Carbon Finance
-
Impacts of Environmental Service Payments on Households in Central Sulawesi, Indonesia

Christina Seeberg-Elverfeldt,
Stefan Schwarze & Manfred Zeller

STORMA Discussion Paper Series
Sub-program A on
Social and Economic Dynamics in Rain Forest Margins

No. 25 (May 2008)

Research Project on Stability of Rain Forest Margins (STORMA)

Funded by the Deutsche Forschungsgemeinschaft through the SFB 552 „STORMA“

www.storma.de
ISSN 1864-8843

SFB 552, Georg-August-Universität Göttingen,
Büsgenweg 1, 37077 Göttingen

Table of contents

Table of figures

Abstract

Up to 25 percent of all anthropogenic greenhouse gas emissions are caused by deforestation, and Indonesia is the third largest greenhouse gas emitter worldwide due to land use change and deforestation. On the island of Sulawesi in the vicinity of the Lore Lindu National Park (LLNP), many 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 (1979) to nearly 18,000 hectares (2001). Some of these plots have been established inside the 220,000 hectares of the LLNP. An intensification process is observed with a consequent reduction of the shade tree density.

This study assesses which impact carbon sequestration payments for forest management systems have on the prevailing land use systems. Additionally, 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. To the extent that 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 LLNP. Four household categories are identified according to their dominant agroforestry systems. These range from low intensity management with a high degree of shading to highly intensified systems with no shade cover.

At the plot level, the payments required to induce the adoption of more sustainable land use practices are the highest for the full shade cocoa agroforestry system, but with low carbon prices these constitute less than 5 percent of the cocoa gross margin. Focusing on the household level, however, an increase up to 18 percent of the total gross margin can be realised. Furthermore, for differentiated carbon prices up to 32 €/t the majority of the households have an incentive to adopt the more sustainable shade intensive agroforestry system. Additionally, the results show that the deforestation activities of most households could be stopped with current carbon prices.

Keywords

Payments for environmental services; carbon sequestration; agroforestry; linear programming; economic incentives, avoided deforestation

1. Introduction

The net global change in forest area has been slowing down from –8.9 million hectares per year in the 1990s to –7.3 million hectares during the last years due to plantations and restoration of degraded land, especially in Europe, North America and East Asia. However, 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 (FAO 2006). 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 (IPCC 2007). Thus, global carbon stocks in forest biomass are decreasing by 1.1 Gt of carbon annually (Marland, Boden, and Andres 2006). Indonesia has the second highest annual net loss in forest area worldwide. During the last five years two percent of its remaining forest area was lost every year (FAO 2006). Additionally, it is among the top three greenhouse gas emitter primarily because of deforestation, peatland degradation and forest fires.

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. (Geist and Lambin 2002). 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 the framework of the Kyoto Protocol, forestry activities, or so-called "carbon sink projects[1]" are recognized as an important means of mitigating greenhouse gas emissions, since carbon dioxide 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 "carbon credits" or certified emission reductions (CER)[2]. In order 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 (UNFCCC 1997). Under the current rules established for 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 in 2007, other sink activities, such as reducing emissions from deforestation or "compensated reduction" 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

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

[3] For fulfilling the reduction obligations, the Kyoto Protocol offers three flexible mechanisms, namely Emissions Trading, Joint Implementation and the CDM. 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 and contributing to the ultimate objective of the convention. The generated CERs can be used by Annex I countries to help meet their emission targets (FAO 2004).

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 (Maertens 2003). A satellite image analysis detected a mean annual deforestation rate of 0.3 percent in the research region between 1983 and 2002 (Erasmi and Priess 2007). However, cocoa plantations under shade trees cannot be detected by optical satellite instruments, thus the encroachment process at the forest margin is not reflected by this figure. In the vicinity of the LLNP, a great spatial heterogeneity of agricultural production can be observed. In general, human activities are much more concentrated in the northern and western part of the Park than in the south. For example in Palolo, one of the four main valleys embracing the LLNP 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 (Rohwer 2006). 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 twofold. We assess the impact of payments for carbon sequestration activities on the land use systems of smallholders in the regions bordering the LLNP in Indonesia, and whether such payments can provide an incentive for the adoption of more sustainable land use practices and contribute to the conservation of the rainforest margin.

2. Framework

The research is motivated by the need to understand which level of incentives is needed to stimulate the farmers to desist from further deforestation and land use intensification activities. Internationally the awareness for the requirement to develop and support 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 (2007), 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. In reality, so far very few of the existing PES schemes fully satisfy all conditions, but should be referred to as “PES-like schemes” (Wunder 2007). Basically, they are based on the principle of externalities. Carbon sequestration is a typical positive externality, as it is an unplanned side effect of sustainable forest management and conservation in a specific area, and the benefits are not confined locally, but accrue to all of humanity. Already Meade (1952) recommended to generalise the Pigouvian welfare theory to find a market solution for a positive externality situation, so that private production by using a subsidy results in additional social benefits. Thus, it is argued that the discrepancy between the private marginal costs for the provision of sustainable forest management systems and the social marginal cost of such measures can be reduced by offering incentive payments for external benefits of management measures.

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 (Santilli et al. 2005).

In the region around the LLNP four cocoa AFS 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 (Belsky and Siebert 2003). 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 (Siebert 2002). Another study assessed the species-richness of plants and animals and ecosystem functioning (Steffan-Dewenter et al. 2007). This second study did not discover a linear gradient of biodiversity loss in the four AFS, 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 AFS among the local farmers, supports these results (Glenk et al. 2006). Thus, to prevent an intensification of the AFS 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. Recently premiums have been introduced for fair trade and organic cocoa. The fair trade premium for standard quality cocoa is €100 per tonne. The minimum price for fair trade standard quality cocoa, including the premium, is €1,250 per tonne. Also for organic cocoa producers receive a higher price than for conventional cocoa, ranging between €75 to 225 per tonne (ICCO 2007). Alternatives could also be price premiums offered through carbon certificates to offer an incentive for the more shade grown, biodiversity rich and sustainable cocoa AFS and slow down the intensification process.

Another important phenomena in the region is that many of the 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 indigenous Kaili and Kulawi households. In turn the indigenous households often had obtained this land previously through encroachment of the National Park (Sitorius 2002; Faust et al. 2003). They usually needed the money for ceremonial purposes, which require substantial amounts of cash.

Incentive-based schemes have become very common during the last decade, and hundreds of new and very elaborate PES initiatives have been implemented. For example, in Costa Rica the National Fund for Forest Financing (FONAFIFO) operates a scheme which bundles funding from various sources, including international donors, carbon buyers, the Costa Rican public through a national fuel tax, and local industries interested in water quality and flows. Consequently, land users can receive payments for specified land uses, such as new plantations, sustainable logging, and conservation of natural forests. In Mexico, a payment for a hydrological environmental services programme is carried out. Other PES examples are found in Colombia, Ecuador and El Salvador (Pagiola, Arcenas, and Platais 2005). In Asia one of the most prominent programmes is RUPES (Rewarding the Upland Poor for Ecosystem Services), which is coordinated by the World Agroforestry Centre (ICRAF). In one of these projects in Indonesia farmers are assisted by RUPES to obtain conditional land tenure in exchange for adopting mixed agro-forestry systems that increase erosion control and biodiversity (Jack, Kousky, and Sims 2007).

A great variety of studies have been conducted employing different methods and considering the supply and/or the demand side aspects to determine the value of environmental services as done by Pattanayak (2004), Olschweski and Benítez (2005) and Antle *et al.* (2007). The trick, however, remains to find the specific price at which the marginal cost of the payment equals the marginal benefit of the behaviour that it stimulates. The prices for carbon certificates fluctuate widely, depending on the type of certificate, whether it is an emission reduction generated through a project-based activity, such as CER, or allowance based transactions, allocated under existing (or up-coming) cap-and-trade regimes, such as the EU allowances. 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 (Capoor and Ambrosi 2007). In the CDM counter issued by the GTZ in December 2007, the CER prices per tCO_2e observed were between €5 Euro and €18.

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.

3. Data and Methods

3.1. 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 (Barbier and Bergeron 1999). Linear programming has proven to be a reliable method for studying the impact of policy activities, such as in this case carbon payments (Vosti, Witcover, and Carpentier 2002). 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. The field research followed the method developed by Diagne and Zeller (2001). 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 (Taher 1996).

3.2. 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 AFS 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 (Zeller, Schwarze, and Rheenen 2002) 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. Some characteristics are presented in Table 1 in order to indicate the differences between them.

	Household class			
	I	**II**	**III**	**IV**
Total cultivated area (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-indigenous HHs)	0	19	22	80

Table 1. Characteristics of household classes I – IV

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 indigenous 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. Within these household classes the share of migrants, such as Bugis, Toraja and Poso families, becomes more dominant. Household type IV, who is mainly non-indigenous, 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 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 (Zeller et al. 2006) the households in the region were gathered 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}.

3.3. 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. The biomass can then be converted to carbon using a conversion factor of 0.5g of carbon respectively for 1g of biomass (Brown 1997). 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 (Hamburg 2000), 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, 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 (UNFCCC 2003). The tCER are limited to five years, after which they can be re-issued. 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. However, we argue that additionally the annual net rate of carbon accumulation of the shading trees, which are present 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 AFS. This could even foster further cutting down of the shading trees. The prices for tCERs represent only a fraction of the prices for

[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.

regular CERs from other project categories. This is due to the fact that in forestry projects the certificates expire after a certain time period, so that they are only allocated non-permanent certificates. These must be replaced by permanent ones at some point in the future, therefore the non-permanent credits need to be converted to permanent CER. Using equation (1) the difference between permanence and non-permanence can be accounted for (Olschewski and Benitez 2005):

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

where T is the expiring time of tCER, the index “0” refers to credits bought today (Subak 2003), and d* is the discount rate in Annex I-countries.

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. 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.

Finally, 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.

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

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, and the time span is 25 years. Finally the annuity factor is multiplied by the net present value to obtain the annuity.

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

4. Results and Discussion

4.1. Carbon sequestration potential

At the plot level, the results indicate that the net carbon accumulation is the highest for both the most shade intensive agroforestry system I and for the shade free cocoa plantation IV (67 $tCO_2e\ ha^{-1}$) in a 25 year project. The two other agroforestry systems II and III accumulate 64 and 62 $tCO_2e\ ha^{-1}$, respectively. The resulting payments for carbon sequestration in turn depend then on the net carbon accumulation, the expiring time of the tCER, the discount rates, the time span of the project, as well as on the CER prices. As mentioned above, the prices for permanent CER vary considerably on carbon markets, hence different prices are considered (Table 2) to indicate the range. A price of €5 tCO_2e^{-1} is comparable to the lowest traded medium-risk CER price, whereas €25 tCO_2e^{-1} at the other end represents the trading prices in the European Climate Exchange for 2008-10 carbon allowances in May 2007 .

	Agroforestry System			
Annuity payments € ha^{-1}	**I**	**II**	**III**	**IV**
d 10%, CER €5 tCO_2e^{-1}	5.54	5.18	5.00	5.09
d 10%, CER €12 tCO_2e^{-1}	13.30	12.40	12.00	12.20
d 10%, CER €25 tCO_2e^{-1}	27.70	25.90	25.00	25.50

Table 2. Annuity payments for different prices of CER

With low carbon credit prices of €5 tCO_2^{-1}, the resulting annuity payments constitute 5 percent of the cocoa gross margin for the high shade AFS, and less than 1 percent of the fully sun grown AFS cocoa gross margin. At carbon credit prices of €25 tCO_2e^{-1}, the payments amount to 28 and 2 percent of the respective cocoa gross margins. We can derive from the results, that the variation between the four AFS is not very pronounced. However, the highest annuity payments from carbon sequestration are always obtained for the high shade AFS and decline towards the AFS III. The AFS IV obtains payments in the mid-range, because the cocoa trees are more densely planted in comparison to the other three shaded systems.

In 2007 in a survey conducted in 80 of the 119 villages in the research area 20,590 hectares were used for cocoa plantations. Approximately 1% of this area was planted with the AFS type I, 31% with AFS II, 60% with AFS III and 8% with AFS IV (S. Reetz, personal communication, 16. April 2008). Thus, if a carbon sequestration project were to be implemented in this region, the approximate carbon offset potential of the cocoa AFS would be 1,300,000 tCO_2e^{-1}, amounting to 3.855.699 tCER in 25 years. At low carbon prices of €5 tCO_2e^{-1} this would amount to an annuity payment of €104.000, at a price of €12 tCO_2e^{-1} to €250,000 and at €25 tCO_2e^{-1} to €522,000 for a 25 year project.

4.2. Baseline results

Focusing on the household level, the baseline TGMs of the crop activities were calculated. The baseline indicates the TGM for the four household types (Table 3). As explained previously, the cocoa gross margins increase in profitability when moving along the cocoa AFS intensification gradient from I towards IV. However, the farmers in the region do not only employ the AFS with the highest gross margin. There is a variety of complex factors and circumstances, which are not reflected in the model, such as the distance of the plot to the forest, traditional land use practices and cultural preferences, which play important roles in the households' decisions with respect to their AFS. The farmers who predominantly grow the AFS I might not just be restricted because of labour, land and credit constraints to this land use system, but also because their cocoa plot borders the forest and they also grow a variety of other tree crops in the same plot. Some farmers also believe that the shade trees prevent diseases from spreading. The baseline exhibits an increase of the TGM from crop activities from HH_I towards HH_{IV}. This result mirrors the poverty gradient, which was obtained when we categorised the households according to their relative welfare. Hence, it corroborates the fact that there seems to be a wealth gradient from household type I towards household type IV.

	Household class			
Total gross margin (€ yr^{-1})	**I**	**II**	**III**	**IV**
Baseline	375	1,063	1,331	2,705
Scenario 1 CER €5	389	1,076	1,344	2,715
Scenario 2 CER €12	408	1,094	1,361	2,729
Scenario 3 CER €25	443	1,128	1,312	2,756

Table 3. Total gross margins for the household types for different CER price scenarios

4.3. Impact of changing prices of carbon and cocoa

Consequently, the baseline model was compared with different scenarios which included the payments for carbon sequestration of the AFS. The impact of changing carbon credit prices is assessed with a constant discount rate of 10 percent (Table 3).

With the introduction of the payments, the HH_{I} experiences the most pronounced relative impact on its TGM. The rise in total gross margin when comparing the baseline situation with the different payments is an increase of 4, 9 and 18 percent respectively for the price scenarios 1,2 and 3 (see Table 3.). For household types II and III, the increase is smaller (between 1 and 6 (HH_{II}) and 1 and 5 percent (HH_{III})), whereas for household type IV the corresponding impact is almost negligible (between 0 and 2 percent). When looking at the absolute impact of the carbon payments on the TGM in Table 3, household III receives the highest additional payments for all three CER prices, and the amounts gradually decline for HH_{I}, HH_{II} and HH_{IV}. At this range of carbon prices none of the households is induced to shift its land use management practices.

Shifts in land use are only observed if carbon prices for carbon sequestration of cocoa trees are set at higher levels. The household type III starts to take up the AFS I once the carbon prices reach €55, and household type IV needs a carbon price of €238 to induce a change in its land use practices, also shifting towards AFS I. Household type II only starts to realise any shifts in land use activity when CER prices are at €600, switching towards AFS I and II. Interestingly, household type I does not realise any further shifts in land use activities, since its land, labour and capital constraints are binding.

Currently, world market FOB cocoa prices are at 2,194 US$/tonne (January 2008). However, in the past this has been very different. During the time of the survey in 2006, prices were about 1,550 US$/tonne. The lowest price was observed in 2001, when prices were at 960 US$/tonne. This means there has been an increase of 38 percent in world market prices of cocoa between 2001 and 2006. Thus, in scenario 4 we look at whether, with this low cocoa price as observed in the past, the carbon payments would actually cause a difference and induce any shift in land use activity or in the TGM. Considering the impact on land use activity, for household types I, III and IV no shift is to be observed, and the change in TGM ranges from 14, 3 to 2 percent respectively. However, HH_{II} shifts its land use activities towards AFS I and II and realises an increase in its TGM of 93 percent. Summarising, for shifts in land use activities to occur, when all AFS receive equal payments, very high carbon credits would be necessary. Thus, we next assess whether shifts occur if explicit land use systems are targeted with payments.

4.4. Incentives for environmentally friendly agroforestry systems

In this section we assess whether carbon credits could be used as an incentive for the farmers if the credits are targeted only towards the two more shade intensive AFS, which have a higher biodiversity and are more sustainable in the long run. Hence, using the reduced costs or opportunity costs of the different cocoa AFS activities, the minimum prices for carbon certificates can be determined, which are needed for a specific activity to enter the farming plan. Therefore, in scenario 5 we assess at which minimum credit price the household types would adopt the full shade AFS I or the slightly less shaded AFS II to slow down the intensification trends. The results indicate that household I needs a credit price of €14 to adopt more of the AFS I, household II is stimulated to shift more towards the fully shaded AFS with credit prices of €27 and household III adopts more AFS II with carbon credit prices of up to 32€ tCO_2e^{-1}. These prices are in a range of CER to be observed on carbon markets currently and they are lower than the price premiums paid for organic cocoa. However, household 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.

4.5. Reducing emissions from deforestation and forest degradation

Nowadays on the climate change policies agenda avoided deforestation is increasingly discussed, since it can provide an important strategy for avoiding greenhouse gas emissions in the first place. In a study by Jung (2005) 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 with respect to reducing emission from deforestation and forest degradation (REDD) usually focuses on the national level. But 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. For this case study we appraise the feasibility of these compensation payments with a simple projection. The current estimate for the carbon content of the LLNP forest is 435 tCO_2e/ha (M. Kessler, personal communication, 9. April 2008). Assuming that the current deforestation rate of 0.4% is reduced to 0, every year emissions of 17 tCO_2e /ha could be avoided. Depending on the prices paid for avoided emissions from deforestation, payments between €87 and €435 per hectare could arise[6] (see Table 4.) 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.

[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.

		Scenarios of different CO_2e contents		
		Low	**Middle**	**High**
Carbon content LLNP	t CO_2e /ha	326	435	479
Annual emissions avoided (deforestation rate reduced from 0.4% to 0)	t CO_2e /ha	13	17	19
Payments for different prices per tCO_2e avoided				
5 €/tCO_2e	€/ha	65	87	96
12 €/tCO_2e	€/ha	157	209	230
25 €/tCO_2e	€/ha	326	435	479

Table 4. Scenarios of potential payments for avoided emissions from deforestation reduction

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, even using the lower scenario. If the prices were increased to €25/tCO_2e 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 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 beforehand, many of the indigenous households are the drivers of the encroachment at the forest margin, selling the land to the newcomers who tend to have more intensively managed cocoa AFS (see also Table 1). If the compensation payments would be specifically targeted towards the first two household types, who are mainly indigenous, a solution could provided to stop this vicious circle of forest conversion.

Are the payments for avoiding emissions from deforestation therefore a cost-efficient solution for the abatement of greenhouse gases? 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 AFS, 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 5. lists these different options and one can see that bioethanol from sugar cane in Brazil is the most cost-efficient solution with abatement costs of –27 € /t CO_2e. Still, as a second option comes the avoided deforestation of the LLNP ((AD LLNP) 23 or 55 € /t CO_2e), which is far more effectual than the other biofuel options. These numbers do not take into account other environmental services of the forest, which obviously raises its value even more.

[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.

	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 € /t CO_2e	154	83	291	-27[8]	290	23	53

Table 5. Abatement costs of biofuels and avoided deforestation (Source: (Schmitz 2006; Steenblick 2007))

We can conclude, that if one searches for cost-efficient solutions for the abatement of greenhouse gases, it is reasonable to invest in the conservation of the LLNP before investing further in the other biofuel options in Germany.

5. Conclusions

The present study demonstrates the importance to include smallholders, 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, 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. From this study we can derive that per hectare payments for carbon sequestration of cocoa agroforestry systems are the highest for fully shaded land use systems. Depending on the certificate prices, a farmer could obtain between €6 and €28 per hectare for the carbon sequestration of the cocoa AFS. With low certificate prices of €5 tCO_2e^{-1}, the additional remuneration for the AFS in general is quite low, especially in comparison to the very high gross margin of €1,460 per hectare of the intensively managed cocoa. However, with carbon certificate prices at the upper end, the households who obtain the lowest total gross margin from their crop activities can realise an 18 percent increase of their gross margin from cropping activities with the introduction of payments. These households also realise the second highest increase in absolute terms of their gross margin. Additionally, these households provide the second highest (and only marginally lower than the highest) environmental benefit in terms of the annual carbon sequestration rate of their cocoa agroforestry systems. Thus, carbon payments seem to have a positive impact on the income derived from cropping activities for the households which seem to be least well endowed with financial resources. The payments resulting from avoided deforestation may additionally reduce the need of poor indigenous households to sell their land to the migrants.

On a regional scale 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 AFS. However, the limits for a small scale afforestation project under the CDM, which only allows for an annual average greenhouse gas

[8] Abatement costs are negative, because of a very good greenhouse gas balance and the 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 (Henniges and Zeddies 2006).

removal by sinks of less than 8.000 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, and they would only need to gather a total area of their shade intensive cocoa agroforestry systems of 120 hectares.

Carbon certificates could also 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 AFS I and II. 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 avoided greenhouse gas emissions. The analysis shows that the current carbon prices could be sufficient for three household types to stop them from further 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. Obviously the question remains, whether in the long run these systems will be sustainable and not experience a decline in yields due to anticipated agronomic risks such as declining soil fertility.

To conclude, one can say that for the carbon payments to be efficient and promote a shift towards land uses 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.

Bibliography

Antle, J. M., J. J. Stoorvogel, and R. O. Valdivia. 2007. Assessing the economic impacts of agricultural carbon sequestration: terraces and agroforestry in the Peruvian Andes. *Agriculture, Ecosystems and Environment* 122 (4):435-445.

Barbier, B., and G. Bergeron. 1999. Impact of policy interventions on land management in Honduras: results of a bioeconomic model. *Agricultural Systems* 60 (1):1-16.

Belsky, J. M., and S. F. Siebert. 2003. Cultivating cacao: Implications of sun-grown cacao on local food security and environmental sustainability. *Agriculture and Human Values* 20 (3):277-285.

Brown, S. 1997. Estimating biomass and biomass change in tropical forests: A primer. FAO Forestry Paper 134. Rome: FAO.

Capoor, K., and P. Ambrosi. 2007. State and Trends of the Carbon Market 2007. Washington D.C.: World Bank, IETA.

Diagne, A., and M. Zeller. 2001. *Access to credit and its impact on welfare in Malawi*. Washington, D.C.: International Food Policy Research Institute.

Erasmi, S., and J. Priess. 2007. Satellite and survey data: a multiple source approach to study regional land-cover / land-use change in Indonesia. In *Geovisualisierung in der Humangeographie,* edited by F. Dickmann: Kirschbaum Verlag.

FAO. 2004. A review of carbon sequestration projects. Rome: FAO.

———. 2006. Global Forest Resources Assessment 2005. FAO Forestry Paper 147. Rome: Food and Agricultural Organization.

Faust, H., M. Maertens, R. Weber, N. Nuryartono, T. v. Rheenen, and R. Birner. 2003. Does Migration lead to Destabilization of Forest Margins? - Evidence from an interdisciplinary field study in Central Sulawesi. Discussion Paper Series 11. Göttingen: STORMA.

Geist, H. J., and E. F. Lambin. 2002. Proximate causes and underlying driving forces of tropical deforestation. *Bioscience* 52 (2):143-150.

Glenk, K., J. Barkmann, S. Schwarze, M. Zeller, and R. Marggraf. 2006. Differential influence of relative poverty on preferences for ecosystems services: Evidence from rural Indonesia. In *International Association of Agricultural Economists Conference*. Brisbane, Australia.

Hamburg, S. 2000. Simple rules for measuring changes in ecosystem carbon in forestry-offset projects. *Mitigation and Adaptation Strategies for Global Change* 5 (1):25-37.

Henniges, O., and J. Zeddies. 2006. Bioenergy and Agriculture: Promises and Challenges - Bioenergy in Europe: Experiences and Prospects. Brief 9 of 12 Focus 14. Washington D.C.: IFPRI.

ICCO. 2007. The Chocolate Industry, edited by I. C. Organization.

IPCC, ed. 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. T. and and H. L. Miller. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Jack, B. K., C. Kousky, and K. E. Sims. 2007. Lessons Relearned: Can Previous Research on Incentive-Based Mechanisms Point the Way for Payments for Ecosystem Services? CID Graduate Student and Postdoctoral Fellow Working Paper No. 15.

Jung, M. 2005. The role of forestry projects in the clean development mechanism. *Environmental Science and Policy* 8 (2):87-104.

Maertens, M. 2003. *Economic Modeling of Land-Use Patterns in Forest Frontier Areas: Theory, Empirical Assessment and Policy Implications for Central Sulawesi, Indonesia*. Berlin: dissertation.de.

Marland, G., T. Boden, and R. J. Andres. 2006. Global, Regional, and National CO2 Emissions. In *Trends: A Compendium of Data on Global Change*, edited by O. R. N. L. Carbon Dioxide Information Center, U.S. Department of Energy. Oak Ridge, Tenn., U.S.A.

Meade, J. 1952. External Economies and Diseconomies in a Competitive Situation. *Economic Journal* 62 (245):54-67.

Olschewski, R., and P. C. Benitez. 2005. Secondary forests as temporary carbon sinks? The economic impact of accounting methods on reforestation projects in the tropics. *Ecological Economics* 55 (3):380-394.

Pagiola, S., A. Arcenas, and G. Platais. 2005. Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date. *World Development* 33 (2):237-253.

Pattanayak, S. K. 2004. Valuing watershed services: concepts and empirics from southeast Asia. *Agriculture, Ecosystems & Environment* 104 (1):171-184.

Rohwer, N.-K. 2006. Object Oriented Image Analysis of High Resolution Satellite Imagery: A Land Cover Change Analysis in the Palolo Valley, Central Sulawesi, Indonesia, Based on QuickBird and IKONOS Satellite Dat. Diplomarbeit, Geographisches Institut, University of Göttingen, Göttingen.

Santilli, M., P. Moutinho, S. Schwartzmann, D. Nepstad, L. Curran, and C. Nobre. 2005. Tropical Deforestation and the Kyoto Protocol. *Climatic Change* 71:267-276.

Schmitz, N. 2006. Biokraftstoffe, eine vergleichende Analyse. Gülzow: Fachagentur Nachwachsender Rohstoffe e.V.

Siebert, S. F. 2002. From shade- to sun-grown perennial crops in Sulawesi, Indonesia: implications for biodiversity conservation and soil fertility. *Biodiversity and Conservation* 11 (11):1889-1902.

Sitorius, F. 2002. Land, Ethnicity and the Competing Power Agrarian Dynamics in Forest Margin Communities in Central Celebes, Indonesia. Discussion Paper Series 5. Göttingen: STORMA.

Steenblick, R. 2007. Biofuels - at what cost? Government support for ethanol and biodiesel in selected OECD countries. Geneva, Switzerland: The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD).

Steffan-Dewenter, I., M. Kessler, J. Barkmann, M. M. Bos, D. Buchori, S. Erasmi, H. Faust, G. Gerold, K. Glenk, S. R. Gradstein, E. Guhardja, M. Harteveld, D. Herteld, P. Höhn, M. Kappas, S. Kohler, C. Leuschner, M. Maertens, R. Marggraf, S. Migge-Kleian, J. Mogea, R. Pitopang, M. Schaefer, S. Schwarze, S. G. Sporn, A. Steingrebe, S. S. Tjitrosoedirdjo, S. Tjitrosoemito, A. Twele, R. Weber, L. Woltmann, M. Zeller, and T. Tscharntke. 2007. Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proceedings of the National Academy of Sciences of the United States of America* 104 (12):4973-4978.

Subak, S. 2003. Replacing carbon lost from forests: an assessment of insurance, reserves, and expiring credits. *Climate Policy* 3 (2):107-122.

Taher, S. 1996. Factors influencing smallholder cocoa production: a management analysis of behavioural decision-making processes of technology adoption and application. Dissertation, Wageningen University, Wageningen.

UNFCCC. 1997. Decision 2/CP.3. Methodological Issues Related to the Kyoto Protocol.

———. 2003. Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol, Decision 19/CP9 (Doc. FCCC/CP/2003/6/Add.2).

Vosti, S. A., J. Witcover, and C. L. Carpentier. 2002. Agricultural Intensification by Smallholders in the Western Brazilian Amazon. Research report 130. Washington D.C.: IFPRI.

Wunder, S. 2007. The efficiency of payments for environmental services in tropical conservation. *Conservation Biology* 21 (1):48-58.

Zeller, M., S. Schwarze, and T. v. Rheenen. 2002. Statistical Sampling Frame and Methods Used for the Selection of Villages and Households in the Scope of the Research Program on Stability of Rainforest Margins in Indonesia (STORMA). STORMA Discussion Paper Series No. 1: Universities of Göttingen and Kassel, Germany and Institut Pertanian Bogor and Universitas Tadulako, Indonesia.

Zeller, M., M. Sharma, C. Henry, and C. Lapenu. 2006. An operational method for assessing the poverty Outreach performance of development policies and projects: Results of case studies in Africa, Asia, and Latin America. *World Development* 34 (3):446-464.