

Carbon finance options for smallholders' agroforestry in Indonesia

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Abstract: Up to 25 percent of all anthropogenic greenhouse gas emissions are caused by deforestation, and Indonesia is the third largest 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 cacao 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 are used as a tool for policy analysis, the output can indicate the adjustments in resource allocation and land use shifts when introducing compensation payments.

The data were 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 for inducing the adoption of more sustainable land use practices are the highest for the full shade cacao agroforestry system, but with low carbon prices of €5 tCO₂e⁻¹ these constitute 5 percent of the cacao 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 tCO₂e⁻¹ 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: Avoided deforestation, cacao, carbon sequestration, economic incentives, linear programming, Lore Lindu National Park, payments for environmental services

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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). Indonesia has the second highest annual net loss in forest area worldwide. Between 2000 and 2005 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 et al. 2002). The majority of deforestation incidences are 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 Kyoto Protocol, forestry activities, or so-called carbon sink projects¹ 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 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 (CO₂e) which means that the climate change potential of each greenhouse gas is expressed as an equivalent of the climate change potential of CO₂ (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. Especially the forest-rich countries, such as Brazil and Indonesia, are pushing for a 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

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

² The terms certificates, carbon credits and CER are used interchangeably. One credit is the equivalent of one tonne of CO₂ 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. The CERs can be used by Annex I countries to help meet their emission targets (FAO 2004).

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, cacao plantations under shade trees cannot be detected by optical satellite instruments, thus the encroachment process at the forest margin is not fully reflected by this figure. In the vicinity of the LLNP a great spatial heterogeneity of agricultural production is apparent. In general, human activities are much more concentrated in the northern and western part of the park than in the south. In the north-east the closed forest decreased by 35 percent between 2001 and 2004 due to logging, whereas the area covered by cacao plantations increased by 11 percent (Rohwer 2006). In addition, an intensification process among the cacao 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.

2. Framework

The research is motivated by the need to understand which level of incentives is required 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 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. 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.

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 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 cacao AFS can be distinguished according to the species type of shade trees and their canopy cover proportion, as well as the management intensity: AFS I exhibits a high degree of shading with natural forest trees with a canopy cover above 85 percent and they are managed with very few agricultural inputs; AFS II is shaded by a diverse spectrum of planted trees and naturally grown after clear-cutting, it has a shade cover of approximately 66–85 percent; AFS III exhibits a low density of a shade tree layer, which is dominated by the non-indigenous leguminous trees *Gliricida sepium* and *Erythrina subumbrans*, with a canopy cover between 36–65 percent; finally, the AFS IV has very few to no shade trees (5–35 percent shade canopy cover) and is intensively managed. The forest and the cacao agroforestry systems provide a variety of goods and services such as non-timber forest products, watershed and pollination services (Priess et al. 2007). The gross margins of cacao consistently increase along the cacao AFS gradient from I towards IV. There seems to be a trade-off situation between an intensification of the cacao cultivation with shade free plantations and higher economic returns and shade-grown, low intensity management cacao with lower returns and biodiversity conservation. Even though the cacao grown in full sun has higher mean yields and obtains substantially higher gross margin values in comparison with shade grown cacao, in the long run the intensification is likely to be ecologically unsustainable. Results from studies show that tree crops which are grown in shaded systems tend to maintain productivity in the long run and are less susceptible to insect and disease losses than full-sun monocultures (Belsky and Siebert 2002; Young 1989). Reducing shade often implies an increase in yields, but increases physiological stress, the susceptibility to pests and diseases and thus, the amount of inputs required (Y. Clough, personal communication). Previous research in the same region indicates that shaded AFSs provide high biodiversity values and habitat for the native fauna, whereas completely shade free systems harbour significantly lower species richness (Schulze et al. 2004). Similarly, studies with other perennial crops indicate that at the transition from shaded agroforestry systems to intensively managed shade free monocultures, a major loss of overall biodiversity occurs (Perfecto et al. 1996). The species-richness of plants, animals and ecosystem functioning of the AFS was assessed in a multi-disciplinary study by (Steffan-Dewenter et al. 2007). They did not discover a linear gradient of biodiversity and ecosystem functioning loss from the first to the third AFS, but deduced that the complete reduction of shade trees as a consequence of the land use intensification is an ecologically unsustainable path and results in disproportionate ecological losses in the long run. Unfortunately, the intensification 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. Also for organic cocoa producers receive a higher price which ranges between €75 to 225 per tonne (ICCO 2007). Alternatives could also be price premiums offered through carbon certificates to provide an incentive for the more shade grown, biodiversity rich and sustainable cacao AFS and slow down the intensification process.

An important phenomenon in the region is that many Bugi households settled in the 1990s from South Sulawesi and Poso into the research area and started to buy land from the local Kaili households. In many cases the local ethnic households had originally obtained this land by clearing primary forest on the border of the National Park (Faust et al. 2003). They consider themselves to be the owners 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 provokes a vicious cycle, because after a while the local households spend the income gained through the land sales on ceremonial purposes or status symbols. In due course, when they are short of money again, they convert further forest to satisfy their financial needs.

Incentive-based schemes have become very common during the last decade, and throughout the world hundreds of new and very elaborate PES initiatives have been implemented. For example, in Costa Rica the National Fund for Forest Financing 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. In Asia one of the most prominent programmes is RUPES (Rewarding the Upland Poor for Ecosystem Services). In one of these projects in Indonesia farmers are assisted to obtain conditional land tenure in exchange for adopting mixed agroforestry systems that increase erosion control and biodiversity (Jack et al. 2007). For avoided deforestation projects the main sources of funding are from voluntary sources, but also the World Bank provides through its newly established Forest Carbon Partnership Facility additional financial resources.

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 Antle et al. (2007), Olschweski and Benítez (2005) and Pattanayak (2004). The challenge, 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 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 €5 up to €21.50 per tCO₂e, with an average of €10.90 (Capoor and Ambrosi 2007).

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; Bertomeu et al. 2006; Mudhara et al. 2003). Linear programming has been used by several authors as a method for studying the impact of policy activities (Vosti et al. 2002), such as in this case carbon payments. 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. While one has to be aware of these problems, for the purpose of this research linear programming has been considered an appropriate method. 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 time dimensions are not included in the model. 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 cacao tree cannot be clearly separated from other activities necessary for the already productive trees on the cacao plots. As the farmer has information about alternative production activities and input and output prices, risk does not need to be accounted for (Vosti et al. 2002). In another study in the same region which focused on smallholder cacao farmers' technology adoption, application and optimisation, the same conditions apply and similar assumptions were used for the linear programming model (Taher 1996). In Appendix I the linear programming model for Household II is depicted.⁴

3.2. Farm household types

The data on the existing agricultural production systems for the model were collected in a household survey in the surroundings of the LLNP in 2006. We categorised the households according to the dominant AFS among their cacao plots, and determined four corresponding household types (HH_I – HH_{IV}). A random sample of 46 households in six villages was drawn from the total sample of 325 households in 13 villages from the research project. These had been randomly selected based on a stratified sampling method for a household survey in 2001 and 2004. For the specific sampling procedure see (Zeller et al. 2002). The survey at hand focused on general aspects of the household and farm characteristics, land resources and their use, agricultural production activities, and forest usage. The four household types have different resource endowments, such as land and labour availability and credit limit. The major characteristics are presented in Table 1 to indicate the differences between them.

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 cacao AFS I. Mainly the indigenous 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 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 and land availability they adopt a more intensive production system in comparison to the other household types. With the help of a poverty assessment

⁴ Interested readers can contact the authors for further LP models and base data.

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
Rice (ha)	0.18	0.18	0.10	0.13
Maize (ha)	0	0.012	0.012	0.38
Cacao AFS I (ha)	1.49	0.24	0	0
Cacao AFS II (ha)	0.77	1.31	1.09	0.33
Cacao AFS III (ha)	0.25	1.16	1.73	0
Cacao 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
Poverty status	Poorest	Poor	Poor	Better-off

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 poverty index allows grouping 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 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 cacao trees, a logarithmic growth regression model was adopted. 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 cacao 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 exist. Due to lack of data, the calculation for carbon accumulation in soils is assumed to occur linearly in time.⁵ All carbon measurements for above-,

⁵ 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.

below-ground and soil carbon were added up to obtain an estimate of the total carbon per hectare of the cacao trees. Finally, this amount was converted to CO₂e, which is the basis to calculate the amount of certificates to be obtained for the different agroforestry systems.

According to the Kyoto protocol, all credits from sink projects have a temporary status and expire after a certain time. Only trees which are planted at the beginning of the crediting period can be assigned temporary certificates of emission reductions (tCER). A tCER is defined as a CER issued for an afforestation project activity under the CDM, which expires at the end of the commitment period following the one in which it is issued (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 cacao 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 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 AFS 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 CO₂ 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:

$$P_{\text{tCER}_0} = P_{\text{CER}_0} \frac{P_{\text{CER}_T}}{(1+d^*)^T} \quad (1)$$

where P is the price, CER₀ 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 ($p_{\text{CER}_0} = p_{\text{CER}_T}$), and a three percent discount rate (d^*) is taken, which reflects the current low real 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.

$$\sum t\text{CER} \cdot (1+d)^{-T} = \frac{(\text{net CO}_2 \text{ storage})_5}{(1+d)^5} + \frac{(\text{net CO}_2 \text{ storage})_{10}}{(1+d)^{10}} + \dots + \frac{(\text{net CO}_2 \text{ storage})_{25}}{(1+d)^{25}} \quad (2)$$

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

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

4. Results

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 cacao plantation IV ($67 \text{ tCO}_2\text{e ha}^{-1}$) in a 25 year project. The two other agroforestry systems II and III accumulate 64 and 62 $\text{tCO}_2\text{e ha}^{-1}$, 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 $\text{€}5 \text{ tCO}_2\text{e}^{-1}$ is comparable to the lowest traded medium-risk CER price, whereas $\text{€}25 \text{ tCO}_2\text{e}^{-1}$ at the other end represents the trading prices in the European Climate Exchange for 2008–10 carbon allowances in May 2007.

Table 2: Annuity payments for different prices of CER.

Annuity payments € ha ⁻¹	Agroforestry system			
	I	II	III	IV
d 10%, CER €5 tCO ₂ e ⁻¹	5.54	5.18	5.00	5.09
d 10%, CER €12 tCO ₂ e ⁻¹	13.30	12.40	12.00	12.20
d 10%, CER €25 tCO ₂ e ⁻¹	27.70	25.90	25.00	25.50

With low carbon credit prices of €5 tCO₂e⁻¹, the resulting annuity payments constitute 5 percent of the cacao gross margin for the high shade AFS (€100 ha⁻¹), and <1 percent of the fully sun grown AFS cacao gross margin (€1,460 ha⁻¹). At carbon credit prices of €25 tCO₂e⁻¹, the payments amount to 28 and 2 percent of the respective cacao 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 cacao trees are more densely planted in comparison to the other three shaded systems.

In a village survey conducted in 80 of the 119 villages in the research area 20,590 hectares were used for cacao plantations in 2007. Approximately 1 percent of this area was planted with the AFS type I, 31 percent with AFS II, 60 percent with AFS III and 8 percent with AFS IV (S. Reetz, personal communication). Thus, if a carbon sequestration project were to be implemented in this region, the approximate carbon offset potential of the cacao AFS would be 1,300,000 tCO₂e⁻¹, amounting to 3,855,699 tCER in 25 years. At low carbon prices of €5 tCO₂e⁻¹ this would amount to an annuity payment of €104,000, at a price of €12 tCO₂e⁻¹ to €250,000 and at €25 tCO₂e⁻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 above, the cacao gross margins increase in profitability when moving along the cacao 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 cacao plot borders the forest and they also grow a variety of other tree crops on the same plot. Some farmers also are of the opinion 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

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

Total gross margin (€ yr ⁻¹)	Household class			
	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	1,393	2,756

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.

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 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. When comparing the baseline situation with the different payments the total gross margin increases by 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 I receives the highest additional payments for all three CER prices, and the amounts gradually decline for HH_{II}, HH_{III} 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 cacao 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 €1,755 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 €1,240 per tonne. The lowest price was observed in 2001, when prices were at €768 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 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 to 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 higher biodiversity and are more sustainable in the long run. Hence, using the reduced costs or opportunity costs of the different cacao 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 €32 tCO₂e⁻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 tCO₂e⁻¹ to provide a sufficient incentive to adopt more of the less intensive cacao 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 uptake⁶ through avoided deforestation are 11 times higher than for plantations, regeneration and agroforestry together.

The discussion on reducing emissions from deforestation and forest degradation (REDD) usually focuses on the national level. Yet incentives can also be

⁶ 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.

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 substantial differences between household types. 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 $435 \text{ tCO}_2\text{e ha}^{-1}$ (M. Kessler, personal communication). Under the assumption that the current deforestation rate of 0.3 percent is reduced to 0, annual emissions of $13 \text{ tCO}_2\text{e ha}^{-1}$ could be avoided. Depending on the prices paid for avoided emissions from deforestation, payments between €65 and €326 per hectare could arise⁷ (see Table 4). Different scenarios are calculated with a safety margin of a 25 percent lower and a 10 percent higher CO_2e content of the forest, as it is not homogeneous over the entire Park area.

If the prices paid for every ton of CO_2e avoided are €12, the evolving payments are sufficiently high enough to provide an incentive for the household types I and II to stop forest conversion activities. If the prices were increased to €25 $\text{tCO}_2\text{e}^{-1}$ avoided, even the household type III – who needs a compensation of €300 per hectare – could be stimulated to desist from further tree cutting. Household type I – which only cuts down a few original forest trees and sets seedlings under the remaining shade trees – obtains a much lower cacao gross margin and, hence, needs

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

		Scenarios of different CO_2e contents		
		Low	Middle	High
Carbon content LLNP	$\text{t CO}_2\text{e ha}^{-1}$	326	435	479
Annual emissions avoided (deforestation rate reduced from 0.3% to 0)	$\text{t CO}_2\text{e ha}^{-1}$	13	17	19
Payments for different prices per tCO_2e avoided				
5 € $\text{tCO}_2\text{e}^{-1}$	€ ha^{-1}	49	65	72
12 € $\text{tCO}_2\text{e}^{-1}$	€ ha^{-1}	117	157	172
25 € $\text{tCO}_2\text{e}^{-1}$	€ ha^{-1}	245	326	359

⁷ Transaction costs are not considered, their inclusion would reduce the evolving payments.

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 cacao. The need for these very high compensation payments arises through the opportunity costs of not converting forest which is the cacao gross margin.

As mentioned above, many of the local households are the drivers of the encroachment at the forest margin, selling the land to the newcomers who tend to have more intensively managed cacao 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 be provided to stop this vicious circle of forest conversion.

5. Discussion

In the specific context of the Lore Lindu National Park in Central Sulawesi in Indonesia, the intensification process among the cacao 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 cacao 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 cacao AFS. With low certificate prices of €5 tCO₂e⁻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 cacao. 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 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 cacao agroforestry systems. Thus, carbon payments seem to have a positive impact on the income derived from cropping activities for the households which are the least well endowed with financial resources. The payments may additionally reduce the need of poor indigenous households to open up further land at the forest border and sell their land to the migrants.

On a regional scale for the research area there is a carbon offset potential of 1,300,000 tCO₂e from all cacao 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 and €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 removal by sinks of <16,000 tCO₂e, 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 cacao plantations is planted with the full shade cacao (264

hectares), and they would only need to gather a total area of their shade intensive cacao 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. 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 is due to the fact that the fully sun grown cacao 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 be not be sustainable and are likely to experience a decline in yields due to anticipated agronomic risks such as declining soil fertility.

6. Conclusion

If carbon payments are applied in general to all agroforestry systems there will not be such a great impact in terms of a contribution to environmental services. 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 AFS. We conclude 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.

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Appendix I

Linear programming model household type II.

Activities	Sawah Padi ladang	Maize	Cacao I	Cacao II	Cacao III	Cacao IV	Cacao I new	Cacao II new	Cacao III new	Cacao IV new	Forest Cacao I	Forest Cacao II	Forest Cacao III	Forest Cacao IV	Hired Labour	RHS
Objective values (GM 000 IDR/ha)	4,310	1,446	1,188	1,453	4,488	8,696	7,009	1,453	4,478	8,666	6,989	66	87	153	197	-437
Constraints																
Land (ha)																
January	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.74≤2.81
February	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.74≤2.81
March	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.81≤2.81
April	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.58≤2.81
May	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.58≤2.81
June	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.58≤2.81
July	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.69≤2.81
August	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.81≤2.81
September	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.81≤2.81
October	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.81≤2.81
November	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.81≤2.81
December	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	2.74≤2.81
Forest Conversion Cacao I											1	-1	-1	-1		0.00≥0.00
Forest Conversion Cacao II				1												0.00≥0.00
Forest Conversion Cacao III					1					1						0.77≥0.00

Appendix I: (Continued)

Activities	Sawah	Padi ladang	Maize	Cacao I	Cacao II	Cacao III	Cacao IV	Cacao I new	Cacao II new	Cacao III new	Cacao IV new	Forest to Cacao I	Forest to Cacao II	Forest to Cacao III	Forest to Cacao IV	Hired Labour	RHS
Labour (mandays per month)																	
January	21.33	16.00	3.50	4.75	9.50	10.45	3.50	5.17	10.75	11.28	1.25	1.67	2.92	3.75	-1	13.74≤29.50	
February	24.93	16.00	11.00	4.75	7.50	9.35	11.00	5.17	8.75	10.18	1.25	1.67	2.92	3.75	-1	10.70≤29.50	
March	42.68	40.40	9.12	4.75	14.20	9.35	9.12	5.17	15.45	10.18	1.25	1.67	2.92	3.75	-1	29.50≤29.50	
April	1.33		4.50	5.25	14.20	10.45	4.50	5.67	15.45	11.28	1.25	1.67	2.92	3.75	-1	13.18≤29.50	
May	9.34		5.40	14.15	7.50	17.95	5.40	14.57	8.75	18.78	1.25	1.67	2.92	3.75	-1	22.12≤29.50	
June	14.00		1.84	14.15	9.45	9.35	1.84	14.57	10.70	10.18	1.25	1.67	2.92	3.75	-1	9.03≤29.50	
July	42.78		10.50	11.75	10.40	9.35	10.50	12.17	11.65	10.18	1.25	1.67	2.92	3.75	-1	12.79≤29.50	
August	19.01	56.40	13.40	4.75	7.50	10.20	13.40	5.17	8.75	11.03	1.25	1.67	2.92	3.75	-1	17.97≤29.50	
September	11.34	44.87	16.00	3.67	4.75	14.20	9.90	3.67	5.17	10.73	1.25	1.67	2.92	3.75	-1	19.91≤29.50	
October	0.89	45.33	16.00	4.50	4.75	14.20	9.35	4.50	5.17	15.45	1.25	1.67	2.92	3.75	-1	18.27≤29.50	
November	23.56	56.00	16.00	4.00	14.15	7.50	16.85	4.00	14.57	17.68	1.25	1.67	2.92	3.75	-1	29.50≤29.50	
December	10.67	16.00	4.67	9.75	9.93	11.30	4.67	10.17	11.18	12.13	1.25	1.67	2.92	3.75	-1	14.62≤29.50	
Capital (miscellaneous costs VC/ha 000IDR)	4,527	345	140	0	1,226	171	311	0	1,236	201	331	30	40	70	90	437	8,296≤8,296
Solution	0.07	0.11	0.12	0.00	0.06	0.77	1.74	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	16.41	12,578

Sawah=Paddy rice; Padi ladang=Upland rice; VC=Variable costs; ha=hectare; RHS=Right-hand-side.