent of all anthropogenic greenhouse gas emissions are caused by deforestation, and Indonesia is the third largest emitter worldwide due to land use change and deforestation. On the island of Sulawesi in the vicinity of the Lore Lindu National Park, smallholders contribute to conversion processes at the forest margin as a result of their agricultural practices. Specifically the area dedicated to cocoa plantations has increased from zero in 1979 to nearly 18,000 hectares in 2001. Some of these plots have been established inside the 220,000 hectares of the National Park. An intensification process is observed with a consequent reduction of the shade tree density.**

This study focuses on the impact of carbon sequestration payments for forest management systems on smallholder households. The level of incentives is determined which motivates farmers to desist from further deforestation and land use intensification activities. Household behaviour and resource allocation is analysed with a comparative static linear programming model. As these models prove to be a reliable tool for policy analysis, the output can indicate the adjustments in resource allocation and land use shifts when introducing compensation payments.

The data was collected in a household survey in six villages around the Lore Lindu National Park. Four household categories were identified according to their dominant agroforestry systems.

With carbon credit prices up to €32 tCO_2e^{-1} an incentive can be provided for the majority of the households to adopt the more sustainable shade intensive agroforestry systems. The results show that with current carbon prices the deforestation activities of the majority of households could be stopped. A win-win situation seems to appear, whereby, when targeting only the shade intensive agroforestry systems with carbon payments, the poorest households economically benefit the most, the vicious circle of deforestation can be interrupted and land use systems with high environmental benefits are promoted.

Keywords— **Payments for Environmental Services, Avoided Deforestation, Linear Programming.**

I. INTRODUCTION

Primary forests are still lost or modified at a rate of six million hectares per year because of selective logging or deforestation, and there is no indication that the rate is slowing [1]. Deforestation in turn plays an important role in the global warming process, as it accounts for up to 25 percent of global greenhouse gas emissions [2]. About 49 percent of Indonesia's land area is covered by forest. The remaining forest area, however, is under constant threat, as Indonesia has the second highest annual net loss in forest worldwide with two percent per year between 2000 and 2005 [1]. Indonesia is among the top three greenhouse gas emitters in the world with three billion tonnes of carbon dioxide (CO_2). The main factor for this high rate are the emissions caused by deforestation and land conversion, which account for 83 percent of the annual greenhouse gas emissions in Indonesia [3].

Deforestation is a difficult issue to tackle on a national scale, as its drivers are complex. Five broad categories can be determined as its underlying driving forces. These are demographic, economic, technological, policy and institutional, and cultural factors. In general, at the proximate level infrastructure extension, agricultural expansion, as well as wood extraction are the main driving forces for tropical deforestation and land use change. [4]. The majority of deforestation incidences is connected to agricultural expansion. The incentive for forest conversion for many smallholders can be attributed to the fact that other land uses such as permanent cropping, cattle ranching, shifting cultivation, and colonization agriculture yield higher revenues than forestry. Through their traditional land use practices, smallholders often contribute to deforestation processes. Hence, local emissions of carbon are affected and carbon stocks and associated fluxes are often negatively influenced. In Indonesia, the main factors for forest conversion are wood extraction, unplanned agricultural expansion and forest fires. An additional driving force has been the accelerated demand for palm oil. Approximately 27% of the concessions for new palm oil plantations are on peatland tropical rainforests, covering 2.8 million hectares [5].

In the Kyoto Protocol forestry activities, or so-called "carbon sink projects[1]" are recognized as an important means of mitigating greenhouse gas emissions, since CO_2 is removed through photosynthesis. Thus, forestry projects which result in additional greenhouse gases being actively sequestered from the atmosphere and stored in sinks, can generate certified emission reductions (CER)[2]. To create a homogenous tradable commodity, emission reductions of any greenhouse gas are traded in form of tonnes of carbon dioxide equivalent (CO_2e) which means that the climate change potential of each greenhouse gas is expressed as an equivalent of the climate change potential of CO_2 [6]. Under the current rules of the Clean Development Mechanism (CDM)[3] only afforestation and reforestation activities are considered eligible. However, in the on-going climate discussions, as during the UNFCCC Climate Conference in Bali, Indonesia in 2007, other sink activities, such as reducing emissions from deforestation and degradation (REDD) are high on the political agenda. This discussion was first initiated by the Rainforest Coalition, a group of developing nations with rainforest who formally offered voluntary carbon emission reductions by conserving forests in exchange for access to international markets for emissions trading. It is especially the forest-rich countries, such as Brazil and Indonesia, who are pushing for the financial acknowledgement of forest conservation.

On the island of Sulawesi in Indonesia, the forest margin of the Lore Lindu National Park (LLNP), which covers 220,000 hectares, has been facing encroachment and consequently deforestation. The main activities to be observed are an expansion of the area dedicated to agricultural activities by 20 percent during the last two decades, the tripling of the perennial crop plantations area and expansion into former forest areas, as well as selective and clear-cut logging. A village survey in 2001 revealed that 70 percent of the villages bordering the LLNP have agricultural land inside the Park [8]. A satellite image analysis detected a mean annual deforestation rate of 0.3 percent in the research region between 1983 and 2002 [9]. However, cocoa plantations under shade trees cannot be detected by optical satellite instruments, thus, the encroachment process at the forest margin is not fully reflected by this figure. In the vicinity of the LLNP, a great spatial heterogeneity of agricultural production is apparent. In general, human activities are much more concentrated in the northern and western part of the Park than in the south. For example in the north-east the closed forest decreased by 35 percent between 2001 and 2004 due to logging, whereas the area covered by cocoa plantations increased by 11 percent [10]. In addition, an intensification process among the cocoa agroforestry systems (AFS), whereby farmers gradually reduce the shade tree cover, can be observed. The focus of the present research is therefore to assess the impact of payments for carbon sequestration activities on the smallholders in the regions bordering the LLNP in Indonesia, and whether such payments can provide an incentive for the adoption of more sustainable and shade tree intensive land use practices and contribute to the conservation of the rainforest.

II. FRAMEWORK

The research is motivated by the need to understand which level of incentives is required for a stimulation of the farmers to desist from further deforestation and land use intensification activities. Internationally the awareness for the requirement to develop and support

[1] The term carbon sinks is applied to pools or reservoirs, such as forests, oceans and soils, which absorb carbon, and for which carbon storage exceeds carbon release. The process of capturing carbon from the atmosphere and storing it in vegetation biomass is referred to as sequestration.

[2] The terms certificates, carbon credits and CER are used interchangeably. One credit is the equivalent of one tonne of CO_2 emissions.

[3] The CDM provides for Annex I Parties (most OECD countries and countries in transition) to implement projects that reduce emissions in non-Annex I countries in return for CER, and assist the host Parties in achieving sustainable development. The CERs can be used by Annex I countries to help meet their emission targets [7].

payment mechanisms and incentives for the provision and preservation of environmental services such as biodiversity conservation, preservation of landscape beauty, watershed management and carbon sequestration is growing. Initiatives and projects are promoted where local actors are given payments in return for switching to more sustainable land-use practices and ecosystem protection. They usually imply the payments to be made by the beneficiaries of the environmental services. These "payments for environmental services" (PES) policies have been defined by Wunder [11], as voluntary, conditional agreements between at least one "seller" and one "buyer" over a well-defined environmental service – or a land use presumed to produce that service. PES, being market-based mechanisms, can render forestry to be a competitive land use and farmers and loggers might decide to change their land use practices to retain or replant trees if they receive sufficient remuneration. In the case of deforestation avoidance, farmers can receive a compensation payment as an incentive not to cut down the forest and use the timber or put the land to agricultural use. This is in line with the "compensated reduction" proposal, according to which countries electing to reduce their national emissions from deforestation would be authorized to issue carbon certificates, similar to the CERs of the CDM, which could be sold to governments or private investors to fulfil their emission targets [12].

In the region around the LLNP four cocoa agroforestry systems can be distinguished according to the degree of shading and shade tree species, as well as the management intensity: AFS I exhibits a high degree of shading with natural forest trees and a low management intensity, while at the other end of the spectrum AFS IV involves intensive management and fully sun grown cocoa. The gross margins of cocoa consistently increase along the cocoa AFS gradient from I towards IV. There seems to be a trade-off situation between an intensification of the cocoa cultivation with shade free plantations and higher economic returns and shade-grown, low intensity management cocoa with lower returns and biodiversity conservation. Even though the cocoa grown in full sun has higher mean yields and obtains substantially higher gross margin values in comparison with shade grown cocoa, in the long run the intensification is likely to be unsustainable. Anticipated consequences are agronomic risks, such as declining soil nutrient levels, as well as socio-economic dangers like the dependency on single crops and a negative impact on local food security [13]. Additionally, the AFS I provides high biodiversity values and habitat for the native fauna, whereas the establishment of shade free cocoa plantations reduces the landscape level diversity by eliminating secondary forests on fallow land and may adversely affect the soil fertility [14]. Another study assessed the species-richness of plants and animals and ecosystem functioning [15]. This study did not discover a linear gradient of biodiversity loss in the four agroforestry systems, but deduced that only small quantitative changes in biodiversity and ecosystem functioning occurred when changing from AFS II to III. However, they also conclude that in the long run the intensification and reduction of shade trees is an unsustainable path. Unfortunately, this process already takes place in the region. A willingness to pay study, which suggests a higher preference for low shade agroforestry systems among the local farmers, supports these results [16]. Thus, to prevent an intensification of the agroforestry systems to monocultures in the region, economic incentives are required. These could be price premiums, as they are already available for a long time for fair trade and organic coffee. Alternatives could also be carbon certificates which can offer an incentive for the more shade grown, biodiversity rich and sustainable cocoa agroforestry system and slow down the intensification process.

Another important phenomenon in the region is that many of the Bugis households who were resettled by the government in the 1990s from South Sulawesi and Poso into the research area started to buy land from the local ethnic groups, the Kaili's and Kulawi's. In many cases the local ethnic households had originally obtained this land by clearing primary forest on the border of the National Park [17, 18]. They consider themselves to be the owner's of the village territory and do not see the necessity to buy land, but in turn realised the opportunity to generate additional income by selling parts of their land. This money is usually used for buying status symbols or for ceremonial purposes, which require substantial amounts of cash [19]. In due course they are often in need for further land for their own cropping activities, since the majority of them are at least to some extent subsistence farmers, leading to additional encroachment of the forest margin of the National Park.

The debate with respect to REDD has gained momentum after the UNFCCC Conference in 2007. Before this date very few of these avoided deforestation projects existed and many policy makers, scientists and NGOs have been very sceptical of their practical implementation and success. In 1997, one of the most prominent forest conservation projects was set up, the Noel Kempff Mercado Climate Action Project in Bolivia. Three private investors, American Electric Power, PacifiCorp and BP Amoco, as well as the Nature Conservancy and the Bolivian Government implemented this 11 million US$ project to protect 832,000 hectares of tropical forest. Approximately one million tCO_2e are generated within the project lifespan of 30 years and the offsets are awarded to the Bolivian Government which will sell these on the Chicago Climate Exchange. The revenue earned goes towards the park protection, community development and capacity building [20]. The notion of avoided deforestation has been given considerable prominence in the Stern Review published in 2006 by the British Government. Currently, the World Bank establishes the Forest Carbon Partnership Facility which is designed to set incentives for reducing deforestation rates and decrease greenhouse gas emissions. It will support a REDD project to protect 750,000 hectares of the Ulu Masen rainforest in Sumatra, Indonesia which is expected to generate over 100 million tonnes of carbon offsets over 30 years. Additional finance comes from the US investment bank Merrill Lynch, as well as the World Bank Multi-Donor Fund's Aceh Environment and Forest project.

Several studies look at the potential of avoided deforestation projects in terms of contributing towards the reduction of greenhouse gas emissions, as well as the possible markets for REDD credits. Laurance [21] sees the potential for a viable mechanism for using tradable carbon offsets to protect rainforests. By reducing deforestation a significant cutback of greenhouse gas emissions can be attained and developing countries, especially forest-rich nations, could potentially gain large revenues from carbon credits. Ebeling and Yasue [22] calculate that if 10% of the deforestation rate is reduced, for a range of carbon prices of €5-30 tCO_2e^{-1} between €1.5-9.1 billion per year could be generated globally. The prices for carbon certificates fluctuate widely, depending on the type of certificate. Additionally, the voluntary greenhouse gas emission offset markets are evolving rapidly, especially in the United States. Looking at permanent CER, a wide variation of prices can be observed. In 2006 certificates were traded in a range between US$ 6.30 up to US$ 27.01 per tCO_2e, with an average of US$ 10.90 [23]. In the CDM counter issued by the GTZ in December 2007, the CER prices per tCO_2e observed were between €5 and €18. The usual range for voluntary forest offset projects was between €3-30 tCO_2e^{-1} [24], and avoided deforestation prices averaged $4.80 tCO_2e^{-1} [25].

Accordingly, we investigate whether current carbon credit prices are sufficient on the one hand to induce farmers to adopt more sustainable land use practices and on the other hand to make them desist from further forest conversion activities. The purpose of this paper is to provide an insight into whether environmental service payment schemes could have an impact on land use changes, and specifically which level of incentives would be necessary for the currently demanded policies to reduce emissions from deforestation, and thus, contribute to the conservation of the rainforest.

III. DATA AND METHODS

A. Linear programming model

We chose a comparative static linear programming model to analyse the behaviour of the households and their resource allocation. These models simulate the farmers' reaction to interventions and the effect of technology changes on economic decisions about natural resource use management [26]. Linear programming has proven to be a reliable method for studying the impact of policy activities, such as in this case carbon payments [27]. As with all methods, there are some limitations, such as the assumption of certain values and preferences when specifying the objective function, the possibility of non-linearity and feedback between variables, as well as the dynamics of systems.

One has to be aware of these problems, but for the purpose of this research linear programming has been considered an appropriate method. Especially, since it is a useful technique to assess technology changes or adoption potentials *ex ante*, so that careful planning for new policies or strategies can be undertaken. As an input for the model, the gross margins for the main cropping activities paddy rice, upland rice, maize and cocoa were calculated. Additionally, forest conversion activities based on various economic-political-environmental parameters from the research region were included to portray the behaviour of the smallholders as realistically as possible. Given the objective function, the solution procedure maximises the total gross margin (TGM) of the farm by finding the optimal set of activities for the household type, under the respective restrictions such as farm size, suitability of the land for various crops, food security, the credit limit, family work force, and the seasonal peak requirement of labour for each activity. The credit limit is the maximum amount of credit that a household expects to be able to borrow from formal and informal sources [28]. The farm conditions are stable, thus risk and time dimensions are not included in the model. Risk is not accounted for, as the farmer has information about alternative production activities, and input and output prices. In the research region most of the agroforestry plots contain trees of mixed age, therefore there is no clearly defined investment period and time of returns. Hence, the time lag between investment and returns has been ignored, as there are always some trees which can already be harvested whilst the others still mature. Furthermore, initial investment costs are very low and the additional labour in the first three unproductive years of the cocoa tree cannot be clearly separated from other activities necessary for the already productive trees on the cocoa plots. In another study in the same region which focused on smallholder cocoa farmers' technology adoption, application and optimisation, the same conditions apply and similar assumptions were used for the linear programming model [29].

B. Farm household types

The data on the existing agricultural production systems for the model was collected in a household survey in six villages in the surroundings of the LLNP in 2006. We categorised the households according to the dominant agroforestry system among their cocoa plots, and determined four corresponding household types (HH_I - HH_{IV}). A random sample of 46 households was drawn from the total sample of 325 households in 13 villages from the research project. These were randomly selected based on a stratified sampling method [30] for a household survey in 2001 and 2004. The survey at hand focused on general aspects of the household and farm characteristics, land resources and their use, agricultural production activities, forest use, as well as the households' perception of the LLNP, the forest, and its functions. The four household types have different resource endowments, such as land and labour availability and their credit limit. The major characteristics are presented in Table 1 in order to indicate the differences between them.

Table 1 Characteristics of household classes I-IV (Source: own data)

	Household class			
	I	**II**	**III**	**IV**
Total cultivated land (ha)	2.5	2.8	2.8	2.5
Cocoa AFS I (ha)	1.49	0.24	0	0
Cocoa AFS II (ha)	0.77	1.31	1.09	0.33
Cocoa AFS III (ha)	0.25	1.16	1.73	0
Cocoa AFS IV (ha)	0.02	0	0	1.72
Family labour days per month	32.4	29.5	34.4	31.6
Credit limit (€/year)	33	720	1,015	570
Ethnicity (% non-local HHs)	0	19	22	80

Thus, one can see that the household type I has the lowest credit limit and the least cultivated land. The main share of the land is dedicated to the cocoa AFS I. Mainly the local Kaili, Kulawi and Napu households own this plot type. Household types II and III have an increasing credit limit and most land available for cultivation, and they dedicate most of their land to AFS II and AFS II, respectively. In these household classes the share of migrants, such as Bugis, Toraja and Poso families, becomes more dominant. Household type IV, who is mainly non-local, predominantly grows the intensively managed AFS IV. However, its credit limit is only the second highest and its land availability is the same as that of household type I. This could be an indication that with limited credit and land availability they adopt a more intensive production system in comparison to the other household types. With the help of a poverty assessment tool based on principle component analysis [31] the households in the region were classified into poverty groups according to their relative welfare. The N (0.1)-normally distributed poverty index allows to group the households into terciles and makes it possible to draw comparisons between the poorest, poor and better off households. 67 percent of the type I households belong to the poorest households, whereas 63 percent of the type IV households can be categorised as better off. The households of the two other categories fall into all three welfare groups. We note, that there is a poverty gradient to be found from HH_I towards HH_{IV}.

C. Carbon accounting methodology

For carbon accounting the amount of carbon sequestration which is to be claimed as a "carbon credit" is limited to the net amount of change in the total forest carbon pool from one period to the next. In order to obtain the site specific total above- and below ground biomass for cocoa trees, a logarithmic growth regression model was adopted (highest R^2 value of 0.76). The biomass can then be converted to carbon using a conversion factor of 0.5g of carbon respectively for 1g of biomass [32]. To obtain the tradable commodity CO_2e, the conversion factor for carbon of 3.667 is used. The results show that for this specific region a cocoa tree, on average, stores 8.05 kg carbon over a time span of 25 years, with the more intensively managed and densely planted AFS IV accumulating more carbon (46 kg/ha) than the less intensively managed systems I-III (39 kg/ha). Additionally, 0.5 t ha^{-1} yr^{-1} of soil organic carbon was added, a figure from the literature [33], as no site-specific data exists. Due to lack of data, the calculation for carbon accumulation in soils is assumed to occur linearly in time.[4] All carbon measurements for above-, below-ground and soil carbon were added up to obtain an estimate of the total carbon per hectare of the cocoa trees. Finally, this amount was converted to CO_2e, which is the basis to calculate the amount of certificates to be obtained for the different agroforestry systems.

According to the Kyoto protocol, all credits from sink projects have a temporary status and expire after a certain time. Only trees which are planted at the beginning of the crediting period can be assigned temporary certificates of emission reductions (tCER). A tCER is defined as a CER issued for an afforestation project activity under the CDM, which expires at the end of the commitment period following the one in which it is issued [34]. The tCER are limited to five years, after which they can be re-issued. Once the tCER are not re-certified, a permanent solution is needed to fulfil the reduction requirements. As we envisaged a total project horizon of 25 years and applied an accounting scheme of tCER, we assume the carbon credits will be issued five times. To make things straightforward for this calculation, we assumed that the credits are synchronous with the commitment periods, so that they are issued at the end of the first commitment period and expire five years later at the end of the next commitment period [35, 36]. In addition, we argue that the annual net rate of carbon accumulation of the shading trees in the first three land-use systems should be accounted for. Otherwise there is a great incentive for purely sun grown cocoa plantations, as these are more densely planted and hence, the total carbon accumulation per hectare is higher than in the more shade intensive agroforestry systems. This could even foster further cutting down of the shading trees. The carbon fixation of the shade trees has been estimated based on a study by Brown et al. [37] and included in the carbon budget for the AFS I, II and III. The tCER for the first five year crediting period are related to the cumulative carbon storage of the agroforestry system. The first credits are generated after five years. These tCER expire after five years, but are reissued in year 10 together with additional tCER. The same procedure is applied for the following 5-year periods until the last issuance of tCER in year 25, and reflects the total net storage of CO_2 since the project started.

The prices for tCERs represent only a fraction of the prices for regular CERs from other project categories such as energy projects. Forestry certificates expire after a certain time period, so they are only allocated non-permanent certificates. These

[4] For comparison, the total carbon pool has also been calculated excluding soil carbon. As the difference is quite small (3 percent decrease in annuity payment), it is assumed that it is acceptable to include soil carbon.

must be replaced by permanent ones at some point in the future, hence, the non-permanent credits need to be converted to permanent CER. Therefore, the value of the temporary credits can be seen as the difference between the current permanent credit price and the discounted value of the future permanent credit price:

$$P_{tCER_0} = P_{CER_0} - \frac{P_{CER_T}}{(1+d^*)^T} \quad (1)$$

where CER_0 is the price of the CERs today and CER_T the price of permanent CERs discounted at rate d* found in Annex I-countries and T is the expiring time of tCER [38].

For the conversion the CER prices are assumed to be constant over time ($p_{CER\,0} = p_{CER\,T}$), and a three percent discount rate (d*) is taken, which reflects the current low interest rates in Annex I countries [39]. As a tCER has a duration of five years, its value according to the equivalence relation in (1) is only about 14 percent of that of a permanent credit.

The annual remuneration to the farmer was obtained for each land-use system through the calculation of the net present value, using equation (2), where d represents the discount rate in Indonesia and T the 5 year periods from year 5 until 25. The calculations refer to the net carbon accumulation.

$$\Sigma tCER\,(1+d)^{-T} = \frac{(\text{net}\,CO_2\,\text{storage})_5}{(1+d)^5} + \frac{(\text{net}\,CO_2\,\text{storage})_{10}}{(1+d)^{10}} + \ldots + \frac{(\text{net}\,CO_2\,\text{storage})_{25}}{(1+d)^{25}} \quad (2)$$

For the linear programming model the net present values are converted to annuities, in order to show the annual payments which the farmer would receive from a 25 year sequestration project. The equivalent annuity method expresses the net present value as an annualised cash flow by dividing it by the present value of the annuity factor. The annuity factor is calculated according to formula (3), where i represents the interest rate and n the number of years. The real interest rate of 10 percent is taken, which is the rate to be found in Indonesia in 2006 [40], and the time span is 25 years. Finally the annuity factor is multiplied by the net present value to obtain the annuity.

$$AF_{n,i} = \frac{i \times (1+i)^n}{(1+i)^n - 1} \quad (3)$$

IV. RESULTS AND DISCUSSION

A. Impact of carbon payments on smallholders' land use systems

Results from the linear programming model indicate that when payments for carbon sequestration are introduced for the prevailing agroforestry system, the impact in absolute terms on the TGM from cropping activities does not differ very much between the four household types. Depending on the credit prices, the increase in the TGM ranges between €10 and €70 annually. This is due to the fact, that the net carbon accumulation does not differ very much between the four different systems. The relative impact is the most pronounced for the household type I which can realise an increase of up to 18 percent for high carbon credit prices of €25 tCO_2e^{-1}, whereas for household type IV the corresponding impact is almost negligible. However, with current carbon prices no switches between the different systems are observed.

Additionally, we assessed whether carbon payments could provide an incentive for the households to take up more of the biodiversity rich, shade intensive agroforestry system. Therefore, credits were targeted only towards the first two agroforestry systems which provide elevated environmental benefits due to their high-level ecosystem functioning and in the long run are more sustainable. The results from the linear programming model indicate that with carbon credit prices of up to 32€ tCO_2e^{-1} the first three household types will adopt more of the sustainable agroforestry systems. These prices are in a range of offset credits to be observed on carbon markets currently and they are lower than the price premiums paid for organic cocoa. Only household type IV would need very high credit prices of 185€ tCO_2e^{-1} to induce him to adopt more of the less intensive cocoa production practices.

On a regional scale for the research area there is a carbon offset potential of 1,300,000 tCO_2e from all cocoa plantations which in comparison to the BioCarbon Fund Projects of the World Bank would be in the upper range of their projects. This could lead to annual payments between €100,000 to €500,000 from the carbon sequestration of the agroforestry systems. However, the limits for a small scale afforestation project under the CDM, which only allows for an annual average greenhouse gas removal by sinks of less than 16.000 tCO_2e, would be exceeded. Such a small-scale project could be an option for the AFS type I farmers, as the smallest area share among the cocoa plantations is planted with the full shade cocoa (264 hectares), and they would only need to gather a total area of their shade intensive cocoa agroforestry systems of 240 hectares. For more details on the results, please see [41].

B. Reducing emissions from deforestation and forest degradation

Avoiding deforestation is increasingly discussed nowadays on the climate change policies agenda, since it can provide an important strategy for avoiding greenhouse gas emissions in the first place. In a study by Jung [42] the estimates for the global potential for carbon uptake[5] through avoided deforestation are 11 times higher than for plantations, regeneration and agroforestry together.

The discussion on deforestation avoidance usually focuses on the national level. Yet incentives can also be set at the local level, as agricultural activities are often a major driving force of conversion processes. Therefore, we used the linear programming model to determine the necessary carbon prices at which households stop deforestation activities at the forest margin of the LLNP. The prices we obtained show a huge range. Annual payments of €5 per hectare are necessary to stop conversion activities of household type I, whereas household type II would need annual payments of €125, household type III of €300 and household type IV of even €700.

It depends on the future arrangements for payment modalities for emission reductions from avoided deforestation whether the above calculated payments can be made. Discussions are still on-going and evolve around up-front and annual payments, setting the year of the baseline etc. In addition, much discussion remains of who should be receiving payments for avoided deforestation, the state, the community or the farmers and how are these schemes to be implemented? For this case study we appraise the feasibility of these compensation payments made to farmers for not converting further forest with a simple projection. The current estimate for the carbon content of the LLNP forest is 435 $tCO_2e\ ha^{-1}$ (M. Kessler, personal communication, 9. April 2008). Under the assumption that the current deforestation rate of 0.3% is reduced to 0, annual emissions of 13 $tCO_2e\ ha^{-1}$ could be avoided. Depending on the prices paid for avoided emissions from deforestation, payments between €65 and €326 per hectare could arise[6] (see Table 2). Different scenarios are calculated with a safety margin of a 25% lower and a 10% higher CO_2e content of the forest, as it is not homogeneous over the entire Park area.

Table 2 Scenarios of potential payments for avoided emissions from deforestation reduction (Source: own data)

		Scenarios of different CO_2e contents		
		Low	**Middle**	**High**
Carbon content LLNP	$t\ CO_2e\ ha^{-1}$	326	435	479
Annual emissions avoided (deforestation rate reduced from 0.3% to 0)	$t\ CO_2e\ ha^{-1}$	10	13	14
Payments for different prices per tCO_2e avoided				
5 € tCO_2e^{-1}	€ ha^{-1}	49	65	72
12 € tCO_2e^{-1}	€ ha^{-1}	117	157	172
25 € tCO_2e^{-1}	€ ha^{-1}	245	326	359

If the prices paid for every ton of CO_2e avoided are €12, the evolving payments are sufficiently high enough to provide an incentive for the household types I and II to stop forest conversion activities. If the prices were increased to €25 tCO_2e^{-1} avoided, even the household type III, who needs a compensation of €300 per hectare, could be stimulated to desist from further tree cutting. Household type I, which only cuts down a few original forest trees and sets seedlings under the

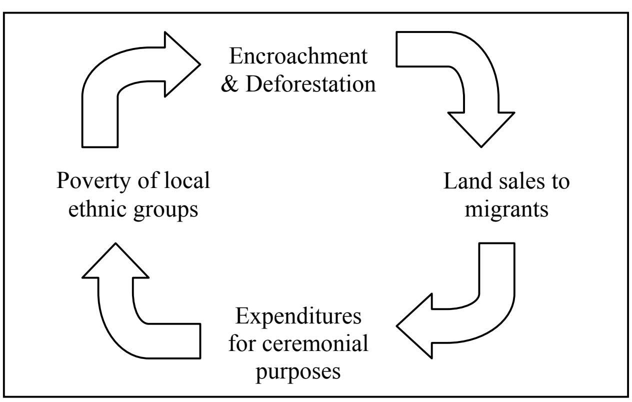
[5] This does not represent the real carbon uptake but the one accounted for by the carbon accounting scheme used for forestry projects in the CDM.

[6] Transaction costs are not considered, their inclusion would reduce the evolving payments.

remaining shade trees, obtains a much lower cocoa gross margin and, hence, needs a much lower compensation payment to stop forest conversion. In comparison, the household type IV receives a very high gross margin for the intensively managed cocoa. The need for these very high compensation payments arises through the opportunity costs of not converting forest which is the cocoa gross margin.

As mentioned above, many of the households from the local ethnic groups are the drivers of the encroachment processes at the forest margin, selling the land to the newcomers who tend to have more intensively managed cocoa agroforestry systems (see also Table 1). This provokes a vicious circle, as after a while the local households who spend the income gained through land sales often on ceremonial purposes, will convert further forest to fulfil their subsistence needs (see Figure 1). If the compensation payments would be specifically targeted towards the shade intensive AFS I and II, who are mainly cultivated by the local ethnic groups, a solution could be provided to stop this vicious circle. On the one hand the increase in income will enable the poorest households to escape poverty and on the other hand they will not have the need anymore to convert additional forest in order to obtain more income and/or land.

Figure 1. Vicious cycle of poverty and deforestation (Source: own illustration)



Are the payments for avoiding emissions from deforestation therefore a cost-efficient solution for the abatement of greenhouse gases when focusing only on agricultural production activities? Currently, there is much debate regarding biofuels and whether they actually contribute towards the reduction of greenhouse gases. Therefore, there is a call to develop an accounting system which calculates the entire life cycle analysis of the biofuels, and takes into account the direct and indirect land use changes and associated emissions, as well as air and toxic emissions, biodiversity, water and soil impacts. In addition, the discussion is now turning to the practical challenges of where and how emission reductions can best be achieved, at what costs, and over what periods of time. Therefore, it is interesting to also consider at a global scale which options can provide a cost-efficient solution to reach the abatement targets established by now in most countries. We compare the abatement costs of alternative biofuels to the opportunity costs of not converting the LLNP forest into a cocoa plantation. These are calculated by converting the net present values of the average cocoa agroforestry system, as well as the AFS IV to annuities, to derive the annual payments from a 100 year project horizon and divide these by the annually avoided tons of CO_2e per hectare when completely reducing deforestation.[7] Table 3 lists these different options of activities in the agricultural domain from different countries and one can see that bioethanol production from sugar cane in Brazil is the most cost-efficient solution with negative abatement costs of –27 € tCO_2e^{-1}. Still, as a second option comes the avoided deforestation of the LLNP ((AD LLNP) 23 or 55 € tCO_2e^{-1}), which is far more effectual than the remaining biofuel options. These numbers, however, do not take into account other environmental services provided by the forest, which obviously will raise its value even more. Also, the environmental costs associated with land use changes caused through diverting land from previous agricultural activities or forest to biofuel production have not been considered. In Brazil the cerrado is converted for sugar cane or soybean production and the Amazon logged for producing soybeans, which increases the carbon debt of the obtained biofuels considerably. Bioethanol from sugar cane produced on ex cerrado land would take approximately 17 years to

[7] The biofuels displace fossil fuels forever, whereas in this calculation the carbon emissions which are avoided by reducing deforestation are only displaced for 100 years. However, in 100 years we should have hopefully encountered sufficient alternative energy sources to meet our needs.

repay its carbon debt [5]. Yet, the transaction costs when implementing and carrying out a REDD project have also not been included in the calculation of the abatement costs for avoiding deforestation, which would lower its benefits. The costs can be quite considerable, and results from a study by Michaelowa and Jotzo [43] indicate transaction costs for forestry carbon projects to range from US$ 1.48 per tCO_2 for large to US$ 14.78 per tCO_2 for small ones.

Table 3. Abatement costs of biofuels and avoided deforestation (Source: [44], [45] and own calculations)

	Biofuel rapeseed (Germany)	Rapeseed oil (Germany)	Bioethanol sugar beet (Germany)	Bioethanol sugar cane (Brasil)	Bioethanol (USA)	AD LLNP Average AFS	AD LLNP Type IV AFS
Abatement costs € tCO_2e^{-1}	154	83	291	-27[8]	290	23	53

Therefore, if one searches for cost-efficient solutions on a global scale for the abatement of greenhouse gases among activities in the agricultural sector, it is reasonable to invest in the conservation of the LLNP before investing further in other biofuel options in Germany.

V. CONCLUSIONS

The present study demonstrates the importance to include options of decreasing deforestation activities when targeting the reduction of greenhouse gas emissions and searching for policy approaches. As discussed, it is the uncontrolled agricultural expansion at forest frontiers which undeniably contributes to its conversion and loss. Market-based mechanisms and incentive schemes, such as carbon credits either for land uses which offer additional carbon sequestration potential or for preserving land uses which store great quantities of carbon, can offer solutions for the sustainable management and conservation of forests.

In fact, in this specific context of the Lore Lindu National Park in Central Sulawesi in Indonesia, the intensification process among the cocoa production systems leads to a gradual removal of original forest shade trees towards fully sun grown monocultures. This trend is not sustainable in the long run, as soil productivity declines and species-richness is reduced. Carbon certificates could be used as a price premium to reward households to carry out less intensively managed land use practices. Results show that they can offer the possibility to provide an incentive for the majority of households to adopt more of the shade intensive agroforestry systems. The analysis indicates that the farmers of the household types I-III would need differentiated prices to stimulate the switch towards the more sustainable land use systems, but that current prices which are observed on the carbon markets could doubtlessly be sufficient. Additionally, compensation payments can be used as an incentive for deforestation reduction, which ultimately leads to avoiding further greenhouse gas emissions. The analysis shows that the current carbon prices could be sufficient for three household types to stop them from forest conversion, whereas the better off households need extremely high compensation payments, which could not be generated with the current prices for carbon certificates. The inherent problem lays in the fact that the fully sun grown cocoa receives very high net-revenues, which makes it very difficult to provide viable and financially attractive alternative activities for these farmers. However, the poorest farmers, which are typically from the local ethnic groups, could be provided an additional income through the compensation payments. This can, in turn, have the benefit of reducing poverty and also decreasing their need of opening up further land in the National Park.

If carbon payments are applied in general to all agroforestry systems there will be an impact on the households' income, but no change with respect to land use systems. However, if other criteria, such as the provision of further environmental services are included, specific systems can be targeted in order to promote a switch towards these agroforestry systems. To conclude, one can say that for the carbon payments to be efficient and promote a shift towards land uses

[8] Abatement costs are negative, because of a very good greenhouse gas balance and very low production costs. These are caused because Brazil has a long experience in developing sugar-growing and processing technology and its relatively low taxation of fossil fuels used in biofuel production [46].

which provide higher environmental benefits, payments targeted towards medium to high shade intensive land use systems would be needed. This could ensure that the changes are made into the desired direction. Additionally, we have observed that the poorer households seem to benefit relatively more than the better off from carbon payments. It seems as if win-win situations are possible, where both deforestation processes and poverty can be reduced with carbon payments and land use systems with high environmental benefits promoted.

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