Incentive mechanisms for a sustainable use system of the montane rain forest in Ethiopia

Inaugural-Dissertation
zur Erlangung des akademischen Grades eines Doktors
der Wirtschafts- und Sozialwissenschaften
der Wirtschafts- und Sozialwissenschaftlichen Fakultät
der Christian Albrechts Universität zu Kiel

vorgelegt von
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Berlin, 2006

Acknowledgements

I wish to thank Till Requate for his support and patience during the last 3 1/2 years. My thanks also go to Detlef Virchow, who took me on the coffee project, Eva Camacho, who coauthored chapter 4, and Zacharias, Mengistu, Tilahun, Andinet, Bedilehu, and Kassahun for their help and kindness in the field.

To Martin

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Chapter 1

General Introduction

1.1 Research Focus

Biodiversity is a vital but poorly appreciated resource for all of humankind that underpins the achievement of the Millennium Development Goals.[1] Biodiversity represents the foundation of ecosystems that, through the services they provide, affect human well-being. These include provisioning services such as food, water, timber, and fiber; regulating services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfillment; and supporting services such as soil formation, photosynthesis, and nutrient cycling. The relationship between biodiversity and supporting ecosystem services depends on composition, relative abundance, functional diversity, and, to a lesser extent, taxonomic diversity. If multiple dimensions of biodiversity are driven to very low levels, both the level and stability of services may decrease. In 2000 the United Nations Secretary-General Kofi Annan called for The Millennium Ecosystem Assessment (MEA). The objective of the MEA was to assess the consequences of ecosystem change for human well-being and the scientific basis for actions needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MEA has involved the work of more than 1,360 experts worldwide. They come to the conclusion that, unless, the rate of loss of biodiver-

[1] At the Millennium Summit in September 2000, the states of the United Nations reaffirmed their commitment to working toward a world in which eliminating poverty and sustaining development would have the highest priority. The Millennium Development Goals have been commonly accepted as a framework for measuring development progress. Among them are: Eradicate extreme poverty and hunger, reduce child mortality, improve maternal health, and ensure environmental sustainability.

sity and the resulting degradation of ecosystem services are significantly reduced, efforts to combat poverty, reduce hunger, and provide clean water and a healthy environment will be undermined (MEA [2005]).

However, there exist trade-offs between biodiversity conservation and economic gains. More economic development often means less biodiversity. Take the construction of a road. One of the main problems in Africa is mobility. A new road provides access to markets, schools and clinics. The negative side effects are often the fragmentation of habitats and pollution. Another prominent example for trade-offs is tropical deforestation for logging and farming. It is responsible for a large part of species extinction worldwide (Pearce et al. [2003]).

Especially with respect to forest biodiversity conservation and poverty alleviation there has been an intensive search for synergies and win-win options. Lee and Barret [2001] discuss whether the intensification of agriculture can lessen the pressure on tropical forests and simultaneously increase rural incomes. Other contributions investigate the potential of agro-forestry systems to combine environmental objectives with the aspirations of local communities (Collins and Qualset [1998], Buck et al. [1998]). Pearce et al. [2003] highlight the role sustainable forest management can play in maintaining forests and biodiversity. A number of cases study the role of non-timber forest products for household incomes and their potential to lift households out of poverty (Shanley et al. [2002], Byron and Arnold [1999]). Pointing to experiences in Latin America Wunder [2001] concludes that the prospects for synergies are rather bleak.

Proponents of direct payments for environmental services recognize existing trade-offs and seek to reconcile conflicting interests through compensations. The underlying idea of paying for environmental services has been globally adopted by various initiatives. As a result the term Payments for Environmental Services (PES) has evolved which denotes a distinct class of market-based conservation approaches. With respect to poverty Wunder [2005] and Pagiola et al. [2005] find that the question in how far PES can contribute to poverty alleviation has not been sufficiently answered.

Sunderlin et al. [2005] summarize theory and evidence concerning two questions: To what extent can forests be relied on to support poverty alleviation in developing countries? Can the use of forests for poverty alleviation be compatible with conservation efforts? With respect to the first question they emphasize that forests play an important role in mitigating extreme poverty by providing essential services, like medicinal plants and food, especially in remote areas. Their role in lifting people out of poverty is, however, less clear and depends on enabling conditions, like markets for environmental services and non-timber forest products. With respect to the second question they conclude that more site level research is needed which is integrated with a society-wide view. Chapter 2 of this dissertation will provide an answer to both questions for the case of Ethiopia.

Ethiopia is a particularly interesting example as it involves a biological diversity which is of local and global importance, an alarming rate of deforestation, and a high level of poverty. Most of the highlands in South-west Ethiopia are covered by cloud forests, but these are being removed at a rate of 8% per year. This loss is of global importance because the East-African Mountains belong to the most biological diverse regions in the world. In order to prevent further deforestation and conversion into arable land an initiative of the Ethiopian government and the European Commission has transformed the cloud forests into protected parks. This initiative conflicts with the interest of the local communities. Half of their territory is covered by forest, which is used for the production of semi-forest coffee. The collection of non-timber forest products and fuel wood generates additional income and provides a safety net for the extremely poor. The people living around the forests are subsistence farmers. Arable land is scarce and farmers are sometimes forced to expand their agricultural fields into the forest.

Chapter 2 describes and compares the local, national, and global perspective. Based on these results it is shown in how far the forests can support poverty alleviation and whether such a process is compatible with biodiversity conservation.

The Millennium Ecosystem Assessment does not only assess the degradation of ecosystem services and their impact on humanity, it also gives some policy advice. It lists a whole portfolio of actions which can be taken, for instance the protection of sensitive areas, direct Payments for Environmental Services, and initiatives which try to combine economic development with conservation like the sustainable intensification of agriculture. Obviously no blueprint does exist. The main recommendation that flows from the MEA is that the conservation and use of biodiversity have to be integrated into social, economic, institutional and legal frameworks. Key elements of any policy for biodiversity conservation and use are regulation, an appropriate set of property rights, and a supporting structure of economic incentives and disincentives. The optimal design of incentive mechanisms is the topic of chapters 3 and 4. Chapter 3 investigates the design of contracts in PES, while chapter 4 compares different enforcement mechanisms.

1.2 Research Design and Main Findings

This research is embedded into a German-Ethiopian research project called "Conservation and use of the last wild populations of Coffea Arabica in South-West Ethiopia". Its main objective is to develop a conservation and use system for the wild populations of coffee Arabica which are growing in the montane rainforest in Ethiopia. Among the cooperating partners are universities in Germany and Ethiopia, Ministries and Non-Governmental Organizations in Ethiopia[2]. Due to the support from the Ethiopian partners the author was provided access to information and data, which, most likely, would have been denied otherwise. In order to gather this information and data the author spent 12 months of field research in Ethiopia in 2003 and 2004. At the end of the research project the Ethiopian partners will ensure that the results are made available to those concerned.

The project combines sub-projects from natural science, social science and economics. Especially chapter 2 and 4 benefited greatly from the results of the other sub-projects.

Chapter 2 compares three different use systems for the Ethiopian forest: conversion into arable land, sustainable use of the forest with production of semi-forest coffee, and strict conservation of the forest as currently directed by the Ethiopian government. First it calculates the income associated with each of the three alternatives in order to illustrate the private financial incentives faced by the local communities. Then a cost-benefit analysis of the three alternative use systems is conducted, taking into consideration national and global values.

It turns out that the private incentive structure is leading towards further deforestation. In contrast, the cost-benefit analysis suggests that the management of the forest with production of forest coffee is the most beneficial land use option for Ethiopia, even if international transfers for the production of global public goods are not included. Finally, the financial and economic results are brought together. This allows to discuss whether a price premium for biodiversity-friendly forest coffee can reconcile private and social benefits

[2]For a complete list of partners, objectives, methods and outputs of the project see www.coffee.uni-bonn.de. The research project is funded by the German Ministry for Education and Research.

of conservation. Price premia for environment-friendly products represent transfers from environmentally-minded consumers to producers such that social benefits are factored into individual decision making. They can be classified as PES mechanisms.

The third chapter resumes the discussion of direct payments from a different perspective. Building on contract theory and case studies chapter 3 presents a general characterization of existing PES schemes and reveals common pitfalls for their success. The theoretical analysis builds on earlier research on voluntary incentive designs. As an innovation ecological characteristics of different ecosystem services are integrated into the model. The theoretical analysis then identifies characteristic differences between the schemes aiming at watershed protection, biodiversity conservation, or carbon sequestration.

The analysis further gains by the inclusion of multiple agents as compared to the standard principle agent model used in previous studies. It highlights the importance of synergies in biodiversity schemes and the benefits of effort coordination among farmers.

Finally theoretical results are compared with practical experiences. It turns out that the main problems of PES schemes are the difficulty to technically detect and measure the desired services and the pursuit of side objectives linked to the schemes.

In contrast to the voluntary character of the PES schemes dealt with in the previous chapter chapter 4 tackles the optimal design of a regulatory scheme. The forest in Southwest Ethiopia is a quasi open-access common pool resource. The lack of a functioning system to regulate access and use has contributed to the already high rates of deforestation and biodiversity loss.

By conducting a framed field experiment chapter 4 tests different mechanisms suggested by the theoretical economic literature to mitigate the problem of over-exploitation when individual users cannot be observed. They are based on the deviation of the observed total consumption of a resource from a level considered socially optimal. If the observed consumption level exceeds the optimal level a collective punishment mechanism is triggered. The subject pool consists of Ethiopian farmers.

Unlike the subjects in earlier laboratory experiments on collective enforcement mechanisms the farmers have a common history. Therefore the analysis does not only compare the decisions with the theoretical benchmark given by non-cooperative game theory, but also takes into consideration the group context and individual effects. In the results the positive influence of group cohesion on the aggregate outcomes becomes clearly visible. In general, the effectiveness of the enforcement mechanisms is remarkable. A more detailed analysis of individual behavior, however, reveals the undesirable effects of asymmetric equilibria on equity.

Chapter 5 provides a general conclusion.

Chapter 2

A Sustainable Use System of the Montane Rain Forest in Ethiopia

2.1 Introduction

Most of the highlands in South-west Ethiopia are still covered by cloud forests, but these are being removed at an alarming rate of 8% per year (FAO [b]). This loss is of global importance as the East-African Mountains belong to the most biological diverse regions in the world. Cloud forests in general are concentrations of biodiversity with high levels of endemism. The cloud forests in Ethiopia give habitat to the last wild populations of Coffee Arabica. Coffee Arabica originates from Ethiopia and these wild plants represent its genetic base. During the 13^{th} century a few trees were extracted to Yemen which thereupon spread out across the globe. Consequently, the genetic make-up of the coffee plants growing on plantations in other coffee producing countries is very similar. This renders them vulnerable to new pests and diseases. In contrast, the populations growing in Ethiopia's cloud forest are characterized by a high genetic diversity due to the evolutionary processes which have been taking place for centuries. The information contained in the wild coffee genes is therefore a valuable resource for breeding purposes.

In order to prevent further deforestation and conversion into arable land an initiative of the Ethiopian government and the European Commission has transformed the cloud forests into protected parks. This initiative conflicts with the interest of the local communities. Half of their territory is covered by forest. They use it for the production of semi-forest coffee. The collection of non-timber forest products and fuel wood generates additional income and provides a safety net for the extremely poor. The people living around the forests are subsistence farmers. Arable land is scarce and farmers are sometimes forced to expand their agricultural fields into the forest.

The situation described here is not unique to Ethiopia but similar developments can be observed in several Sub-Saharan countries. Perrings [2000] identifies as the main drivers of biodiversity loss the growth in demand induced by population expansion and economic growth; market and policy failure; and a distribution of assets that often leaves people with little choice but to use natural resources in an ecologically unsustainable way.

The literature on the environmental Kuznets curve suggests that environmental degradation displays an inverted-U shaped pattern over time. It is high in the course of economic development, and then decreases when income reaches a certain level and society places a higher value on the environment (Grossman and Krueger [1995]). The inference drawn from this relation is that economic growth may eventually take care of one of the main drivers of biodiversity loss.

A different view is that biodiversity conservation and use is an integral part and necessary for sustainable development. This strand of the literature searches for local win-win options and synergies between environmental conservation and poverty alleviation (Wunder [2001]). For instance, the potential of agro-forestry systems to combine environmental objectives with the aspirations of local communities has been discussed (Collins and Qualset [1998], Buck et al. [1998], Lee and Barret [2001]). Pearce et al. [2003] highlight the role sustainable forest management can play in maintaining forests and biodiversity. A number of case studies investigate the role of non-timber forest products for household incomes as well as the conditions for and impacts of their commercialization (Shanley et al. [2002], Byron and Arnold [1999]). It has been observed that income potential and successful commercialization of these products depend very much on the existence of appropriate infrastructure and access to skills and services (Ruiz-Pérez et al. [2004]).

Having recognized the financial incentives often leading to deforestation many institutions are looking for innovative ways to compensate local communities for their conservation efforts. Markets for environmental services are created where consumers pay premia for "green" products identified by eco-labels. In general, Payments for Environmental Services (PES) induce farmers to take into account the external environmental effects associated with their activities. With respect to poverty Wunder [2005] and Pagiola et al.

[2005] find that the question in how far PES can contribute to poverty alleviation has not been sufficiently answered.

Sunderlin et al. [2005] summarize theory and evidence concerning two questions: To what extent can forests be relied on to support poverty alleviation in developing countries? Can the use of forests for poverty alleviation be compatible with conservation efforts? With respect to the first question they emphasize that forests play an important role in mitigating extreme poverty by providing essential services, like medicinal plants and food, especially in remote areas. Their role in lifting people out of poverty is, however, less clear and depends on enabling conditions, like markets for environmental services and non-timber forest products. With respect to the second question they conclude that more site level research is needed which is integrated with a society-wide view. This study can be regarded as a contribution to fill this gap.

The objective is to analyze if the interests of the global community, the Ethiopian government and local farmers can be reconciled. Three competing use systems stand out as possible scenarios for the forest: conversion into arable land, sustainable use of the forest with production of semi-forest coffee, and strict conservation of the forest as currently directed by the Ethiopian government. We calculate the income associated with each of the three alternatives in order to illustrate the private financial incentives of the local communities. Then an economic analysis of the three alternative use systems is conducted, taking into consideration national and global values. Finally, bringing together the financial and economic results, we discuss the potential of a price premium for forest coffee to save the cloud forests and alleviate poverty.

The chapter is organized as follows. The next section describes the main characteristics of the three competing forest use systems. Section 2.3 presents the income analysis. The economic analysis is conducted in section 2.4. In section 2.5 we wrap up our results and present some policy conclusions.

2.2 The Competing Forest Use Systems

In the following we describe the three competing use systems: maize production, strict conservation of the forest as currently directed by the Ethiopian government, and the sustainable use of the forest with production of semi-forest coffee. Our study areas are the two districts of Sheko and Yayu (see table (I)). In preparation of this study primary and secondary data were collected in Yayu, Sheko and the capital of Ethiopia, Addis Ababa, in 2003 and 2004. The respective sources of data will be indicated in the text. A list of experts consulted in the course of the field research is given in the appendix. In Sheko and Yayu several experts from the local departments of agriculture and the administration were interviewed, and provided access to data. These sources will be indicated by "DoA".

2.2.1 Maize Production

Farmers in Yayu and Sheko practise low-input, rain fed subsistence farming. They cultivate on average 1.5 ha of land in Sheko and 1 ha in Yayu (DoA). 1 ha is the Ethiopian average size of land per household and is regarded as the absolute minimum to provide sufficient food for one household (Berhanu et al. [2002], p. 58). The current cultivation practices are considered ecologically unsustainable. Facing the rising population and being constrained by scarcity of arable land, farming communities follow mainly two coping strategies. They reduce fallow periods by cultivating continuously, and they put unsuitable land with steep slopes of up to 50% under cultivation. Only 10% of farmers use fertilizer. The result is serious land degradation with a high degree of soil erosion and nutrient mining. Associated annual productivity losses on croplands in the South-western highlands of Ethiopia are estimated to be 10% (Denboda [2005]).

To achieve an ecologically sustainable increase in production that would offset the population growth of 2.3% and the negative effects of land degradation farmers would have to intensify their land management and to adopt soil conservation measures. Intensification involves the application of fertilizer and improved seeds. The profitability of these new technologies is, however, severely constrained by imperfect input and output markets and

	Sheko	Yayu
Number of households	4,454	17,127
Number of villages	17	37
Total area	50,000 ha	163,000 ha
Total forest	25,042 ha	80,420 ha
Protected forest	9,025 ha	10,000 ha

Table I: The study areas Yayu and Sheko in 2003, source: DoA poorly developed infrastructure (Techane [2001], Demeke [2001]).

Conservation of the basis of production requires both biological and physical measures to prevent or at least significantly reduce soil erosion and land degradation. There exist, of course, concepts which are widely accepted among agricultural and development professionals but their dissemination among farmers is difficult. The main obstacle for sustainable land use is the ill defined allocation of property rights and the land tenure system in Ethiopia. According to the country's constitution, the ownership of land vests with the State and the people of Ethiopia. Private ownership and land markets are not allowed under the Ethiopian constitution. Instead, farmers are given use rights for land. Repeated land redistribution practices in the Ethiopian history have led to a high degree of insecurity among farmers concerning the tenure rights of their holdings. During a nation wide survey related to tenure rights and farmers' reactions, only 3.5% of the households believed that they can retain their current holdings for over 20 years whereas the overwhelming majority of households did not believe that their claim towards their existing holdings would last more than five years (Berhanu et al. [2002], table 19). This insecurity reduces the incentive to invest in the maintenance of land.[1] To take account of the two possible forms of maize production, the traditional and ecologically unsustainable way on the one hand, and the improved but rather unrealistic version on the other, we will calculate income, costs and benefits in section 2.3 and 2.4 for each of the two.

2.2.2 Strict Forest Conservation

The polar strategy to conversion of forest into farm land is its strict conservation. In the distant past one third of Ethiopia was covered by forest. Today only 2% of the former forest is left. The northern and central highlands have been already completely deforested. The remaining forests of Ethiopia are currently under the special protection of the government which has demarcated 58 national forests as National Forest Priority Areas (NFPA) (EFAP [1994]). By law no encroachment into the NFPA is tolerated and the cutting of trees is often punished by prison sentences. In practice, for most of the NFPA the enforcement of this policy is difficult and too expensive. The forests of Yayu and Sheko, however, receive

[1] The Ethiopian government is determined to keep this land legislation by constitution (Berhanu et al. [2002], Teklu [2003]), and has no intention to fundamentally change the current system. On the contrary, the government claims that it promotes equity among farmers, prohibits speculation on land, and prevents rural urban migration

special attention due to the last populations of wild coffee still growing there. The Coffee Improvement Project, which is financed by the European Commission, aims to conserve this coffee gene pool for future breeding activities (Agrisystems [2001]).

One reason why it is difficult to conserve coffee germ plasm ex situ in seed gene banks is that its seeds do not stay viable for a long time. Another option is to store genes in field gene banks, where live plants are stored. These collections are not very secure, however, as the plants might succumb to diseases and pests. They are also expensive to maintain. Coffee plants conserved in situ are kept in their natural forest ecosystem. Its main advantage is that the evolutionary process can continue as plants adapt to changes in environmental conditions (Gole et al. [2002]).

The conservation authorities in Ethiopia suspect that permitting the local communities to enter into the demarcated areas would entail further disturbance in the form of illegal logging and harvesting of wild coffee. Therefore guards gazette the demarcated areas in Yayu and Sheko which cover areas of 10,000 and 9,000 hectare.

2.2.3 Sustainable Forest Management

Between the two polar strategies to deal with the remaining share of natural forest, namely complete conversion and strict conservation of forest, sustainable use strategies may be considered as a viable alternative. One sustainable use strategy is to grow coffee in the forest and to harvest renewable resources such as honey, plants for medical purposes etc. from the forest. The harvest of non-timber forest products leads to a diversification of available income sources thus serving as a risk management strategy and safety net for the poor.

Coffee accounts for 60% of the country's exports and the government estimates that about 15 million households either directly or indirectly depend on coffee for their livelihoods. 94% of Ethiopia's coffee is produced by 700,000 smallholders who grow coffee either in their gardens or in nearby forests as so-called semi-forest coffee (Oxfam [2002]). The remaining 6% are produced on plantations.

Semi-forest coffee is organically produced and grown in the forest under the canopy of shade trees. The forest is thinned out in order to give the coffee plants some space. As the agronomic conditions are almost optimal only some minimum husbandry practices are needed to produce a very fine Coffea Arabica.

It is important to notice that producing semi-forest coffee is different from harvesting wild coffee which grows completely uncontrolled deep inside the less accessible regions of the forest. The practices of semi-forest coffee production are definitely disturbing and to a certain extent damaging to the natural forest system. A vegetation study conducted by Gole [2003] in the Yayu forest finds that the diversity of higher plants in the semi-forest coffee areas is half of the diversity of the diversity in the natural forest. Nevertheless, the managed coffee forest can still be considered as a relatively intact forest ecosystem which serves as an eco support system and provides a variety of services such as the regulation of water quality and quantity and the conservation of soil.

Management can affect the diversity of coffee populations in several ways. By planting coffee trees from different parts of the forest and introducing land races[2] farmers can increase the diversity. Removing weaker races achieves the opposite. An overall effect of management on the diversity of coffee populations has not been observed so far. The genetic diversity of coffee populations growing in semi-forest is similar to the diversity of coffee populations growing wild in the natural forest (pers. com. T. Borsch).

In order to bypass low world market prices of commodity coffee and to capture price premia a minority of Ethiopian farmers has managed to enter the niche market for differentiated coffee. Differentiated coffee can be clearly distinguished because of distinct origin, defined processes, or exceptional characteristics such as superior taste or zero defects (Lewin et al. [2004]). Premia for organic coffee or so-called gourmet coffee are around 100%. These markets are still small though. Mainstream qualities, including coffee Robusta, account for an estimated 85% - 90% of world coffee consumption, whereas the share of exemplary and high quality coffee is no more than 10% or perhaps 15% of the world market (ITC [2002]). Even though, the share of differentiated coffee is increasing in Western countries. For organic coffee the industry predicts future growth rates in sales of up to 20% per year (Lewin et al. [2004]).

Most niche market suppliers in Ethiopia are represented by the Oromiya Coffee Farmers Cooperative Union (OCFCU), which exports certified organic fair trade coffee. In 2002 and 2003 the price paid to farmers was double the price for conventional coffee (pers. com. T. Meskela (OCFCU)). Currently only a minority of farmers manages to sell their coffee as

[2]Land races are varieties which came out of a process of selection by the farmers themselves. They are usually found in gardens and on plantations.

certified. They lack the necessary organizational and financial resources. We will consider both scenarios for the income analysis: farmers selling differentiated coffee and farmers selling conventional coffee.

In summary, there are three main use systems competing for the forest resource: The conversion into arable land and cultivation of food crops, notably maize, in two different ways, the traditional system which is ecologically unsustainable and which provides low yields, or a modern sustainable way of production, the skills for which, however, are not yet disseminated in the area under investigation; the sustainable use of the forest including harvesting of renewable resources and producing semi-forest coffee and, finally, the strict protection of the forest for biodiversity conservation.

2.3 Income Analysis

We now proceed with estimating the private income generated by the three use systems. We assume that strict conservation does not generate any income. The conversion into farm land yields returns from logging and maize. The sustainable use of the forest is characterized by a variety of income sources, like coffee, wood products and several non-timber forest products. The financial flows will be expressed in US$ per hectare[3]. Recall that one hectare is the average size of land per household in these areas. The time frame is 24 years.

The time preference rate of individuals determines how they trade off current against future consumption. According to the standard economic model with perfect capital markets individuals smooth their consumption over time such that their time preference rate approaches the market determined interest rate in equilibrium. In our situation farmers do not have access to perfect capital markets in order to smooth consumption. Instead, the local financial infrastructure is heavily distorted. In order to approximate the discount rate farmers use to evaluate different income streams we apply an estimation of their time preference rate as an upper bound and a realistic value of the local interest rate as a lower bound.

There are only a few studies published on rates of time preference in developing coun-

[3]We apply an exchange rate of 1$:8.6 Ethiopian Birr, which has been the average exchange rate from 2003 to 2005 (NBE [2005]).

tries. Holden et al. [1998] use a stated preference method to measure rural households' annual discount rates for money in Indonesia, Zambia, and Ethiopia. Assuming that time preferences are characterized by a constant exponential discount function they estimate mean annual discount rates of 93% in Indonesia, 105% in Zambia, and 53% in Ethiopia. These very high discount rates are in line with an earlier study conducted in India (Pender [1996]), which found median discount rates of over 50%.

It is usually assumed that these high time preference rates reflect the high risk environment farmers face. Note, that the life expectancy in Ethiopia is 42 years. The main risk factors are frequent droughts, coffee and maize price fluctuations and health risks like malaria and HIV/Aids. Farmers are very vulnerable to these risks as private and public risk management strategies are often ineffective (World Bank [2005]).[4]

Farmers in Sheko and Yayu have access to formal and informal financial services. In the informal sector financing is obtained from family and friends, rotating savings and credit associations, and commercial moneylenders. Interest rates and repayment terms for commercial money-lending are often quite flexible, but rates can be as high as 100%. Credit associations are traditional institutions through which group members meet each other's financial needs, but their capacity is limited (Aredo [2001]).

Formal financial services in Yayu and Sheko are offered by two micro finance institutions. They are public entities with the objective to deliver micro-loans and micro-savings to resource-poor but productive people. Credits are group based and require group guaranties. The main characteristics of these schemes are given in table (II). Farmers use these credits in order to buy fertilizer, seeds and livestock. However, not all farmers are willing to form a group, which is associated with transaction cost and risk, or are informed about this possibility.

Regarding these limitations of the local financial system and the high time preference rate of farmers in general we apply a discount rate of 30% as a lower bound and 53% as the upper bound.

[4]For example, well-known household strategies to deal with risk after it occurred is to sell lifestock, and reduce health expenditures, which involve forgoing future income and increase the risk of becoming destitute after the next shock.

Terms of small credits	Sheko	Yayu
Amount of credit (ETB)	50 - 1200	1000 - 5000
Interest	15%	12,5%
Farmers per group	5	4-6
Collateral	group members, house, lifestock	group members
Payback period	variable	1 year

Table II: Micro finance in Yayu and Sheko

2.3.1 Maize

Traditional Land Management

The local departments of agriculture in Yayu and Sheko report that the traditional maize production achieves an output of 1800kg per hectare. A recent study investigating the consequences of deforestation in the South-western Ethiopian highlands on soil erosion finds that the productivity of maize cultivated on deforested lands in the traditional way declines by 10% per year due to nutrient mining and erosion (Denboda [2005]). We incorporate this productivity decline in our valuation of future outputs.

The farm gate price for 100kg lies at US$ 4.7, during the harvesting period, and US$ 7 in Sheko and US$ 10.5 in Yayu later in the year. As farmers sell half of their produce right after the harvest, when the price is the lowest, we apply a price of US$ 6 in Sheko and US$ 7 in Yayu.

The labor input has been assessed by the Ethiopian Agricultural Research Organization. According to the respective cropping calendars farmers work approximately 4 months on their fields for tillage, sewing and harvesting (Shibru et al. [2002]). We estimated the opportunity costs of rural labor, based on the value of agricultural production and labor input, to be US$ 0.4 per man and day[5]. Thus we arrive at labor costs for maize production of 48 US$/ha. Following these calculations one hectare of maize leads to net returns of US$ 60 and US$ 78 in the first year.

[5] The details of the calculation are given in the appendix

Improved Land Management

For the improved land management we assume the application of fertilizer and biological measures against erosion. Under these conditions the average production of maize in Yayu and Sheko is 3200 kg per hectare (DoA).

Input costs include fertilizer costs, labor and investment in soil conservation. Fertilizer costs are around US$ 50 per ha (DoA). The additional costs associated with soil conservation are approximated by the investment in a biological measure to prevent erosion. Very popular in the Yayu and Sheko region is the biological soil boundary of Vetiver grass, because it can also be used for other purposes (DoA). Hence, its planting generates additional benefit. Here only the planting material will be included as costs. As the farmers are willing to plant the grass in case they are provided with the planting material it is assumed that labor cost associated with planting are less or equal to the additional benefit of the grass. The planting material costs US$ 13.5 for one hectare. Labor cost and farm gate price are the same as for the traditional land management. To sum up, maize produced in an ecologically sustainable way on one hectare of land generates a net annual income of US$ 80.5 in Sheko and US$ 112.5 in Yayu.

2.3.2 Semi-Forest Coffee

In semi-forest coffee systems around 450 kg/ha of coffee can be harvested per year (Agrisystems [2001]). In 2003 the average price of conventional Arabica coffee as it is mostly produced by Ethiopian farmers was 0.64 US$/lb (1lb=450g), reflecting a dramatic decline of commodity coffee prices over the last 30 years (price in 1970: 1.80 US$/lb). But the price is expected to rise steadily over the next ten years. Taking into account shifts in global demand and supply on the coffee market the World Bank has forecasted the future prices of Arabica coffee (Lewin et al. [2004]). They expect a rise in prices of up to 0.95 US$/lb in 2015. We use their forecasts for the calculation of income generated by the production of semi-forest coffee sold as conventional commodity coffee.

For certified organic fair trade coffee a minimum price is set for several years by the fair trade market. Currently it is 1.35 US$/lb. In general, the price of differentiated coffee is relatively independent of the commodity price fluctuations due to different marketing channels. These are characterized by closer relationships between producers and buyers and long-term contracts (Lewin et al. [2004]). According to a random sample of more than 2000 actors of the North-American coffee industry 9 out of 10 firms expect the price premia for organic, fair-trade and shade grown coffee to continue (Giovannucci [2001]). For this reason we do not consider a future change in the price of organic coffee for our calculations.

Based on information provided by the Coffee and Tea Authority (federal regulatory institution), OCFCU and own calculations[6] the costs of production, processing and expenses for export amount to 0.1 US$/lb.

The net return of differentiated coffee production is therefore 1250 US$/ha per year. The net return of conventional coffee in 2003 was 540 US$/ha.

2.3.3 Non-Timber Forest Products

The valuation of NTFP in Sheko and Yayu builds on earlier research of the Institute of Biodiversity Conservation and Research (IBCR), Addis Ababa, (IBCR [a], IBCR [b]), and the FAO (Deffar [1998]). The IBCR conducted participatory rural appraisals and focus group discussions in Yayu and Sheko to determine status and use of the forests and their products. The author then carried out a market survey and interviews with traditional health practitioners in the study areas.

The NTFP are classified into 3 main groups: Honey, medicinal plants, and miscellaneous goods. The miscellaneous goods are: Brown Cardamom ("Kororima"); "Gesho", a condiment for making a local drink; "Desha", used to clean the oven; "Ensosela", used for decorating the skin with color; mats and baskets made out of a liana and baskets made out of bamboo. The three groups of NTFP take different channels from the forest to the farmers. Hence the appropriate valuation methods differ and are explained more in detail in the following paragraphs.

For the valuation of the net income production costs are deducted. Peters et al. [1998] estimate production costs to be 40% of the product value for their valuation of timber and non-timber forest products from the Amazon. Batagoda et al. [2000] estimate costs of production via a questionnaire survey to be 50% in Sri Lanka. These figures are likely to overestimate the production costs in Yayu and Sheko, which, in contrast, hardly involve capital costs and processing. For most of the NTFP the time specifically spent on collection is modest, because these products are gathered during the work in the semi-forest coffee

[6] The details of the cost calculation are given in the appendix.

areas. Only the production of honey, mats and baskets requires more time. Thus, a more reasonable estimate of production costs as a share of total plant based NTFP value for this area is 20% for all products except honey, mats and baskets. For them 40% of gross value for production costs are deducted. To arrive at a per hectare income of NTFP the estimated values are divided by the areas used for collection, which are approximated by the semi-forest coffee areas.[7]

Miscellaneous Goods

The miscellaneous goods are only to a small amount collected by the farmers themselves. Rather, they are bought on local markets. Basically two methods to value the miscellaneous NTFP are possible: a household survey and a market survey. During a household survey farmers are asked about their collection and purchase of NTFP, and sometimes they record these activities in a logbook. Because of the sporadic fashion in which farmers collect these products it would be very difficult for them to remember exactly how often they collect or purchase them and to provide a correct and comparable account of the physical quantities involved. Thus a market survey was chosen as the appropriate method of valuation.

During this market survey all local markets in Sheko had been visited. Sheko is a district of 17 villages but only 5 of them host markets. These villages had been visited at the respective market day. The survey was carried out at the peak of the activities, around midday. The villages are on average 90 minutes away from the nearest road. That is why the markets are relatively small and hardly any professional traders are present. Mostly farmers sell the production of their garden. Despite the simplicity of the event no barter trade was observed but exchange by money. The results were transferred to Yayu.

The vendors of NTFP were asked how much they sell of the respective product and to which price, differentiating between a "good" day and a "bad" day. Based on this information an average income per seller of NTFP was calculated and multiplied by the number of traders present on the market to arrive at the total value per market per day. The sum of all total market values allowed calculating the annual value. Deducting the cost of production reveals a value of miscellaneous NTFP of US$ 0.70 per hectare.

[7] The semi-forest coffee areas are half of the total forest areas as given in table I page 15.

Honey

Ethiopia has a long tradition of beekeeping. Although the production system is still very traditional Ethiopia was fourth in beeswax and tenth in honey production on a world level in 1998 (Deffar [1998]). Honey is almost exclusively used for local consumption, to a very large extent for the brewing of mead, called *tej*. In Sheko and Yayu beeswax is regarded as a by-product of tej-making and wasted. Even though honey satisfies local demand, its quality does not meet international standards. The productivity of honeybees is low and only an average of 5 kg of honey can be cropped per hive per year in Sheko and Yayu. However, in areas where improved technology has been introduced, an average of 15 kg/hive/year has been recorded (DoA). The average number of beehives per household, which is 10, was multiplied by the average output per beehive and the total number of households.[8] The production of the modern beehives was added. This total production was valued with the average local price of 0.9 US$/kg (DoA). Production costs of 40% are deducted. Accordingly, the annual production in Sheko and Yayu is worth US$ 14.6 and US$ 11.6 per hectare.

Medicinal Plants

Medicinal plants are mostly collected by traditional health practitioners (THP) and then employed for the cure of patients. THP are normal farmers who learned how to prepare medicine out of medicinal plants. This knowledge is usually kept as a secret within one family.

For the valuation of medicinal plants the author conducted interviews with traditional health practitioners in Yayu and Sheko. Villages for the survey were randomly selected. The survey revealed that on average 2 THP practice per village. This number was confirmed by the local health office. It was possible to talk to 80% of all THP. Guides in each village contacted the local THP. During the interview the THP were asked which illnesses they could cure. The other questions concerned the average number of patients asking for these treatments and the price of each treatment.

Our findings are that a THP knows on average 4 treatments, which cost on average US$ 2.40. Among the illnesses that are most often treated are tuberculosis, haemorrhage, snake

[8] The number of modern beehives in Sheko is 6910, and in Yayu it is 346. 4,454 households live in Sheko and 17,127 live in Yayu.

and dog bites, and skin and liver diseases. The average number of patients per treatment is 12 per month. This leads to an annual income per THP of US$ 1382.40. Multiplying this by the number of THP per district and adjusting for collection costs leads to a total income for Sheko and Yayu of US$ 3 per hectare and US$ 1.80 per hectare.

2.3.4 Fuel Wood and Timber

The stock of the Ethiopian natural high forest lies between $30 - 300m^3/ha$ depending on the level of disturbance (EFAP [1994]). For semi-forest coffee the average stock is $200m^3/ha$ with an incremental yield of $4m^3/ha$. Gole [2003] carried out a vegetation survey in Yayu and assessed the volume of timber trees. We use his results for both districts. The difference to the total volume is in each case the amount of fuel wood that can be harvested[9].

According to the local department of agriculture the local price for $1m^3$ of timber is approximately US$ 23. We deduct two labor days for production and arrive at $22.2US\$/m^3$[10].

The price of fuel wood is difficult to determine because of the local units of measurement like "women's load" or "donkey load". A survey, undertaken by the German technical development cooperation in 2000, estimates the rural fuel wood price to be $20US\$/m^3$ (GTZ [2000]). Relying on their result we also deduct labor cost of 2 days and arrive at $19.2US\$/m^3$.

Based on these data the income gained from timber and fuel wood production if one hectare of natural forest is converted into farming land is US$ 6174. One hectare of forest converted into semi-forest coffee production results in a single income of US$ 2022 from fuel wood and timber and a recurrent income of US$ 76.8 out of fuel wood production.

2.3.5 Results

The results of the income analysis for Sheko are given in tables (III) a and b. The figures for Yayu can be found in the appendix (table (IX) a and b). They are similar to those of Sheko. The results show clearly that for many farmers maize production is more profitable than sustainable forest management. Insecure livelihoods and imperfect financial markets

[9] For further details see appendix.

[10] The same opportunity cost of labor as for maize production are assumed.

result in discount rates in the range of 30 to 50%. Although the harvest of non-timber forest products represents an additional income source, and despite the fact that coffee generates a stable and relatively high income, these high discount rates favor the immediate returns from sales of timber and fuel wood preceding maize production.

(a) **Net income discounted at 53%**

Good	Sustainable forest management		Maize production	
	differentiated coffee	conventional coffee	improved	traditional
NTFP	37	37	0	0
Fuel wood (once)	1267	1267	3110	3110
Fuel wood (annually)	154	154	0	0
Timber	755	755	3064	3064
Maize	0	0	161	100
Coffee	2499	1743	0	0
Total	4712	3956	6335	6274

(b) **Net income discounted at 30%**

Good	Sustainable forest management		Maize production	
	differentiated coffee	conventional coffee	improved	traditional
NTFP	61	61	0	0
Fuel wood (once)	1267	1267	3110	3110
Fuel wood (annually)	256	256	0	0
Timber	755	755	3064	3064
Maize	0	0	268	150
Coffee	4159	2764	0	0
Total	6498	5103	6442	6324

Table III: Discounted net income in US$/ha per use system in Sheko

In the near future the financial superiority of conversion will most probably increase, because the prices for timber and fuel wood can be expected to rise sharply. The fuel wood demand and supply projections made by the Ethiopian Forestry Action Plan indicate that the current annual demand for fuel wood is 58 million m^3 whereas only 11 million m^3 can be supplied (EFAP [1994]). As no substantial investment has taken place the gap between supply and demand of wood is predicted to widen considerably during the next ten years. This prediction is in line with a report of GTZ [1998] which observes an increase in the price of fuel wood of 70% every ten years from 1970 up to 1995. Higher prices in the future will put more pressure on standing forests.

Comparing the two maize systems, the revenues of the improved maize production are higher than the ones arising from traditional practices. Nonetheless, under the current conditions it seems unlikely that the improved management will become the dominant farming system. In order to push this transformation reforms targeted at input markets, tenure security and infrastructure should have priority.

Selling differentiated coffee, namely certified organic fair trade coffee, is much more profitable than selling conventional coffee (more than US$ 1000 per hectare). By intention, premia paid for organic coffee raise the private profitability of sustainable forest management. However, the current premium is not high enough to ensure that sustainable forest management is regarded as the most profitable land use option by farmers. In order to tip the balance the price had to raise to a level of about 2 US$. In any case, switching from one coffee system to the other does not come costless. Many farmers still sell their coffee as simple commodity because switching requires investments in new marketing channels and in certification. Cheaper and more reliable access to credit would therefore not only raise the profitability of sustainable forest management, by lowering farmers' discount rates, but also facilitate switching to differentiated coffee production.

2.4 Economic Analysis

After the income analysis has highlighted the current financial incentives leading to the conversion of the forest, we now turn to the economic analysis of the allocation problem faced by Ethiopia. The valuation of costs and benefits associated with each land use system builds on the concept of Total Economic Value (TEV) (Pearce and Moran [1994]). The TEV consists of direct use values, indirect use values, option values and non-use values. A direct use value arises from the use of resources in production and consumption (e.g. agriculture, gathering) and non-consumptive uses (e.g. research). Indirect use value relates to the indirect support and protection provided to the production of resources which have direct use value. For example the watershed protection function of a forest may have indirect use value through controlling the water supply to downstream agriculture. Option value denotes a type of use value in that it relates to future use of the environment (e.g. preserving information). Non-use values are also often referred to as "intrinsic values". Individuals who do not intend to make use of a certain resource might feel a loss if it was to disappear.

Prior to the identification of the relevant costs and benefits we reviewed empirical studies and surveys on the economic values of forests and other land use systems (Pearce and Pearce [2001], Bishop [1999],Pearce et al. [2002], Chomitz and Kumari [1998], Yaron [2001]). In general, the highest values are attached to direct uses, like timber extraction and the indirect use of the carbon storage capacity of forests.

We present estimates of values which arise on global, national and local level. A cost-benefit analysis is then conducted to establish the best possible use of the forest areas from Ethiopia's perspective. This procedure allows us to put in contrast global and national interests.

Except the economic value of the genetic diversity of coffee Arabica, all values are expressed in per hectare values. This is consistent with the income analysis. It should be kept in mind, however, that the outcome for the forest as a whole might be a different one. This is due to two reasons. First, the complete conversion of the ecosystem into cultivated land and the related loss of biodiversity may result into irreversible processes of change, the ecological and economic consequences of which cannot be foreseen. Second, not all the forest areas are suitable for each use system, because of the mountainous terrain.

As in standard CBA practice market prices are used whenever markets are functioning well (Squire and van der Tak [1995], Dinwiddy and Teal [1996]). The semi-forest coffee in Sheko and Yayu is valued as a niche product by its premium price, which is the best possible approximation of its value. The NTFP included in the income analysis are non-tradable goods, which are only locally consumed. Their prices can be trusted to represent the true willingness to pay of the consumers, because the goods are traded competitively on local markets[11]. If markets are not functioning well values are estimated by using the replacement cost method, the avoided cost method, benefit transfer, or the opportunity

[11] To be precise, we value the flow of NTFP and assume it to be sustainable. The figures for medicinal plants include the value of the traditional knowledge of the health practitioners. But as this knowledge would invariably vanish with the loss of the forest it can be regarded as an additional benefit.

cost. These cases are now examined more in detail before the overall results are presented.

2.4.1 Direct Use Values: Timber and Fuel Wood

Ethiopia is a net-importer of wood products. The local market is distorted by state intervention which deters private investment in the forestry sector (Yemshaw [2002], Bekele [2001]). Local market prices are set more or less arbitrarily. Hence, we did not apply local market prices to value timber and fuel wood.

For fuel wood the replacement cost method is chosen. Its value is approximated by the cost of a eucalyptus plantation needed to supply the equivalent amount of wood. The expected annual yield of a planted eucalyptus plantation is $20m^3/ha$ (Pohjonen and Pukkala [1990]). The average cost of production are $205US\$/ha$ (Wirtu and Gong [2000]).[12]

Timber is valued by its border price. In 2001 and 2002 the average prices of logs imported into Africa were $251US\$/m^3$ and $252US\$/m^3$ (ITTO [2002]). Similarly, the average value of sawn wood imported into Ethiopia in 2002 was $241US\$/m^3$ (FAO [a]). We attach a price of $245US\$/m^3$ to timber. In 2003 the Sawmill and Joinery Enterprise reported processing and transport costs of $163US\$/m^3$ (sawmill based in Addis Ababa). We deduct this figure from the gross value of timber. Accordingly the unit value of timber is $82US\$/m^3$. For the volume of wood the same data as in the income analysis are applied.

2.4.2 Direct Use Value: Maize

In Ethiopia, 5 million people are chronically dependent on food aid. Varying from crop year to crop year further emergency assistance is provided by international donor organizations. Grain markets in Ethiopia function through a limited number of small traders who buy surpluses from farmers and sell in the nearby markets at relatively small margins. These markets are segmented and grain movements from surplus to deficit areas are constrained by high transport costs due to poor road infrastructure, limited competition in the transport sector, and weak market information systems. The donor organizations rely on imports to meet the food requirements.[13] For this reason we will value the direct use value of maize by its import parity price. According to OECD estimates the world

[12] Cost include establishment, weeding, guarding, thinning, harvesting, and land rent. Example: to replace $162m^3$ of fuel wood as associated with 1 ha of maize production, 8.1 ha of eucalyptus plantation have to be established, leading to a cost of 1660.5 US$ per ha of maize.

[13] For further information on food assistance for Ethiopia see FAO [c].

price for maize will be about 113US$/t in the next 10 years[14] . We use their estimation and add ocean freight and insurance costs of 40 US$/t for transport from Gulf ports to Djibouti.[15] To arrive at the import parity price of maize in Addis Ababa we have to add transportation costs from Djibouti. However, due to the same distance (ca. 600 km) and similar road infrastructure these are approximately equal to the transportation costs from Yayu and Sheko to Addis Ababa, which will then be deducted from the import parity price. Thus we arrive at a unit value for maize of 153 US$/t.

Again, we look separately at maize produced in a sustainable way and under the traditional management, using the same data as in the income analysis for production costs and yields. Thus we arrive at a per hectare value of maize produced under the traditional management of US$ 227.4 in the first year. Improved maize production leads to annual benefits of US$ 378.1 per hectare.[16]

2.4.3 Direct Cost: Wild Animals

Farmers in Sheko and Yayu incur substantial losses due to wild animals inhabiting the forest and looting their fields. These losses are seen as costs associated with the forest. Bonger et al. [2002] value these costs by taking the average amount of time farmers have to guard their fields multiplied by the opportunity cost of labor. Following their results for different areas (10 US$ up to 73 US$) annual losses of 40 US$ per household due to wild animals are assumed. This takes into account the proximity of the forest to the fields in Sheko and Yayu. Multiplying the cost per household by the number of households and dividing it by the number of hectare of forest lead to a cost of 7.4 US$ per hectare of forest in Sheko and 7.6 US$ in Yayu.

2.4.4 Direct Cost: Implementation of Strict Conservation

The strict conservation of the forest requires investment into infrastructure and the employment of personnel to ensure the protection of the forest and to facilitate the exploration of the plant and, especially, wild coffee diversity. The calculation of these costs is based on project documents of the European Commission for the conservation of the forest in Sheko

[14]Price for No2 yellow maize, US f.o.b. Gulf Ports, see OECD [2004].

[15]40 US$/t is an estimation based on freight rate data obtained from FAO [d]

[16]Traditional: $1800kg/ha \times 153US\$/t - 48US\$/ha = 227.4US\$/ha$ Improved: $3200kg/ha \times 153US\$/t - 48US\$/ha - 50US\$/ha - 13.5US\$/ha = 378.1US\$/ha$

and Yayu (Agrisystems [2001]). These provisions include guards, forest management offices and one person per district responsible for conflict prevention. Initial investment costs are 79 US$/ha and annually 3 US$/ha of labor costs will arise.[17]

2.4.5 Indirect Use Value: Watershed Services

Typically, watershed services resulting from upstream land uses subsume services such as regulation of water quantity and quality, and erosion control. Their magnitude and direction completely depend on local conditions and, in case of conversion, on the subsequent land use system (Calder [1999]). Technical studies, investigating these services for the South-western highlands of Ethiopia and the forest in particular are lacking (pers. com. "Ethiopian Nile Basin Project", Ministry of Water Resources, Addis Ababa). Potential costs and benefits relating to the watershed could therefore not be calculated. Nevertheless they deserve attention. The montane forest in the study areas belongs to the class of cloud forests. Tropical montane cloud forests are frequently covered in clouds or mist and so, in addition to rainfall, capture water droplets that condense on the vegetation. Cloud water interception generally lies within the range of 5-20% of ordinary rainfall at wet tropical locations but can be much higher at certain particular exposed locations (Bruijnzeel [2004]). This results in stream flows from cloud forest areas which are greater than what can be attributed to rainfall. Another aspect is the magnitude of stream flows in dry periods. There is a growing body of evidence from Latin America that cloud forest clearance for pasture or annual cropping may lead to decreased flows in the dry season. Several capital cities in Latin America benefit from the augmented water supply provided by cloud forests: Quito (Ecuador), Mexico City (Mexico) and Tegucigalpa (Honduras) (Bubb et al. [2004]). We therefore attach a non-quantifiable benefit, which will be called 'watershed services' to the use systems strict conservation and sustainable forest management.

2.4.6 Non-Use Values

Non-use values of forests are also very specific to the respective location and situation. Studies report that their magnitudes are very modest in general and hardly exceed 1% of household income (Bishop [1999]), unless the forests have some unique features like a rare beauty or fascinating animals living inside (Pearce and Pearce [2001]). Anecdotal evidence

[17] A detailed list of costs is given in the appendix.

from interviews with farmers in Sheko confirms the view that they mostly appreciate the several useful products they can obtain from the forest (IBCR [a], IBCR [b]).

Stated preference techniques are usually regarded as the only way to estimate non-use values. Despite the theoretical and methodological progress made since the early debates on contingent valuation stated preference techniques are still very sensitive towards language and cultural influences leading to a considerable danger of bias and unreliable results (Carson et al. [2001]).[18] As the author is not Ethiopian and the magnitude of non-use values did not seem to have a decisive influence on the result of the CBA they were not included in the analysis.

2.4.7 Indirect Use Value: Carbon Storage

By storing carbon forests can slow down global warming. This is a benefit which accrues to the world as a whole. Any conversion of forests into other uses entails a carbon flux, whose magnitude depends on the subsequent use system. The conversion into agro-forestry is for example less damaging to the atmosphere than to maize fields. For a valuation of the carbon stored in the trees and plant material of the forest one can either estimate the avoided marginal cost or use the market price for tradable emission reduction certificates.

With the avoided cost method the value of a tonne of carbon is approximated by the global warming damage a tonne of carbon would contribute to. Estimates of the Intergovernmental Panel on Climate Change suggest that the marginal damage of a tonne of carbon would hardly exceed 50 US$/tC (Smith et al. [2002]). Their result was recently confirmed by a study conducted by Tol [2005], who reviewed 22 studies of marginal costs containing 88 estimates.

Current market prices for emission reductions vary depending on the possibility of registration under the Kyoto protocol. Average prices lie between 1 and 6 US$/tCO2 (1tC = 3,667 tCO2). For projects not intended for Kyoto compliance the average price is 1.34 $/tCO2 (World Bank 2004b). Avoided deforestation is currently not admissible under the Kyoto protocol.

The subsequent use system after strict conservation and sustainable forest management would most probably be the typical farming system, considering the current situation and

[18] Whittington [2002] describes the most common mistakes made in administering contingent valuation studies in developing countries.

similar developments in other regions of Ethiopia. The country does not dispose of any data on the amount of carbon stored in its land uses (pers. com. Ministry of Agriculture, Addis Ababa). The data used instead is taken from a study conducted by Gockowski et al. [2001]. They compare dense cocoa agro-forest, primary forest and intensive farming with respect to their time averaged carbon stocks in Southern Cameroon. The primary forest stores 307 tonnes of carbon per hectare. The amount of biomass and consequently the amount of carbon stored in the agro-forestry system is reduced. With an average age of tree stock of 25 years 132 tonnes of carbon are stored. The most intensive farming system with 1.5 years of fallow period stores 82 tonnes of carbon. Accordingly, the global value of the carbon stored in the untouched rainforest protected by strict conservation ranges somewhere between 11,250 US$/ha and 1,106 US$/ha, depending on the price attached. The carbon stored by the semi-forest-coffee system has a global value between 2,500 US$/ha and 246 US$/ha based on the avoided marginal cost and market price respectively.

2.4.8 Indirect Use Value: Biodiversity

Ethiopia is an important center of biodiversity and endemism on the African continent. The highest levels of endemism and biodiversity are principally found in the highlands and the Somali region. An inventory of fauna and flora in Ethiopia indicates that there are 277 species of terrestrial mammals, 862 species of birds, 201 species of reptiles, 63 species of amphibians, 150 species of fish and 7000 species of higher plants. Among these, 11% of mammals, 3.3% of birds, 4.5% of reptiles, 38% of amphibians, and 12% of higher plants are endemic (EFAP [1994]). Even more important for our study, cloud forests are concentrations of biodiversity. 86% of the worldwide cloud forest sites, as identified by a UNEP-WCMC inventory (Bubb et al. [2004]), are found on the list of priority forests defined by Olson and Dinerstein [1998]. They chose the priority forests based on the following set of parameters: species richness; species endemism; higher taxonomic uniqueness; unusual ecological or evolutionary phenomena (such as migrations); global rarity; and keystone habitats.

To put a global value on the amount of biodiversity existing in the study areas we consider its option value, represented by its value for future pharmaceutical research and coffee breeding. As the level of general plant diversity is significantly reduced in the semi-forest coffee areas the value for pharmaceutical research is only attached to the use system of strict conservation.

Pharmaceutical Research

Up to now three generations of studies have dealt with the informational value of biodiversity for pharmaceutical research. Most of them approximate the informational value by estimating private values of biodiversity for respective companies. These companies are assumed to search for substances in plant material or animals suitable for pharmaceutical products. The approaches of the first and second generation multiply the probability of discovering a commercially valuable substance by the value of a substance (based on sales values of pharmaceutical companies and estimates of plant based drug sales) to estimate the average value of a species for pharmaceutical research (e.g. Principe [1989], Mendelsohn and Balick [1992]).

More refined models of the third generation estimate the values of the marginal species instead of the average values of all (Simpson et al. [1996], Rausser and Small [2000]). In order to describe the willingness to pay of pharmaceutical firms for the right to "bioprospect" a certain area, they value the marginal species on the basis of its incremental contribution to the probability of making a commercial discovery. This is a consequence of the probability of redundancy among research leads. Several leads may enable the same innovation, just as caffeine can be found in coffee and tea. This feature of redundancy leads to relatively small values of the marginal species and respective areas for bioprospecting. The results of Simpson et al. [1996] lie between US$ 0.2 and US$ 20.6 per hectare for 18 hot spot areas as defined by Myers [1988].

Rausser and Small [2000] claim that these low values are related to the way the search process is modelled. They introduce a targeted search process in contrast to the random search assumed in the earlier models. Here prospecting firms take into account already existing information on different sites and their expected quality for research. Then they rank potential research sites according to their quality. When promising sites are examined first, research costs decline and the values for the same 18 hot spot sites lie between US$ 231 and US$ 9,000 per hectare. These high values are largely due to information rents, which result from prior existing information on the quality of these hot spots.

Ethiopia did not appear on the list of 18 hot spots. Recently, Myers et al. [2000]

presented new information on biodiversity hot spots. They enlarged the list to twenty five areas worldwide. Their basic analysis is driven by two criteria: species endemism and degree of threat. Ethiopia is still not on their list, because they find that the Ethiopian highlands "appear to feature exceptional plant endemism and exceptional threat, but are not sufficiently documented to meet the hot spots criteria." Considering this apparent lack of exact information on the Ethiopian highlands but taking into account its position as an "almost hot spot" a modest value of US$ 20 per hectare will be assumed.

Agronomic Research

The option value of biodiversity for agronomic research is approximated by the value of the diversity of coffee Arabica which is growing in the forest. Ethiopia is the country of origin of coffee Arabica. It was introduced to Yemen during the 13th century. Here, the habit of drinking coffee was developed in the 15th century and gradually spread to the rest of the world (Ferwerda [1976]). As the spread of Arabica coffee across the world was based on only a few trees, the coffee plantations in producer countries posses a very narrow genetic base. As a result they are very vulnerable to diseases or pests. For instance, the occurrence of coffee leaf rust in Sri Lanka in 1869 forced that country to abandon coffee production and shift to tea. The fact that in Ethiopia coffee production is still possible despite leaf rust being endemic to the country and the outbreak of a new disease called coffee berry disease in 1971 is attributed to the availability of genetic diversity and its ability to release resistant varieties in a very short time (Demel [1999]).

For the economic value of this diversity we draw on the results of Hein [2005]. He uses the potential of genetic resources to enhance the value of coffee production in order to establish an economic benefit. Specifically, coffee genetic resources are valued on the basis of three main aspects: the potential to use them for the breeding of disease resistant varieties (avoided cost of damages), the potential for breeding a caffeine free coffee cultivar (avoided cost of decaffeinating), and their potential to increase yields of coffee (increased profit). He obtained estimates of the potential costs and benefits of a breeding program for enhanced coffee by conducting an extensive literature survey and interviews with experienced coffee breeders. His result is that the total net benefits of the coffee genetic diversity in Ethiopia amount to US$ 222 million at a 5% discount rate over a period of 30 years and US$ 58 million at a discount rate of 10%.

Hein [2005] argues that his estimates represent minimum values because they do not include all potential benefits that can be obtained from genetic coffee resources. He mentions the potential resistance to other diseases than those included in his study. The study, however, suffers from the assumption of constant prices over the next decades. This requires that global demand of coffee will sufficiently increase over the next decades, in order to absorb the increased supply which results from higher yields and reduced disease induced losses.

One important issue for our analysis remains. It concerns the availability of Ethiopian coffee accessions in coffee collections around the world and in field gene banks. Table IV (page 38) shows the major field gene bank collections of coffee Arabica.

Lately, naturally decaffeinated coffee varieties were found in Ethiopian accessions maintained in Brazil (Silvarolla et al. [2004]). Apparently, part of the economic value of the coffee diversity generated by Ethiopia has already been transferred to other countries and cannot be attributed to our study regions. The above estimates are therefore regarded as very rough indicators of the value of coffee diversity. They are attributed to strict conservation as well as sustainable management of the forest areas as a whole.

2.4.9 Results

This section will first present the results of the cost-benefit analysis conducted for Ethiopia. These findings are then brought together with our assessment of the global values of the forest. All future costs and benefits are discounted by rates of 10%, 5% and 2%. A discount rate of 10% is recommended for the evaluation of projects by the Ethiopian Ministry of Economic Development and Cooperation (GoE [1998]). We only report here the figures for Sheko. Those for Yayu convey the same picture and are given in the appendix (table (X)).

According to the available data and above calculations only two of the three use systems achieve positive net present values, maize production and the sustainable use of the forest (table V, page 39). The negative net present value of strict conservation is most probably due to the lack of data on the local benefits of watershed services provided by the forest, i.e. the regulation of the water quantity and quality in the region. Nevertheless, the conservation initiative of the government of Ethiopia and the European Commission is, at least according to these estimates, not in the best interest of Ethiopia.

Country	Institute	No of accessions
Brazil	Centro Nacional de Recursos Geneticos	275
Colombia	Centro Nationales de Investigaciones de Café Pedro Uribe Mejia	886
Costa Rica	Centro Agronomico Tropicale de Investigacion y Ensenanza	1498
Côte d'Ivoire	Orstom Institut Français de recherche scientifique pour le développement et coopération	1787
Ethiopia	Institute of Biodiversity Conservation and Research	4000
Ethiopia	Jimma Research Station	679
India	Central Coffee Research Institute, Kamataka	329
Kenya	Coffee Research Foundation	592
Madagascar	Recherche Agricole *à* Madagascar	329
Tanzania	Tanzanian Agricultural Research Organization	42
USA	US Department of Agriculture	292

Source: Gole et al. [2002]

Table IV: Major C. Arabica field gene bank collections

(a) **Maize production, traditional management**

Value	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
Maize	1,123	1,469	1,770
Fuel wood	1,661	1,661	1,661
Timber	14,490	14,490	14,490
Total	17,274	17,620	17,921

(b) **Maize production, improved management**

	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
Maize	3,397	5,217	7,151
Fuel wood	1,661	1,661	1,661
Timber	14,490	14,490	14,490
Total	19,548	21,368	23,302

(c) **Strict forest conservation**

	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
(Watershed services)	n.a.	n.a.	n.a.
Wild animals	-67	-102	-140
Implementation	-106	-120	-136
Total	-173	-222	-276

(d) **Sustainable forest management**

	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
(Watershed services)	n.a.	n.a.	n.a.
NTFP	164	253	346
Fuel wood	716	716	716
Timber	3,570	3,570	3,570
Coffee	11,231	17,249	23,643
Wild animals	-67	-102	-140
Total	15,614	21,686	28,135

Table V: Results of CBA for Sheko

At discount rates of 2% and 5% the sustainable use of the forest is the most profitable option, whereas maize production is associated with the highest benefits at a discount rate of 10%. Unfortunately it is not possible to establish whether the difference between maize production and sustainable forest management of 4,000 US$/ha at the maximum is outweighed by the benefits of the watershed services provided by the forest.

The high net present value of maize production highlights two points. First, it reflects the timber value stored in Ethiopia's forests. Second, it calls attention to the value of food in this drought-stricken and aid-dependent country. Regarding the maize output only, the improved version is 2 up to 3 times more profitable than the traditional one.

The high positive result of the sustainable forest management is the sum of mid-range benefits like timber and non-timber forest products combined with the returns from coffee production. As compared to the income analysis, here the long term benefits of continuous high income generated by coffee receive more weight because of the lower discount rates.

From a global perspective, which adds the indirect values of biodiversity conservation and carbon storage of the forest to its direct use values, the sustainable management of the forest is the most beneficial use option, whereas, from a national perspective, the sustainable forest management is only the most beneficial solution at a discount rate of 5%. It follows that, if the Ethiopian farmers were to switch from their dominant use system, which is maize production, to the sustainable use of the forest, they could rightfully claim compensation from the global community, especially the coffee producing countries, for their efforts to provide global environmental services.

It remains to be said, though, that the sustainable management of the forest is associated with a trade-off, as part of the forest biodiversity will be irreversibly lost.

2.5 Conclusions

We analyzed three alternative use systems for the remaining montane rain forest in South-West Ethiopia with respect to their financial returns as well as their economic costs and benefits, namely conversion into crop production, strict conservation and sustainable use of the forest. The objective was to establish if conservation of biodiversity can be compatible with poverty alleviation in the Ethiopian highlands.

The cost-benefit analysis shows that the sustainable forest management is the most beneficial land use option from a global perspective. From the national point of view the sustainable forest management produces the highest net benefits at discount rates of 5 and 2 %. It generates high benefits in the form of income from coffee production and other forest products, which accrue foremost to Ethiopia; and it also provides global environmental services like the conservation of the coffee genetic diversity and the storage of carbon. We therefore argue that, in theory, conservation is compatible with local economic development. However, it involves a trade-off as the management of the forest will reduce the forest biodiversity. In contrast, the results of the income analysis confirm what the deforestation rate of 8% is already painfully illustrating: maize and timber production generate the largest financial returns for the farmers. The local factor and product prices are neither conducive to the official plan of strict conservation nor to the sustainable use of the forest. At the moment farmers face a set of incentives which is inducing further conversion. They take their land use planning decisions in a high risk environment and are further constrained by malfunctioning land and financial markets. Under these circumstances farmers do not plan for the longer term. Note, that current distortions on the maize and timber market are reducing the financial profitability of conversion and thereby prevent even further deforestation. The local price of timber is about one quarter of its economic value. Likewise, due to a segmented market, the farm gate price for maize lies at 25% of its estimated value.

Some farmers receive premium prices for certified organic fair trade coffee and, thereby, take into account the positive external environmental effects associated with sustainable forest management. The price premium raises the financial profitability of the sustainable use of the forest to some extent, but the current monetary incentive is not sufficiently high. According to our estimates, a premium price of 2 US$/lb compared to currently 1.35 US$/lb, would be necessary to tip the balance. Such a price is hardly conceivable and would be difficult to justify on environmental grounds. It would amount to a transfer payment of 1350 US$/ha which sums up to US$ 26 million annually for the currently protected forest areas. Recall that the discounted net benefit of the coffee genetic diversity lies between US$ 222 million and US$ 58 million depending on the discount rate.

Can coffee save Ethiopia's cloud forest and alleviate poverty? We conclude that it could help doing so. It would serve as a vehicle for transfer payments from consumers to farmers with the objective to protect global environmental benefits. Moreover, at its current level it already raises the incomes of those farmers who successfully entered the niche market of differentiated coffee. To prevent further conversion, however, timber plantations are necessary. In addition, better conditions for private investment would facilitate the entrance onto niche markets and increase the profitability of the sustainable forest management in general, by lowering discount rates. This could be achieved by improving the local financial infrastructure and tenure security.

In closing one point deserves emphasis. Forest based poverty alleviation can be reconciled with conservation in Ethiopia. The sustainable use of biodiversity should be an integral part of economic development in the forest areas. But a deforestation rate of 8% per year calls for quick action.

2.6 Appendix

2.6.1 Income out of timber and fuel wood

(a) Sustainable forest management

	A) Natural forest	B) Sustainable forest management
1. Stock	$300m^3/ha$	$200m^3/ha$
2. Volume of standing timber	$138m^3/ha$	$104m^3/ha$
3. Volume of fuel wood (1.-2.)	$162m^3/ha$	$96m^3/ha$
4. Incremental annual yield	n.a.	$4m^3/ha$
5. Value of timber	-	$[2A) - 2B)]22.2US\$/m^3 = 754.8US\$/ha$
6. Value of fuel wood	-	$[3A) - 3B)]19.2US\$/ha = 1267.2US\$/ha$
7. Value of fuel wood annually	-	$4m^3/ha \times 19.2US\$/ha = 76.8US\$/ha$

(b) Maize production

	A) Natural forest	C) Maize production
1. Stock	$300m^3/ha$	0
2. Volume of standing timber	$138m^3/ha$	0
3. Volume of fuel wood (1.-2.)	$162m^3/ha$	0
5. Value of timber	-	$[2A) - 2C)]22.2US\$/m^3 = 3063.6US\$/ha$
6. Value of fuel wood	-	$[3A) - 3C)]19.2US\$/ha = 3110.4US\$/ha$

Table VI: **Income out of timber and fuel wood** (Price of fuel wood: $19.2US\$/m^3$, price of timber: $22.2US\$/m^3$), Source: DoA, GTZ [2000], EFAP [1994],

2.6.2 Opportunity cost of rural labor

A Value of agricultural production in 2003 (US$'000)	2,800,600
B Labor cost relative to A (60%)(US$'000)	1,680,360
C Economically active rural population in 2003	23,360,100
D Adult equivalent to C (75%)	19,629,721
E Agricultural opportunity cost (B/D) in 2003 (US$)	143
Opportunity cost of rural labor per day (ETB)	3

Table VII: **Opportunity cost of rural unskilled labor in Ethiopia** The opportunity cost of rural unskilled labor was estimated on the basis of the value of agricultural production and the number of full-time adult equivalent workers. 60% of the value of agricultural production is a return to labor. Source: GoE [1998] updated with World Bank Development Data

2.6.3 Cost of semi-forest coffee

A Production costs ETB/ha (450kg of green coffee)[a]	
Weeding, 60 man-day a 3 ETB	180 ETB
Pruning, 30 man-day a 3 ETB	90 ETB
Harvesting, 60 man-day a 3 ETB	180 ETB
A Total	450 ETB
A Total/kg	1 ETB
B Processing costs ETB/kg of green coffee[b]	
Transport from producer to hullery	0.07 ETB
Hulling costs	0.23 ETB
B Total	0.3 ETB
C Marketing and export expenses[c]	0.3 ETB/kg
A + B + C	**1.6 ETB/kg**

[a]Data provided by Coffee and Tea Authority, Addis Ababa
[b]Data provided by Coffee and Tea Authority, Addis Ababa
[c]Data provided by Oromiya Coffee Farmers Cooperative Union, Addis Ababa

Table VIII: Cost of semi-forest coffee

2.6.4 Results of income analysis for Yayu

(a) **Net income discounted at 53%**

Good	Sustainable forest management		Maize production	
	differentiated coffee	conventional coffee	improved	traditional
NTFP	28	28	0	0
Fuel wood (once)	1267	1267	3110	3110
Fuel wood (annually)	154	154	0	0
Timber	755	755	3064	3064
Maize	0	0	225	130
Coffee	2499	1743	0	0
Total	4703	3947	6399	6304

(b) **Net income discounted at 30%**

Good	Sustainable forest management		Maize production	
	differentiated coffee	conventional coffee	improved	traditional
NTFP	47	47	0	0
Fuel wood (once)	1267	1267	3110	3110
Fuel wood (annually)	256	256	0	0
Timber	755	755	3064	3064
Maize	0	0	374	195
Coffee	4159	2764	0	0
Total	6484	5089	6548	6369

Table IX: Discounted net income in US$/ha per use system in Yayu

2.6.5 List of interviewed experts per topic

Coffee

Ato Assefa, Coffee and Tea Authority, Addis Ababa

Martin Grunder, Menschen für Menschen, Yayu

Tadesse Meskela, General Manager, OCFCU, Addis Ababa

Dr. Demel Teketay, Director General, Ethiopian Agricultural Research Organization, Addis Ababa

Dr. Tadesse Gole, Forestry Department, Ethiopian Agricultural Research Organization, Addis Ababa

Dr. Thomas Borsch, botanist, University of Bonn, Germany

Dessialo Fantai, forester, DoA in Sheko

Ibrahim Mohammed, extension officer, DoA in Sheko

Lako Asrat, coffee agronomist, DoA in Sheko

Abebe Diori, agronomist, DoA in Yayu

Bely Legesse, extension officer, DoA in Yayu

Dinga Amente, forester, DoA in Yayu

Forest

Pierric Fraval, Ethiopian Nile Basin Project, Ministry of Water Resources, Addis Ababa

Jean B. Laffitte, UNDP, Environment Unit, Addis Ababa

Stefano Latella, UNDP, Environment Unit, Addis Ababa

Abebe Tadege, National Meteorological Services Agency, Addis Ababa

Million Bekele, forester, Ministry of Agriculture, Addis Ababa

Nicholas Petit, European Commission, Addis Ababa

Ben Irvin, Farm Africa, Addis Ababa

Ato Mesfin, Institute for Biodiversity Conservation and Research (IBCR), Addis Ababa

Ato Taye, Institute for Biodiversity Conservation and Research (IBCR), Addis Ababa

Martin Neumann, Gesellschaft für Technische Zusammenarbeit (GTZ), Addis Ababa

Trudy Koenemund, Gesellschaft für Technische Zusammenarbeit (GTZ), Addis Ababa

Maize production

Dr. Tasfa Bogale, agronomist, Jimma Agricultural Research Center, Jimma

Volli Carucci, World Food Program, Addis Ababa

Dr. Abiye Astatke, agronomist, International Live Stock Research Institute (ILRI), Addis Ababa

Dr. Kai Sonder, agronomist, International Live Stock Research Institute (ILRI), Addis Ababa

Dr. Legesse Dadi, agricultural economist, Ethiopian Agricultural Research Organization, Addis Ababa

2.6.6 Results of cost-benefit analysis for Yayu

(a) **Maize production, traditional management**

Value	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
Maize	1,123	1,469	1,770
Fuel wood	1,661	1,661	1,661
Timber	14,490	14,490	14,490
Total	17,274	17,620	17,921

(b) **Maize production, improved management**

	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
Maize	3,397	5,217	7,151
Fuel wood	1,661	1,661	1,661
Timber	14,490	14,490	14,490
Total	19,548	21,368	23,302

(c) **Strict forest conservation**

	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
(Watershed services)	n.a.	n.a.	n.a.
Wild animals	-75	-105	-144
Implementation	-106	-120	-136
Total	-181	-225	-280

(d) **Sustainable forest management**

	Present value per ha discount: 10%	Present value per ha discount: 5%	Present value per ha discount: 2%
(Watershed services)	n.a.	n.a.	n.a.
NTFP	127	195	257
Fuel wood	716	716	716
Timber	3,570	3,570	3,570
Coffee	11,231	17,249	23,643
Wild animals	-75	-105	-144
Total	15,569	21,625	28,042

Table X: Results of CBA for Yayu

2.6.7 Implementation cost of strict conservation

I Investment	**ETB '000**
A Infrastructure	
Office	410
Stores	450
Houses	3120
Vehicle shelter	7.5
Fire break	760
Fire towers	6
Nursery fencing	10
Water wells	180
Water tank	30
Subtotal infrastructure	4970
B Vehicles, Machinery & Equipment	
Double cabin pick-up 4x4	350
Tractor	570
Motorcycles	120
Electric generator	290
House furniture kits	320
Office furniture kits	30
Office equipment	140
Water pump	10
Water hose	3
Forest inventory equipment	30
Subtotal Vehicles, machinery & Equipment	1860
Total investment cost	**6830**
II Recurrent cost	**ETB/month**
A Salaries and wages	
Project site manager	2500
Conservation officer	2000
Community development officer	2000
Assistants (2)	1000
Secretary/cashier	1000
Pick-up driver	600
Tractor driver	500
Nursery foreman	400
Storekeeper	500
Guards (10)	150
Subtotal salaries and wages	13000
B Operating cost	8330
Total recurrent cost	**21330**

Table XI: Estimated costs of implementation of strict conservation, Yayu forest (Agrisystems [2001])

Chapter 3

Direct Payments for Biodiversity Conservation, Watershed Protection, and Carbon Sequestration - Comparing Theory with Practice

3.1 Introduction

Payments for Environmental Services (PES) have been described as a voluntary transaction where a well-defined environmental service is being bought by at least one buyer from at least one provider if and only if the provider secures the environmental service provision (Wunder [2005]). They have become an important tool in world-wide efforts to preserve biodiversity, protect watersheds and slow down global warming by carbon sequestration.

All of these environmental services are related to land use. Most of them are provided by forests. A global review of markets for forest environmental services conducted in 2001 identified over 280 cases of actual or proposed payments. These include 75 deals for carbon, 72 for biodiversity conservation, 61 for watershed protection, 51 for landscape beauty and 28 for multiple services (Landell-Mills and Porras [2002]). 7 percent of the cases reviewed were located in Africa, 24 percent in Latin America and the Caribbean, 14 percent in

Europe and 17 percent in North America. The Millennium Ecosystem Assessment (MEA [2005]) comes to the conclusion that such market-oriented mechanisms show considerable promise. It points out, however, that improving the design and institutional frameworks is essential for conservation and use of environmental services.

The sums spent within these deals are quite substantial. In France, Perrier-Vittel, a company that sells bottled water, has paid a total of US$ 3.8 million to farmers for their services to protect downstream watersheds. The US Conservation Reserve Program, which is rewarding watershed protection and biodiversity conservation, has an annual budget of US$ 1.8 billion. The World Bank has established a fund which is envisaged to invest US$ 100 million in forest carbon projects.

Considering the general scarcity of resources which are earmarked for nature conservation, we expect the buyers to have a keen interest that the desired services are provided in the most efficient manner. Often the providers live dispersed in large, remote areas, where they go about their daily farming activities, observed only by their neighbors. Due to these special circumstances the buyers can rarely assess the actual effort exerted by the providers. As a consequence, moral hazard may occur. Contract theory suggests how incentives are set in a voluntary transaction to achieve efficiency. We take PES at its face value and analyze the role of incentives in PES. For this purpose we apply a principal multi-agent model developed by Holmström and Milgrom [1990] to the context of PES. Drawing on individual case study material and surveys we then compare the theoretical benchmark with the actual use of incentive contracts in practice. This allows a more detailed characterization of existing schemes and reveals possible pitfalls.

Previous work on voluntary incentive designs for the supply of environmental goods has highlighted the risk of inefficiency due to asymmetric information between provider and buyer concerning the cost of provision. Building on the standard principle agent model with a high and low cost type research recommended incentive compatible contracts (Wu and Babcock [1996], Moxey et al. [1999]) and auction mechanisms (Latacz-Lohmann and van der Hamsvoort [1997]) to increase efficiency.

Another concern is the cost-effectiveness of payments facing the spatial variation of benefits. Waetzold and Drechsler [2005] analyzes the value of spatially differentiated payments as compared to uniform payments. Ferraro [2004] describes how computer assisted combinatorial procedures can be used to rank parcels by explicitly incorporating their environmental value for a better targeting of conservation finance. In the context of land-set aside programs for biodiversity conservation Parkhurst et al. [2002] propose the payment of an agglomeration bonus for every acre a landowner retires that borders on any other retired acre. They show that such a mechanism provides incentive for non-cooperative landowners to voluntarily create a contiguous reserve across their common border.

The present work is in line with previous recommendations as it incorporates incentive compatibility. It also considers the specifics of biodiversity conservation with respect to contiguity by examining the benefits of group incentives. Our main focus lies on 3 aspects and their influence on the design of PES contracts. Theory suggests that the level of risk involved in the production process, cooperation among providers, and the specific production technologies underlying the environmental services should determine the design. It turns out that payment schemes are determined by the environmental service concerned. We further find that cooperation influences the design to some extent but group incentives should receive more attention. The main challenges for the future are the scientific underpinning and side objectives linked to the schemes.

The next section relates the concepts of risk, technology and group contracts to the context of PES. Section 3.3 states the theoretical model, which we use as benchmark for our analysis. Section 3.4 describes how incentive contracts are used in practice. In section 3.5 we summarize how the observed practices match with theory, discuss the variation, and conclude.

3.2 Risk, Technology and Cooperation in the Context of PES

In what follows we describe how the concepts of risk, technology and cooperation relate to PES. In particular, we focus on PES for watershed protection, biodiversity conservation and carbon sequestration. Note, that all three considered environmental services are the result of particular kinds of land use, and payments made under these PES programs are payments to land users, i.e. farmers.

3.2.1 Risk

The production of environmental services is a risky business. The final outcome depends to a large extent on external factors. Major sources of risk are temperature, rainfall intensity and frequency, pests and diseases, fire, and invasive alien species. Small shocks can have enormous impacts on the production of the desired service. Imagine the outbreak of a fire, for example. It takes only a small accident to risk the burning of a whole forest.

Farmers often know best about these local risks and conditions because of their own experience and the accumulated knowledge of their community. They are also the first to encounter an unforeseen external event. During the period of a PES contract farmers presumably face frequent, small, random events. The management of these events and the farmers' continuous attention is leading to the final outcome, i.e. the environmental service. This role of the farmer renders variable payments based on the outcome, as compared to fixed payments, particularly useful, because they increase his incentive to choose the best possible action and allows him to react in a flexible way. Reviewing 62 evaluation studies of agri-environmental schemes in Europe, Kleijn and Sutherland [2003] emphasize the critical importance of farmers having an incentive to contribute to the environmental objective for the success of the scheme.

As the outcome is a function of the farmer's effort and external factors, the farmer carries some of the risk involved in the production process if his payment is based on the outcome. The typical trade-off between risk and reward is especially difficult to balance in the context of PES as many of the participating farmers are poor. Pagiola et al. [2005] find it difficult to assess the exact extent of poverty among participants. However, they report that some PES programs especially target poor farmers, if they are situated in environmentally sensitive areas. In these cases PES is assumed to contribute to poverty reduction. In general, farmers in developing countries are relatively poor. Their risk aversion and associated risk costs are very high, because they are more vulnerable to external shocks and have less financial reserves. Therefore, an optimal contract has to strike a delicate balance between the allocation of risk and reward.

3.2.2 Technology

We now describe the role of different production technologies for PES. Ecological and physical processes underlying watershed protection, biodiversity conservation and carbon sequestration reveal characteristic differences. These different characteristics can be interpreted as different functional forms of the underlying production technologies.

Watershed protection

Mostly cited downstream benefits resulting from upstream watershed protection are a regulated water flow, that is maintenance of dry season flows and flood control, a higher annual water flow, and a better water quality, that is minimization of sediment load, nutrient load, chemical load and salinity. Related protection activities target forest cover and improved land management.

In general, the linkages between land use and hydrology are very complex. In particular, the impacts of forests on water quantity and quality, erosion and groundwater levels depend on many site-specific features, including terrain, soil composition, tree species and vegetation mix (Calder [1999], Chomitz and Kumari [1998]). However, some conclusions can be drawn from the growing body of evidence.[1]

- Cloud forest clearance for pasture or annual cropping leads to decreased flows in the dry season.
- Total annual water yield is seen to increase roughly proportional to the fraction of non-cloud tropical forest biomass removed.
- A good plant cover is generally necessary to prevent surface erosion.
- Run-off and resulting catchment sediment yield increase with the number of hectares converted to selective logging, agriculture or plantation, and, above all, urbanization, mining and road construction.

These findings suggest two main characteristics of watershed protection technologies: First, the relation between input and output is roughly proportional. Second, the effects of individual farmers' efforts are difficult to distinguish. Hence, only a joint outcome can be observed.

[1] See Bruijnzeel [2004] for an up-dated survey on the hydrological functions of tropical forests.

Biodiversity conservation

The conservation of biodiversity often depends on the joint effort of several farmers in one area and is characterized by synergies. If habitat supporting endangered species cuts across several private lands, the likelihood of species survival rises if landowners create a single large habitat reserve that minimizes so-called edge effects (Eisner et al. [1995]). Edge effects occur at the boundaries between different habitats, e.g. the edge between a forest and a field. Some species, like game animals, thrive along the edge, while others are driven deeper into the forest. Fragmentation creates more edges that can adversely affect species protection. Fragmentation also increases the risk to species when it alters the microclimate of the habitat (Saunders et al. [1991]).

Another biological example for synergies is the meta-population concept (Hanski [1999]). A meta-population consists of a number of sub-populations that are physically separated but interact with each other through the exchange of individuals. For a meta-population consisting of two sub-populations Frank and Wissel [2002] show that its expected lifetime is approximately related to the product of the expected lifetimes of the two sub-populations.

While the effects of individual efforts aiming at watershed protection are relatively independent of each other, the impacts of individual efforts engaged in biodiversity conservation depend very much on the total effort provided. Hence, the synergies of conservation efforts ask for a stronger coordination of efforts. Similar to watershed protection, the effects of individual inputs are difficult to identify, since only the joint output can be observed.

Carbon sequestration

The links between tree-based systems and carbon sequestered are well documented. Through the process of photosynthesis, trees absorb carbon dioxide which remains fixed in wood and other organic matter in forests for long periods. Data for different tree species and land uses are available.[2]

Afforestation is a typical activity in carbon projects. The number of trees surviving or the amount of carbon sequestered per farmer are convenient performance indicators which can be monitored separately for each farmer. Experiences of The Small Group Tree

[2]See for example Tomich et al. [2001] for an analysis of carbon sequestration in the humid tropics by different vegetation types.

Planting Program (TIST), which is operating in Tanzania, Kenya, India and Uganda, shows that measurement tools can even be used by farmers. Here, small-holders employ tools like geographical positioning systems and palm computers to measure the carbon stored in their trees.[3] Hence, in contrast to the watershed and biodiversity schemes, in carbon schemes individual outputs can be identified. Their values can be correlated, though, if farmers plant trees in the same geographical area or use the same seedlings. Common risk factors might be fire, climate, and pests or diseases.

3.2.3 Cooperation

We begin by explaining what may happen, if agents do not cooperate. In a team with only one performance signal, like the joint outcome of watershed protection and biodiversity conservation of many farmers, the link between individual effort and reward is weakened. Agents have therefore greater incentives to shirk, which reduces total output.

Holmström [1982] suggests a collective penalty as solution to the so-called problem of "moral hazard in teams". The penalty has to be higher than the gain from free-riding in order to induce the desired outcome as a Nash equilibrium. Although effective for a relatively small group of risk neutral agents, collective punishment as proposed by Holmström [1982] has several disadvantages. First, it performs less well for a group of risk averse agents or a large group in general. Another drawback is the perceived unfairness of collective punishment. Farmers might be reluctant to sign a contract which includes such an enforcement mechanism. It carries the risk that free-riders dominate the group and take advantage of complying agents who are forced to contribute more than they are supposed to in order to avoid the punishment. The actual outcome is then determined by the coordination capability and composition of the group.[4]

Having observed a significant compliance problem in the practice of agri-environmental schemes in Europe and the US, optimal effort monitoring has received increased attention (Hart and Latacz-Lohmann [2005], Choe and Fraser [1999]). Ozanne et al. [2001] point to the potential trade-off between increased environmental benefit and increased monitoring costs.

Whether collective punishment or increased monitoring is the more effective enforce-

[3] See http://www.tist.org for a presentation of The Small Group Tree Planting Program.

[4] See chapter 3 in this document.

ment instrument depends on the situation. Small group size, rather risk neutral farmers and high monitoring costs would favor collective penalties.

However, the problem of moral hazard in teams does not necessarily occur. Evidence from the field as well as experimental studies have shown, that, if agents can monitor each other and dispose of some kind of sanction mechanisms, free-riding can be prevented (Ostrom [1990]). The potential for peer monitoring is typically higher in non-industrialized countries. Holdings are smaller and change is easier to observe[5]. Farmers tend to have larger families, and are tied closer to their local communities. Frequent visits and cooperation on other matters increase the pool of information available to farmers and their ability to monitor each other. Since the legal system is not as developed as in richer countries, in many rural areas in developing countries compliance with norms and agreements is achieved via social sanctions and other informal enforcement mechanisms.

The advantages of peer monitoring have been analyzed by the literature on group credits. In group lending schemes the members are made jointly liable for repayment. By explicitly modelling a social penalty function Besley and Coate [1995] show how repayment rates can be increased via group credits for communities with a high degree of social connectedness and effective social sanction mechanisms. Aghion [1999] and Stiglitz [1990] also analyze collective credit agreements and their potential to reduce strategic default. Both authors demonstrate that peer monitoring can be valuable, if social sanctions can be imposed, but has to be balanced against increased monitoring costs for participant borrowers.

The relevance of inter-agent cooperation for PES is therefore straightforward. On the one hand, PES schemes involving production technologies with only one performance signal, like biodiversity conservation and watershed protection, inevitably run the risk of free-riding if the output is used as performance indicator and the members of the group are not cooperating. On the other hand, high social connectedness and the ability of farmers to monitor each other are conditions which are often attributed to PES environments and could prevent free-riding.

[5]For comparison, the average size of a holding in Ethiopia is 1 ha, whereas in the United States, it was 179 ha in 2004. Information available from Berhanu et al. [2002] and the U.S. Department of Agriculture: www.usda.gov

3.3 The Model

We will now illustrate and further specify some of the above considerations by applying the theoretical model of Holmström and Milgrom [1990] to the context of PES. Having done so we will derive some hypotheses for the design of PES contracts.

3.3.1 Risk

Two agents, A and B, provide effort, a and b, for producing an environmental service S. The term effort is interchangeably used with action and comprises labor as well as physical inputs. The two agents, sometimes also referred to as farmers, are rewarded by a principal for their efforts. The principal cannot observe the effort provided by the agents. He does not know how much time they spend on planting trees, or, to what extent they reduce the application of chemicals to their fields. Instead, the amount of environmental service produced serves as performance signal. As basis for the reward it represents only an imperfect performance signal, as the output is a function of the agents' effort and a random variable ε representing *nature*.

$$S = f(a,b) + \varepsilon \tag{3.1}$$

The function $f = f(a,b)$ is concave in inputs. The random variable ε is normally distributed and has an expected value of zero and a variance σ^2. Both agents incur costs of effort, denoted by $C^A = C^A(a)$ and $C^B = C^B(b)$. These cost functions are assumed convex and private information to the agents. The principal receives S. The payment functions to the agents are linear and given by

$$\Pi^A(S,\alpha) = \alpha_0 + \alpha_1 S, \quad \Pi^B(S,\beta) = \beta_0 + \beta_1 S. \tag{3.2}$$

For the incentive shares α_1 and β_1 and the fixed compensation payments α_0 and β_0 we can write $\alpha = (\alpha_0, \alpha_1)$ and $\beta = (\beta_0, \beta_1)$.

Optimal incentive contracts in principal agent models tend to be complicated and difficult to work with. Theory suggests finely tuned rules, which depend on all the available information for an accurate evaluation of the agents' efforts. The assumption of a linear contract might, therefore, seem restrictive. For our context it is, however, justified.

Holmström and Milgrom [1987] consider the problem of providing incentives over time for an agent with constant risk aversion. They find the optimal compensation scheme to be a linear function of the aggregated outputs over time. They interpret the linearity as a result of the agent having a great freedom of action over a certain period of time.[6] The linearity of the contract in the model of Holmström and Milgrom [1990] is based on the results of Holmström and Milgrom [1987].

The agents A and B have strictly concave preferences defined by an exponential utility function. Based on the Arrow-Pratt measure of absolute risk aversion their levels of risk aversion, r^A and r^b, are constant. Agent A incurs risk costs which are defined as

$$R^A = 1/2 r^A \alpha_1^2 \sigma^2 \tag{3.3}$$

They represent the difference in expected utility between a risky prospect and its certain equivalent. For agent B the risk premium is analogous. The authors follow Pratt [1964] who described risk aversion as "twice the risk premium per unit of variance for infinitesimal risks".

Each agent's preferences can be expressed in certainty equivalent terms, because the reward structure is linear and the random variable is normally distributed with expected value of zero. Agent A's certainty equivalent is then:

$$CE^A(a,b,\alpha) = \alpha_0 + \alpha_1 f(a,b) \; - C^A(a) - R^A \tag{3.4}$$

The certainty equivalent of agent B is analogous. The certainty equivalent of the principal, who is, by assumption, risk neutral, is described by

$$CE^P(a,b,\alpha,\beta) = (1 - \alpha_1 - \beta_1) f(a,b) \; - \alpha_0 - \beta_0. \tag{3.5}$$

The principal will choose contracts (a, α) and (b, β) in order to maximize his own payoff (3.5) subject to the agents' incentive compatibility conditions given in (3.6) and rationality constraints given in (3.7).

[6] See Schmidt and Hellwig [2002] for an analysis and an additional justification of the linearity in the model of Holmström and Milgrom [1987].

$$
\begin{aligned}
CE^A(a,b,\alpha) &\geq CE^A(a',b,\alpha), \qquad \text{for every } a' && (3.6)\\
CE^B(a,b,\beta) &\geq CE^B(a,b',\beta), \qquad \text{for every } b' &&\\
CE^A(a,b,\alpha) &\geq 0 && (3.7)\\
CE^B(a,b,\beta) &\geq 0 &&
\end{aligned}
$$

Recall that the constraint (3.6) reflects the restriction that the principal can observe S but not a and b. If he could observe individual actions, a forcing contract could be used to guarantee that the agents select a proper effort. The shares α and β would be chosen to solve (3.5) subject to (3.7) only. The latter can be referred to as the first best solution. Due to the information asymmetry between the agents and the principal only a second best solution can be obtained.

Utility, as expressed by certainty equivalents, is assumed transferable. Then, an efficient contract must maximize the sum of utilities. This process is independent of the constants α_0 and β_0. They only serve to guarantee (3.7).

The principal's problem can therefore be written as:

$$
\text{Maximize} \quad f(a,b) - C^A(a) - C^B(b) - R^A - R^B, \quad \text{s.t.} \tag{3.8}
$$

$$
\alpha_1 \partial f/\partial a - \partial C^A/\partial a = 0, \tag{3.9}
$$

and

$$
\beta_1 \partial f/\partial b - \partial C^B/\partial b = 0, \tag{3.10}
$$

3.3.2 Technology

Holmström and Milgrom [1990] consider two types of production technologies: *Joint* and *independent* production. Joint production is characterized by only one performance signal for both agents, which means that only the total output, S can be observed. The inputs simply add or enter as a product into the production process as described by equations (3.11) and (3.12) respectively:

$$
f(a,b) = f^A(a) + f^B(b) \tag{3.11}
$$

or

$$f(a,b) = f^A(a)f^B(b). \tag{3.12}$$

Holmström and Milgrom [1990] point out that the availability of only one performance signal for two agents does not raise any concerns of free-riding, since the principal can employ collective punishment, as proposed by Holmström [1982].

Independent production generates one performance signal for each farmer S^A and S^B with $S = S^A + S^B$. They are characterized by the following production functions

$$S^A = f^A(a) + \varepsilon_A \tag{3.13}$$

and

$$S^B = f^B(b) + \varepsilon_B. \tag{3.14}$$

The two random variables ε_A and ε_B are normally distributed with expected values of zero and variances σ_A and σ_B. The outputs S^A and S^B are correlated with the correlation coefficient $\rho = \sigma_{AB}/\sigma_A\sigma_B$. We proceed by stating the optimal contracts for three simple production functions. The purpose is to demonstrate the main differences in the optimal contracts which result from the three production technologies.

Joint additive production

Substituting the function (3.11) into (3.8) and maximizing we arrive at two separate problems:

$$\text{maximize} \quad f^A(a) - C^A(a) - R^A - \lambda_A(\alpha_1 \partial f^A/\partial a - \partial C^A/\partial a) \tag{3.15}$$

and

$$\text{maximize} \quad f^B(b) - C^B(b) - R^B - \lambda_B(\beta_1 \partial f^B/\partial b - \partial C^B/\partial b). \tag{3.16}$$

λ_A and λ_B denote the respective Lagrange multipliers. It follows that in the optimum the incentive shares α_1 and β_1 are independent of each other.

We consider the simple technology

$$f = ha + gb. \tag{3.17}$$

The parameters h and g are the marginal products of A and B. In order to find the optimal incentive share for agent A we maximize the first problem of (3.15) with respect to a and α_1 and substitute $\alpha_1 h$ for $C^A/\partial a$.[7]:

$$\alpha_1 = \frac{h^2}{h^2 + r^A \sigma^2 C^{A''}} \tag{3.18}$$

Equation (3.18) says that the incentive coefficient of agent A will be set below 1 by an amount that positively depends on the agent's risk aversion, risk (σ^2) and the agent's cost function. Another result is that α_1 is increasing in h, which can be interpreted as a measure of the contribution of agent A's actions to the total output relative to nature. The principal can use the fixed payment to adjust the total payment to agent A such that his rationality constraint holds. Note, that A's payment does only indirectly depend on the effort and payment of B, since what B does and receives affects the shared outcome.

Joint multiplicative production

If the agents' efforts enter as a product into the production process the principal's problem (3.8) cannot be separated. It is now defined by

$$\text{maximizing} \quad f^A(a) f^B(b) - C^A(a) - C^B(b) - R^A - R^B \tag{3.19}$$

subject to the constraints

$$\alpha_1 \partial f^A/\partial a - \partial C^A/\partial a = 0 \tag{3.20}$$

$$\beta_1 \partial f^B/\partial b - \partial C^B/\partial b = 0. \tag{3.21}$$

Consider the following example:

$$f = hagb \tag{3.22}$$

Solving the maximization problem with respect to a and α subject to the first constraint we arrive at (3.23).

$$\alpha_1 = \frac{(hgb)^2}{(hgb)^2 + r^A \sigma^2 C^{A''}} \tag{3.23}$$

[7] In what follows, we will only state the results for agent A, whenever the results for agent B are analogous to those of agent A.

As compared to the additive production function, the incentive share of agent A is no longer independent of B's but increases with the effort provided by B and B's marginal product. It is, again, negative related with agent A's risk aversion and the variance in output, and positive related with the strength of the effect of his own effort on outcome.

Independent production

We now turn to the case of independent production, characterized by (3.13) and (3.14). Recall, that the principal can now base the payments on two separate performance signals. It is therefore correct to specify the payment functions as

$$\Pi^A(S^A, \alpha) = \alpha_0 + \alpha_1 S^A \tag{3.24}$$

$$\Pi^B(S^B, \beta) = \beta_0 + \beta_1 S^B. \tag{3.25}$$

As a result, the risk premia of the two agents differ:

$$R_I^A = 1/2 r^A \alpha_1^2 \sigma_A^2 \tag{3.26}$$

$$R_I^B = 1/2 r^B \beta_1^2 \sigma_B^2. \tag{3.27}$$

The general structure of the problem does not change.[8] As for the joint additive production the principal maximizes two separate problems

[8] Holmström and Milgrom [1990] show how incentive costs can be reduced by comparing agents with each other. The reason is, that randomness of individual outcomes can be filtered out by comparing agents' performances such that individual performance can be exactly evaluated. Such relative performance evaluation requires separate contracts which include negative (positive) weights on the other agent's outcome if outcomes are positively (negatively) correlated. Their argument is based on Holmström [1982] who found that aggregate measures like peer averages often provide sufficient information about common uncertainties and, thus, schemes that compare agents with such aggregate measures will be efficient. Several field studies, however, observed that relative performance evaluation, besides being uncommon, is ineffective if agents interact closely with each other, because agents are encouraged to penalize "rate busters". For a comprehensive treatment see Che and Yoo [2001].

$$f^A(a) - C^A(a) - R_I^A - \lambda_A(\alpha_1 \partial f^A/\partial a - \partial C^A/\partial a) \quad (3.28)$$

and

$$f^B(b) - C^B(b) - R_I^B - \lambda_B(\beta_1 \partial f^B/\partial b - \partial C^B/\partial b). \quad (3.29)$$

An exemplary technology is given by (3.30,3.31)

$$f^A = ha + \varepsilon_A \quad (3.30)$$

$$f^B = gb + \varepsilon_B. \quad (3.31)$$

Substituting and maximizing gives:

$$\alpha_1 = \frac{h^2}{h^2 + r^A\sigma_A^2 C^{A''}} \quad (3.32)$$

$$\beta_1 = \frac{g^2}{g^2 + r^B\sigma_B^2 C^{B''}}. \quad (3.33)$$

The structure of the incentive shares is similar to those under joint additive production. They differ only in the different risk factors.

3.3.3 Cooperation

This part considers the possibility of cooperation among agents. In particular, it focusses on cooperation among agents which is beneficial.[9] Varian [1990] has shown, that, in general, cooperation among agents is only beneficial if agents dispose of superior knowledge about each other, i.e. they can monitor each other. Cooperation is formalized in the model by side trades among agents. Side trades can be pecuniary or nonpecuniary, implicit or explicit. Important is that they are enforceable by the agents and cannot be directly controlled by the principal.

The side contract $T(a, b, t, \varphi)$ specifies that agent A pays agent B an amount t contingent on actions a and b. In contrast to the principal the agents know which actions have been carried out. It is further determined that risk is shared via φ. For this situation we

[9] If agents collude it can be detrimental for the principal. The associated cost and the design of collusion-proof contracts have been analyzed, among others, by Tirole [1986] and Laffont and Martimort [1997].

look at the most general production technology (3.1). The risk premium of agent A is defined as

$$R_C^A = (1/2)r^A(\alpha_1 - \varphi)^2\sigma^2 \tag{3.34}$$

For agent B it is:

$$R_C^B = (1/2)r^B(\beta_1 + \varphi)^2\sigma^2 \tag{3.35}$$

His share of the risk is increased by φ and he receives a compensation of t. The side contract is agreed upon after the principal has announced the incentive schemes (a, α) and (b, β). The agents will then choose (a, b, φ, t) to

$$\text{maximize} \quad (\alpha_1 + \beta_1)f(a, b) - C^A(a) - C^B(b) - R_C^A - R_C^B \tag{3.36}$$

$$\text{subject to}$$

$$\text{a maximizes} \quad (\alpha_1 - \varphi)f(a', b) - C^A(a') - t(a', b) \tag{3.37}$$

$$\text{b maximizes} \quad (\beta_1 - \varphi)f(a, b') - C^B(b') + t(a, b') \tag{3.38}$$

$$\text{for every } a' \text{ and every } b'.$$

Considering the behavior of the agents the principal faces the new problem of choosing (a, b, α, β) such that they

$$\text{maximize} \quad f(a, b) - C^A(a) - C^B(b) - R^A - R^B \tag{3.39}$$

$$\text{subject to}$$

$$(a, b, \varphi) \qquad \text{is an optimal solution to (3.36), (3.37), and (3.38)} \tag{3.40}$$

Referring to the results of Wilson [1968], Holmström and Milgrom [1990] show that the principal will optimally offer only one contract to the agents, as they can be regarded as a single agent.[10] This follows from the fact that φ has no effect on incentives. It serves only to minimize total risk costs. At its optimal value the agents choose a and b to maximize their common objective. Their cost function is the sum of their individual cost

[10] Itoh [1993] provides a different proof of the same result.

functions and their risk tolerance is the sum of their individual risk tolerances[11]. What does this imply? Whenever agents side trade they should be offered a group contract. The principal can then take advantage of their effort coordination and improved risk sharing. The total costs will also be lower because of the higher risk tolerance. This applies to every technology and it is irrelevant if the principal can observe a joint performance signal or individual ones.

3.3.4 PES in Theory

Bringing together the theoretical results and the context of the general PES environment as described in 3.2 this section derives some propositions for the optimal design of PES contracts. A first observation is that the general structure of contracts should be the same for all services, a two-part linear payment. The linearity can be justified by the dynamic character of the deals. Their outcome is the final result of a production process during which farmers fulfill many small related tasks. The two parts of the payment scheme are a fixed compensation and a variable payment based on the produced amount of the environmental service, i.e. water, biodiversity, carbon. They serve to balance risk and reward. The relative weight attached to these two parts and the specific design of the variable part will depend on risk, technology and the level of cooperation among farmers.

Section 3.2 described how external factors result in a high risk environment of PES. Moreover, farmers in developing countries can be expected to have a high risk aversion. In general, risk and risk aversion increase the risk premia of the farmers and thereby the cost associated with incentive shares. In section 3 we further derived that variable payments optimally increase with the effect of individual effort on total output relative to the effect of nature. All these three aspects suggest that the incentive shares relative to the total payment will be small for all environmental services.

The theoretical payment functions following from our analysis are given in table I.

The table shows how the specific design of the variable payments will reflect the technology underlying the respective service. Certainly, the theoretical production functions are only rough approximations but they capture the main idea.

Watershed protection can be approximated by an additive joint production function. Only total output is measurable, i.e. water quantity or quality downstream, which is a

[11]Risk tolerance is defined as the inverse to risk aversion.

Service	Technology	Payment to farmer A
Water	joint additive	$\Pi^A = \alpha_0 + \frac{h^2}{h^2+r^A\sigma^2 C^{A''}} S$
Biodiversity	joint multiplicative	$\Pi^A = \alpha_0 + \frac{(hgb)^2}{(hgb)^2+r^A\sigma^2 C^{A''}} S$
Carbon	independent	$\Pi^A = \alpha_0 + \frac{h^2}{h^2+r^A\sigma_A^2 C^{A''}} S^A$

Table I: Theoretical payment functions per environmental service

result of the accumulated individual efforts of the farmers upstream. Optimal variable payments to farmers will depend on the common output (S). Moreover, they will be independent unless group contracts are signed due to reasons of cooperation.

The technology underlying biodiversity conservation can be represented by a multiplicative joint production function. Theory suggests that variable payments will be based on the total level of biodiversity (S). Whenever individual contracts for biodiversity conservation are awarded, the incentive shares will take into account the amount of effort employed by neighbors (gb).

Carbon sequestration can be characterized by independent production functions with individual performance measures (S^A). Accordingly, optimal payments will be independent and variable payments will depend on individual outcomes and individual risk (σ_A) only, unless farmers cooperate.

It applies to every technology, that group contracts are beneficial under two conditions: farmers cooperate in a way, which cannot be controlled by the principal, and they can monitor each other. Under these two conditions the principal cannot do better than offer them a group contract. Farmers in developing countries can relatively easy monitor each other. In addition, due to their often informal character, agreements in developing countries are difficult to control by a principal. We therefore expect to find more group contracts in developing countries than in industrialized ones.

3.4 PES in Practice

This section describes how contracts for PES are designed in practice. We draw on two surveys of payment schemes for forest environmental services (Landell-Mills and Porras [2002], Scherr et al. [2004]) and individual case studies. The presented case studies cover all three environmental services discussed above and are either public or private schemes. (See table (II) for a list of the individual case studies and their main characteristics as they relate to our analysis.)

Following the structure of the previous sections we describe how the schemes deal with risk, and in which way they take account of the different technologies and group incentives.

3.4.1 Risk in Practice

The payments in almost all watershed protection and biodiversity conservation schemes are fixed payments ($\alpha = \alpha_0, \alpha_1 = 0$). The amount of a biological resource under protection or the area of land subject to certain management practices are decided upon ex ante and a fixed payment is derived accordingly. Compliance monitoring is part of most of the programs, the quality and frequency of which depend on the financial and institutional capacity of the program. The observed land use then serves as indicator of compliance. Auditing is mostly carried out on the basis of satellite pictures or personal visits. Note, that the compliance indicators do not measure effort itself but rather assess if farmers are following the basic terms of the contract.

The simplest approach was initially implemented by Costa Rica's Pago por Servicios Ambientales (PSA) program. Rewarding the services of carbon sequestration, watershed protection, biodiversity conservation and scenic beauty, every landowner, who agreed to either conserve or manage his forest in a sustainable manner, or establish a plantation was paid a fixed annual sum per hectare (Pagiola [2002]).

Perrier-Vittel, a French company that sells bottled water, pays upstream landowners for best management practices on their land to ensure that the company has a supply of high quality water. Every farm receives about US$ 230 per hectare per year for seven years. Vittel does not make payments based on the relationship between pollutant contents and water quality but compensates farmers for the reduced profitability associated with the transition to the new technology (Perrot-Maître and Davis [2001]).

(a) Water related services

Case study	Payment	Technical study	Country	Individual/Group	Source
CRP	fixed	yes	USA	individual	Bernstein et al. [2004]
La Esperanza	variable	no	Costa Rica	individual	Rojas and Aylward [2002]
Perrier-Vittel	fixed	yes	France	individual	Perrot-Maître and Davis [2001]
Pimampiro	fixed	no	Ecuador	individual	Echavarria et al. [2003]
PSAH	fixed	no	Mexico	group	Muñoz Piña et al. [2005]
Work for Water	fixed	yes	South Africa	individual	Postel and Thomsen Jr. [2005]
Catskills	fixed	yes	USA	individual	Postel and Thomsen Jr. [2005]

(b) Biodiversity conservation

Case study	Payment	Technical study	Country	Individual/Group	Source
CRP	fixed	yes	USA	individual	Bernstein et al. [2004]
PSA	fixed	no	Costa Rica	individual/group	Pagiola [2002]
Silvopastoral	fixed	yes	Costa Rica, Nicaragua, Columbia	individual/group	World Bank [2002]
Coffee	fixed	yes	Ethiopia, Mexico, El Salvador	individual/group	Pagiola and Ruthenberg [2002]

(c) Carbon

Case study	Payment	Technical study	Country	Individual/Group	Source
PSA	fixed	no	Costa Rica	individual/group	Pagiola [2002]
Silvopastoral	fixed	yes	Costa Rica, Nicaragua, Columbia	individual/group	World Bank [2002]
Plan Vivo	variable	yes	developing countries	individual/group	Tipper [2002]
TIST	variable	yes	developing countries	group	www.tist.org

Table II: PES case studies

Traded products can also serve as vehicle for environmental payments. Coffee which is produced in a biodiversity-friendly way is a prominent example. These kind of mechanisms seek to harness consumers' willingness to pay for conservation by inducing them to pay a premium for biodiversity-friendly coffee[12]. The premium increases the relative attractiveness to farmers of growing this coffee rather than other crops or less biodiversity-friendly plantation coffee. In Ethiopia some farmers receive a premium for so-called "Wild Coffee" which is growing unmanaged in the rain forest (see chapter 2). The premium is fixed and compensates them for the opportunity cost of not converting the rain forest into more profitable land uses.[13] Thus we state that in the schemes PSA, Perrier-Vittel, and coffee schemes the payments to farmers are not tied to the environmental service produced.

A more advanced approach is to differentiate between fixed payments with respect to the expected value of output in order to achieve higher cost efficiency. Mexico's Payment for Hydrological Services program (PSAH) compensates forest owners for the benefit of watershed protection and aquifer recharge. Because cloud forests are expected to provide higher benefits, their owners receive a higher payment than owners of non-cloud forests (Muñoz Piña et al. [2005]).

The International Institute for Environment and Development (IIED) reports that in Pimampiro, a small town in Ecuador which compensates forest owners for their watershed protection, also different payment categories exist for different forest types. For example owners of untouched primary forest receive a higher, fixed, payment than owners of young secondary forest (Echavarria et al. [2003]).

Similar initiatives exist for biodiversity conservation. Supported by the World Bank, the Silvopastoral project in Costa Rica, Nicaragua, and Columbia is now testing a refined instrument, which ranks land uses according to their expected or believed benefit in terms of biodiversity conserved and carbon sequestered (World Bank [2002]). The ranking is performed by giving points to specific land uses according to their biodiversity and carbon benefit, which are then transformed into a total environmental service index. The payments are higher for higher ranked land uses (see table III).

This ranking mechanism is similar to the Environmental Benefit Index (EBI) which is used in the Conservation Reserve Program (CRP) in the United States. Environmen-

[12] Coffee which is grown under shade trees instead of on plantations gives habitat to birds and insects.

[13] Similar initiatives exist in El Salvador and Mexico (Pagiola and Ruthenberg [2002]).

Table III: Environmental Service Indices used in the Silvopastoral Project

Land use	*Biodiversity index*	*Carbon sequestration index*	*Environmental service index*
Annual crops	0.0	0.0	0.0
Degraded pasture	0.0	0.0	0.0
Natural pasture without trees	0.1	0.1	0.2
Improved pasture without trees	0.4	0.1	0.5
Semi-permanent crops	0.3	0.2	0.5
Natural pasture with low tree density	0.3	0.3	0.6
Natural pasture with recently-planted trees	0.3	0.3	0.6
Improved pasture with recently-planted trees	0.3	0.4	0.4
Monoculture fruit crops	0.3	0.4	0.7
Fodder bank	0.3	0.5	0.8
Improved pasture with low tree density	0.3	0.6	0.9
Fodder bank with woody species	0.4	0.5	0.9
Natural pasture with high tree density	0.5	0.5	1.0
Diversified fruit crops	0.6	0.5	1.1
Diversified fodder bank	0.6	0.6	1.2
Monoculture timber plantation	0.4	0.8	1.2
Shade-grown coffee	0.6	0.7	1.3
Improved pasture with high tree density	0.6	0.7	1.3
Bamboo (*guadua*) forest	0.5	0.8	1.3
Diversified timber plantation	0.7	0.7	1.4
Scrub habitats (*tacotales*)	0.6	0.8	1.4
Riparian forest	0.8	0.7	1.5
Intensive silvopastoral system	0.6	1.0	1.6
Disturbed secondary forest	0.8	0.9	1.7
Secondary forest	0.9	1.0	1.9
Primary forest	1.0	1.0	2.0
New live fence or established live fence with frequent pruning (per km)	0.3	0.3	0.6
Wind breaks (per km)	0.6	0.5	1.1

Notes: Points per hectare, unless otherwise specified.
The environmental service index is the sum of the biodiversity and carbon sequestration indices
Source: World Bank [2002]

tal services included are biodiversity conservation, watershed protection, and air quality. Farmers receive a base payment of US 125 per hectare per year and are compensated for 50 per cent of the cost to establish approved conservation practices. Their applications to the program are evaluated based on the expected environmental benefits and implementation costs, which have to be estimated for the application (Scherr et al. [2004]). Even in these more elaborate schemes payments are not linked to the actual service produced.

The only known case of incentive shares for watershed services is La Esperanza in Costa Rica. Here, a hydropower producer and an upstream landowner agreed on an output-based payment scheme which links payments to the actual water flow. The service provider is compensated for maintaining his land under forest, which is expected to provide a higher water flow in dry seasons and less floods in wet seasons, as compared to a deforested landscape. The reward increases with the power produced which positively depends on a regulated water flow (Rojas and Aylward [2002]).

Summarizing we find that a large majority of water and biodiversity schemes do not place any risk involved in producing the environmental service onto the shoulders of the producers because they rely on fixed payments. This risk is carried alone by the buyers. Basically, the farmers are only required to carry out the tasks described in the contract. It is however possible that contracts are terminated if the concerned area has been rendered unproductive by an accidental fire for example (Muñoz Piña et al. [2005]). Farmers, who made initial investments for the scheme, then have to start from scratch.

Let us turn to carbon projects. Carbon projects have been strongly influenced by the provisions of the Kyoto Protocol. The Protocol administers credit, so-called certified emission reductions for each metric tonne of carbon dioxide reduced. Most carbon projects are either registered under the Kyoto Protocol or aim to be registered (Scherr et al. [2004]). Registered projects meet strict criteria for the certification of carbon credits. In contrast to watershed and biodiversity schemes the payments in carbon projects are generally variable payments ($\alpha_1 = \alpha, \alpha_0 = 0$). The participants in the International Small Group and Tree Planting Program (TIST) receive payments for every living tree. In the Plan Vivo system, currently employed by projects in Uganda, Mozambique, Mexico, and India, payments are derived directly from the amount of carbon produced.[14] As a result the producers of

[14] See Tipper [2002] and http://www.planvivo.org for a description of the system.

carbon are exposed to the full risk involved in the production process.

3.4.2 Technology in Practice

This section describes how technological aspects of the different services are incorporated into project design of PES schemes, and, in particular, how aspects like joint output and synergies enter the payment functions.

Many project documents admit the lack of a scientific or technical justification for the watershed and biodiversity schemes. In these cases project developers, buyers and sellers do not know if the action specified in the PES contract will eventually produce the desired service. Authors point to a "common perception" (Echavarria et al. [2003], page 18) or a strong belief that there exists a link between action and output. They also argue that the precautionary principle is applied (Pagiola [2002]).

Notable exceptions are the Conservation Reserve Program in the US, the Catskill program of New York City, the Silvopastoral project financed by the World Bank, the Work for Water program in South Africa, and biodiversity-friendly coffee programs. In the United States agricultural extension officers in every county evaluate and rank applications for the CRP Program taking into account a large body of evidence on species diversity and ecosystem characteristics.

New York City commissioners initially planned investing in filtration systems to clean up non-point source contamination of its watersheds. These watersheds deliver 1.2 billion gallons of water per day for the people living in the city and its suburbs. However, detailed technological and economic studies showed that a comprehensive program of watershed protection would cost far less than filtration and would be even more effective (Postel and Thomsen Jr. [2005]).

South Africa is paying workers to remove non-native eucalyptus, pine, black wattle and other invasive alien trees from the watershed of the Western Cape. Researchers have determined that a restored catchment would yield nearly 30 per cent more water than one of equivalent size populated with alien species (Postel and Thomsen Jr. [2005]). These results then determined where and how many trees should be removed.

The Silvopastoral project in Costa Rica, Nicaragua, and Columbia is implemented in cooperation with three national agricultural research institutes from the participating countries and the Food and Agriculture Organization of the United Nations (FAO) who provide technical assistance. The design of the project was based on scientific evidence on the performance of different ecosystems in the different regions (World Bank [2002]).

The biodiversity impacts of different coffee production systems have been analyzed by Moguel and Toledo [1999], Perfecto et al. [1996], and Gole et al. [2002]. Their results led to an increased investment into biodiversity-friendly production systems, at least in Ethiopia and El Salvador.

The cases above are examples where scientific studies underpin the PES schemes. However, even for these cases it is rarely possible to exactly describe the link between action and output. Apart from these exceptions the technological foundation of PES schemes aiming at watershed protection and biodiversity conservation is rather weak.

We now describe the effect of technological differences on payment functions. Due to the joint but additive production technology of most watershed services theory suggests variable payments which are based on the joint output but are otherwise independent, unless farmers cooperate. In contrast, real payments in watershed schemes are, as mentioned above, to a large majority fixed and not always independent. Group schemes exist in Mexico and Costa Rica for example. They are discussed in section 3.4.3.

Real payments for biodiversity conservation are also fixed payments and therefore, in general, do not include incentive shares depending on the effort provided by other participating farmers, as proposed by theory. However, some projects indirectly recognize the synergies associated with conservation efforts. The Silvopastoral project encourages farmers to increase connectivity between their lands and channels the payments to farmers operating in target or priority areas. The CRP program in the US can assign a higher Environmental Quality Index to farm land bordering on a protected area.

As to carbon projects, whenever they involve individual farmers their payments are independent as predicted by theory. Group schemes also exist.

3.4.3 Groups and Cooperation in Practice

Group contracts are employed in several schemes. As predicted, they cover all services and are, to our knowledge, only used in developing countries. Effort coordination and cooperation among farmers are mentioned as reasons for group contracts by the International Small Group and Tree Planting Program. It is operating in Tanzania, Kenya, India, and Uganda based on small groups of 10-12 farmers who own a common account, onto which the payments for the planted trees are transferred. Farmers instruct each other on the best ways to plant trees, monitor each other and share the production risk.

All other group schemes do not explicitly cite cooperation as the main reason but rather a reduction in transaction costs. In Mexico, for example, groups are formed based on institutional grounds. 44 million hectares of land are held by communities, so-called *ejidos*. Farmers, who are organized in ejidos participating in the PSAH program, are collectively paid for hydrological services (Muñoz Piña et al. [2005]). Each period the members of the ejido collectively decide how to allocate the money.

Another example is the PSA program in Costa Rica, which is rewarding carbon sequestration, watershed protection, biodiversity conservation, and scenic beauty. Here it is possible to bundle small-scale farmers together into one contract. A study conducted between 1995 and 1997 found that 60 per cent of all PSA program participants, accounting for about 40 per cent of all land contracted, used group contracts (Pagiola [2002]). The main motivation behind these group contracts was to coordinate application processes and thereby save costs for farmers.

Bundling of contracts has been described as a means to reduce transaction costs especially for carbon projects. (Landell-Mills and Porras [2002], Pagiola et al. [2005]). Emerging markets for carbon sequestration world wide provide opportunities for producers in developing countries, who face low production costs. However, in assessing the comparative advantage and profitability of producers in developing countries, who tend to be smallholders, transaction costs have to be taken into account. Cacho et al. [2005] identify seven types of transaction costs associated with carbon projects: search costs, negotiation costs, approval costs, administration costs, monitoring costs, enforcement costs, and insurance costs. Projects with groups of smallholders spread the fixed transaction costs of design and implementation, thus leading to lower transaction costs per certified emission reduction.

3.4.4 Side Objectives

Officially, PES schemes are meant to supply users with environmental services, but the pursuit of side objectives with many schemes is quite remarkable. We will only name the most obvious cases. The Mexican PSAH has included priority mountains into its target area, although these areas had no water-related crises (Muñoz Piña et al. [2005]). (As it happened, during the year of program design, the United Nations had called for increased attention to mountain areas.) Agri-environmental programs in the United States and the EU like the Conservation Reserve Program represent a form of farm income support. Recasting farm support in a "green" light makes it easier to comply with strict WTO rules on domestic farm support payments (Bernstein et al. [2004]). Another example is Costa Rica, which, initially, built the PSA program on an existing subsidy scheme for unprofitable forest industries. The payment per hectare was exactly the same as the former subsidy (Pagiola [2002]). The TIST program and the Silvopastoral project explicitly state the objective of improving local livelihoods.

A positive public image is probably an important side objective attached to private deals. Pagiola [2002] mentions the case of Cerveceria Costa Rica, a beer maker, who is rewarding PSA program participants situated above an aquifer. Cerveceria is hoping to protect infiltration into the aquifer, which feeds the spring from which the company draws water to make beer and bottled water. Although other groups also benefit from the scheme, Cerveceria wants to pay the rewards on its own, because it is keen on positive publicity.

3.5 Conclusion

Two observations initiated this research. The investment into PES is increasing, while the general funding for nature conservation is scarce. Further, the general PES environment is prone to moral hazard and monitoring very expensive. Considering the business-like approach of PES we found it worthwhile to investigate if PES schemes make use of efficiency enhancing incentive contracts.

Section 3.3 presented a theoretical model describing how optimal PES contracts should vary with the type of technology, risk and the level of cooperation among farmers. Section 3.4 reported on the actual use of contracts for a diverse set of PES schemes in various countries. We will now summarize how the observed practices match with theory, discuss the variations and conclude.

First, we observe a striking difference in the design of contracts in carbon schemes compared to watershed and biodiversity schemes. Participants in carbon schemes receive only variable payments, whereas producers of watershed and biodiversity services receive only fixed payments. Why is risk differently allocated in carbon schemes on the one side and the other two services on the other side?

It is reasonable to assume that the levels of risk and risk aversion are similar for both kind of schemes. The participants are farmers, most of them rather poor, and the risk factors are due to the same outdoor conditions. Thus risk cannot be the reason for the difference in payment schemes.

Technology in its broadest meaning might be the reason. Our second observation is that the scientific underpinning of most biodiversity and watershed schemes is, apart from a few exceptions, rather weak. Pagiola [2002] reports that the effectiveness and efficiency of water service provision of the PSA Program in Costa Rica, a scheme with no scientific underpinning, was "probably not very high" due to a lack of targeting. But "the paucity of data on forest-hydrology links makes this very difficult to evaluate" (page 53). A recent report, commissioned by the British Tropical Forestry Research Programme and funded by the UK's Department for International Development, summarizes a series of research projects on investments in water resource projects (Hayward [2005]). The authors find that many projects which are intended to improve the water conditions in developing countries pursue solutions that are not supported by scientific evidence.

Similarly, biodiversity schemes find it very difficult to exactly define and measure the desired total output (Landell-Mills and Porras [2002]). The Convention on Biological Diversity (Article 2) defines biodiversity as:

"... the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

It is reasonable to suggest that the lack of scientific evidence, objective indicators, and measurement units for the desired services is the main reason for fixed payments in water and biodiversity schemes. If $f(a, b)$ is unknown and S hardly measurable the risk costs of the farmers increase tremendously if their payments depend on output. Furthermore, positive incentive shares can only induce valuable effort if farmers know the underlying production technology.

It turns out that the design of a PES payment is determined by the type of environmental service concerned. If it is carbon the payments are variable and all risk is carried by the producer. If it is water or biodiversity the payments are fixed and all risk is carried by the buyer. A first conclusion therefore is that the average biodiversity and water PES scheme does not fit the definition given by Wunder [2005]. The average buyer does not pay for a well-defined environmental service, but rather a well-defined action carried out by a farmer. In contrast, carbon schemes are real deals in which the output and underlying production technology are well-known. No general pattern of risk sharing between buyers and providers can be found. Better methods to monitor the desired outcome and more information on the underlying technologies would certainly facilitate risk sharing and improve the performance of water and biodiversity deals. Taking water and biodiversity schemes at face value and regarding them as business deals which trade environmental services might currently be misleading.

Relevant for the general performance of PES schemes irrespective of their category is the observation of the prevailing group incentives. Group contracts have found wide application in PES schemes in developing countries. Cooperation among farmers is taken into account for contract design but equally important aspects are the prevailing institutional structure in communities, as in Mexico, or the declared objective to reduce transaction costs. Recall that group incentives can increase efficiency of PES schemes under certain conditions, i.e. superior knowledge of the farmers concerning the activities of their colleagues and the willingness and ability to side trade. Efficiency gains due to risk reduction via effort coordination are however removed by fixed payments. Nonetheless, group contracts can still improve performance if peer pressure increases compliance.

In the described group based schemes it is most likely that the farmers sharing a contract dispose of superior knowledge about their colleagues' activities, because they live close to each other. The ejidos in Mexico and the small groups participating in TIST govern themselves, which means that they are willing to cooperate. In the case of Costa Rica's PSA program it is less certain if the ability and willingness to monitor each other is given, because these farmers are organized into the contracts by a Non-Governmental Organization. In a non-cooperative environment the risk of free-riding is high and the associated losses should be balanced against transaction cost reductions, especially with view to the considerable costs of monitoring. For future output-based schemes we recommend a stronger focus on farmers' incentives in groups in order to avoid the costs of free-riding but benefit from effort coordination and synergies.

Finally it should not be overlooked that the general performance of PES can be influenced by the pursuit of side objectives. Depending on the circumstances the principal's problem (3.8) and the certainty equivalent of the farmers (3.4) can change completely. Trying to achieve several objectives with the help of PES is definitely challenging, to say the least. For the future it might be useful to investigate the importance of side objectives of buyers and intrinsic conservation incentives of farmers and their interplay with external incentives for the performance of PES.

Chapter 4

A Framed Field Experiment on Collective Enforcement Mechanisms with Ethiopian Farmers

4.1 Introduction

The exploitation of common pool resources often leads to overuse and extinction. The reason behind this so-called Allmende problem is that individual users do not take into account the external effects associated with their actions.[1]

In this chapter we study a particular problem of a commons, where these conditions are not given. In Ethiopia, a long period of institutional change from feudalism over centralized socialism to democracy and decentralization combined with large scale resettlements and incoherent environmental policies has created many quasi open access areas. The formerly abundant montane rain forests in South-West Ethiopia belong to them. The lack of a functioning system to regulate access and use has resulted in high rates of deforestation

[1]Research has shown that this problem is not inevitable. Under certain conditions users of a commons are able to and have established rules and regulations to use their natural resources sustainably. These conditions for successful self-governance are, however, difficult to find. Amongst them are the existence of effective enforcement mechanisms and the right of the users to govern themselves without interference from external authorities (Ostrom [1990], Gibson et al. [2005]).

and biodiversity loss (FAO [b]).

By conducting a framed field experiment we test different mechanisms suggested in the theoretical economic literature, to mitigate the problem of over-exploitation. They are based on the deviation of the observed total consumption of a resource from a level considered as socially optimal. If the observed consumption level exceeds the level considered socially optimal, an enforcement mechanism is triggered. Segerson [1988] and Xepapadeas [1991] proposed two different mechanisms. Both mechanisms include a collective tax that is charged if the observed consumption level exceeds the aggregate standard set by the regulator. Segerson designed a collective tax (subsidy) proportional to the difference between the actual and optimal consumption levels that is charged (paid) when the actual consumption lies above (below) the optimal level, whereas Xepapadeas proposed a lump-sum tax that combines with a collective subsidy.

Several economic laboratory experiments[2] have been undertaken to study the effectiveness of these mechanisms. In all contributions the socially optimal outcome was designed as Nash equilibrium. They established that a collective tax as suggested by Segerson is effective for small groups of homogenous agents. The relative efficiency of the studied mechanisms varies for the different experiments. A common concern has been the existence of multiple equilibria as the effectiveness of mechanisms is reduced if subjects coordinate on suboptimal equilibria. Closely related is another problem: Even if compliance is achieved on aggregate level, individual compliance is not guarantied. Groups may coordinate on asymmetric equilibria in which some subjects consume considerably less than optimal, while others free-ride (Spraggon [2002], Cochard et al. [2002]).

The main objective of this study is to investigate how the mechanism proposed by Segerson performs in the field. Since our subject pool consists of Ethiopian farmers and since we use field context when explaining our experiments to the subjects, our experiment can be considered as a *framed field experiment*, following the taxonomy of Harrison and List [2004]. In contrast to the previous experimental studies our subjects have a common history because they are neighbors and members in the same informal savings organization. We expect their shared experience in daily life, i.e. the reputation of individuals, trust - or lack thereof, to influence their decisions, also with respect to coordination.

Our analysis is guided by the framework of Cárdenas and Ostrom [2004] for studying

[2]See Camacho and Requate [2004], Spraggon [2002], Cochard et al. [2002] and Vossler et al. [2002].

field experiments on local commons and social dilemmas. It suggests that subjects facing such an experiment may not only use information about the material incentives defined by the rules of the game but also private information about the context, the group members and themselves. According to Cárdenas and Ostrom [2004] an external game defined by material payoffs can thereby be transformed into an internal subjective game. The incentives in the internal game may induce a behavior as rational strategy which differs from the one predicted by the payoff structure.

So far the experiments on collective enforcement mechanisms were cast in the terms of the control of non-point pollution from industrial or agricultural sources. The frame of our experiments is biodiversity conservation and the harvest of honey in the forest. Apiculture is an important part of the livelihood in the forest areas in South-western Ethiopia. Households usually own 10 to 100 traditional beehives. Liana are the major raw material for traditional beehives in the study areas. As farmers prefer certain liana species, over-exploitation of these has resulted in a severe reduction of liana diversity (Senbeta et al. [2005]). This reduction is a problem as liana diversity plays an important role in the ecosystem stability of the forest.

The imposition of a collective punishment mechanism in such an environment is not as far fetched as it seems. The forest areas are currently undergoing a process of certification for the production and sale of biodiversity-friendly forest products, i.e. honey. Prices for certified products are higher than those paid for conventional commodities. These certificates contain provisions on maximum harvests. In case of over-harvesting the certificate can be withdrawn, which immediately reduces the return to all farmers, irrespective of their individual harvests. The withdrawal could be regarded as a collective enforcement mechanism.

In Costa Rica, farmers participating in the *Payments for Environmental Services* Program receive cash from the state if they agree to protect their standing forests. Some of them are grouped together in group contracts. Originally, farmers were collectively punished if deforestation was observed in a contracted area. However, this mechanism was perceived as unfair by those farmers who abided by the contract. As a result the collective punishment was abolished in 2003.[3]

[3]See Pagiola [2002] for a description of the Payments for Environmental Services Program in Costa Rica, and Ortiz et al. [2003] for a description of the group contracts.

Both examples indicate that collective punishment might be difficult to implement, especially in developing countries where farmers are more vulnerable to financial risks. We therefore test if a tax which is lower than prescribed by non-cooperative game theory also achieves the desired outcome. This would be the case if the mere presence of collective punishment deterred free-riding. A low tax would be easier to implement.

We think that our study not only enriches the experimental research on collective enforcement mechanisms by having a field character, but also adds a new perspective on the applicability of these mechanisms.

In our results the positive influence of group cohesion on the aggregate outcomes becomes clearly visible. In general, the effectiveness of the enforcement mechanisms is remarkable. A more detailed analysis of individual behavior, however, reveals the undesirable effects of asymmetric equilibria.

The remainder of the chapter is organized as follows. The next section summarizes the analytical framework. In section 4.3 we describe the subject pool, the theoretical predictions that we use as benchmark, and the experimental design. We report on our main findings in section 4.4. Finally, in section 4.5 we draw some conclusions.

4.2 Analytical Framework

The framework proposed by Cárdenas and Ostrom [2004] posits that participants in a field experiment on the use of common pool resources use three layers of information, namely the material payoffs layer, the group context layer, and the identity layer. This section provides a brief description of these three layers, and explains why they are especially relevant for field experiments on common pool problems.

The material payoffs layer of information answers the question which payoffs are associated with the possible actions of the players. It is given by the set of formal rules which are common knowledge. In repeated games subjects do not only observe the structure of the one-shot game but also gather information about past rounds and make projections about future rounds. The repetition of a situation creates conditions which are conducive for collusion through reputation building and retaliation.

Further, empirical evidence suggests that intrinsic motivation of individuals can be undermined or strengthened by external, monetary incentives. The phenomenon has been referred to as crowding-out or crowding-in of motivation.[4] Cárdenas et al. [2000] argue, that "cooperative" behavior seems to be crowded out, in the long run of the game, by the material incentives set by the one-shot game. Players who initially try to escape a dilemma situation by contributing to the group-optimal outcome, become frustrated by observing others free-riding, and reduce their efforts.

In addition to the formal rules of the game subjects try to gather information on the other members of their group. This kind of information is contained in the group context layer. Based on this information subjects try to better estimate which strategies the other subjects will choose. The context of the group can also influence an individual's own decision if it induces other regarding preferences.

Empirical evidence has shown that group identity, group cohesion, and social distance affect the likelihood that individuals cooperate. For example, Cárdenas and Ostrom [2004] cite a study on prisoner's dilemma experiments with college students. The behavior of the students changed depending on the information they received about the other players (being from the same fraternity, from any other fraternity, from the same campus, from another campus, from the police department).

Information stored in the identity layer describes the individual's own attitude towards cooperation or defection in general. Cárdenas and Ostrom [2004] argue that positing this layer is consistent with the common observation that humans are not exclusively motivated by egoism. This is most clearly shown by non-negative voluntary contributions in public good games (Ledyard [1995]). Field and laboratory experiments have shown that individuals confronting a social dilemma tend to follow different types of strategies. These range from strict cooperation over conditional cooperation and reciprocal fairness to no cooperation (Fischbacher et al. [2001], Fehr and Gaechter [2000], Ostrom [2002]).

The framework suggests that the more a situation resembles a social dilemma, the more the players will search for additional information from one or more of the three layers and use these to create an internalized version of the game. In field experiments the impact of the group context layer becomes more important as more information may be available to the participating individuals.

[4]See Frey and Jegen [2001] for a survey.

4.3 The Experiment

Because our experiments were administered in the field and the subjects participating were largely illiterate, we tested and adapted our experimental design and procedure during four weeks of pilot experiments conducted in the area. In order to ensure internal validity and comprehension among the subjects we tried to keep the experiment as close as possible to the daily life of the Ethiopian farmers. In this way the farmers were familiar with the context used and the task demanded. We frame our experiment as harvesting of beehives by several reasons. First, the harvesting activity constitutes an integral part of the farmers' livelihood strategy in the forest areas. Second, the traditional way of honey production causes non-negligible damages to the forest. Usually Liana are cut down in order to get the raw material of the beehives (bark and stems). This has resulted in a severe reduction in liana diversity which may have repercussions on the general ecosystem stability of the forest (Senbeta et al. [2005]). Moreover, during the harvesting period, it is a usual practice to set fire next to the beehives in order to drive the bees out of the hives and these small fires can easily become forest fires.

Third, although beehives are countable, the owner cannot be readily identified by an outsider. Consequently, the number of beehives collected can be used as an indicator of compliance with the imposed standard.

4.3.1 Subject Pool

In this section we will first describe the environment in which the experiment has taken place and which defines the special characteristics of our subject pool.

The experimental sessions were conducted in the villages of Kayakela, Yehebito and Ermo. They are located near Bonga, the capital of the Zone of *Kaffa* in the South West of Ethiopia. In these villages the main activity of the population is subsistence farming. The farmers own 1 hectare of land on average where they produce staple crops, like maize and enset.[5] One important feature is that all three villages have access to the forest. The forest is used collectively for forest-coffee production, apiculture, the collection of other non-timber forest products, and fuel wood.

Ethiopia has been subject to continuous institutional change which resulted in an

[5] 1 ha is the Ethiopian average size of land per household and is regarded as the absolute minimum to provide sufficient food for one household (Berhanu et al. [2002] p. 58).

institutional vacuum in many areas. The most fundamental reforms occurred with the change from a socialist dictatorship to a democratic state in 1994 when Ethiopia moved from a centralized to a market economy. Since then Ethiopia has been restructured from a unitary and highly centralized state into a federal one. The decentralization process has resulted in new political and administrative institutions, also in the field of natural resource management and the forest sector. The new formal institutions on regional and local level have little capacity to shoulder the new responsibilities. Policies are formulated independently from each other, and are often conflicting (Bekele [2001]). In South West Ethiopia traditional forest management regimes are confronted with inappropriate policies and have lost their grip. As a consequence of incoherent policies and powerless, out-dated informal rules the forests have become quasi-open access systems (Stellmacher [2005]).

The four main pillars of the social infrastructure in our study villages are the family, an informal organization called *Idir*, ethnicity and religion. Due to continuous resettlements in the past the population in the study area belongs to at least 10 different ethnic groups. At least 6 different religions are practiced, among them orthodox, catholic, and protestant christianity, animism and islam. One village comprises between 10 and 20 Idir, and each Idir contains around 30 households that are usually close neighbors and often also relatives. These organizations, governed by the elderly, play an important economic, financial and social role in the villages. Basically they serve as informal savings and insurance organizations. But their social role is often even more important since they perform tasks of conflict prevention and resolution in regions where no formal institutions are present, as it is the case in our study areas. Compliance to certain rules is achieved via social sanctions, the most serious of which are malediction and dismissal.[6]

In the recruiting process we took into account the organization of the farmers in Idirs. In each village we contacted the head and asked him to select groups of farmers (or "head of households")[7] living in the same Idir, for each session.[8]

[6]See Stellmacher [2005] for an analysis of Idirs in Yehebito.

[7]As a consequence, our subject pool is composed only by male subjects. Although there are some households headed by females, those are a minority and are discriminated against by male-headed households.

[8]We used also the authority of the heads of the villages and asked them to organize the farmers and ensure that they arrive on time for the session since some farmers live an hour walk away from the place where the experimental sessions were conducted. It could happen that relatives were grouped together for one session, but only if they lived in separate households.

4.3.2 Theoretical Benchmark

In this section we describe the theoretical basis of the conducted experiments. The theoretical predictions of the model will serve as a benchmark to evaluate the farmers' behavior observed in the experimental treatments.

Consider a group of n identical farmers who set out $b_i \in [0, \bar{b}]$ beehives in a forest close to their livelihoods in order to harvest honey, where $\bar{b}$ is used to denote the number of beehives owned by each farmer. The honey harvested is proportional (for simplicity identical) to the number of beehives set out in the forest. The farmers sell the honey in the market earning a market price p per unit. For simplicity we assume that there is no cost of harvesting. Thus, in the absence of regulation, the profit is equal to revenues and each farmer has an incentive to operate at full capacity, i.e., $b_i = \bar{b}$.

Harvesting activity, however, causes non-negligible damages to the forest, and since the farmers partially earn a living on the forest, it causes a negative social externality $D(B)$, where $B = \sum_{i=1}^{n} b_i$ is the total number of beehives harvested by the whole community. We assume that $D(B)$ is increasing and convex, i.e. $D'(B) > 0$, and $D''(B) > 0$.

In this partial model the social planer's objective is to maximize social welfare (SW) defined as the sum of the farmers' profits minus the social damage resulting from the degradation of the rain forest through harvest activity:

$$SW = \sum_{i=1}^{n} pb_i - D(B) \tag{4.1}$$

The socially optimal allocation is then simply characterized by the first order condition $p = D'(B)$, the solution of which is denoted by B^*. If the conservation effort is equally distributed among the farmers, we denote by $b^* = B^*/n$ the optimal number of beehives to be collected by each farmer.

Further we assume that monitoring the harvest activities of each individual farmer causes extremely high costs but that the total amount of harvest B can be easily observed.

In order to induce the farmers to comply with the aggregate socially optimal standard, a regulator can apply different economic incentive schemes. In the following we describe the different control instruments that are subject of our experimental investigation: a collective tax and a tax-subsidy scheme.

Under the *collective tax mechanism* the farmers will be charged a tax $t > 0$ if the aggregate number of beehives harvested exceeds the number considered as socially optimal.

For each farmer the tax bill is proportional to the total harvest exceeding the socially optimal level. Thus a farmer's profit can be expressed as:

$$\Pi_i(b_i, b_{-i}) = \begin{cases} pb_i - t\,[B - B^*] & \text{if} \quad B > B^* \\ \\ pb_i & \text{if} \quad B \leq B^* \end{cases} \tag{4.2}$$

where b_{-i} denotes the vector of decisions of the other farmers in the community except farmer i. Note that the total tax bill is the same for each farmer.

The *Tax-Subsidy mechanism*, suggested by Segerson [1988], is similar to the collective tax described above. Here, farmers are not only charged a tax in case of $B > B^*$, but they also receive a subsidy that compensates them for an additional conservation effort whenever $B < B^*$ holds. Thus, a typical farmer's profit can now be written as:

$$\Pi_i(b_i, b_{-i}) = \begin{cases} pb_i - t\,[B - B^*] & \text{if} \quad B > B^* \\ pb_i & \text{if} \quad B = B^* \\ pb_i + s\,[B^* - B] & \text{if} \quad B < B^* \end{cases} \tag{4.3}$$

where s denotes the marginal subsidy rate.

Under both mechanisms, the efficient outcome $b^* = (b^*, ..., b^*)$ is a Nash equilibrium if the tax rate is chosen larger than p, and the subsidy is chosen no greater than p, i.e. if the incentive compatibility condition $\Pi_i(\tilde{b}_i, b^*_{-i}) < \Pi_i(b^*, b^*_{-i})$ for all $\tilde{b}_i \neq b^*$is satisfied. In addition to this symmetric equilibrium, there exist other asymmetric equilibria, i.e. any strategy profile $b = (b_1, ..., b_n)$ satisfying $\sum_{i=1}^{n} b_i = B^*$ is an equilibrium.

Note that depending on parameters under both mechanisms farmers can improve upon the one-shot Nash equilibrium by engaging in explicit or tacit collusion. Under the tax-mechanism, $b_i = b^*$ is a collusive outcome of $t > p/n$, even though for $t < p$, $b_i = \bar{b}$ is the symmetric equilibrium outcome.

The tax-subsidy scheme is not collusion proof for $s > p/n$. This is the case because the whole group would receive a subsidy of $n^2 s$ when reducing harvest by one unit. Thus each farmer would receive ns which would exceed the market price for the resource if $s > p/n$.

4.3.3 Design

Specifying the theoretical model described in the last section, we fixed the parameters as $n = 5$, $\bar{b} = 10$, $b^* = 5$, and $p = 30$ cents.[9] Then we chose two different versions of the tax mechanism, one with a low tax rate of $t = 10$ cents, and a second one with a high tax rate of $t = 40$ cents. We refer to the corresponding treatments as Tax10 and Tax40, respectively. For the tax-subsidy mechanism we chose $t = 40$ cents and $s = 20$ cents. We refer to the corresponding treatment simply as Tax-Subsidy.

For Tax10, it can be easily seen that the unique one shot equilibrium is $b_i^N = \bar{b} = 10$, yielding a payoff of $30 \cdot 10 - 10 \cdot [50 - 25] = 50$. For both Tax40 and Tax-Subsidy, the symmetric one shot equilibrium is $b_i^N = b^* = 5$, and the equilibrium payoffs in both cases amount to $30 \cdot 5 = 150$. Note, however, that by colluding the players could increase their payoffs under both Tax10 and Tax-Subsidy. Under Tax10, the collusive play would be $b_i^{C,Tax10} = 5$ yielding a profit of 150. Under Tax-Subsidy the collusive play would be $b_i^{C,Tax-Sub} = 0$ yielding a profit of 500. Under Tax40 players cannot improve upon the Nash-payoff by collusion.

A total of 23 sessions, lasting about 2 hours each, were conducted in local schools during the summer holidays. Since the news about the experiment spread quite fast, we switched to a different area as soon as we noticed that the recruited participants had already information about the experiment. As a consequence, we stayed a maximum of 4 days in each area.

For each session we recruited 5 farmers who participated in two out of the three treatments. Table I illustrates the different sessions and the order of the treatments conducted per session. Each type of session was played at least twice.

When the farmers arrived at the room where the experiment was conducted, they were assigned to a desk. The instructions were explained aloud and translated into the local language by a local assistant.[10] In order to make our results more general no environmental motivation was given for the application of the different control mechanisms. Moreover, we avoided any mention of an external principal or agency since the farmers immediately

[9] To achieve an optimal aggregate harvest of $B^* = 5$, we could choose the damage function according to $D(B) = 12B^2/5$. The damage function is, however, not important for the experiment.

[10] A transcription of the instruction script is provided in the appendix.

Session	Treatment 1	Treatment 2
1	Tax-Subsidy	Tax 40
2	Tax-Subsidy	Tax 10
3	Tax 10	Tax-Subsidy
4	Tax 40	Tax-Subsidy
5	Tax 40	Tax 10
6	Tax 10	Tax 40

Table I: Sequence of the treatments conducted in each session.

associate the government with the words "agency" or "principal" and this association may bring to mind problems of delayed payments and hidden agendas that can bias farmers' behavior.

Each farmer was told that he owned 10 beehives ($\bar{b} = 10$) and that for each beehive collected he could earn 30 cents ($p = 30$). They were also informed that the desired aggregate level of harvesting was equal to 25 beehives ($B^* = 25$) and, therefore, every farmer is advised to collect no more than 5 beehives ($b^* = 5$). Additionally, the application of different control mechanisms corresponds to the different treatments: Tax10, Tax40 and Tax-Subsidy. Table II summarizes both the parameters used for each treatment, the resulting symmetric equilibria and the collusive outcome.

Treatment	Instrument	Tax	Subsidy	Equilibrium	Collusion
Tax 10	collective tax	10	0	10	5
Tax 40	collective tax	40	0	5	-
Tax-Subsidy	collective tax or subsidy	40	20	5	0

Table II: Experimental design and symmetric equilibria.

At the beginning of each session, each farmer was randomly given an envelope containing several decision cards. Each card displayed 10 empty boxes representing the 10 beehives owned. Since most of the farmers were illiterate, the decision cards also displayed symbols (e.g. flower, tree, sun, etc...) indicating the identity of the farmer in the session.

In order to keep anonymity, farmers were not allowed to show their cards to the other farmers.

In each period, representing a harvesting season, each farmer was asked to decide on the number of beehives he wants to collect. In order to submit his decision, each of them was told to cross the number of boxes that corresponds to the number of beehives he wants to harvest in one of the decision cards provided. Afterwards, the participants were told to put the cards into a box. Once all the cards were collected, the number of beehives harvested by each farmer was displayed on the board next to the corresponding symbol. Although the participants could observe individual decisions, anonymity was guaranteed since they could not match the decisions with the individuals. The revelation of individual decisions made clear to the farmers which impact their actions had on the other group members' payoffs and it facilitated a coordination of actions.[11]

Finally, the total number of beehives harvested was announced and the rule of the respective mechanism was applied. Then the payoffs[12] were calculated and distributed to each participant by putting the money on plates, each of which had the same symbol as the decision card of the corresponding participant (i.e. flower, tree, sun, etc.).

The transparent procedure used here allowed us to gain the trust of the farmers and helped them not to forget the rules during the game. Moreover, the distribution of the money at the end of each period fascinated them and incited them to continue one round more.

After we had explained the procedure to the participants we conducted three trial periods using the board. Once we had made sure that the participants had understood the task and procedure, the experiment was started. The first treatment was then repeated for 12 periods. Thereafter, the second treatment was explained, following the same procedure, and it was also repeated for 12 periods.

At the end of the session the subjects were given the money accumulated in the respective plates. The average payoff was 40 Birr[13] (equivalent to 4€). To assess the saliency of the reward, note that the daily salary of an unskilled rural worker ranges between 10 and 20 Ethiopian Birr.

[11]Furthermore this design was realistic, as in the forest farmers are often able to observe individual behavior.

[12]The participants were informed that negative payoffs will be set to zero.

[13]The minimum payoff was 0 Birr and the maximum 70 Birr.

Farmers were not allowed to communicate. We acknowledge that communication in social dilemma experiments has shown to shift outcomes closer to the social optimum. Surveying the experimental literature Ostrom [2002] finds that trust-building seems to be the main reason behind this effect of communication, even in the absence of enforceable agreements. As our subjects are no strangers this effect would be negligible. Another effect, however, would most probably influence the outcome: Powerful subjects could threaten other group members with sanctions as they are most likely to meet after the sessions. As described in section 4.3.1 traditional enforcement mechanisms like social sanctions are ineffective in the context of forest use because of conflicting other rules and regulations. Allowing subjects to communicate would therefore not be useful for our purpose but rather interfere with it.

After the games, when being asked directly about their motivation, the farmers were reluctant to reveal the truth. This is the reason why formal interviews were not conducted after the games.

4.4 Results

Our data set consists of observations from 115 subjects gathered in the 23 sessions conducted.[14] Each subject participated only in one session. However, the data of 4 sessions (20 subjects) have been eliminated from the data set used in the analysis since we suspected that the participants of those sessions could have been previously informed about the game, or any kind of explicit agreement could have existed among them.

When describing our results, we will distinguish between *inexperienced* and *experienced* subjects. With *inexperienced* subjects we refer to subjects that have participated in "Treatment 1" of each session, that is, those who participated in a particular treatment for the first time. By contrast, we refer to *experienced* subjects, whenever they had already participated in a different treatment during one session, that is, those participating in "Treatment 2" of each session.[15]

[14] A Kruskal-Wallis test indicates differences among villages. These differences, however, do not weaken our general results. They also do not reveal any distinctive pattern, but instead, could be the result of specific conditions prevailing during the experiments. We therefore abstain from a separate presentation of the three villages in the following.

[15] A M-W test shows that the difference between inexperienced and experienced farmers is statistically significant only for the Tax10 and Tax40 treatments.

4.4.1 Aggregate Behavior

As a first approach we look at the frequency distributions of strategies per treatment and per experience condition, aggregated over all periods per treatment. Figure 4.1 gives a first impression of the performance of all three mechanisms.

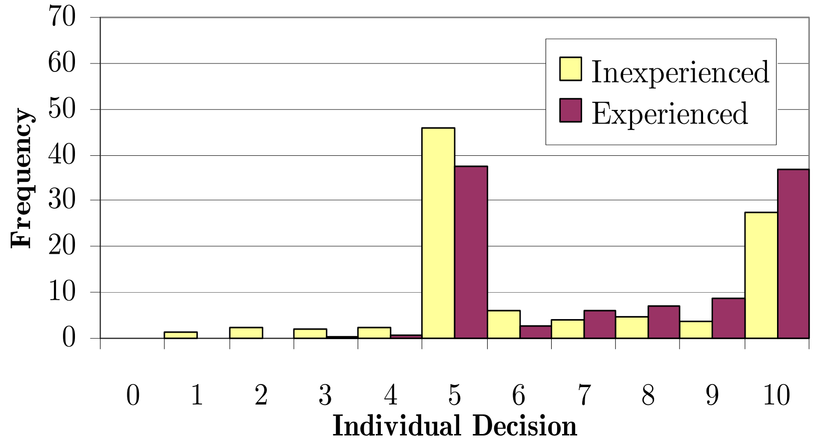
Let us first look at the distribution of decisions for the treatment Tax10 displayed in figure 4.1(a). We observe a bimodal distribution of strategies. Surprisingly, less than a third of the inexperienced participants and about a third of the experienced participants play the one-shot Nash-equilibrium action, whereas almost half of the inexperienced and almost 40% of the experienced participants comply with the desired harvest level of 5 units. This result could be explained in at least two different ways: either, a considerable share of the participants have fully understood the mechanism and recognized that collusive compliance would yield them a higher payoff than individual payoff maximization, or those participants that harvested only 5 units believed that compliance was socially desired. Recall that all subjects of one group belong to the same Idir. We therefore believe that the group context had a strong influence on behavior and is mainly responsible for the deviation from Nash-equilibrium play. Most likely group cohesion facilitated the coordination on the collusive outcome.

At least this happened in the first periods. If we look at the evolution of strategies over time, displayed in figure 4.2, we see, however, that the aggregate harvest level increases slightly over time and that the small fraction of subjects that collect less than 5 beehives when being inexperienced cease to do so after having gathered experience. Nevertheless table III confirms that on aggregate both inexperienced and experienced farmers collect much less beehives than predicted by applying the concept of one-shot Nash equilibrium.[16]

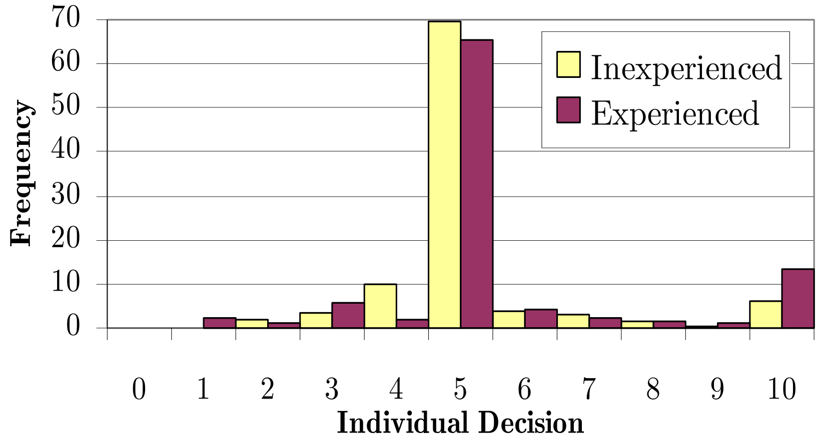
The fact that the number of collusive outcomes decreases over time suggests that complying farmers observed others following Nash-play, became frustrated and harvested more. Using the terms of Cárdenas et al. [2000] the intuition is that cooperative play was crowded out by short-term individual payoff maximization.

When we apply the Tax40 mechanism (figure 4.1(b)), the frequency of compliance is 70% and 65% for inexperienced and experienced participants, respectively. The proportion of participants that decided to comply with the standard of five beehives is double as high

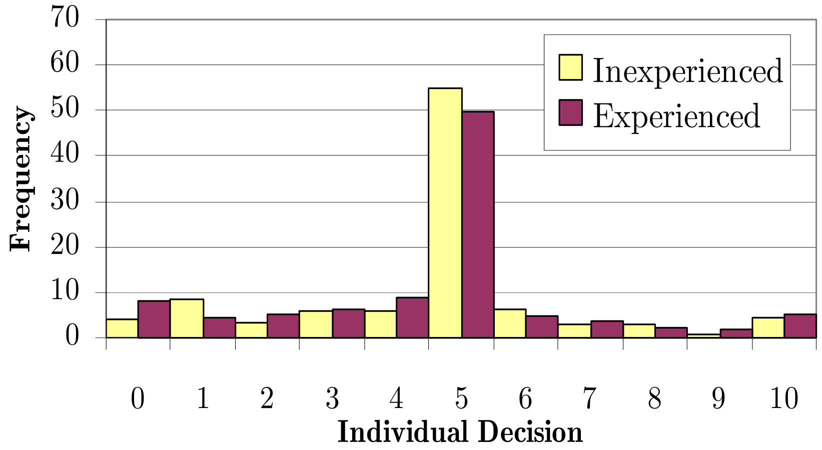
[16] A Mann-Whitney (M-W) test shows that the average amount of beehives harvested per farmer is significantly lower than 10 for both, inexperienced and experienced farmers.



(a) Collective Tax 10

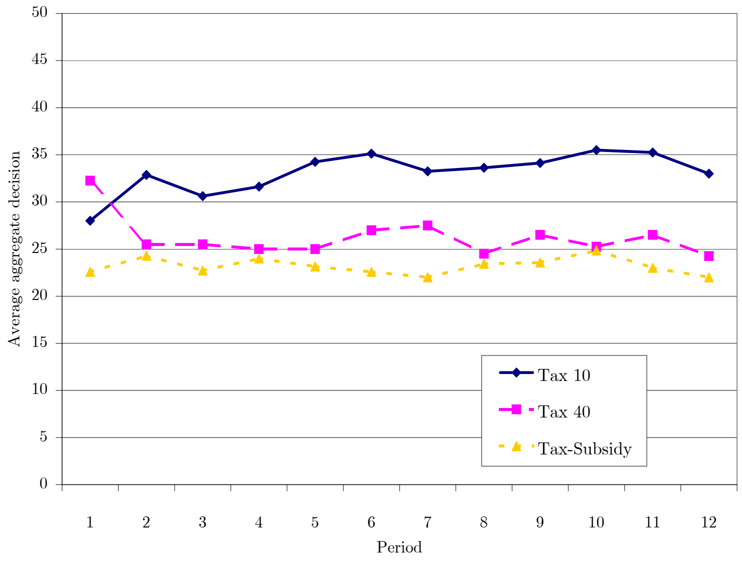


(b) Collective Tax 40

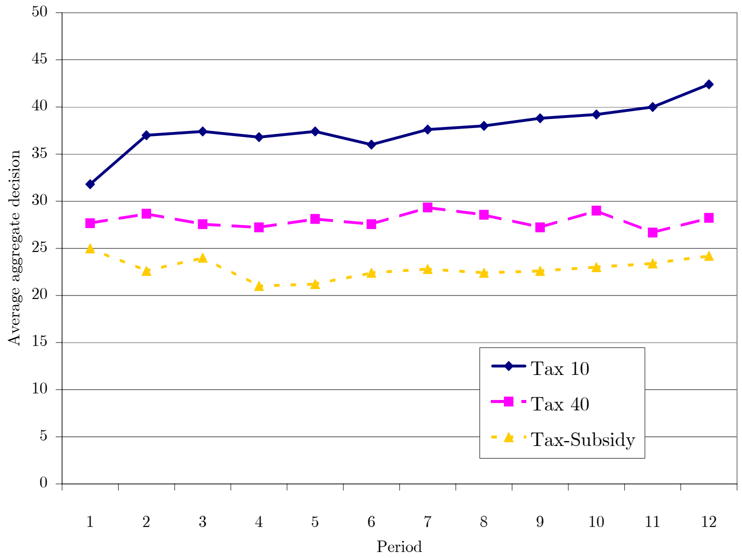


(c) Tax-Subisdy

Figure 4.1: Frequency distribution of individual decisions.



(a) Inexperienced Subjects



(b) Experienced Subjects

Figure 4.2: Dynamics of the average aggregate harvest.

Treatment	Aggregate		Inexperienced		Experienced	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Tax 10	6.97	2.42	6.62	2.45	7.54	2.26
Tax 40	5.49	1.92	5.25	1.52	5.60	2.07
Tax-Subsidy	4.62	2.20	4.64	2.12	4.58	2.31

Table III: Summary statistics per treatment and experience condition.

as under the Tax10 for both experienced and inexperienced subjects.

Nevertheless there is a surprisingly high share of participants that harvest more than 5 units. Looking at table III and employing a M-W test confirms that the average number of beehives collected is indeed significantly higher than 5 for both inexperienced and experienced participants. Harvesting more than 5 units is only individually rational, if one expects the other participants to harvest less than 5. Indeed, over- and under-harvesting is equally likely when participants are inexperienced. However, the probability of over-harvesting is double the probability of under-harvesting when participants are experienced.

Finally, under the Tax-Subsidy mechanism, where the participants are not only punished for over-harvesting but are also rewarded for under-harvesting by a subsidy of 20 cents per unit, we observe a uni-modal distribution of strategies with a peek at the Nash-equilibrium outcome (see figure 4.1(c)). However, in comparison to the pure tax mechanisms, the probability of observing less than 5 collected beehives increases significantly. Now, in half of the cases participants decided to collect only 5 beehives, while in approximately one third of the cases they decided to collect fewer units than predicted by the one-shot Nash equilibrium.[17] As pointed out in the last section, although it is not individually rational to harvest less than 5 beehives, for the group as a whole it is best to harvest nothing because in that case each of them would earn 600 cent. This is more than four times the individual payoff of 150 cents in the symmetric Nash equilibrium.

How do these distributions of decisions fuel into group outcomes per round? The answer to this question sheds some more light on how reliable the three mechanisms are in achieving the socially optimal outcome of 25 beehives. We find that Tax-Subsidy and

[17] A M-W test shows that the mean is significantly lower than 5.

Tax10 lead to identical low frequencies. In only 19% of outcomes in both mechanisms the total harvest was 25 beehives. Clearly the existence of collusive equilibria in Tax10 and Tax-Subsidy reduced their reliability. The tax of 40 cents performs much better: 30% of all outcomes were 25 beehives.

Recall that in addition to the Nash equilibrium multiple asymmetric equilibria do exist in Tax40 and Tax-Subsidy which also lead to the aggregate harvest of 25 beehives. The degree of symmetry can be regarded as an indicator of equity of these mechanisms. In this respect Tax40 outperforms Tax-Subsidy too. 89% of all socially optimal outcomes in Tax40 were symmetric, whereas only 82% in Tax-Subsidy (cf. 93% of these cases in Tax10 were symmetric).

For a final evaluation of the aggregate results under the tested mechanisms table IV illustrates the efficiency of each mechanism depending on the experience of the subjects. Spraggon [2002] defines efficiency as the ratio of the difference of the actual welfare and the welfare in the *status quo* to the difference between the welfare in the social optimal state and the *status quo* state:

$$E = \frac{SW actual - SW status\ quo}{SW optimal - SW status\ quo} \times 100$$

At a first glance we see that all mechanisms perform remarkably well with respect to relative efficiency. However, the efficiency level obtained under a collective tax of 40 cents and the Tax-Subsidy mechanism is higher than that resulting from a collective tax of 10 cents.

Instrument	Inexperienced	Experienced
Tax40	99.7	98.6
Tax10	89.5	74.2
Tax-Subsidy	99.5	99.3

Table IV: Efficiency comparison (in %).

We summarize our observations on aggregate behavior as follows:

Result 1: In general, the collective tax of 40 and the combined tax-subsidy mechanism lead to the desired aggregate outcome. The collective tax of 10 does not.

Result 2: The collective tax of 40 and the combined tax-subsidy mechanism perform equally well with respect to overall efficiency, but the collective tax of 40 is more reliable.

Result 3: The collective tax of 10 is, initially, surprisingly efficient due to group cohesion among participants. This effect is, however, reduced by experience.

4.4.2 Individual Behavior

Due to the panel structure of our data set (we have observations on each individual over time), we can use panel data analysis to account for the heterogeneity across individuals, in particular the dynamics of individual behavior over time.[18] Our analysis considers the three layers of information subjects use when deciding about their strategy during a field experiment, as they are described in section 4.2: material payoffs, group context and identity.

Since the individual observations are not independent within each group, we used a *group fixed effects* panel regression to deal with differences across groups.

Table V shows how the farmers reacted to both the behavior of the group in the past and to the material incentives provided by each mechanism. As the dependent variable we use the individual decisions per period. The independent variables are:

- Harvest in $t = 1$: Harvest decision in the first period. Since farmers were already familiar with the task and all the group members were selected from the same community, one might expect them to have other-regarding preferences and some kind of ex-ante beliefs on the others' behavior in this task. This variable is used as a proxy to measure the farmers' heterogeneity regarding their initial willingness to comply with the regulation, i.e. some kind of individual effect that signals the subject type, independently of the group dynamic. Therefore, we include this variable only in the case of inexperienced farmers.

- Period: Period number. This variable accounts for the time trend in the decisions usually observed in the public goods experiments.

The second group of explanatory variables identifies the effect of the material incentives, tax or subsidy, as a result of the application of the corresponding mechanism in the

[18] See Hsiao [1996] for a more detailed explanation on the panel data analysis.

case of over- or under-harvesting:

- Tax charged in $t-1$: Dummy variable that takes the value 1 if the group was charged a tax in the previous period, and 0 otherwise. Additionally, we multiply this variable by one of the next three dummy variables characterizing the individual harvest decision in $t-1$
  - Equal to five: takes the value 1 if the subject's past decision was equal to 5, and 0 otherwise,
  - Lower than five: equals the absolute deviation from 5 when the subject's past decision was lower than 5, and 0 otherwise
  - More than five: equals the absolute deviation from 5 when the subject's decision was higher than 5, and 0 otherwise
- Subsidy paid in $t-1$: Dummy variable that takes the value 1 if a subsidy was paid to the group in the previous period, and 0 otherwise. Following the same procedure as explained above, we then use dummies to account for the farmers' reaction to the monetary incentives depending on their decision in the past.

Since the farmers could observe the individual decisions of the other members of the group, we include also a group of independent variables that account for the farmers' reaction to the other group members' decisions in the previous period:

- Decisions over 5: Number of group members whose harvesting decision in the previous period was higher than 5. This variable accounts for the farmers' reaction to free-riding.
- Decisions equal to 5: Number of group members whose harvesting decision in the previous period was 5. With this variable we intend to detect the farmers' response in the presence of group members who comply.

First, we observe that the effect of an initial willingness to comply (the coefficient on Harvest in $t=1$) is positive and significant for all three mechanisms. This suggests that the ex-ante willingness to comply has a strong impact on the behavior along the treatment. As a consequence, those participants who decided to harvest more in the first period tend to harvest more in later periods, independently of the mechanism applied.

Variable	Tax 10				Tax 40				Tax-Subsidy			
	Inexperienced		Experienced		Inexperienced		Experienced		Inexperienced		Experienced	
	Coef.	$p > \|z\|$	Coef.	$p > \|z\|$	Coef.	$p > \|z\|$	Coef.	$p > \|z\|$	Coef.	$p > \|z\|$	Coef.	$p > \|z\|$
Constant	4.521	0.000	7.200	0.000	3.555	0.000	8.092	0.000	5.191	0.000	5.268	0.000
Harvest in $t = 1$	0.130	0.005	-		0.243	0.000	-		0.162	0.012	-	
Period	0.017	0.497	0.067	0.011	0.000	0.992	-0.018	0.527	-0.006	0.801	0.016	0.540
Information on the group's decisions in $t-1$												
Decisions over 5	0.005	0.972	-0.550	0.028	0.262	0.123	-1.032	0.000	-0.024	0.877	-0.222	0.242
Decisions equal to 5	0.049	0.736	0.158	0.548	0.033	0.815	-0.783	0.000	-0.162	0.232	-0.254	0.046
Material Incentives												
Tax charged and the harvest decision in $t-1$:												
More than 5	0.673	0.000	0.477	0.000	-0.142	0.080	0.701	0.000	0.324	0.001	0.825	0.000
Equal to 5	0.236	0.376	-0.729	0.048	-0.685	0.027	0.208	0.365	-0.774	0.041	0.254	0.459
Fewer than 5	0.295	0.204	-0.026	0.908	-0.678	0.012	-0.629	0.004	-0.761	0.283	0.107	0.605
Subsidy paid and the harvest decision in $t-1$:												
More than 5	-	-	-		-		-		0.273	0.175	0.875	0.000
Equal to 5	-	-	-		-		-		-0.523	0.116	0.122	0.698
Fewer than 5	-	-	-		-		-		-0.842	0.000	-0.784	0.000
N. obs.	430		275		220		494		385		275	
N. groups	8		5		4		9		7		5	
R^2	0.3864		0.5589		0.1482		0.4603		0.4416		0.5172	
F-test ($p - value$)	5.62 (0.000)		12.95 (0.000)		4.47(0.004)		11.01(0.000)		3.95(0.008)		4.57(0.001)	

Table V: Group Fixed Effects Regression to explain the dynamics of the decisions depending on the group's behavior and material incentives. F-test for the H_0: Group Fixed Effects=0.

Regarding the time trend, we observe a positive and significant coefficient on the variable "Period" only in the treatment Tax10 with experienced farmers. This contrasts with observations made in public good experiments where contributions decrease over time. Our intuition was that the lack of time trend might be due to opposite trends of different types of individuals which cancel out after aggregation. To investigate this question further we grouped inexperienced individuals according to their decision in $t = 1$, separately for the three mechanisms, and calculated the correlation coefficients of their decisions and time. The group "5 and below" was formed by individuals who harvested 5 or less than 5 units in the first period. The other group "above 5" contained individuals who harvested more than 5 beehives in the first period.

For Tax40 we find that the harvests of the group "5 and below" slightly increase over time ($\rho = 0.5$), whereas the decisions of the group "above 5" are negatively correlated with time ($\rho = -0.5$). Similar results apply to Tax-Subsidy, where the trends are somewhat stronger. The correlation coefficient for the decisions of the group "5 and below" with time is $\rho = 0.6$. The negative trend of the group "above 5" is illustrated by $\rho = -0.9$. For the individuals harvesting more than 5 or harvesting 5 and below in the first period of the Tax 10 mechanism the correlation coefficients are $\rho = -0.1$ and $\rho = 0.7$ respectively. Thus, we state that, indeed, we have two distinct types of subjects, which can be grouped according to their decisions in the first period. Their decisions follow trends which lead into opposite directions in the Tax40 and Tax-Subsidy game and, therefore, cancel out in the panel data analysis. The general movement is towards Nash play, which is in line with the observations made in public good games and our earlier results concerning the crowding out effect.

As to the effect of the material incentives in the panel data analysis, we observe similar patterns for all mechanisms applied: when a tax was charged the previous period, farmers who over-harvested in the previous period tend to increase their harvest in the following period, while those who harvested 5 or less tend to reduce their harvest in the next period. The coefficients are especially high and significant for experienced subjects when a tax was charged in Tax40 and when a subsidy was paid in Tax-Subsidy. Again, we state that there exist individual effects indicating different types of players.

It is reasonable to suggest that those subjects who show an initial willingness to comply in the first period correspond to those who react to imposed sanctions and rewards by reducing their harvests. Following the same reasoning we suggest that those subjects with an initial reluctance to comply also tend to increase their harvest if any penalty or subsidy was charged or paid to the group. It even seems as if they try to take advantage of the cooperative behavior of the other subject type.

Let us now turn to the farmers' feedback to the individual decisions of the other group members. In general, we find a significant effect only in the case of experienced farmers. The coefficients for both variables "decisions over 5" and "decisions equal 5" are negative. This indicates that the more group members harvested 5 or more than 5 beehives in the previous period the more likely it is for an experienced individual to decrease one's own harvesting decision in the next period. The first effect is only observed if a collective tax is charged. The second effect is only significant for the Tax40 and Tax-Subsidy treatments.

Under the collective tax of 40 cents a decrease of one's own harvest the higher the number of decisions over or equal to 5 is a plausible reaction to reduce the tax burden. Here it is important to keep in mind that the average individual harvest is above 5 such that a reduction is individually rational. In the Tax-Subsidy treatment the negative coefficients also reveal tax-aversion. An additional motivation could be tacit collusion.

Summarizing our results concerning the individual behavior of participants, we find:

Result 4: Individual effects are strong. They determine whether subjects play a rather cooperative strategy with harvesting the socially optimal amount or less, or whether they follow less cooperative play with the tendency to harvest more than socially optimal.

Result 5: The decisions of both types of players follow a general trend towards Nash play.

4.5 Conclusion

The remaining rain forest in South-West Ethiopia is a quasi open-access common pool resource and suffers from severe over-exploitation. One example is the ecologically unsustainable practice of honey production in the forest which is reducing its biological diversity. Our main objective was to test if a collective tax and a collective tax-subsidy mechanism, originally proposed by Segerson [1988], could solve this problem. For that purpose we conducted a framed field experiment with Ethiopian farmers, studying the performance of a high and a low collective tax as well as a tax-subsidy mechanism. The experiment was cast in the terms of honey production, which allowed an easy identification of the subjects with the situation.

The mechanisms were designed such that the social optimum was a symmetric Nash equilibrium for the high tax and the tax-subsidy mechanism. With the low collective tax the socially optimal outcome was not individually rational as one shot Nash-equilibrium but could be attained via collusion. The tax-subsidy mechanism also had a collusive outcome, which was characterized by over-abatement.

In addition to the theoretical benchmark given by non-cooperative game theory, we used a framework proposed by Cárdenas and Ostrom [2004] for the analysis of outcomes. It suggests that participants in a field experiment on common pool resources and social dilemmas use three layers of information: material incentives set by the formal rules of the game (our theoretical benchmark), the group context, and their personal identity. Since the participants in each group of our experiments knew each other from daily life, we expected a strong influence of the information contained in the group context layer on the decisions.

In general we found that the high collective tax and the tax-subsidy mechanism lead to the socially optimal outcome. The low collective tax does not. Still, the low collective tax is remarkably effective, because 40 - 50% of the decisions comply with the socially desired outcome. We attribute this surprising result to group cohesion which facilitated the coordination on the collusive outcome. This positive influence of the group context is, however, diminishing as experience with the mechanism grows, with decisions approaching the one-shot Nash equilibrium.

As to relative efficiency, the high tax and the tax-subsidy perform equally well (around 99%). With respect to reliability, the high tax outperforms the tax-subsidy. The socially optimal Nash equilibrium can be observed in 30% of the outcomes in the high tax game, whereas only in 19% in the tax-subsidy game.

The panel structure of our data allowed us to analyze the individual decisions in more detail. Our results suggest that individual effects are strong. They determine whether subjects play a rather cooperative strategy with harvesting the socially optimal amount or less, or whether they follow less cooperative play with the tendency to harvest more than socially optimal. The co-existence of these two types of subjects can lead to asymmetric outcomes, with not complying free-riders taking advantage of the accommodating play of complying subjects.

The coordination on asymmetric outcomes has also been observed by other experimental studies testing collective mechanisms in the laboratory with standard subject pools. Apparently, this problem persists for a group of subjects who are used to coordinate their actions in their daily life. It would be an interesting question for future research, how the strategies followed by the two types of subjects relate to their actual societal position in their respective groups. Cárdenas [2003] examined a similar question. He explored how real wealth and wealth inequality affects cooperation in a field experiment with actual commons users. His result is that both have a negative effect on the willingness of subjects to solve a local commons dilemma via a self-governed mechanism.

Concluding, we find that the high collective tax is an efficient and relatively reliable mechanism to solve the problem of excess exploitation of an open-access common pool resource. Its major drawback is and remains that complying individuals may pay for the gains of others.

4.6 Appendix

4.6.1 Instructions

A) Welcome and introduction

Thank you for coming. I am a German PhD student doing research here in Ethiopia. I have been living in Ethiopia for almost one year. I was working in Metu and Mizan Teferi and I am glad that I can now work here in Bonga. I am economist and I want to play games with you - not games for children but games for grown ups, because we play for money. We will play two games, and each one has 12 rounds. Please understand: there are no right or wrong answers. And do not worry, we will play three test rounds before each game in order to make sure that everybody understands how it works.

B) General rules

There are three general rules. The first rule is anonymity. This means that no one knows who is doing what. For this reason we play with symbols. Each one of you will get a symbol. You can find the same symbols here on the board and on these plates. Can everybody see the plates and symbols?

The second rule is that I do not want you to communicate with each other. You can ask me as many questions as you want, but please do not talk to each other.

The third rule is that you can earn money, but you cannot lose money. The amount of money you can earn depends on how you play the game. At the end of the games you can take the money with you.

C) Specific rules

Each one of you owns 10 beehives. All beehives are full. You have an agreement with us, that you only harvest 5 of these ten beehives. If you harvest one beehive you earn 30 cents. After each round we calculate the total number of beehives harvested. If, in total, more than 25 beehives are harvested you will have to pay a tax of 40 (10) cents for every beehive harvested over 25. Every one of you will have to pay this tax. (For the Tax-Subsidy treatment: If in total less than 25 beehives are harvested you will receive a subsidy of 20 cents per beehive harvested less. Every one of you will receive this subsidy.) Now you have to decide how many beehives you want to harvest. You have 10 full beehives. You can harvest all or nothing or something in between. This is your own decision.

The amount of money you can earn depends on your decision and the decision of the other person paying this game. I repeat. Harvesting gives you 30 cents. If the total is more than 25 you have to pay a tax of 40 (10) cents per extra beehive harvested. (For the Tax-Subsidy treatment: If the total is less than 25 you will receive a subsidy of 20.)

D) Procedure

You can now take the envelopes, but do not open them. Inside there are these playing cards, enough for 2 games (Exemplary cards are shown). On each playing card there are ten boxes for ten beehives. For each round you take one playing card and write crosses into the boxes according to the number of beehives you want to harvest. (Translator shows how to make a cross into a box.) Then you fold the playing card and put it into this cardboard box. Then we write the decision of each one next to the corresponding symbol, calculate the total and distribute the money in each of the plates.

Chapter 5

General Conclusion

The Millennium Ecosystem Assessment issues a stark warning: We are living beyond our means. The global extinction of species and the degradation of ecosystems is threatening human well-being. But the goals of local economic development and nature conservation are sometimes difficult to combine. This dissertation has explored the compatibility of biodiversity conservation and poverty alleviation for the forested highlands in South-west Ethiopia.

A cost-benefit analysis shows that the sustainable use of the forest is the most beneficial land use option from the national point of view at a moderate discount rate of 5%. It would simultaneously conserve the genetic diversity of wild populations of coffee Arabica growing in the forest and strengthen economic development at the cost of a reduction in the general plant diversity of the forest. Thus, basically, biodiversity conservation and poverty alleviation are compatible to a certain degree. A slight trade-off remains with regard to overall biological diversity.

In contrast, an income analysis demonstrates that the farmers currently face a financial incentive structure which favors further conversion into arable fields. Among the main factors driving this process are high private discount rates and a high value of timber and fuel wood. We then ask if a premium price for forest coffee might reconcile local aspirations with conservation objectives. The data reveal that such a monetary incentive increases the private profitability of sustainable forest management to some extent but it is not sufficiently high to prevent further conversion.

The conclusion therefore is that several additional reforms are necessary to save the Ethiopian cloud forest: increased investments into plantations for timber and fuel wood and improved conditions for private investment in the coffee sector. Private investment in general is currently deterred by insecure property rights on land, limited access to local financial services, poor road infrastructure, and a lack of information about markets.

Price premia for environment-friendly products represent transfers from environmentally-minded consumers to producers such that social benefits are factored into individual decision making. The underlying idea of paying for environmental services has been globally adopted by various initiatives. The Millennium Ecosystem Assessment is still skeptic with regard to its potential for conservation and notes that it hinges on the proper design of incentives and supportive regulations.

The third chapter takes a closer look at such deals for biodiversity conservation, watershed protection and carbon sequestration. Building on contract theory, findings from natural sciences, and case studies a detailed characterization is presented and likely pitfalls for the performance of PES deals are revealed. It turns out that carbon deals differ considerably from schemes aiming at watershed protection and biodiversity conservation. The first represent real business deals in which a well-defined service is traded. The latter find it difficult to define and measure the service which is being paid for, because the scientific evidence for the ecosystem service is often lacking. Taking them at face value and regarding them at business deals might therefore be misleading. We conclude that better methods to monitor the desired outcome and more information on the underlying technologies would certainly facilitate risk sharing and improve the performance of water and biodiversity deals.

A second focus lies on the provision of group contracts. Theory suggests that they are beneficial if farmers dispose of superior information about each other and can effectively coordinate their efforts. As a result risk costs are reduced. By reviewing case study material we find that cooperation among farmers is taken into account for contract design by some schemes, but practitioners have also promoted group contracts as a means to save transaction costs. The study suggests that farmers' incentives in teams should receive more attention in order to avoid the cost of free-riding and benefit from effort coordination. This aspect is especially relevant if future schemes make use of variable output-based payments.

The working title of this dissertation was "Designing *an* incentive mechanism for a sustainable use system of the montane rain forest in Ethiopia". During the course of the study the author realized that *one* incentive mechanism could not save the Ethiopian cloud forests. A price premium for coffee would internalize the positive global externality associated with the conservation of the coffee genetic diversity. However, another, local, externality is leading towards further degradation of the forest: The forest is a quasi-open access area and the benefits of an ecologically sustainable harvest of its products are shared by all farmers. As a result it is characterized by over-exploitation. Chapter 4 therefore compares different mechanisms to regulate the use of the forest and the title of the dissertation was changed accordingly.

The last chapter describes the results of a framed field experiment which was conducted with Ethiopian farmers in the rainforest area. The experiment tested two different mechanisms, which are suggested by theory to deal with the problem of over-exploitation when individual users are not known: a collective tax and a collective tax-subsidy which are charged whenever the observed total consumption of a resource is exceeding the socially optimal level. As the participating farmers knew each other from their daily life the decisions were not only compared with the theoretical benchmark given by non-cooperative game theory but the group context and individual effects were also taken into account for the analysis.

A first result is that a collective tax which was higher than the gain from free-riding performed best with respect to effectiveness, efficiency, and reliability in achieving the desired and socially optimal outcome. Second, group cohesion was found to positively influence the groups' ability to coordinate on collusive outcomes. This effect was however diminishing over time with the decisions approaching Nash play. The results further suggest that individual effects are strong and determine whether individuals follow a rather cooperative and complying strategy of whether they do the opposite. The coexistence of these two types of players can lead to asymmetric outcomes with free-riders taking advantage of the accommodating play of complying subjects. This can be considered as the main drawback of a mechanism which is otherwise performing remarkably well.

One last remark in closing. Currently, some farmers in Ethiopia receive premium prices for their forest coffee if it is produced in an environment-friendly way. The required management practices depend on the specific deals, i.e. organic production, and are certified by external agencies. None of these arrangements does exactly define the environmental service produced nor do the payments depend on any produced service. We call these arrangements PES schemes but, according to the results of chapter 3, it would be misleading to regard them as business deals which trade a well-defined environmental service.

This reservation does not put in question the important role price premia play for biodiversity conservation. However, an important question that directly follows from the results of chapter 3 is: Could impact and efficiency be increased if payments were linked to a specific service and farmers had an incentive to contribute to the objective?

Take for example the coffee genetic diversity. Regarding its relatively high global value its conservation could be the main desired service. Chapter 2 has described the effect of forest management on the diversity of the coffee plant populations. This link between action and output is common knowledge of farmers and foresters. Further scientific evidence is documented by the research project this doctoral study is part of. Thus the service is well-defined. Chapter 3 then suggests that the payments to the farmers should be based on the produced output, i.e. the amount of coffee genetic diversity conserved. The coffee schemes in the South-west should try it out.

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Eidesstattliche Erklärung:

Ich erkläre hiermit an Eides Statt, dass ich meine Doktorarbeit "Incentive mechanisms for a sustainable use system of the montane rain forest in Ethiopia" selbständig und ohne fremde Hilfe angefertigt habe und dass ich alle von anderen Autoren wörtlich übernommenen Stellen, wie auch die sich an die Gedanken anderer Autoren eng anlehnenden Ausführungen meiner Arbeit, besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert habe.