Discussion Paper No. 02/2008

Payments for Environmental Services - Incentives through Carbon Sequestration Compensation for Cocoa-based Agroforestry Systems in Central Sulawesi, Indonesia

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Forschung zur Entwicklungsökonomie und -politik
Research in Development Economics and Policy

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Department of Agricultural Economics and Social Sciences in the Tropics and Subtropics (Ed.), Forschung zur Entwicklungsökonomie und –politik Research in Development Economics and Policy, Discussion Paper No. 02/2008.

ISSN 1439-4952

Printed in Germany.
Druck: F. u. T. Müllerbader GmbH
Forststr. 18, 70794 Filderstadt, Germany

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Discussion papers in this series are intended to stimulate discussion among researchers, practitioners and policy makers. The papers mostly reflect work in progress. The discussion papers have been reviewed by at least two reviewers.

This paper has been reviewed by Dr. Andreas Neef and Dr. Oliver Frör, both from the University of Hohenheim. The authors would also like to thank Professor Dr. Stephan von Cramon-Taubadel of the Georg-August-University Göttingen who provided constructive feedback and very helpful comments on earlier drafts of this paper. The authors gratefully acknowledge the financial support for the research by the German Research Foundation (DFG) through the Special Research Program (SFB 552) titled *Stability of Tropical Rainforest Margins* (www.storma.de).

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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 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. 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 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 shade free systems.

At the plot level, the payments from carbon sequestration are the highest for the full shade cocoa agroforestry system, but with low carbon prices of € 5 tCO_2e^{-1} these constitute 5 percent of the cocoa gross margin. Focusing on the household level, however, an increase of up to 18 percent of the total gross margin can be realised. Furthermore, for differentiated carbon prices up to € 32 tCO_2e^{-1} the majority of the households have an incentive to adopt the more sustainable shade intensive agroforestry system. 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 and land use systems with high environmental benefits are promoted.

Keywords: Payments for environmental services; carbon sequestration; agroforestry systems; cocoa, linear programming; economic incentives; poverty

Payments for Environmental Services -

Incentives through Carbon Sequestration Compensation for Cocoa-based Agroforestry Systems in Central Sulawesi, Indonesia

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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 emitters 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 (tCO_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 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 fully reflected by this figure. In the vicinity of the LLNP, a great spatial heterogeneity of

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[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.

[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).

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 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 and shade tree covered land use practices and contribute to the conservation of the rainforest margin. Additionally, we investigate whether these payments can provide a solution for the poor households to overcome their income constraints.

2. 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 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 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 (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 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 (Glenk et al. 2006). 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. 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 agroforestry systems and slow down the intensification process.

Another important phenomena 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 Kaili and Kulawi households. In many cases the local ethnic households had originally obtained this land by clearing primary forest on the border of the National Park (Sitorius 2002; Faust et al. 2003). They consider themselves to be the owner's of the village territory and do not see the necessity to buy land, but in turn realise 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 (Weber et al. 2007). In due course they are often in need for further land for their own cropping activities, since the majority of them are subsistence farmers, leading to additional encroachment at the forest margin of the National Park. In general, a social stratification can be detected between the economically better-off Bugis' households and the autochthonous households, who are predominantly poorer (Schippers et al. 2007).

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 and € 18.

Accordingly, we investigate whether current carbon credit prices are sufficient to induce farmers to adopt more sustainable land use practices and thus, also promote stable agricultural activities and hence the stability of the margin of the forest. The purpose of this paper is to provide an insight into whether environmental service payment schemes could have an impact on land use changes. Specifically, we determine which level of incentives would be necessary to encourage a shift towards land use practices, which in the long run provide higher environmental benefits and an elevated ecosystem functioning and thus, contribute to the conservation of the rainforest margin.

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 (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 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 (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. The major characteristics are presented in Table 1 in order to indicate the differences between them.

Table 1. Characteristics of household classes I – IV

	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 (Zeller et al. 2006) 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}. This corroborates the findings of Schippers et al . (2007) of the economic marginalisation of the local households, who are much poorer in comparison to the migrant Bugis. These tend to be found in the highest income groups, again a result mirrored by findings of Weber at al. (2007) and own the more intensively managed cocoa agroforestry systems.

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 (highest R^2 value of 0.76). The biomass can then be converted to carbon using a conversion factor of 0.5 g of carbon respectively for 1 g 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, 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

[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.

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. Once the tCER are not re-certified, a permanent solution is needed to fulfil the reduction requirements. 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 (Dutschke and Schlamadinger 2003; Olschewski and Benitez 2005). 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 system. 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. (1996) 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 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:

$$P_{tCER\ 0} = P_{CER\ 0} - \frac{P_{CER\ T}}{(1 + d^*)^T} \tag{1}$$

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 (Subak 2003).

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 (Deutsche Bundesbank 2007). 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.

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

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 (Bank Indonesia 2006), and the time span is 25 years. Finally the annuity factor is multiplied by the net present value to obtain the annuity.

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

4. Results and Discussion

4.1. Carbon sequestration potential

At the plot level, the results indicate that summing up all credits, the most shade intensive AFS system I produces 202 tCER ha^{-1} in a 25 year project. This declines for the AFS systems II, III, resulting in 191 and 185 tCER ha^{-1}, respectively, and for the AFS IV an issuance of 192 tCER ha^{-1} occurs. The resulting payments for carbon sequestration in turn depend then on 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 (Capoor and Ambrosi 2007).

Table 2. Annuity payments for different prices of CER

	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

d = discount rate

With low carbon credit prices of € 5 tCO_2e^{-1}, the resulting annuity payments constitute 5 percent of the cocoa gross margin for the high shade AFS (€ 100 ha^{-1}), and less than 1 percent of the fully sun grown AFS cocoa gross margin (€ 1,460 ha^{-1}). 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 agroforestry systems is very small, as the net carbon accumulation is similar between all four systems. 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 a survey conducted in 80 of the 119 villages in the research area 20,590 hectares were used for cocoa plantations in 2007. 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 agroforestry systems 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 (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 agroforestry system 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 agroforestry system. 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.

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

	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

4.3. Impact of changing prices of carbon and cocoa

The baseline model was compared with different scenarios which included the payments for carbon sequestration of the agroforestry systems. The impact of changing carbon credit prices is assessed with a constant discount rate of 10 percent in the LPM (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.

In January 2008, the world market FOB cocoa prices were at 2,194 US$ per tonne (ICCO 2008). In general, there is a great price volatility to be observed on the cocoa market, as prices respond to supply and demand factors. In the 1970s prices experienced an important increase, after very low prices in the 1960s which encouraged production in Indonesia and Malaysia. In the 1980s prices declined again and even though they modestly recovered in the mid 1990s, they were still low at the turn of the century and only started to increase again in the last few years. During the time of the survey in 2006, prices were about 1,550 US$ per tonne. The lowest price was observed in 2001, when prices were at 960 US$ per tonne (ICCO 2008). 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 of 960 US$ per tonne, a carbon credit payment of € 12 tCO_2e^{-1} 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 agroforestry systems 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 evaluate whether carbon credits could be used as an incentive for the farmers if the credits are targeted only towards the two more shade intensive agroforestry systems, which have a higher biodiversity and are more sustainable in the long run. Hence, using the reduced costs derived from the LP model or opportunity costs of the different cocoa agroforestry 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 the minimum credit price at which the household types would adopt the full shade AFS I or the slightly less shaded AFS II to slow down the intensification trends is determined. The results indicate that household I needs a credit price of € 14 to adopt more (0.12 ha) of the AFS I, household II is stimulated to shift more (0.34 ha) towards the AFS II with credit prices of € 27 and household III adopts more AFS II (0.09ha) 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.

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. This trend is not sustainable in the long run, as the soil productivity declines and species-richness is reduced. 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, but in general hardly differ between the systems. Depending on the certificate prices, a farmer could obtain between € 6 and € 28 per hectare for the carbon sequestration of the cocoa agroforestry system. With low certificate prices of € 5 tCO_2e^{-1}, the additional remuneration for the cocoa 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, they 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. Therefore, the importance of the carbon payments is not so much the absolute impact itself, but more importantly which household type derives more benefit. If the payments were specifically targeted towards the high-shade agroforestry systems, indirectly the poorer households from the local ethnic group would benefit. In turn, this additional income could reduce their need to sell their land to the migrants and open up further forest land at the margin or sometimes even inside of the Lore Lindu National Park.

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.

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. However, the economically better off households need extremely high credit prices to change their land use practices from the highly intensive managed agroforestry systems towards the shade intensive agroforestry systems. 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, in the long run these systems will not be sustainable and experience a decline in yields due to anticipated agronomic risks such as declining soil fertility.

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 a switch in 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 which provide higher biodiversity values and ecosystem functioning, 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 poorest households seem to benefit relatively more than the better off from carbon payments. It seems as if win-win situations are possible, where with carbon payments environmentally more sustainable land uses systems are promoted and poverty can be reduced.

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