Heterogeneity of peasant land use decision as an effect of differences financial and personal capitals in the area of Biosphere Reserve “Podocarpus - El Cóndor”, Ecuador

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Presented by
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Dedication:

I dedicate to my mother and father

Abstract

Environmental protection and poverty reduction are central issues in United Nations Millennium Development Goals. Both aspects have special importance in the Andes biodiversity "hot spot" where high rates of deforestation overlap with high levels of poverty. Peasant households use forest land as cheap means of production to increase their agricultural area in order to maintain or increase their income. Respect to the issues mentioned above, following research questions are relevant: *i)* What are the opportunity costs of the farming households to conserve the native Andes forest?, a production function approach was used to calculate the profitability and determinants of agricultural production. *ii)* Is current agricultural production working efficiently?, a stochastic frontier analysis was used to calculate technical efficiency and its determinants in the cattle production. Futhermore, *iii*) What is the best conservation instrument in order to achieve cost-efficiency and poverty alleviation?, different conservation instruments fostering a forest conversion ban, including payments for ecosystem services schemes, on cost-efficiency and poverty alleviation were also tested.

In order to apply economic models, a socioeconomic sample of 130 households was collected during the farming season 2008 in the area of the UNESCO Biosphere Reserve "Podocarpus - El Condor", south Ecuador.

The most profitable land use found is extensive pasture-based cattle production (net profit 159 USD/ha/yr in average) with huge heterogeneity among households. Factors influencing the gross margin and consequently profitability in cattle production are land size, labor, input expenses, ethnicity, altitude and access to technical assistance and formal credits. The production frontier models revealed that size of pasture, labor and costs of production monotonically have increased cattle production in the sampled farms. Also, the technical inefficiency model shows that the location of the farms (lowland), ethnicity (Mestizo ethnic) and accessibility of technical assistance increased the technical efficiency of cattle farms in the study area. The average technical efficiency of about 70% was obtained from the analysis which implies a technical inefficiency level of about 30%. Of course such inefficiency could be reduced or minimized by providing technical assistance. The design of payment and contract attributes has a pronounced impact on the effectiveness as well as on the distributional impact of PES-type conservation instruments. Voluntary conservation payment instruments tend to be more cost-efficient than mandatory ones, if competitively low payments are offered. Such low offers are incompatible with poverty alleviation goals. Pronounced pro poor distributional impacts are possible, however, but the PES contracts will rather need higher payments per unit area (up to 300 USD/ha/yr) and need to be offered exclusively to the poorest households.

Acknowledgements:

A special acknowledgement to Dr. Jan Barkmann and Prof. Dr. Rainer Marggraf for his support and supervision. I also appreciate the support of my colleagues of Environmental and Resources Economics research group. Moreover, I am grateful to 6 anonymous field assistants and 130 peasant households in the research area, Ecuador.

Furthermore, I am grateful to several institutions: DFG Research Unit 816: Biodiversity and Sustainable Management of a Megadiverse Mountain Ecosystem in South Ecuador (C3.2), Deutscher Akademischer Austausch Dienst, Latin American and Caribbean Environmental Economics Program, Ecuadorian National Secretary of High Education-Science-Technology and Innovation, Fourth World Congress of Environmental and Resource Economists, and Department of Agricultural Economics of Georg-August Universität Göttingen.

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Introduction

1. Research problem

The main threat to the biodiversity in the Ecuadorian Andes biodiversity “hot spot” is deforestation (*Socio Bosque* 2010). South America has the largest forest area loss per year 4.3 million ha/yr in the period 2000-2005 (FAO 2006) compared to deforestation in other world regions. According to FAO (2006), Ecuador has the highest deforestation rate 1.7% (198 000 ha/yr) annually in South America. Land use change from natural ecosystems to pastures was from 2.2 million hectares in the year 1978 increasing to 6 million hectares in 1989 (Wunder 2000). The annual deforestation rate in the buffer zone of Podocarpus National Park is calculated 1.16% (Torracchi et al. quoted by Knoke 2009). Land use change is mainly to pasture land.

One important economic reason to explain tropical deforestation process is that forest is a cheap input for agricultural production (Benhin 2006). The measure variable is the opportunity cost (Naidoo 2006). The private marginal benefits of agriculture are higher than forest. It is because calculations of the private marginal benefits do not include social benefits. Reasons why are not included all social benefits are market, policy, and institutional failures (Benhin 2006).

Several driving forces are related with deforestation in Ecuador. Mosandl et al. (2008) point out some driving forces as low investment in education, land tenure insecurity, and an unsustainable economic system. Also, Wunder (2000) aggregates farmers look for short return of their investments. The driving forces of deforestation push strength with the agricultural national reforms in the early 60s which caused migration to the Amazon, timber extraction and cattle ranching in the 70s and 80s (Pohle & Gerique 2008). In the research area, cattle production has been main cause of deforestation (Wunder 1996) where the natural ecosystem has been change by slash and burn technique (Beck et al. 2008a, Beck et al. 2008b) and the current land use pattern is an extensive field-pasture-rotation system (Beck et al. 2008a).

2. Research area

The research area is located in the south of Ecuador in the Biosphere Reserve “Podocarpus-El Cóndor” located in the provinces of Loja and Zamora-Chinchipe (see Figure 1). The research area is part of the global biodiversity “hot spot” of the Andes Mountains (CIPRB 2005, Brummitt & Lughadha 2003). The protected area “Corazón de Oro” (Area de Bosque y Vegetación Protectora Corazón de Oro; ABVPC) was established to the north of Podocarpus National Park (UNL 2005). It forms a part the buffer zone of the national park which is the core areas of the biosphere reserve (CIPRB 2005).

The region is inhabited by people with heterogenic ethnic and socio-economic structures (Pohle 2009) and the majority of rural households are poor smallholders practicing pasture-based cattle ranching (Beck 2008). The two ethnic groups (“Mestizos” and indigenous group “Saraguros”) are engaged into agricultural activities. The cattle’s ranching is involved market economy. The arable crop production is involved subsistence economy on small plot near of households (Pohle & Gerique 2006, Pohle et. al 2009). Extensive cattle production is the main sources of the income but it is thought with low profitability. Peasants use fire as tool to open new pastures and regenerate old pastures (Pohle and Gerique 2008). Moreover, an additional source of income are small shops, off-farm labor (Pohle and Gerique 2008), and extraction of the timber (Pohle 2006).

3. Objectives of the study

The research aims to estimate different income options of agricultural landholders. It is important for the design of policies to promote forest protection. The research is part of the project C3.2 DFG Research Unit 816: Biodiversity and Sustainable Management of a Megadiverse Mountain Ecosystem in South Ecuador. The research has three specific objectives:

1. Analysis of the profitability of agricultural production systems that later is used as proxy of opportunity cost of forest conservation.
2. Investigation of the technical efficiency in cattle production and determinants of technical efficiency.

Evaluation of differing conservation instruments (*ex-ante* analysis) reducing a forest conversion in mountainous southern Ecuador with respect to cost-efficiency of conservation and to poverty alleviation.

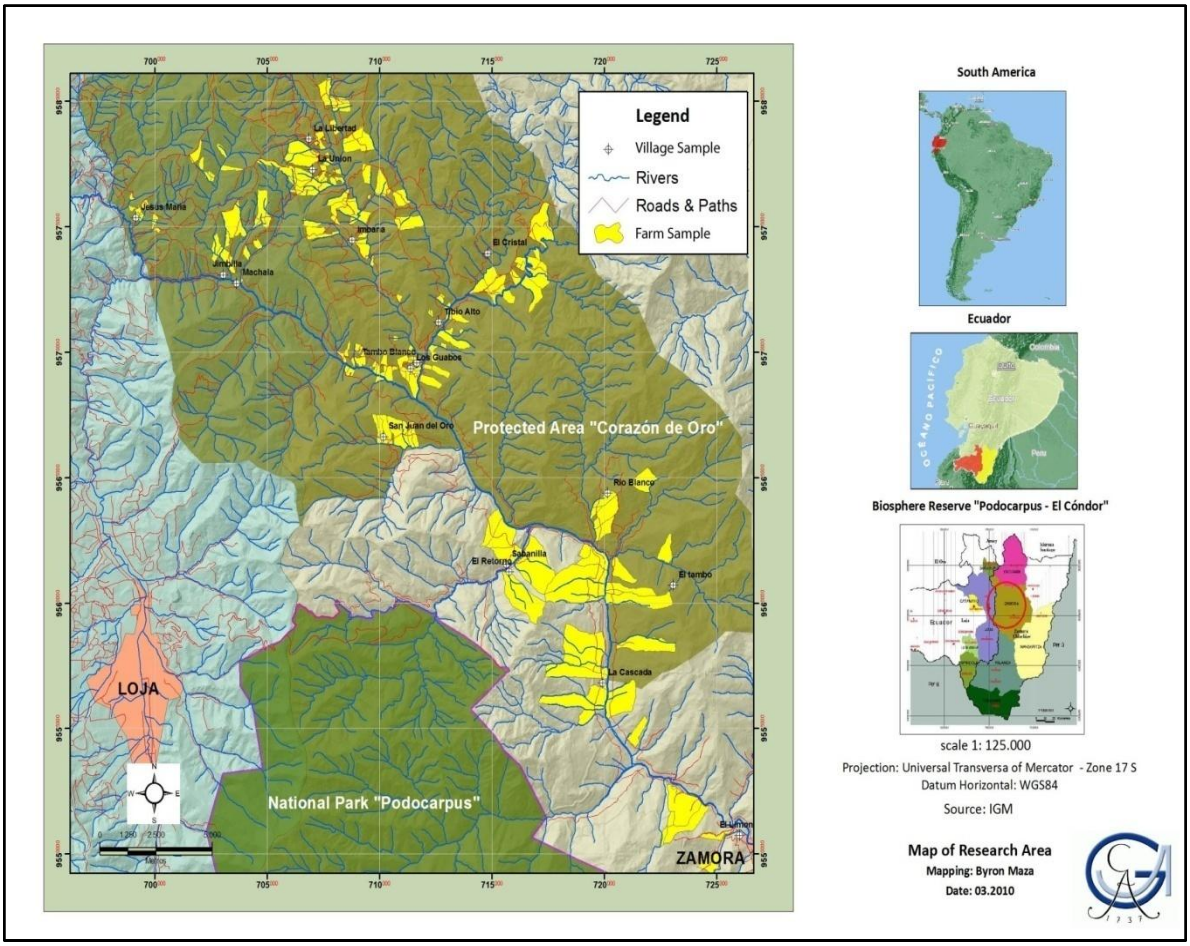

Figure 1: Research area in the Biosphere Reserve "Podocarpus-El Cóndor", south of Ecuador

4. Theoretical framework

Smallholders of developing countries have characteristics of peasant households (Ellis 1993). Peasant household has a context of market failures (i.e. high transaction cost, lack of access to information, credit constrain) and uncertainty (i.e. output prices and weather fluctuations) is non-optimal making decisions about technical and allocative efficiency resources by peasant (Ellis 1993). Also, peasants use their natural capital (i.e. wood extraction or land use intensification) as livelihood strategy to afford market failures and uncertainty (Barbier 2006). Furthermore, farmers make arrangements in the production (i.e. input use, family labor) and consumption (food) decisions (De Janvry & Sadoulet 2006).

Smallholder land use decision is influenced by internal and external factors of the production unit (Crissman et al. 2001, Angelsen & Kaimowitz 1999, Kaimowitz & Angelsen 1998) Fig 2. The internal factors are farmer characteristics such as objectives, perceptions, and with capitals: financial, natural, human, physical and social capitals (Rakodi 1999, Bebbington 1999). External (exogenous) factors influences the decision making in smallholders are markets, world market prices, etc.

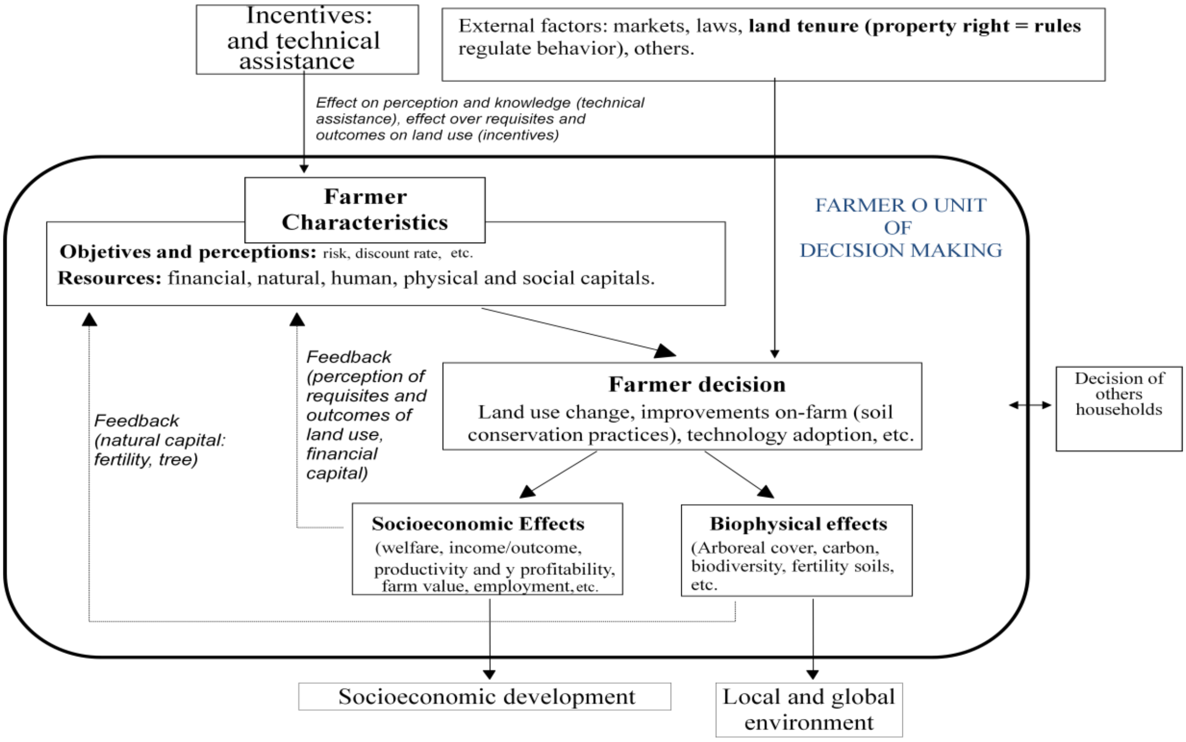

Figure 2: Factors that influences the land use decision making of smallholder
Source:Adapted of Crissman et al. (2001), Kaimowitz & Angelsen (1999), and Kaimowitz & Angelsen (1998).

The framework indicate in the figure 2 is in relation with 3 objectives of the research. The research put emphasis on internal factors that have influence on farmer decision. The research excludes external factors that have little influences on farmer decisions.

5. Outline of the dissertation

This is an accumulative dissertation. The first chapter is entitled “Modelling smallholders production and agricultural income in the area of the Biosphere Reserve Podocarpus - El Condor”. This chapter is the base for the following chapters because it has all socio-economic information compiled in the conducted survey in the research area. A summary similar version is in the second chapter. It is entitled "*Profitability of smallholder agriculture in the area of the Biosphere reserve Podocarpus – El Cóndor, Ecuador*". The importance of this paper is to calculate the profitability of the agricultural production as opportunity cost of forest conservation. A Cobb-Douglas production function approach is used to establish factors that influence profitability. It will be submitted to the Journal of Agriculture and Rural Development in the Subtropics and Tropics.

The third chapter is "*Technical efficiency and its determinants in cattle production in the Biosphere Reserve Podocarpus-El Cóndor, Ecuador*". This paper determines the technical efficiency among farmers and determinants of the cattle production. It will be submitted to Quarterly Journal of International Agriculture.

The fourth chapter is entitled "*Efficiency and Distributional impacts of protected area planning using PES schemes in the Biosphere Reserve Podocarpus - El Cóndor, Ecuador*". The paper investigates the effects of differing conservation instruments fostering a forest conversion ban in mountainous southern Ecuador including payment for ecosystem services schemes on cost-efficiency of conservation and poverty alleviation. It will be submitted to Ecological Economics. A similar version is on web site of the Fourth World Congress of Environmental and Resources Economists (http://www.wcere2010.org/).

References

Angelsen A., Kaimowitz D. 1999. Rethinking the Causes of Deforestation: Lessons from Economic Models. The World Bank Research Observer 14(1):73–98.

Barbier E. 2006. Natural Capital, Resource Dependency, and Poverty in Developing Countries: The Problem of 'Dualism within Dualism. In: Economic development and environmental sustainability: new policy options. López R., Toman M. (edits). Oxford University Press.

Bebbington A. 1999. Capitals and Capabilities: A Framework for Analyzing Peasant Viability, Rural Livelihoods and Poverty. World Development 27(12):2021-2044.

Beck E., Makeschin F., Haubrich F., Richter M., Bendix J., Valarezo C. 2008a. The Ecosystem (Reserva Biológica San Francisco). In: Beck E., Bendix J., Kottke I., Makeschin F., Mosandl R. (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:1-14.

Beck E., Hartig K. ,Roos K. 2008b. Forest clearing by slash and burn. In: Beck E., Bendix J., Kottke I., Makeschin F., Mosandl R. (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:371 -374.

Beck E. 2008. Preface. In: Beck E., Bendix J., Kottke I., Makeschin F., Mosandl R.: Gradients in a tropical mountain ecosystem of Ecuador. Ecological Studies 198:5-7

Benhin J. 2006. Agriculture and deforestation in the Tropics: A Critical Theoretical and Empirical Review. Ambio 35:9-16.

Comisión Interinstitucional Pro Reserva de Biosfera (CIPRB). 2005. Reserva de biósfera "Podocarpus – El Cóndor".Loja, Ecuador

Costanza R., d'Arge R., de Groot R., et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253–60.

Crissman C., Antle J., Stoorvogel J. 2001. Trade offs in agriculture, the environment and human health: Decision support for policy and technology managers. In: Lee D., Barrett C. (Eds.) Tradeoffs or synergies? Agricultural intensification, economic development and the environment. Wallingford, UK: CABI Publishing Co.

De Janvry A., Sadoulet, E. (2006). Progress in the Modeling of Rural Household Behavior Under Market Failures. In Poverty, Inequality and development. Essays in Honor of Erik Thorbecke. 386:155 -182.

Ellis, F. 1993. Peasant economics: Farm Households and Agrarian Development

FAO. 2006. Global forest resources assessment 2005. Progress towards sustainable forest management. Food and Agriculture Organization of the United Nations, Rome.

Kaimowitz D., Angelsen A. 1998. Economic models of tropical deforestation A Review. CIFOR; Indonesia.

Maza B., Barkmann J., von Walter F., Maggraf. 2010. Modelling smallholders production and agricultural income in the area of the Biosphere reserve "Podocarpus – El Cóndor", Ecuador. Internal Discussion paper. Department of Agricultural Economics, Georg-August Universität Göttingen. No. 1009.

Mosandl R., Günter S., Stimm B., Weber M. 2008. Ecuador suffers the highest deforestation rate In: E. Beck, J. Bendix, I. Kottke, F. Makeschin, R. Mosandl (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:37-40.

Pohle P., Gerique A.2006. Traditional ecological knowledge and biodiversity management in the Andes of southern Ecuador. Geographica Helvetica 61(4):275-285.

Pohle P., Gerique A. 2008. Sustainable and Non Sustainable Use of Natural Resources by Indigenous and Local Communities. In: Beck, Erwin; Bendix, Jörg; Kottke, Ingrid; Makeschin, Franz; Mosandl, Reinhard (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador. Ecological Studies 198:347-362.

Pohle P. 2008. The people settled around Podocarpus National Park. In: Beck, Erwin; Bendix, Jörg; Kottke, Ingrid; Makeschin, Franz; Mosandl, Reinhard (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador. Ecological Studies 198:25-36.

Pohle P., Gerique A., Park M., Lopez Sandoval M. 2009. Human ecological dimensions in sustainable utilization and conservation of tropical mountain forests under global change in southern Ecuador. In: Tscharntke, T., Leuschner, C., Veldkamp, E., Faust, H., Guhardja, E., Bidin, A. (eds.): Tropical rainforests and agroforests under global change, Springer, Berlin.

Socio Bosque. 2010. Socio Bosque: Primer Año de implementación 2008-2009. Ministerio de Ambiente. Quito, Ecuador.

Torracchi S., Tapia M., Valdivieso M. (without year). Spatial and temporal analysis of vegetation from Zamora´s basin. Universidad Tecnica Particular de Loja; power point presentation. In Knoke T., Weber M., Barkmann J., Pohle P., Calvas B., Medina C., Aguirre N., Günter S., Stimm B., Mosandl R., von Walter F., Maza B., Gerique A. 2009a. Effectiveness and Distributional Impacts of Payments for Reduced Carbon Emissions from Deforestation. 63(4):365–384.

Universidad Nacional de Loja UNL. 2005. Estado de conservación de áreas protegidas y bosques protectores de Loja y Zamora Chinchipe y perspectivas de intervención. CINFA, Herbario Reinaldo Espinosa. Loja, Ecuador.

Wunder S. 1996. Los caminos de la madera. Probona-Programa Regional De Bosques Nativos Andinos. Quito, Ecuador.

Wunder S. 2000. The economics of deforestation: the example of Ecuador. St. Martin, New York.

Diskussionspapiere

Discussion Papers

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Chapter I

Modelling smallholder production and agricultural income in the area of the Biosphere reserve “Podocarpus – El Cóndor”, Ecuador.

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1. Introduction

1.1. Scope and objectives

Ecuador is a megadiverse country (Brehm et al. 2008), and the Ecuadorian are Andes one of the global biodiversity hotspots (Meyers et al. 2000; Brummitt & Lughadha 2003, Brehm 2005). One important protected area is the Podocarpus National Park (PNP) located in the south Ecuadorian Andes (Barthlott et al. 1996). At the same time, PNP is part of the UNESCO Biosphere Reserve "Podocarpus-El Cóndor".

The main threat to the biodiversity in the Andes "hot spot" is deforestation. South America has the largest forest area loss per year (4.3 million ha/yr in the period 2000-2005) compared to other world regions. According to FAO (2006), Ecuador has the highest deforestation rate 1.7% (198 000 ha/yr) annually in Latin America. Land use change from natural ecosystems to pastures increased from 2.2 million hectares in the year 1978 to 6 million hectares in 1989 (Wunder 2000). The annual deforestation rate in the buffer zone of Podocarpus National Park was calculated as 1.16% (Torracchi et al. quoted by Knoke 2009). Local land use change is mainly to pasture land.

This discussion paper describes in detail the agricultural production and income of smallholders in the PNP region land based on empirical survey data sampled in 2008. It serves as a background document with respect to more specific analysis (Maza 2010) and policy advice base on this analysis. The discussion paper presents three main results on smallholder agriculture in the research area: (*i*) econometric analysis of agricultural production, (*ii*) modeling the arable crop and cattle production systems with Cobb-Douglas production functions, and (*iii*) the structure of the household income.

2. Econometrics analysis of agricultural production

The neoclassic theory of production offers tools for the analysis of the efficiency and productivity of firms (Coelli et al. 2005). Specifically, production theory studies seek to analyse the way how combinations of inputs are used to obtain outputs. Production function analysis is one of the main tools.

2.1. Production function

The production function is the relationship between specific levels of output q which can be obtained with different combinations of inputs X_i (Chambers 1988 p.8, Coelli et al. 2005 p.12):

$$q = f(x),$$

Four main properties of the production function are usually - but not in every single case - associated with economic production analyses (see Table 1):

Table 1. Fundamental properties of the production function (source: Coelli et al. 2005 p.12)

Non-negativity:	The quantitative value production *q=f(x)* is a finite, non-negative real number.
Weak Essentiality:	The production of positive output *f(x)* is impossible without the use of at *least one* input *x*.
Non-decreasing in ***x*** *(or monotonicity):*	Additional units of an input will not decrease output. If the production function is continuously differentiable, monotonicity implies that all marginal products are non-negative.
Concave in ***x****:*	If the production function is continuously differentiable, concavity implies that all marginal products are non-increasing resulting in the law of diminishing marginal productivity.

Typical applications of production functions in econometric research includes (Fuss et al. 1978 p.220-222) investigations on returns to scale, substitution factors of production, and analysis of technical change over the time. If a production function is not expressing the total output of a farm but output per ha, the monotonicity property may be lost.

2.2. Functional forms

There are several functional forms available with different levels of complexity to estimate production function parameters. A detailed list of production functions is provided in Fuss et al. (1978 p. 238 - 239). For our analysis we choose the most common production functions, i.e. Cobb-Douglas and Translog production functions.

2.2.1. Cobb-Douglas and Translog production functions

a) Cobb-Douglas production function

The Cobb-Douglas production function was proposed by Cobb & Douglas (1928) to establish the relationship between labour, capital, and output of a production. A formal representation is given by Nicholson (1998 p.319):

$$q = \prod_{i=1}^{n} X_i^{ß_i}$$ with q=output, x =inputs, ß = input coefficient.

The input coefficients of a Cobb-Douglas production function can be estimated after taking the logarithm of, both, the produced output and the input production factors. Some characteristics of Cobb-Douglas production function are the following.

1. Constant Returns to Scale (CRS) if:

$$\sum_{i=1}^{n} \beta_i = 1$$

2. In a CRS Cobb-Douglas production function, β_i is the elasticity of q with regard to input $\mathbf{X_i}$. Since $0 \leq \beta_i < 1$, each input has diminishing marginal productivity.

b) Translog production function

Translog or Transcendental logarithm is a generalization of the Cobb-Douglas production function. It was developed by Christensen et al. (1973 p.28) with the objective "to develop tests of the theory of production that do not employ additivity and homogeneity", which requires a more flexible function form. A formal representation of the Translog production function is given by Nicholson (1998 p.320):

$$\ln q = ß_0 + \sum_{i-1}^{n} \beta_i \ln X_i + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} ß_{ij} \ln X_i \ln X_j$$

$$ß_{ij} = ß_{ji}$$

It should be noted that:

1. The Cobb-Douglas production function is a special case of the Translog production function where $ß_0 = ß_{ij} = 0$ for all *i, j*.
2. The Translog production function and Cobb-Douglas production function assume any degree of returns to scale. If

$$\sum_{i=1}^{n} \beta_i = 1 \text{ and } \sum_{i=1}^{n} \beta_{ij} = 0$$

for all *i*, the translog production function exhibits constant returns to scale.

3. $ß_{ij} = ß_{ji}$, is an necessary equality of cross-partial derivatives.

2.2.2 Criteria for choosing functional form

Coelli et al. (2005 p.211-212) suggests a guide to choose a functional form following four basic principles. The functional form should be flexible, linear in the parameters, regular and parsimonious:

- First order *flexible* means that a production function provides a first-order differential approximation to an arbitrary function at a single point. Second order flexible means that a second order approximation can be achieved. More flexibility requires more parameters. Thus, more flexible forms may face multicollinearity problems if explanatory variables are not independent.
- *Linear in the parameters* is desirable as non-linear functional forms do sometimes not converge to the global optimum of the function in numerical estimation. It is an advantage of Cobb-Douglas or Translog production functions they are – after

logarithmizing – linear in parameters. Consequently, their parameters can be estimated with linear regression techniques.

- *Regular* means that the functional form satisfies the economic regularity properties of non-negativity, weak essentiality, monotonicity and concavity (law of diminishing marginal productivity).
- *Parsimonious* refers to the desirability to use the simplest functional form, i.e. with the fewest number of parameters that achieves the research objective.

The final decision on the adequacy of a functional form will often be done after residual analysis, hypothesis testing, goodness-of-fit tests, and tests of predictive performance Coelli et al. (2005 p.212). Moreover, the model section problem between Cobb Douglas and Translog production functions can be approached with a "F" test (Wooldridge 2006).

2.3. The Production decision

The ideal objective of the firm is to produce with economic efficiency. Economic efficiency is a combination of technical and allocative efficiency (Ellis 1993 p. 65-81). The act by which the specific combination of the factors of production (inputs) is defined, can be called production decision. The production decision has two elements: the production technology and the selection of inputs themselves (Sadoulet & de Janvry 1995 p.61). The production technology is represented by a production function that represents the relationship between output(s) and inputs. The selection of inputs depends on firm objectives giving market prices.

The firm objective can be represented in three different ways: cost-input minimization (Sadoulet & de Janvry 1995 p.66, Coelli et al. 2005 p.21), output maximization, or profit maximization (Sadoulet & de Janvry 1995 p.61, Coelli *et al*. 2005 p.32). These representations are fundamentally equivalent (principle of duality).

2.4. Determinants of production

The focus of our analysis is on the determinants of production at the level of the single farm. Determinants for agriculture production can be described as natural, physical, financial, human, social and political capital (Rakodi 1999). Thus, other determinants influence the efficiency of production in addition to land, labor and built capital. Alene *et al.* (2005) point out several typical such determinants for a developing country setting:

- *Social capital* can positively impact on efficiency if farmers have access to new information, and could potentially be supported by other farmers or other economic agents.
- *Technical assistance* and *education* can have positive impacts on production.
- *Land size* can positively or negatively impact efficiency. Its effect depends on alternative sources of income, transaction cost of production, dependence on off-farm labor opportunities, etc.
- *Age* can impact the adoption of improved technology negatively or positively.
- *Ethnicity* and *off-farm* employment can, both, have either positive or negative impacts.
- *Access to credit* could have a positive impact (Dercon 2003, Udry 1996). Credit is necessary for increasing land and labor productivity (Zeller et al. 1998, Zeller et al. 1997, Delgado 1995).

Rahman & Kamrul (2008) and Sherlund et al. (2002) point out that the results of productivity and efficiency analyses can be biased if environmental conditions are not accounted for. Typical case include site-specific factors such as soil and topography, or climate variables (Antle & Capalbo 2001). Although these factors are not under the direct control of the farmer, they do have an obvious potential to influence production. For their influence on production follows a unimodal “optimum” pattern. For example, while a certain amount of soil moisture is optimal for most terrestrial crops, too much and too little reduces production. This response patterns violates the monotonicity and potentially the concavity characteristics often presupposed for economic production function analysis (see Table 1). The environmental factors can be combined into a site index, however, that displays a well-behave functional relationship to production (see, e.g., Juhrbandt 2010).

3. Methodology

3.1. Research area

The research area is located in the south of Ecuador in the Biosphere Reserve “Podocarpus-El Cóndor” in the provinces of Loja and Zamora-Chinchipe (see Figure 1). The research area is part of the global biodiversity “hot spot” of the Andes Mountains (CIPRB 2005, Brummitt & Lughadha 2003). The majority of rural households are poor smallholders practicing pasture-based cattle ranching (Beck 2008). The protected area “Corazón de Oro” (Area de Bosque y Vegetación Protectora Corazón de Oro; ABVPC) was established to the north of Podocarpus National Park. It forms a part the buffer zone of the national park, which is the core area of the UNESCO Biosphere Reserve.

The annual deforestation rate in the buffer zone of PNP is calculated as 1.16%. As elsewhere in Ecuador, land use change is mainly to pasture land (Torracchi et al. quoted by Knoke 2009). Peasants use fire to open new pastures and regenerate old pastures (Pohle and Gerique 2008). The main driver of deforestation is population growth. Other drivers are agrarian reform, new infrastructure (roads), land tenure system and agricultural income strategies (Pohle 2008).

The region is inhabited mainly by two ethnic groups at least partly thought to display differing socio-economic characteristics (Pohle 2009). Both, the “Mestizos” settlers (*colonos*) as well as the indigenous “Saraguros” are engaged in agriculture (Beck 2008), mainly cattle ranching including diary production. The farms regularly market their products. The small amount of arable crop production is mostly subsistence production (Pohle et. al 2009). Thus, (extensive) cattle production is the main source of income. Alternative sources were known to include small shops, off-farm labor (Pohle and Gerique 2008), and extraction of timber (Pohle 2006).

3.2. Sampling procedure at village level

Sampled Villages were selected with a weighted random method. The sample was designed to consist of 10 villages with 105 interviews to be administered in total (Table 2). In the field, it turned out that sufficient time and resources were available to expand the survey to 16 villages and 130 valid interviews (for details, see Table 2).

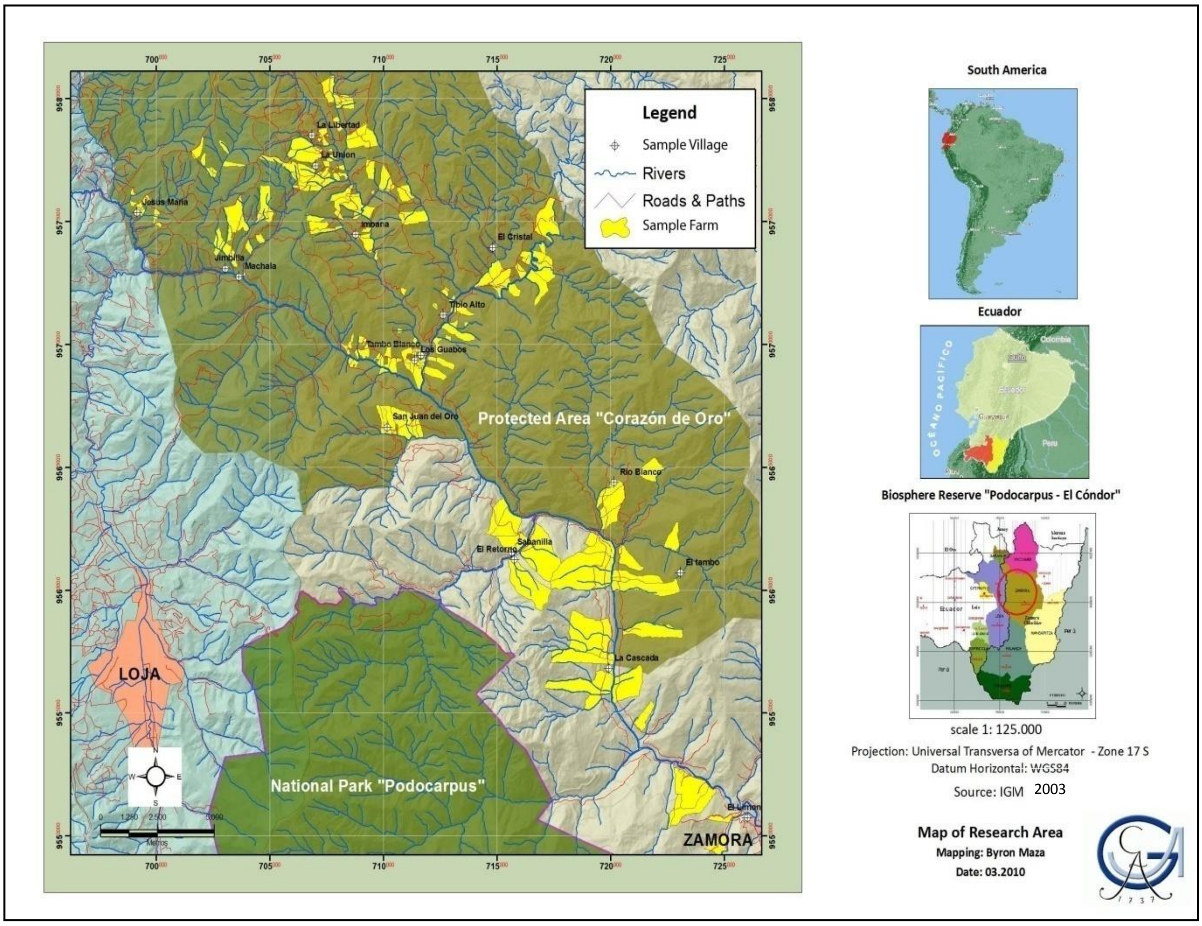

Figure 2: Research area in the Biosphere Reserve “Podocarpus-El Cóndor”, south Ecuador

Table 2: Villages and households covered (see also section 3.5)

Province	Parroquia	Village	Number of interviews calculated according to design	Number of Interviews actually conducted	Number of interviews included in analysis
Loja	Jimbilla	Jimbilla	16.6	5*	3
		Machala	8.3	7	7
		Jesus Maria	8.3	11	11
Zamora	Imbana	El Cristal	8.3	10	10
		Tibio Alto	8	8**	7
		Imbana	8.3	9	9
		La Libertad	8.3	9	9
		La Unión	8	11	11
		Los Guabos	8	11	11
		San Juan del Oro	8.3	7	7
		Tambo Blanco	8.3	9	9
	Sabanilla	El Retorno	12	5	5
		El Tambo		6	6
		La Cascada		8	8
		Río Blanco		10	10

Zamora	El Limón (Chorrillos, San Rafael, and Victoria sectors)	0	11	6***
Total		110	135	130

* two interviews were excluded in the analysis (see explanation on 3.5 problematic data).
** one interview was excluded because the farm was outside of aerial photo available for the research area
***five farms were excluded because of land use restrictions.

3.3. Selection of the respondents

The households in each village were selected by a modified snowball approach. Either our guide knew a farmer or his family, or a farmer who had been interviewed recommended us to other farmers. Farmers also acted as intermediaries to contact other farmers of deemed appropriate. The application of this approach was necessary because the field group (which included the first author) were considered as strangers by most villagers, and treated with suspicion. Particularly, inhabitants feared that

- we were thieves,
- the information we collected may end up in the hands of government institutions, which would either use it to
  - levy a new tax on the land of the inhabitants or to
  - reduce or cancel the payment of the subsidy basic social security payment *Bono desarrollo humano*[2], or to
  - sanction prohibited land use change in the forest reserve.

Without the sampling strategy taken, it would have been nearly impossible to obtain information as true as possible within an acceptable duration of the sampling campaign.

3.4. Data collection, entry, and cleaning

The data were collected through standardized formal questionnaires. An English language version of the questionnaire was designed in Germany in the winter of 2007 and then translated into Spanish. The design of the questionnaire benefited from a comparison of the

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[2] *Bono desarrollo humano* is a based social security payment. The payment is a conditional cash subsidy of the Ecuadorian government of $ 30 per month per family. This payment is only for the very poor. The payment can be received by people who are over 65 years old, disabled, or poor single mother. It is conditional because the beneficiaries must have vaccination certificates, and certificates of study in the case of single mothers.

following successfully used questionnaires: Stability of Rainforest Margins (STORMA) and Integrated Silvopastoral Approaches to Ecosystem Management.

The questionnaire we used, has the following structure.

A. Household Characteristics
  - General characteristics of the properties operated by the farmer conatcted
  - Farmer family characteristics

B. Land Use of the Faming Household
  - Land tenure regime
  - Land use types

C. Arable Crop Production
  - Annual crop and permanent crop production
  - Selling and consumption of the production
  - Production cost
  - Equipment and infrastructure for arable crop
  - Paid labor

D. Cattle Production
  - Herd structure
  - Changes in the herd inventory
  - Management of pastures
  - Production cost
  - Equipment
  - Labor spent for herding
  - Paid labor
  - Sale of dairy products
  - Selling and consumption of cattle products

E. Forest Production
  - Selling forest production
  - Production cost – forest
  - Introduction of forest species

F. Knowledge on Silvo-pasture Techniques
G. Social Capital
H. Technical Assistance
I. Credit Participation
J. Off-farm Income
K. Technology Adoption

The interviewers were trained for 2 days in the city of Loja (07/03/2008 and 10/03/2008) and taken for one day to the field (Imbana 08/03/2008). From 11/03/2008 to12/03/2008 the interviewers studied the questionnaire in detail under the supervision of the first author. Next, the survey instrument was pre-tested with two households, and the questionnaire further improved. The first interview of the main study was administered on 13/03/2008.

The interviews and land-use surveys were conducted (see Table 3) under the supervision of first author. The group was divided in two teams at the end of the first week in the field. During the first two weeks, the interviewers still had many questions because they were confronted with new situations: local measure units, new local names of species, new categories for off farm-income, etc.

For some farmers, the questionnaire was too long. The interviewers reported this situation. In these cases, the interviews were divided into two parts. An acknowledgement gift (3 USD/respondent) was presented to each interviewed farmer at the end of the interview.

Table 3: Staff of field research study in Ecuador

Background	Responsibility
Socio-Economics	Coordinator (Byron Maza)
Geology/ Geographic Information Systems – GIS.	Global Positioning System GIS
Informatics	Access data base programmer
Environmental Management / Experience in land use project around Saraguro city.	Team A Socioeconomic interviews.
Environmental Management / Experience in land use project around Saraguro city.	Team A Land use: verification and Global Position System (GPS).
Management Environmental/ Experience socioeconomic component in Loja.	Team B Socioeconomic interviews.
Agricultural assistant	Team B Land use: verification and GPS points. Local guide.

During the survey, the questionnaires were checked by the field coordinator before the data were stored by the coordinator in an Access database file. In case of doubt, interviewers were contacted and asked to confirm or correct the answers given. The information was checked two more times in Göttingen. Data cleaning includes examining missing values, wild codes, inconsistencies and extreme values (also see next section).

3.5. Problematic data

- ***Jimbilla village***

A total of 24 interviews were planned for Jimbilla & Machala, two directly adjacent villages. The survey was stopped after the fifth interview, however. During fourth and fifth interview, it became apparent that the respective respondents did not collaborate in terms of a truthful representation of their farming household and production characteristics. These last two interviews were not included in the analysis, and the interviews terminated in these two villages.

- ***El Tibio village***

In *El Tibio Alto* is inhabited by members of the Saraguro ethnics. Respondents appeared to strategically exaggerate or understate their endowments. Also, nobody claimed to extract wood from the forest. However, it was possible to see semi-processed wood ready to be sold, in the center of the village. In informal conversations, we found out that the inhabitants hated the protected area, in which their village was located. The residents of *El Tibio Alto* thought that the forest protected area (*Bosque Protector Corazón de Oro*) was to blame for their problems to obtain legal land titles. After an appropriate socialization of the background of our study, a confident relationship could be established that permitted the administration of the survey.

Land use of each single farm was delimited by aerial photographs and sing Global Positioning System data (see section 3.6 for details). One interview was eliminated (El Tibio Alto #15) because the farm was outside the aerial photographs which did not cover extreme North-East part of the research area.

- ***Farms near Zamora***

Five farms near the provincial capital Zamora were not included in the analysis. The farms are located in a place where a small hydro-electrical plant was being constructed. In this area, farmers were forbidden to continue with agriculture.

- ***Data on wood extraction***

Finally, it was not possible to obtain reliable data for wood extraction (section E of the questionnaire). As nearly all forest is located in protected areas, it is not permitted to extract wood by law. Respondents did not want to speak about this topic, or simply denied extracting wood. This behavior was not restricted to *El Tibio Alto* residents.

3.6. Geo-data

The geo-data on land use was collected by technicians (assistants) for each single farm. Aerial photographs available from *Instituto Geográfico Militar* (IGM 2003) at the scale 1: 50,000 were printed. These photographs were used to delimit each farm in collaboration with the farmers. Later, technicians verified the land use using a global positioning system (GPS), and took additional GPS points to delimit different land uses.

The geo-data were input into Arcview by a GIS expert in Loja. The information of each single polygon was checked one more time in Göttingen by the first author.

3.7. Methodology used in the descriptive analysis

Descriptive analysis includes measures of central tendency and measures of variability for continuous data. The measures of central tendency are mean and median. The measures of variability are standard deviation and range (maximum and minimum). For categorical data, we used frequencies. Table 4 shows variables sampled. The analysis was made with SPSS version 17.

Table 4: Descriptive statistics of farms (capital and production characteristics)

Component	Variables
Personal capital	Number, gender , age, ethnicity, and education level of all household members
Financial capital	Access to credit, credit source and reason why farmers do not request formal credit
Social capital	Organization membership, meeting attendance, decision making on organization decisions, labor contribution to the organization, and money contribution to the organization
Operational	a) *Land:* tenure regime, farm origin, requested rental price for hectare

capital	of land (cattle or agriculture), farm size per household, land use distribution (forest, pastures, and arable crops), percent of grass and crops b) *Herd:* structure (number, age, race and sex of animals)
Income sources	a) *Arable crop*: amount sold, amount consumed, labor (hired and family) expenses per hectare b) *Cattle:* dairy production (sold and consumed), animals (sold and consumed), life weight increment, labor (hired and family) and cash input expenses per hectare c) *Off*-farm income: poor income subsidy, *off*-farm employment
Technology adoption	Tree species introduced to the farm, place where the trees were planted, why farmer is satisfied with pasture grass species adopted, potential trees species adoption
Technical assistance	Topics of technical assistance received in the last year, changes in the farms as effect of technical assistance, level of satisfaction with and future topics of technical assistance

Regarding potential technology adoption, farmers were asked if they were willing to introduce new species. *Cesalpinia spinosa* (“Tara” or “Guarango”) was selected as a specimen species. Promising planting experiments in other regions of Southern Ecuador (Loja province) have already been carried out with *Cesalpinia spinosa* (GTT, 2007). Tara is a shrub or a small tree, around 5 m high planted in altitudes up to 2800 m. As a nitrogen-fixer, Tara can contribute to an enhanced pasture. Tara starts to yield fruit at age three to five and reaches a maximum yield of up to 40 kg/yr/tree after 10 years. Trees can be harvested until they reach the age of about 65 years, above which they do not bear much fruit. The uses from the processed seed range from a colorant to hydro-colloids (tannins) (Nieto & Barona 2007, Barona & Ortiz 2007).

At a conservative yield estimation of 10 kg/yr for a young Tara tree, assuming a market price of 0.60 US$/kg and a planting demand of about 600 trees/ha, the accumulated establishment costs (plant 0.10 USD/tree, management 0.10 USD/tree, labor 4 USD/tree) are approximated 1500-2000 US$/ha (interest rate 8%). After 4-6 years the plantation breaks even. Later, attractive net profits are prognosticated (Nieto & Barona 2007, Barona & Ortiz 2007).

During the interview, farmers were introduced to planting Tara. Different silvopastoral uses, such as living fences, or pure plantations were explained using graphs and monetary values. After the explanation, we asked: Would you like to plant one hectare, it is 625 plants, of Guarango?

3.7.1. Herd

The data collected for the cattle herd did not directly include data on life weight increments. Such increments are an important source of income that is not captured by the questionnaire. The reported sale of animals did not exactly track life weight increments although the sampled farmers were mostly able to report the life weights at sale. Thus, we included a section that explains this income component relating to the structure and growth of the herd.

In order to calculate the life weight increment of the herd, we first need to assign life weights at beginning and end of the year to the cattle of each farm. These inventory data are approximated by establishing a relation between the life weights of the animals sold and the characteristics of the animals. First, we tested 8 different regressions in order to predict the life weight of the animals sold. Each equation has a different arrangement of explanatory variables. The variables were coded using effect coding (see Table 5).

Table 5: Characteristic of regressions to predict life weight of individual cattle

Explanatory variables	Equation characteristics
Formula 1. Race and Age. No interaction	Effect coding Adj R^2 = 0.5055 5 explanatory variables, all variables significant
Formula 2. Interaction between two races and three age classes.	Effect coding Adj R^2 = 0.5121 9 explanatory variables, 2 variables are non-significant
Formula 3. Race, Age, and Sex. No interaction.	Effect coding Adj R^2 = 0.5115 6 explanatory variables, one variable non-significant
Formula 4. Race, Age, Sex, and Mean altitude, No interaction.	Effect coding Adj R^2= 0.5831 7 explanatory variables, one variable non-significant
Formula 5. Mean altitude, interaction between race, age and sex.	Effect coding Adj R^2 = 0.5027 20 explanatory variables, seven variables non-significant
Formula 5.1. Interaction between race, age and sex.	Effect coding Adj R^2 = 0.5069 18 explanatory variables, seven variables non-significant (for details, see Table 15)
Formula 6. Mean altitude and interaction between race and age.	Effect coding Adj R^2 = 0.5038 11 explanatory variables, four variables non-significant
Formula 7. Interaction between race and age	Effect coding: 0, mean altitude,- mean altitude Adj R^2 = 0.4594 9 explanatory variables, two variables non-significant

Formula 8. Interaction between race, age and sex	Effect coding: 0, mean altitude,- mean altitude Adj R^2 = 0.588 18 explanatory variables, one variables non-significant

All significant at α =0.05

We selected equation 5.1 to predict the cattle life weights. It includes the interaction between race, age and sex of different animals. It does not have the maximum adj. R^2 (0.506) but has a clear interpretation of the coefficients. Using equation 5.1, we predicted animal life weights at the beginning and end of one year. The resulting calculation was also used to calculate the stocking rate expressed in Tropical Livestock Unit (1TLU= 250 kg life weight) and Animal Units AU (1UA = 400 kg life weight) of the farm.

The predicted life weight was used to calculate the annual weight increments according to Figure 3. Phase I represents the life weight increment from January to July. During Phase II newly born animals are added to the herd. Phase III represents the life weight increment between July – December. Phases I and III represent the weight increment on the whole year. We assume that animals with sex female and more than 3 years old have zero life weight increment per year. The consumption and selling of animals as well as death and purchases are ignored for the calculation of the life weight increment of the herd.

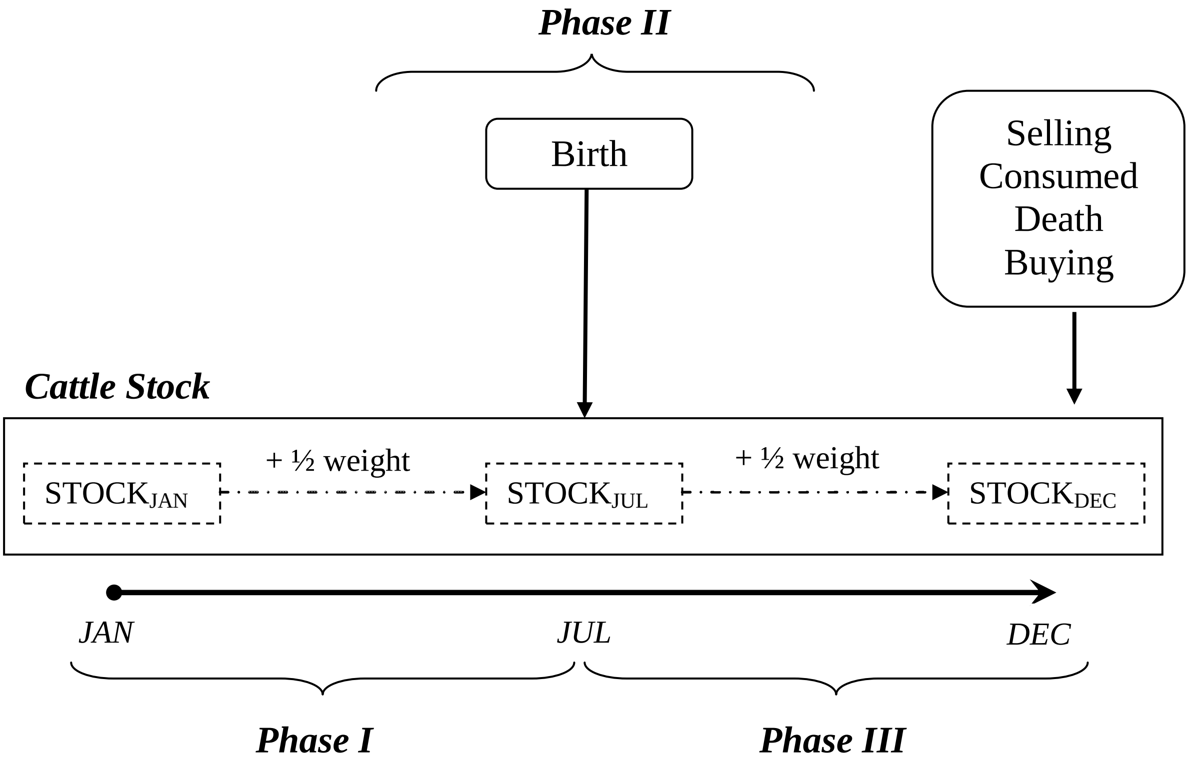

Figure 3: Model of life weight increment

3.8. Methodology used in the causal analysis

All output values used in the causal analysis are expressed as an output intensity, i.e. as output/ha/yr. In effect we accept a violation of the monotonicity property. We gain, however, direct insights into the returns to scale of the farms with respect to the size of their land holding. This is of particular importance if small farms are involved in illegal or at least unwarranted deforestation activities.

3.8.1. Arable crop production

The gross income per year and hectare includes consumed and sold arable crop production. We did not include the production from "home gardens" because it is not in our research scope. Variable cost includes hired labor and cash input cost. Fixed costs include family labor and depreciation of (rudimentary) tools. Variable costs were subtracted from gross income to calculate gross margin. Next, fixed cost was subtracted from gross margin to calculate net profits of each household (See Table 6).

Table 6: Formulas used to calculate net-profit in arable crop production per year (n=130)

Variable	Formula
Empirical Gross Income	$\mathrm{GI_i} = (Amount\ Sold_i * \ Market\ Price_i) + (Amount\ Consumed_i * \ Market\ Price\ \ )$ i:number of household Market prices for consumed amount are the average prices of all households of sold production
Gross Margin	$GM\ _i = \ Predicted\ GI_i - \ Empirical\ Variable\ Cost_i$ i:number of household
Empirical Variable Cost	$VC_i = (Hired\ Labor_i * \ \ Wage_i) + (Input\ Cost_i * Market\ Price_i)$ i:number of household
Empirical Fixed Costs	$FC_i = (Family\ Labor_i * \ Average\ Wage\ \ ) + Depreciation\ of\ Rudimentary\ Tools_i$ i:number of household The Off-farm agricultural wage is used as average wage in fixed cost
Net Profit	$NP_i = \ GM_i$- FC_i i:number of household

3.8.2. Cattle production

The gross income per year includes dairy production (consumed and sold), sold and consumed animals, and life weight increment (see Herd section). He selected strategy to represent the inventory changes to the herd as well as income and costs from the commercial and subsistence use of the cattle will require further refinement in future analyses. The used cattle income model assumes that the herd grows in spite of deaths, sales and auto-consumption. The variable cost includes hired labor and cash input cost. The fixed costs include family labor and depreciation of (rudimentary) tools. Next, the variable cost was subtracted from gross income to calculate gross margins. Fixed costs were subtracted from gross margins to calculate the net-profit of each household. The formulas used are shown in Table 7.

Table 7: Formulas used to calculate the production in cattle

Variable	Formula
Empirical Gross Income	$GI_i = \left[\begin{pmatrix} Amount\_Sold\_and\_ \\ Consumed\_Dairy_i * \\ Market\_Price \end{pmatrix} + \begin{pmatrix} Amount\_Sold\_and \\ Consumed\_Animals_i \\ * Market\_Price \end{pmatrix} + \begin{pmatrix} Life\_Weight\_Increment_i * \\ Market\_Price \end{pmatrix}\right]$ i:number of household Dairy includes sold and consumed dairy products Market prices for consumed amount are the average prices of all households of sold production
Gross Margin	$GM_i = Predicted\ GI_i - Empirical\ Variable\ Cost_i$ i:number of household
Empirical Variable Cost	$VC_i = (Hired\ Labor_i * Wage_i) + (Input\ Cost_i * Market\ Price_i)$ i:number of household Input cost not include buying animals
Empirical Fixed Costs	$FC_i = (Family\ Labor_i * Average\ Wage) + Depreciation\ of\ Rudimentary\ Tools_i$ i:number of household The average Off-farm agricultural wage is used as average wage in fixed cost
Net Profit	$NP_i = GM_i - FC_i$ i:number of household

3.8.3. Econometric estimation of production functions

Several steps were necessary to assess the profitability of the arable crops and cattle production. First, we calculated the empirical gross income[3] from the sampled data (amount sold plus consumed valued at market prices). Subtracting variable costs, the empirical gross margin was calculated. Finally, net profit was expressed calculated as gross margin minus fixed costs (see sections above).

In order to extract summarized information on agricultural production at the single farming household level, we fitted a Cobb-Douglas production function to predict household gross income, gross margin, and net profit. These production functions are an important result to

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[3] Gross Income is the value of the production in monetary terms (Zeller & Schwarze 2006).

be exported to other sub-projects within our research group for the dynamic modelling of farmer decision making.

We also considered using a Translog production function. The problem of model selection (functional form) between Cobb Douglas and Translog was based on the following criteria:

- resulting equation gives significant explanatory variables,
- no problem with multicollinearity and heteroskedasticity,
- superior performance in "F" test of Cobb-Douglas (restricted model) versus Translog (unrestricted model, i.e. including the interaction and squared terms).

"F" test

- **Arable crop production: Cobb-Douglas versus Translog**

- Dependent variable: gross income
- Explanatory variables: Land, labor and input expenses

Ho: Interaction terms have no effect on output

$F_{\text{calculated}} = 3.23$

$F(6,42)_{\text{critical}} = 2.324$ at $\alpha = 0.05$

$F_{\text{calculated}} > F_{\text{critical}}$ = reject Ho

F is significant, we cannot reject Ho

- **Cattle production: Cobb-Douglas versus Translog**

- Dependent variable: gross income
- Explanatory variables: Land, labor, input expenses, altitude, ethnicity, technical assistance and credit.

Ho: Interaction terms have no effect on y

$F_{\text{calculated}} = 5.69$

$F(6,116)_{\text{critical}} = 2.1$ at $\alpha = 0.05$

$F_{\text{calculated}} > F_{\text{critical}}$:reject Ho.

F is significant; we cannot reject the Ho

In both cases, the Ho (interaction terms do not have an effect) could not be rejected. Still, the Cobb-Douglas functional form was selected. The Cobb-Douglas production function gives us more significant explanatory variables in arable crop and cattle production than Translog. Much importantly, the Translog production function had a problem with multicollinearity in arable crop production (Annex 3) and cattle production (Annex 4). With severe multicollinearity present, the relative importance of the predictors cannot be ascertained well. Thus we selected the less flexible but well-performing Cobb-Douglas production function. In addition to gross income, gross margin and net profit were tested as dependent variables with the Cobb-Douglas production function. Gross income was clearly the best predicted dependent variable and used for the following calculations (see in results Tables 24 and 27).

Land, labor, input expenses, altitude (minimum, maximum and average) of pasture land, ethnicity, technical assistance, access to formal credit, household-head age, education level of household-head, part of an organization, cost distance (minimum, mean and maximum) of farms to markets, and off-farm income were tested as explanatory variables. The regressions were run with STATA 9.0. Finally, multicollinearity and heteroskedasticity were evaluated for arable crops and cattle production functions.

Our study includes environmental production conditions, i.e. the site-specific variables altitude and locality in the production function. The topographic factor is represented by altitude. Locality is a dummy variable differentiating between farms close to the inter-provincial road from Loja to Zamora in Sabanilla village, and the more remote “upland” farms. In addition to other soil conditions and a somewhat lower altitude, the main difference of the Sabanilla farms is their much improved market access. Several of these farms directly deliver milk to Loja. In sum, it is assumed that the Sabanilla “lowland” farmers are more productive that the “upland” farmers.

Multicollinearity happens when two or more variables are correlated, *inter alia*, because of the inappropriate uses of dummy variables, variables computed by other variables or if two variables are dependent on a third variable. The consequences are: greater standard error and bigger confidence intervals, the “t” statistic values tend to be smaller, and it is harder to reject the null hypothesis when the multicollinearity is present. However, multicollinearity does not cause bias in the estimation of central tendencies (Wooldridge 2006). The Variance Inflation Factor (VIF) is used to test multicollinearity (Stata version 9 command VIF).

Heteroskedasticity means that the error term of the regression is not constant. The error increases when the value of the independent variables increase. Heteroskedasticity can be caused by the sampling strategy, by subpopulation differences, interaction effects or model misspecification. Heteroskedasticity does not causes biased parameter estimation but it does not provides the estimate with the smallest variance. Standard errors are biased (Wooldridge 2006). For detecting heteroskedasticity, the Breusch-Pragan/Cook-Weisberg test is available. The null hypothesis is "error variance is constant" (no heteroscasdicity) and the alternative hypothesis is "error variance is a multiplicative function of one or more variables" (Wooldridge 2006). The command "hettest" in Stata version 9 is used test for heteroskedasticity. If heteroskedasticity is detected, we use *robust standard errors* that address the problem of biased standard errors (Kohler & Kreuter 2005, Wooldridge 2006).

Based on the predicted gross income, gross margins were calculated by subtracting variable costs. Finally, net profits were obtained by subtracting fixed costs including household labor from gross margins (Zeller & Schwarze 2006). The formulas are described below in detail for arable crop and cattle production.

4. Results

4.1. Descriptive analysis of factors that influence land use decisions

4.1.1. Personal capital

Households of the sample consist of 85% Mestizos and 15% Saraguros (see Table 8). The average number of household members is the 4.1, 53 % are male and 47% female. The self-reported illiteracy rate in the region is 12.5%, and 7.7% for the household head (see Table 9). 36.5% of all individuals and 46.9% of household heads completed at least the primary school. 3.7 % of all household members and 3.1% of the household head completed secondary school.

Table 8: Household composition

Statistics	Number Members			Age (Year)		
	Male	Female	Household	Male	Female	Household
Mean	2.2	1.9	4.1	30.2	28.6	29.5
Median	2.0	2.0	4.0	27.0	24.0	25.0
Standard deviation	1.5	1.5	2.4	21.3	20.8	21.0
Minimum	0	0	1	1	1	1
Maximum	7	6	10	80	88	88
Observations	285	252	537	285	252	537

Table 9: Education level

Education level	Total household		Head household	
	Frequency	Percent	Frequency	Percent
Without education	67	12.5	10	7.7
Partial primary school	164	30.5	38	29.2
Completed primary school	196	36.5	61	46.9
Partial secondary school	63	11.7	9	6.9
Completed secondary school	20	3.7	4	3.1
Partial university	16	3.0	3	2.3
Completed university	11	2.0	5	3.8
Total	537	100.0	130	100.0

4.1.2. Financial capital

While 6 households received a loan for less than one year, 43 households received a loan with a duration of more than one year. The the average amount of the short term credit is 1425 USD at 4.8% annual interest rate (see Table 10). Longer credits have a mean amount of 4012 USD at 7.3 % annual interest rate and a mean duration of 3.4 years.

Table 10: Credit characteristics

Statistics	Less One Year			More one Year		
	Amount (USD)	Interest Rate (%)	Duration (Months)	Amount (USD)	Interest Rate (%)	Term (Months)
Observation	8	8	8	43	43	43
Mean	1425	4.8	7.5	4012	7.3	41.3
Median	1500	5.0	7.5	4800	5.0	36.0
standard deviation	989	3.3	4.3	1770	3.4	15.9
Minimum	100	2.0	1.0	1000	4.0	12.0
Maximum	3000	12.0	12.0	10000	18.0	60.0

The main source of credit in the “less one year” category is the Cooperative of Saving and Credit. In the “more one year” term, it is the governmental bank “Banco Nacional de Fomento” (see Table 11). There is an informal credit market that we were unable to record as informal credit it is considered illegal in Ecuador. Informal credit usually has very high interest rates and can be obtained without collateral or conformance with to official financial solvency standards.

Table 11: Credit source

Source	Less One Year	
	Frequency	Percent
No request credit	122	93.8
Saving association, communal bank	2	1.5
Cooperative of saving and credit	4	3.1
Lender	2	1.5
Total	130	100.0
Source	More One Year	
No request credit	87	66.9
Cooperative of saving and credit	7	5.4
Lender	1	0.8
Merchant	1	0.8
Banco Nacional de Fomento	34	26.2
Total	130	100.0

With the funds obtained, farmers mainly buy animals. Many farmers did not take out formal credit. Farmers mentioned the following reasons: high interest rates (25%), no need for credit (23%), fear to lose property (17%), and lack of a formal land title (15%).

4.1.3. Social capital

Results show that 56% of the households did not take part in any organization. 40% take part in farmer organizations (see Table 12). 9.6% of the farmers are a member of the agricultural & livestock association *Trabajadores Autónomos La Dolorosa and Jesús del Gran Poder*, 6.6% are a member of the ecological association *Amigos de la Naturaleza*, 5.9% of the neighbourhood committee *Comité pro-mejoras del Barrio*, 5.1% of the saving association *Nina Pacari*, 4.4% of the livestock association *Organización Campesino Quichua y Los Hermanos*, and 3.7% of a woman association *Las Orquideas*.

Finally, the members of sampled households are somewhat active in the decision making process in their organizations. They spent is 6.5 times per year in average in meeting attendance in farmer organization. Finally, the respondents were asked how much labor they spent on the organization (8.2 Day/yr on average), and how much money they contributed, (10.2 USD/yr on average) in farmer organization.

Table 12: Meeting attendance, decision making, labor contribution, and money contribution

Organization	Statistic	Meeting attendance (number/yr)		Decision making*	Labor contribution (Day/Yr)	Money contribution (USD/Yr)
		Frequency	Percent			
No organization	Number of observations	76	56	-----	-----	-----
Farmer organization	Number of observations	54	40	-----	-----	-----
	Average	6.5	-----	2.0	8.2	10.2
Other organization	Number of observations	6	4	-----	-----	-----
	Average	5.5	-----	2.7	10.2	38.0

*1=not very active, 2=somewhat active, 3=very active

4.1.4. Operational capital

a) *Land use*

Of the 175 farms[4] owned by the analyzed 130 households, 75% (132 farms) have legal land titles. Moreover, it is reported that 76% of the farms were bought, 17% obtained by heritage, 4% obtained by donation and only 1.1% obtained by forest cleaning. Furthermore, respondents were asked: What is the value to rent one hectare of your farm? The mean value was 67 USD/month (median: 40 USD/month). Higher values are reported from the Sabanilla region where farms are designated mainly to market milk production.

Farmers had 40.4 ha land on average (median 23.4 ha, standard deviation 44.9 ha). The minimum area reported was 1.7 ha, and the maximum 260.6 ha. 28% of households had less than 10 ha and only 12% more that 80 ha (Figure 4). The land use distribution shows that 54.0% (2820 ha) were forest land, and 45.3% (2398 ha) were pastures. Arable crops only represented 0.6% of the area (see Figure 5).

The arable crop production is dominated by a traditional mix of *Zea mays* and *Phaseolus vulgaris* (56.5% in area terms), which is used for subsistence purposes (see Table 13). Home gardens (10.9%) are a source of medicinal and food plants. Other important agricultural crops are *Zea mays* (9.1%), *Musa* spp. (8.6%) and *Saccharum officinarum* (8.5%).

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[4] Some households have more one farm. In some cases, the land tenure regime differs.

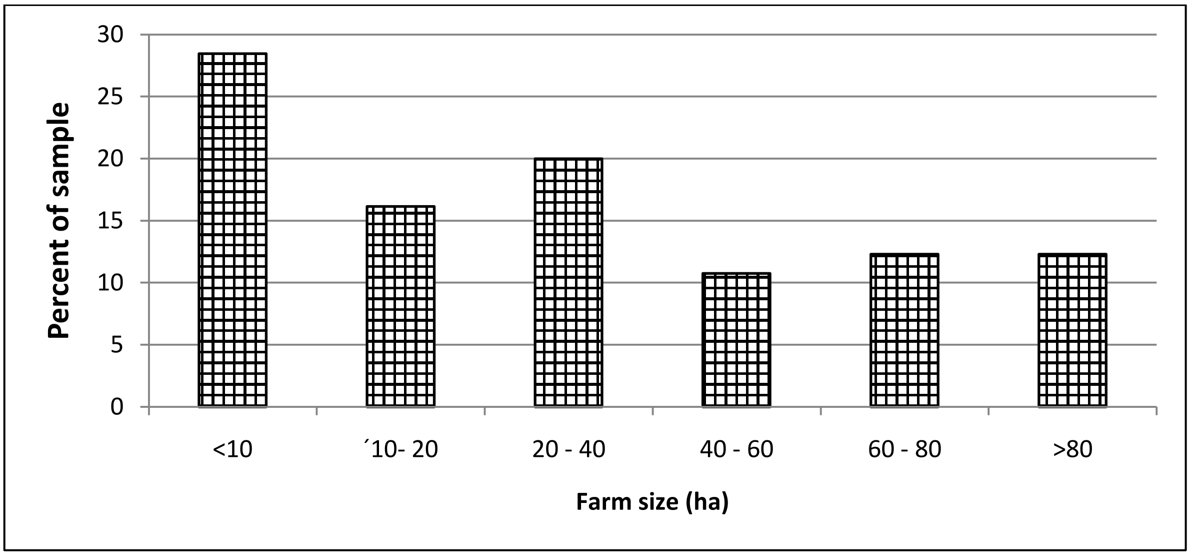

Figure 4: Farm size per household

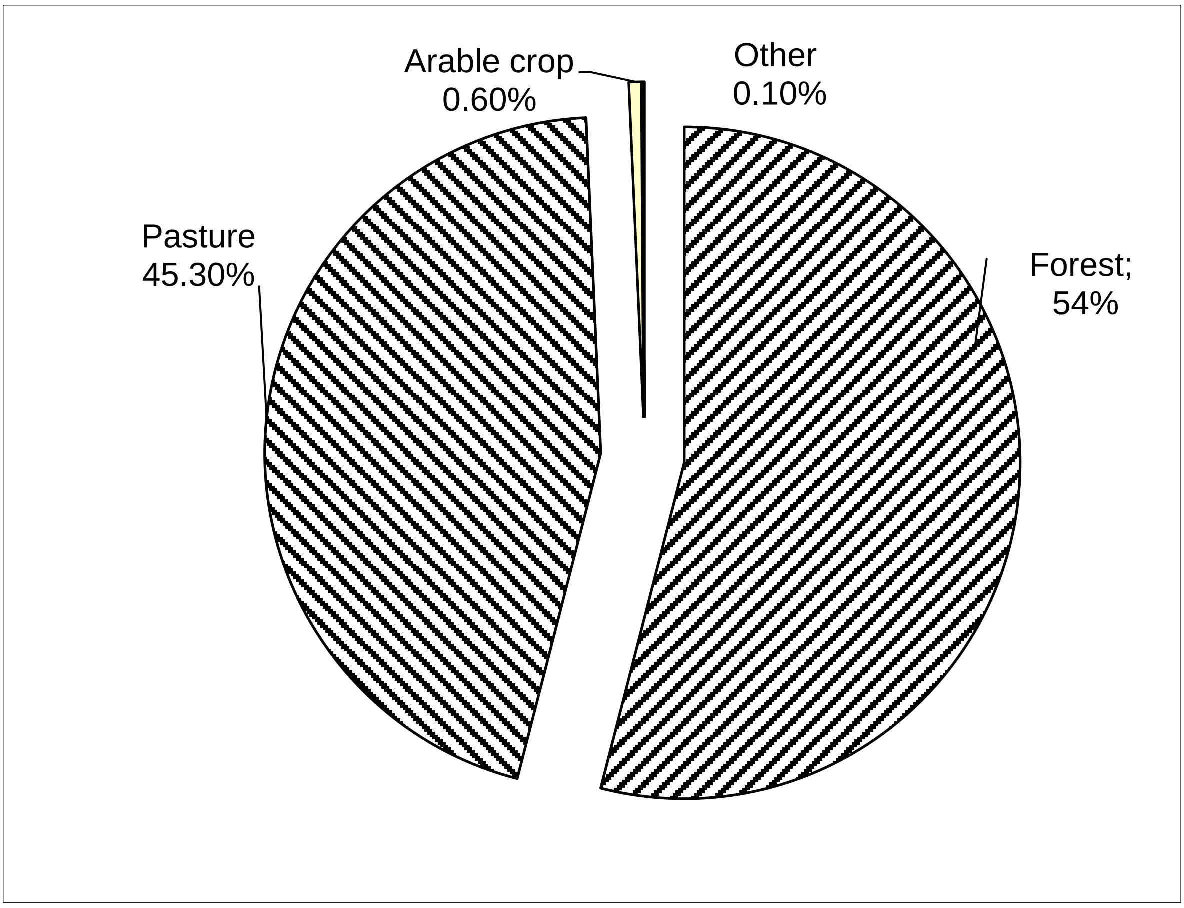

Figure 5: Land use distribution

Most forest is native forest (97.8%, 2757 ha). Furthermore, there are plantations of *Eucalyptus globulus* (0.2%) and *Pinnus patula* (0.2%).

Table 13: Land use distribution by category

Land use	Area (ha)	Percent
Arable crop		
Association *Zea mays* & *Phaseolus vulgaris*	17.33	56.5
Home garden	3.35	10.9
Zea mays	2.78	9.1
Musa sp.	2.63	8.6
Saccharum officinarum	2.60	8.5
Prunus sp.	0.90	2.9
Other crops	1.10	3.6
Total area arable crop	30.69	100.0
Forest		
Native Forest	2757.20	97.8
Natural regeneration	53.82	1.9
Forest plantation *Eucalyptus globules*	4.73	0.2
Forest plantation *Pinnus patula*	4.70	0.2
Total Area Forest	2820.45	100.0
Pasture		
Setaria sphacelata	1275.90	53.2
Sporobulus indicus	481.36	20.1
Pasture associated with trees	296.28	12.4
Degraded pasture dominated by *Pteridium aquilinum*	102.86	4.3
Melinis minutiflora	95.29	4.0
Holcus lanatus, Pennisetum clandestinum, Calamagrostis sp., *Tripsacum laxum,* other pastures	146.67	6.1
Total Area Pasture	2398.36	100.0
Other kinds of land use	7.54	100.0

Most pasture is planted by the two grass species *Setaria sphacelata* “Mequerón” (53.2%) and *Sporobulus indicus* “Morocha” (20.1%). “Mequerón” is preferred by 49% and “Morocha” by 25% of farmers. “Mequerón” is preferred by farmers as it controls fern infestation of the pasture. “Morocha” is preferred because it is preferred by cattle.

One important pasture category is “pasture associated with trees” (12.4%), i.e. a silvo-pastoral system.

b) Herd

Regression equation 5.1 was chosen to predict life weight (see Table 14). Most of the variables (10 variables) are significant at $\alpha = 0.05$, and the model explains (R2=0.57) 57% of life weight. The animal stocking rate in the study area is 0.37 AU per ha in average. This value is below the average of 1.4 AU per ha reported for the cattle dual-purpose (milk and meat) production system in Tropical America (Pearson de Vaccaro, 1986).

Table 14: Regression used to predict life weight

Dependent variable				**Unit**
Life weight animal				Kg
Explanatory variables				
Interaction between Race, Age and Sex	Race: Holstein, Criolla and Mixed Age: <1 year, between 2 and 3 years, >3 years Sex: Male and Female			Dummy
Factor	Estimate	Std. Error	t value	P>|t|
Intercept	149.5952	5.653427	26.46	0.000
Holstein1male	-81.41183	23.07943	- 3.53	0.001
Holstein1female	-104.1452	27.98231	- 3.72	0.000
Holstein2male	20.85483	27.98231	0.75	0.458
Holstein2female	43.58817	23.07943	1.89	0.062
Holstein3male	103.2448	20.18627	5.11	0.000
Holstein3female	73.88817	23.07943	3.20	0.002
Criolla1male	-92.78516	39.16705	-2.37	0.020
Criolla1female	-104.1452	39.16705	-2.66	0.009
Criolla2male	-19.87231	15.7018	-1.27	0.209
Criolla2female	3.812335	14.82307	0.26	0.798
Criolla3male	44.10234	10.34727	4.26	0.000
Criolla3female	32.1266	10.96904	2.93	0.004
Mixed1male	-47.32516	23.07943	-2.05	0.043
Mixed1female		Dropped*		
Mixed2male	5.704836	16.8021	0.34	0.735
Mixed2female	-1.870163	16.8021	-0.11	0.912
Mixed3male	75.40261	10.74295	7.02	0.000
Mixed3female		Base Group		
SS Model = 230279.214 (df: 16)	Number of observ. = 117		R^2 = 0.5750	
SS Residual= 170237.643 (df: 100)	F(16, 100) = 8.45		Adj R^2 = 0.5069	
SS Total= 400516.857 (df: 116)	Prob > F = 0.0000		Root MSE = 41.26	

*The variable term is dropped because there is not data.

Table 15: Stocking rate

	TLU*	AU**	TLU/ha	AU/ha
Observation	130	130	130	130
Mean	9.06	5.66	0.60	0.37
Median	5.54	3.46	0.51	0.32
Standard deviation	9.19	5.74	0.37	0.23
Minimum	0.60	0.37	0.06	0.04
Maximum	50.26	31.41	1.68	1.05

Percentile	25	2.63	1.64	0.33	0.20
	50	5.54	3.46	0.51	0.32
	75	11.95	7.47	0.81	0.51

*Tropical Livestock Unit (TLU): 1TLU = 250 kg life weight
**Animal Unit (AU): 1AU = 400 kg life weight

Additional to the stocking rate, herd structure (number of animals) per race, age and sex is calculated. The predominant race is “Criolla” 47% (Figure 6). The race “Holstein”, with the least percentage 17.5%, is predominant in the “Sabanilla”.

The average production of milk our sample is about 3.7 liter per cow-day. The predominant age group is the category “more 3 years” with 36%. 61% of the cattle are female.

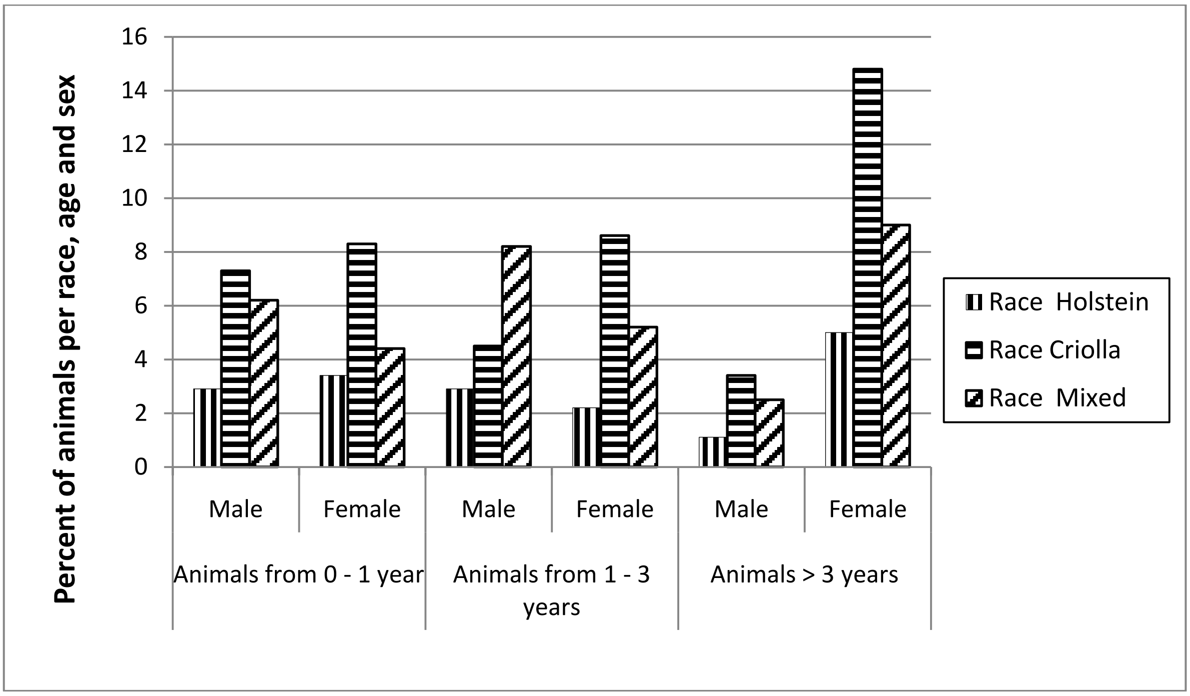

Figure 6: Herd structure per race, age and sex

4.1.5. Production

a) Arable crop production

Family labor input in arable crop production is higher (72.1 person-days/ha) than hired input labor (8.4 person-days/ha). The average cash input is 178 USD/ha (see Table 16).

Table 16: Labor and expenses per hectare of arable crop production

Statistic		Family Labor (person-days/ha)	Hired Labor (person-days/ha)	Total Labor (person-days/ha)	Cash input Expenses (USD/ha)	Hired labor wage (USD/day)
Number of observations		52	52	52	52	43
Average		72.10	8.41	80.52	177.96	8.46
Deviation standard		55.57	13.63	63.04	190.36	0.96
Percentile	25	38.46	.00	44.52	44.25	8
	50	64.03	3.71	71.38	111.20	8
	75	89.31	11.39	100.52	241.85	8

b) Cattle production

The family labor investment on cattle production in average is higher (2.3 person-days/ha) than hired labor (1.69 person-days/ha). The average cash input is 12.18 USD/ha (see Table 17).

Tale 17: Labor and expenses per hectare of cattle

Statistic		Labor Management Pasture (person-days /ha)	Family Labor (person-days /ha)	Hired Labor (person-days /ha)	Total Labor (person-days /ha)	Cash Input Expenses (USD/ha)	Hired labor wage (USD/day)
Number of observations		130	130	130	130	130	29
Mean		6.87	17.76	1.92	19.68	12.18	6.24
Deviation Standar		8.37	19.11	6.10	20.93	18.13	1.97
Percentile	25	2.04	5.84	.00	6.78	2.46	5
	50	3.98	10.19	.00	12.49	5.81	7
	75	8.99	21.57	.00	24.16	13.67	7

c) Off-Farm Income

In the sample, 88% of the households have off-farm income. Mean and median off-farm income per household are 227 and 122 USD/month respectively (Table 18). Average off-farm income per member of the household is 55 USD/person/month. The average off-farm agricultural wage is 4.75 USD/day.

Table 18: Household *Off*-Farm income

Statistic		*Off*-farm income (USD/month)	Agriculture *Off*-farm wage (USD/day)
Number of observations		130	38
Mean		227.4	4.75
Standard deviation		288.8	1.24
Percentile	25	30	4
	50	122	4.8
	75	340	4.8

The most frequent source of off-farm income is the national social security payment ("Bono Desarrollo Humano") with 35% (see Figure 7). Substantial off-farm income comes from off farm work (17%), and from operating small merchant businesses (11%).

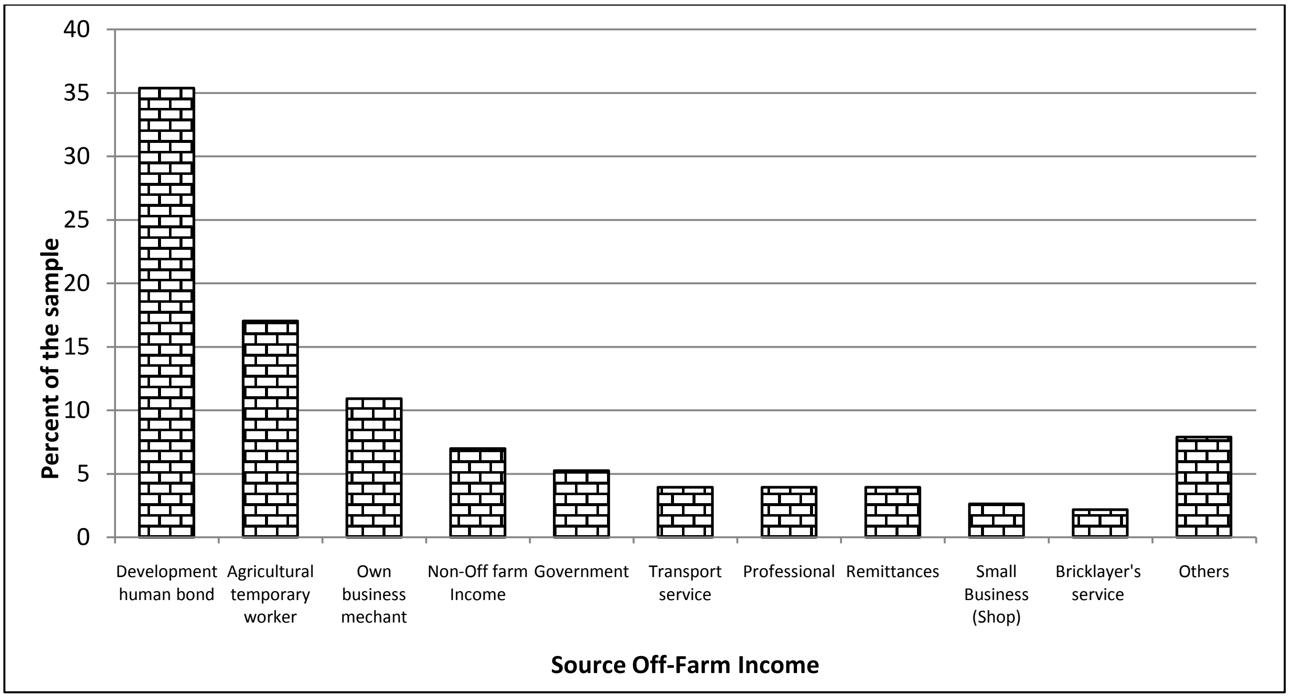

Figure 7: Source of household *Off*-Farm income

4.1.6. Technology adoption

This section is about three topics related to technology adoption. The first is related to introduction of tree species. Second, farmers were asked about the introduction of improved pasture on their farms. Third, respondents were asked about potential technology adoption of *Caesalpinea spinosa* (Tara/Guarango).

a) *Introduction of tree species*

32% farmers (41 farmers) had introduced forest tree species in the last year. The most frequently adopted species were *Pinus patula* (26%), *Alnus acuminata* (16%), *Eucalyptus globulus* (15%) *Cuppressus macrocarpa* (13%). These species are for wood use (See Table 19).

Table 19: Introduction tree species

Specie	Famer sown trees		Origen	Use
	Frequency	Percent		
Pinus patula	20	26.3	Exotic	Wood species
Alnus acuminate	12	15.8	Native	Wood species
Eucalyptus globules	11	14.5	Exotic	Wood species
Cuppressus macrocarpa	10	13.2	Exotic	Wood species
Juglans neotropica	6	7.9	Native	Wood species
Prunus persica	3	3.9	Exotic	Fruit species
Erythrina edulis	2	2.6	Native	Fruit species
Tabebuia chrysantha	2	2.6	Native	Wood species
Inga spp.	1	1.3	Native	Fruit species
Nectandra laurel	1	1.3	Native	Wood species
Ficus spp.	1	1.3	Native	------------
Persea Americana	1	1.3	Native	Fruit species
Grias peruviana	1	1.3	Native	Fruit species
Brugmansia candida	1	1.3	Exotic	---------------
Malus domestica	1	1.3	Exotic	Fruit species
Prunus serotina	1	1.3	Exotic	Fruit species
Citrus sinensis	1	1.3	Exotic	Fruit species
Syzygium jambos	1	1.3	Exotic	Fruit species
Observations	76	100.0		

Trees were most often planted as life fences 67% (Table 20). Life fences delimit properties, need little repair, and do not reduce pasture size. On average, farmers introduced 128 trees. 83% of farmers who planted trees did so their by own initiative, and only 17% by a technician’s advice. 61% of the farmers expect to obtain wood, 10% to improve cattle husbandry, and 10% to obtain fuel wood. 88% of respondents are satisfied with their trees.

Table 20: Place where the trees were planted

Forest specie	Sowing place in the pastures (spread trees)	Life fences	In the mountain	Near to the river	Homogeneous Forest plantation	Replace trees died	Total
Pinus patula	2	15	3	0	0	0	20
Alnus acuminate	2	10	0	0	0	0	12
Eucalyptus globules	0	9	1	0	1	0	11
Cuppressus macrocarpa	2	7	1	0	0	0	10
Juglans neotropica	2	2	0	1	0	1	6
Prunus persica	1	0	0	0	2	0	3
Erythrina edulis	0	2	0	0	0	0	2
Tabebuia chrysantha	0	2	0	0	0	0	2
Inga spp.	1	0	0	0	0	0	1
Nectandra laurel	0	1	0	0	0	0	1
Ficus spp.	0	1	0	0	0	0	1
Brugmansia candida	0	1	0	0	0	0	1
Malus domestica	0	0	0	0	1	0	1
Persea Americana	1	0	0	0	0	0	1
Prunus serotina	0	1	0	0	0	0	1
Citrus sinensis	1	0	0	0	0	0	1
Grias peruviana	1	0	0	0	0	0	1
Syzygium jambos	1	0	0	0	0	0	1
Observation	14	51	5	1	4	1	76

Farmers would like to plant 144 trees per farmer in the near future on average. The species preferred to plant are: *Pinus patula* 31%, *Alnus acuminata* 19%, *Eucalyptus globulus* 11%, *Prunus persica* 7.1%, *Cuppressus macrocarpa* 7.1%, *Juglans neotropica* 5.7%, *Persea americana* 4.3%.

b) Improved pasture

Setaria sphacelata “Mequerón” (49%) and *Sporobulus indicus* “Morocha” (25%) were reported as most important species of pastures grasses planted. The other two important species mentioned were *Pennisetum clandestinum* (12%), *Melinus minutiflora* (6%). 98% of the farmers are satisfied with their pasture grasses planted. Farmers are satisfied for two main reasons: browsing preference by cattle 55% and fern control 36% (Table 21).

Table 21: Reasons of satisfaction with the pasture adopted

Pasture species	Reasons for satisfaction					Total
	No opinion	Fern control	Preference by cattle	Fast growth	Fodder to small domestic animals	
Setaria sphacelata	0	76	27	10	0	113
Sporobulus indicus	1	5	49	3	0	58
Pennisetum clandestinum	1	1	22	5	0	29
Melinus minutiflora	0	0	14	1	0	15
Holcus lanatus	0	1	9	0	0	10
Chloris gayana	1	0	2	0	0	3
Paspalum candidum	0	0	2	0	0	2
Urochloa brizantha	0	0	1	0	0	1
Tripsacum laxum	0	0	0	0	1	1
Introduced Pasture: Tanzania	0	0	1	0	0	1
Total	3	83	127	19	1	233

c) *Potential technology adoption*

24% of the farmers liked the idea to plant Tara, 76% did not like it. The first reason given by farmers to reject Tara was that the land was destined for pastures. Cattle was considered more profitable (28%). 15% of farmers mentioned that they did have not enough money to establish the plantation, 13% mentioned that not enough labor was available, 11% considered it insecure to plant this tree.

If farmers liked the idea of planting Tara, the contract type “The institution gives you the plants and buys your production at a fixed price” has most approval (43%). The next best contract is “You buy the plants and you sell the production on the market” (32%). “The institution gives you the plants and you sell the production on the market” is preferred by 14%. “Farmer buys the plant and sell the production to one institution or merchant” is preferred by 11%.

4.1.7. Technical assistance

Only 22% of the farmers received technical assistance. Of these, most received assistance from their farmer organization, and less than one third from a governmental organization. In 93% of the cases, assistance was initiated by the farmer organization or governmental institution. The assistance was without cost for farmers. 54% of the farmers who received assistance have been started to work with some farmer organization or governmental institution since 3 years and 18% since 2 years ago. In 93% of the cases, assistance was given to head of the household.

Technical assistance was related to cattle production (36%), reforestation (18%), raising small domestic animals (18%), farm administration (14%), vegetable production (11%), and rights of the Saraguros (4%). Of the farmers receiving assistance, 23% of the farmers did not introduce any change, 13% introduced conservation practices, 13% changed management farm, 11% introduced sanitary management of cattle, 9% fight against parasites, 7% planting techniques and 5% new crops.

Furthermore, 93% of respondents were satisfied with the technical assistance. However, 23% of farmers said they did not obtain expected results, 18% improved the prices of their products, 13% reduced production cost, 13% achieved higher yield security, and 11% improved of soil fertility. Near all farmers would like to receive future technical assistance. The main topics they were interested in were cattle reproduction management 33%, pasture management 23% and new crops 12%.

4.2. Causal analysis

4.2.1. Arable crop production function

The descriptive statistics of dependent and explanatory variables of arable crop production is presented in Table 22. Full explanatory variables tested are show in Annex 1. Data from 52 households were used to predict gross income with one extreme data point eliminated for the calculation of gross margins and net profits.

Table 22: Descriptive statistics of dependent and explanatory variables of arable crop production (n=52).

Variable	Mean	Std. Dev.	Min	Max
Gross income (USD/ha/yr)	521.14	478.62	51.70	2465.01
Arable crop area (ha)	0.51	0.64	0.03	4.00
Total labor input (man-days/yr)	28.60	27.85	2.50	116.00
Input expenses (USD/yr)	59.32	59.30	1.37	270.51

The explanatory variables of gross income - arable crop area, labour and input expenses - are significant at $\alpha = 0.05$ (see Table 23). Land has a negative effect on gross income per hectarea. This means that small areas of arable crop are used more intensively. Labour and input expenses have a positive impact.

The coefficient of determination (R^2) between original and predicted gross income is 0.6 (see Figure 8). The Variation Inflation Factors VIF is 3.21, i.e. is below the VIF value 10. Heteroskedasticity was not detected with the Breusch-Pagan/Cook-Weisberg test for linear heteroskedasticity does not reject the null hypothesis (Ho: Constant variance) with prob > chi^2 = 0.8632.

Table 23: Arable crop production function

Dependent variable	**Variable label**
lnGrossIncome	Natural logarithm of gross income (USD/ha/year)
Explanatory variable	
lnLand	Natural logarithm arable crop area (hectare)
lnLabor	Natural logarithm labor (person_day)
lnInputExpenses	Natural logarithm of input cost + depreciation of rudimentary tools + hired labor (USD/year)

Factor	Estimate	Std. Error	t value	P>|t|
Intercept	1.635742	0.601552	2.72	0.009
lnLand	-0.6637674	0.1374833	- 4.83	0.000
lnLabor	0.3771867	0.1548355	2.44	0.019
lnInputExpenses	0.6711692	0.0733388	9.15	0.000

SS Model: 32.9713942 (df: 3)	Number of observ. = 52	R^2 = 0.7058
SS Residual: 13.7421615 (df: 48)	F(3, 48) = 38.39	Adj R^2 = 0.6874
SS Total: 46.7135557 (df: 51)	Prob > F = 0.0000	Root MSE = 0.53507

Multicollinearity Test
Mean Variation Inflation Factors VIF independent variables: 3.21
Rule: VIF greater 10 are generally seem as indicate of severe multicollinearity

Breusch-Pagan / Cook-Weisberg test for linear heteroskedasticity
Ho: Constant variance
chi^2(1) = 0.03
Prob > chi^2 = 0.8632 Result: No reject Ho: Constant variance

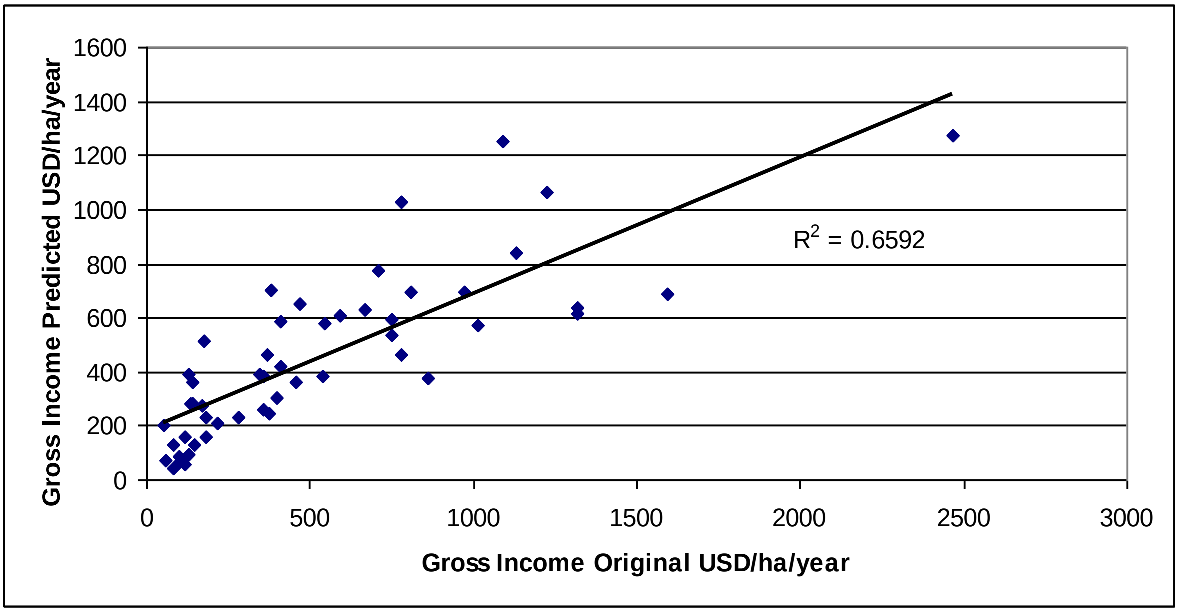

Figure 8: Gross Income Original vs. Predicted

Average gross income is 448 USD/ha/yr, average gross margin 280 USD/ha/year, and average net profit is -43 USD/ha/year (see Table 24).

Table 24: Gross income, gross margin and net profit of arable crop

Statistic		USD/ha/year		
		Gross Income	Gross Margin	Net Profit
Observation		52	51	51
Average		448.33	280.10	-43.16
Standard deviation		296.08	222.13	221.64
Minimum		46.82	-104.79	-550.90
Maximum		1272.25	991.08	510.20
Percentile	25	229.79	134.91	-165.87
	50	388.55	232.83	-55.50
	75	622.54	370.43	96.78

4.2.2. Cattle production function

The descriptive statistics of dependent and explanatory variables of cattle production are presented in Table 25. A list of explanatory variables tested is presented in Annex 2. With the Variation Inflation Factor VIF = 1.36. VIF values auf 10 and above are generally seem as an indication of severe multicollinearity. There is evidence of heteroskedasticity: The test Breusch-Pagan/Cook-Weisberg test for linear heteroskedasticity rejects the null hypothesis

(Ho: Constant variance) with prob > chi^2 = 0.0001. As a consequence, we use robust standard errors to assess the significance of regression coefficients.

Table 25: Descriptive statistics of dependent and explanatory variables of cattle production (n=30)

Variable	Mean	Std. Dev.	Min	Max
Gross Income (USD/ha/yr)	289.21	197.11	0.10	1149.24
Total Labor (person-days/year)	159.46	96.84	19.40	647.50
Pasture Area (ha)	18.34	17.06	0.81	82.81
Mean Altitude of Pasture (m a.s.l.)	1996	263	1261	2668
Input Expenses (USD/yr)	341.95	607.94	2.50	4178.10
Ethnicity (1="mestizo", 0="saraguro")	0.85	0.36	0	1
Technical Asisstence (Dummy)	0.22	0.41	0	1
Access to Credit (Dummy)	0.39	0.49	0	1

The regression of a linearized Cobb Douglas cattle production function shows a casual relationship between gross income and the explanatory variables pasture area, labor, input expenses, and minimum altitude at $P <= 0.05$, and for technical assistance with $P = 0.086$ (see Table 26). The coefficient of determination between original gross income and predicted gross margin is R^2: 0.49 (see Figure 9).

Land has a negative coefficient on arable crop income per hectare. I.e. with each additional hectare of pasture, gross income per ha is reduced. The investment of labor in cattle production system has a positive impact on gross income/ha. For each additional person-day there is an increment in gross income/ha.

The variable altitude has a negative impact on gross income. It means that farmers located at the lower altitudes are more productive in comparison to farmers located at higher altitudes. The simultaneously tested locality variable was less significant. It was decided not included both variables simultaneous to avoid multicollinearity.

The variable ethnicity shows a positive impact on gross income. With the mestizo farms (dummy coding: 1) displaying a higher gross income. Also, technical assistance has a positive impact as well as formal credit.

Table 26: Cattle production function

Dependent variable (y)	Variable label	Unit
Logarithm GrossIncome	Natural logarithm of gross income	USD/ha/year
Explanatory variable (x)		
Logarithm Land	Natural logarithm pasture area	Hectare
Logarithm Labor	Natural logarithm family labor	Person_day
Logarithm InputExpenses	Natural logarithm of (input cost + depreciation of rudimentary tools + hired labor)	USD
Minimum altitude	Minimum altitude of the pasture area	m a.s.l
Ethnicity	Ethnicity of the household. Mestizo=1, Saraguro=0	Dummy
Technical assistance	Receive technical assistance. Yes = 1, NO = 0	Dummy
Credit	Access to formal credit. Yes = 1, NO = 0	Dummy

Factor	Estimate	Std. Error	t value	P>|t|
Intercept	2.88193	0.7783147	3.70	0.000
lnLand	-0.6727434	0.090531	-7.43	0.000
lnLabor	0.9027063	0.1307558	6.90	0.000
lnInput Expenses	0.2179001	0.0522234	4.17	0.000
Minimum altitude	-0.001009	0.0002962	-3.41	0.001
Ethnicity	0.4525599	0.1954111	2.32	0.022
Technical assistance	0.3395173	0.1736333	1.96	0.053
Credit	0.2451793	0.1418492	1.73	0.086

SS Model: 58.3223284	(df: 7)	Numb. of observ.= 130	R^2 = 0.4496
SS Residual: 71.384202	(df: 122)	F(7, 122) =14.24	Adj R^2 = 0.4181
SS Total: 129.70653	(df: 129)	Prob > F = 0.0000	Root MSE = 0.76493

Multicollinearity Test

Mean Variation Inflation Factors VIF independent variables: 1.36

Rule: VIF greater 10 are generally seem as indicate of severe multicollinearity

Breusch-Pagan / Cook-Weisberg test for linear heteroskedasticity

Ho: Constant variance $chi^2(1)$= 125.95

Prob > chi^2 = 0.0001 Result: reject Ho: Constant variance

Dealing Heteroskedasticity

Factor	Robust Estimate	Robust Std. Error	t value	P>|t|
Intercept	2.88193	1.04179	2.77	0.007
lnLand	-0.6727434	0.0587007	-11.46	0.000
lnLabor	0.9027063	0.276375	3.27	0.001
lnInput Expenses	0.2179001	0.0363353	6.00	0.000
Minimum altitude	-0.001009	0.0003826	-2.64	0.009
Ethnicity	0.4525599	0.3119859	1.45	0.149
Technical assistance	0.3395173	0.1958981	1.73	0.086
Credit	0.2451793	.1602379	1.53	0.129

Number of obs = 130	R^2 = 0.4496
F(7, 122) = 24.16 Prob > F=0.000	Root MSE = 0.76493

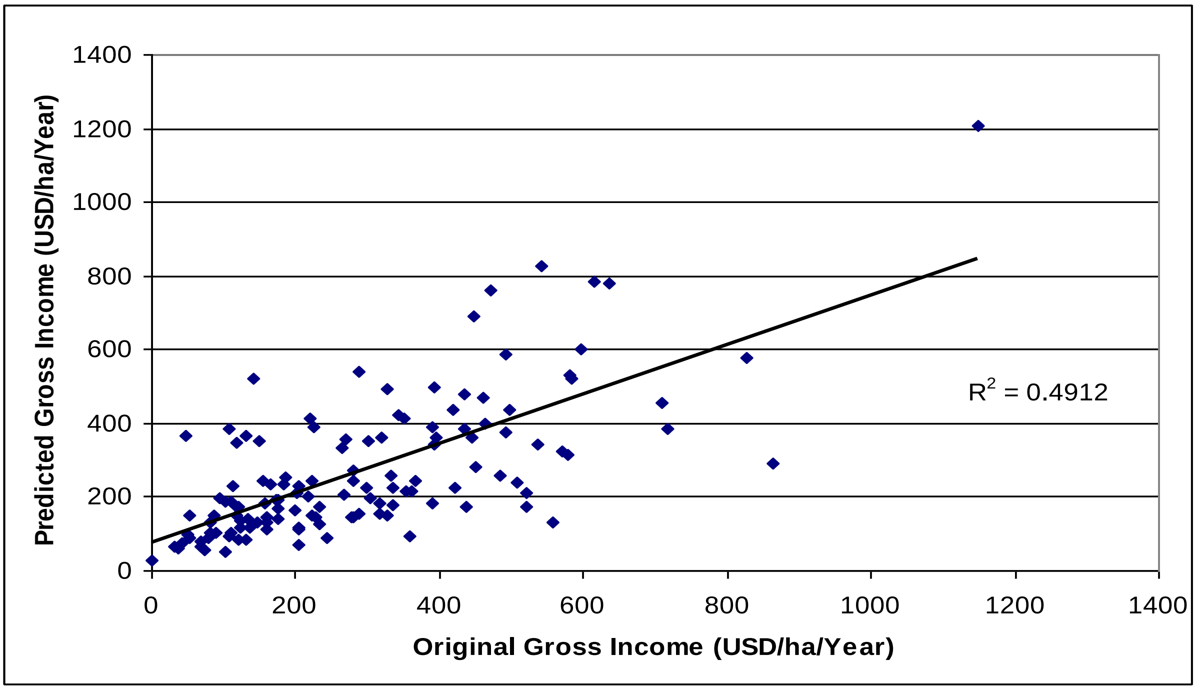

Figure 9: Emprical vs. gross income from cattle production incl. diary predicted by a Cobb Douglas production function (n=130).

The predicted gross income of each single household was used to calculate the gross margins and net profits (Table 27). The average gross income is 268 USD/ha/year, gross margin 244 USD/ha/year, and net profit 159 USD/ha/year. Our results show that pasture-based cattle production is more profitable than arable agriculture.

Table 27: Gross income, gross margin and net profit of cattle production

Statistic		USD/ha/year		
		Gross Income	Gross Margin	Net Profit
Observation		130	130	130
Average		268.06	244.54	158.96
Standard deviation		188.28	161.71	119.70
Minimum		26.97	24.19	-79.08
Maximum		1205.39	865.44	579.32
Percentile	25	143.10	129.99	70.55
	50	210.70	193.81	123.70
	75	361.69	336.80	227.99

4.3. Total Income

In this section, we analyse the contribution of arable crop, cattle and off-farm income to the total income of the households. On average, 333 USD/yr is derived from arable crop production, 4687 USD/yr from cattle production, and 1608 USD/yr from off-farm income.

Cattle production accounts of 70.4%, off-farm for 25.7%, and arable agricultural for 3.9% of total household income (See Table 28). Moreover, cattle production accounts for the largest share of total household income for all quintiles of the income distribution (see Figure 10).

Table 28: Contribution of the arable-crop, cattle, off-farm to the total income income per farm and year (n=130)

Statistic		Total	Arable crop Income		Cattle Income		Off-farm Income	
		USD/Year	USD/Year	Percent	USD/Year	Percent	USD/Year	Percent
Average		6429.95	333.70	3.92	4687.86	70.38	1608.61	25.70
Standard deviation		6788.09	566.62	11.42	5527.08	27.55	3114.39	26.07
Minimum		378.18	9.09	0	0	0	0	0
Maximum		44716.59	2319.33	73.56	29578.62	100	19800	95.19
Percentile	25	2181.17	28.64	0	1211.40	50.59	360	5.01
	50	4288.15	81.82	0	2686.29	79.16	360	16.57
	75	7421.10	310.52	1.86	6157.17	94.54	1500	40.25

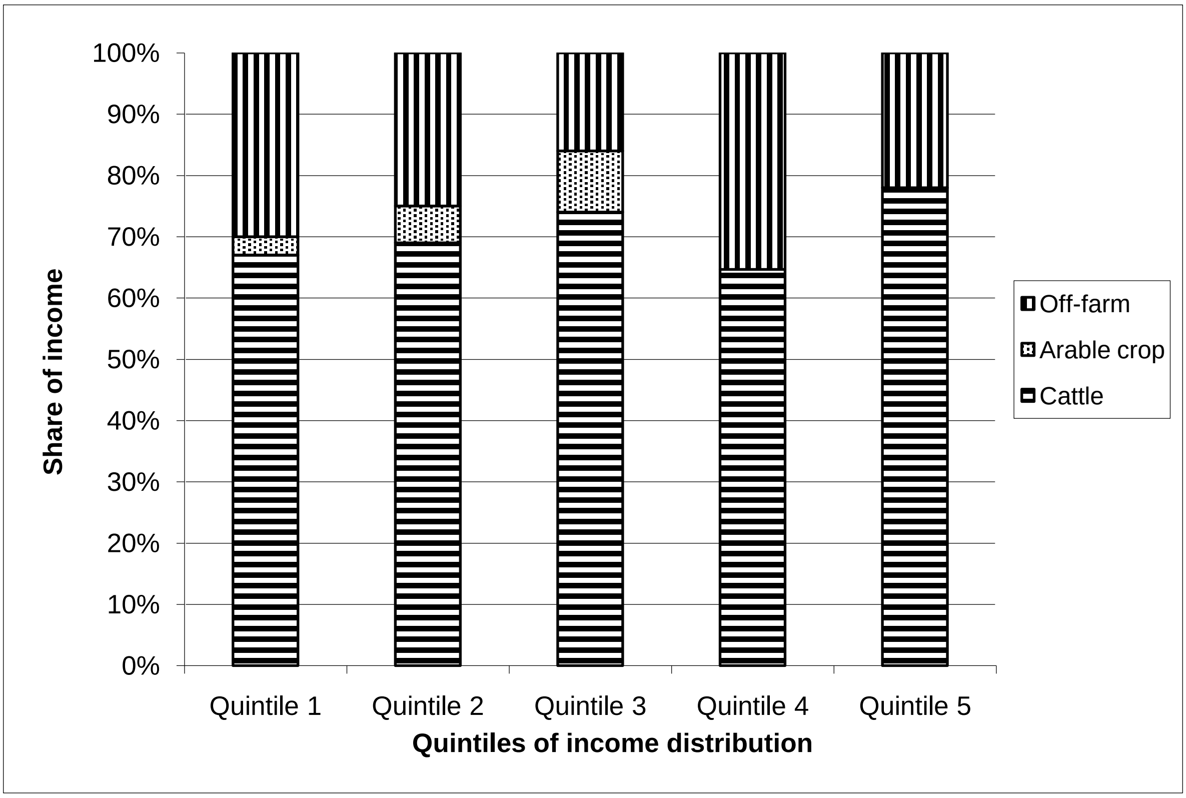

Figure 10: Contribution of the arable crop production, cattle and dairy production and off-farm income to the total household income of the sampled farms (n=130)

5. Discussion

Data on profitability of agricultural production are given by Wunder (2000) for the wider region in Ecuador, and by Knoke et al. (2009) for the local research area. Neither study gives data on the heterogeneity of farm profitability, however. In this study, we fill this information gap.

The snowball sampling approach was better than a random sampling approach in the research area. Peasant households tended to exaggerate or understate farm and production characteristics as strategy of personal protection potentially inducing strategic bias. The snowball approach reduces strategic bias likely to be present when sensitivity information or financial information was to be disclosed as a more trustful relation with respondents could be achieved from the beginning. Still, the non-random sampling requires that the descriptive statistics presented need to be treated with caution. Likewise, the representation of cattle income as a function of growth increments and sales of cattle, will need refinements that potentially affect the conclusions presented.

Arable crop production represents 3.9% only of the total household income, and it is less profitable on average than cattle production (160 USD/ha/yr). Arable crops are restricted to small plots near to houses mainly for auto-consumption. In other side, pasture-based cattle and dairy production accounts for 70.4% of total household income. Our results show that cattle production is a financially profitable land use. The also show that there is considerable heterogeneity in cattle-derived net profits.

Family labour has a strong influence on profitability. Compared to gross margins (280 USD/ha/yr), net profits of arable crop agriculture are reduced drastically when it family labour is accounted for (-43 USD/ha/yr). The gross margin in cattle switches from 245 USD/ha/yr to 160 USD/ha/yr. As consequence of accounting for family labour, some net profits for individual farms in cattle production are negative. The incorporation of family labour as a fixed cost component using observed market prices of agricultural labour may not be a fully realistic assumption, though. If the local labour market is not perfect, “excess labour” at the farming household level is likely incorporated into the own agricultural activities.

The average cattle ranching net profit is 160 USD/ha/yr. This value is lower than the net profit 244 USD/ha/yr (adjusted for inflation[5]) reported by Wunder[6] (2000) for the Ecuadorian Andes. Our value is higher than the net profit reported by Knoke[7] et al. (2009) for research area of about ~100 USD/ha/yr.

The cattle production analysis suggests that several factors that influence production outputs per hectare. The Cobb-Douglas production function analysis found that lower altitude of the farm, "Mestizo" ethnic of the household head, as well as access to technical assistance and to credit results in has higher gross incomes. One reason for the observed differences may be found in the better market access of the Mestizos farms, which are often better connected to the local markets in Loja and Zamora cities. On the contrary, the ethnic "Saraguro" farms are virtually all located far from local markets. Also, the land conditions (i.e. less steep slopes as case of "Sabanilla" region) may be better for "Saraguro" farmers.

References

Antle J., Capalbo, S. 2001. Econometric-Process Models for Integrated Assessment of Agricultural Production Systems. American Journal of Agricultural Economics 83(2): 389-401.

Alene A., Zeller M., Schwartze S., Nuryartono N. 2005. The extent and determinants of production efficiency of farmers in the rainforest margins in Central Sulawesi, Indonesia: implications for land use and support services. Quarterly Journal of International Agriculture 44(4): 335–353.

Battese G., Coelli T. 1995. A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics 20 (2):325-332.

Bagnoli P., Goeschl T., Kovács E. 2008. People and Biodiversity Policies. Impacts, Issues and Strategies for policy action. OECD, Paris.

Barona N., Ortiz S. 2007. Diseño y factibilidad agroindustrial de la cadena agro productiva del Guarango. Bacherlor Thesis. Escuela Politécnica Nacional.

Bawa K., Seidler R. 1998. Natural forest management and conservation of biodiversity in tropical forests. Conservation Biology 12:46–55.

Beck E. 2008. Preface. In: Beck E., Bendix J., Kottke I., Makeschin F., Mosandl R.: Gradients in a tropical mountain ecosystem of Ecuador. Ecological Studies 198:5–7.

Beck E., Hartig K., Roos K. 2008. Forest clearing by slash and burn. In: Beck E., Bendix J., Kottke I., Makeschin F., Mosandl R.: Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:371 -374.

Binam J., Gockowski J., Nkamleu G.. 2008. Technical Efficiency and Productivity Potential of Cocoa Farmers in West African Countries. The Developing Economies 46: 242-263.

Bravo B, Pinheiro A. 1993. Efficiency analysis of Developing Country Agriculture: A review of Frontier Function Literature. Agricultural and Resource Economics Review. 22(1):88-101.

Brynjolfsson E., Hitt L. 1995. Information Technology as A Factor of Production: The Role of Differences Among Firms. Economics of Innovation and New Technology. 3:183-199.

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[5] The value was adjusted with the formula: Future amount = Present value * (1+ % inflation) ^ number of years. Ecuador adopted the dollar as official currency since 2000.

[6] Wunder (2000) reports 125 USD/ha/year for cattle ranching, at 5% discount rate, in the fourth year of deforestation cycle. It is not explicit how was valued the labor.

[7] It is not explicit how was valued and incorporated the labor.

Brummitt N., Lughadha E. 2003. Biodiversity: where's hot and where's not. Conservation Biology 17:1442–1448.

Butler R., Pin Koh L., Ghazoul J. 2009. REDD in the red: palm oil could undermine carbon payment schemes. Conservation letters 2: 67 -73.

Chambers R.1988. Applied production analysis: a dual approach. Cambridge University Press, UK.

Chazdon R. 1998. Tropical forests – log 'em or leave 'em? Science 281:1295–1296.

Christensen L., Jorgenson D., Lau L. 1973. Transcendental Logarithmic Production Frontiers. The Review of Economics and Statistics 55(1):28-45.

Cobb C., Douglas P. 1928. A theory of production. The American Economic Review, Vol. 18, No. 1, Supplement, Papers and Proceedings of the Fortieth Annual Meeting of the American Economic Association 139-165.

Coelli T., Rao D., O'Donnell C, Battese G. 2005. An introduction to efficiency and productivity analysis. Second Edition. Springer, New York, USA.

De Janvry A., Sadoulet E. 2006. Progress in the Modeling of Rural Household Behavior Under Market Failures. In Poverty, Inequality and development. Essays in Honor of Erik Thorbecke. Kluwer publishing,155 -182.

Delgado C. 1995. Africa´s Changing Agricultural Development Strategies: Past and Present Paradigms as a Guide to the Future. Food, Agriculture, and Environmental Discussion Paper no 3. Washington D.C.: International Food Policy Research Institute.

Dercon S. 2003. Poverty Traps and Development: The Equity-Efficiency Trade-Off Revisited. First AFD/EUDN Conference on Poverty, Inequality and Growth: What´s at Stake for Development Aid? Oxford: University of Oxford, Department of Economics.

Diewert W. 1971. An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function. Journal of Political Economy 79(3): 481-507.

Ellis F. 1993. Peasant economics. Farm households and agrarian development. Second edition. Cambridge University Press, UK.

Eichhorn S. 2009. Effekte eines Straßenbaus im Biosphärenreservat Podocarpus-El Cóndor auf die Landnutzung und Biodiversität. Diplomarbeit. Georg-August-Universität Göttingen. Germany.

Feder G., Murgai R., Quizon J. 2004. Sending Farmers Back to School: The Impact of Farmers Field Schools in Indonesia. Review of Agricultural Economics 26 (1): 45-62.

Fisher B., Christopher T. 2007. Poverty and biodiversity: Measuring the overlap of human poverty and the biodiversity hotspots. Ecological Economics 62(1): 93-101.

Fuss M., McFadden D., Mundlak Y. 1978. A Survey of Functional Forms in the Economic Analysis of Production in: Production Economics: A Dual Approach to Theory and Applications 221-268.

GTT (Grupo Trabajo Tara). 2007. Proyecto "Tara". Gobierno provincial de Loja, PREDESUR, Municipio de Celica, Municipio de Pindal and Municipio de Calvas. Loja, Ecaudor.

IGM (Instituto Geográfico Militar del Ecuador). 2003. Aerial photographs, scale 1:5000 resolution pixel 1m, pancromaticas, Proyection UTM, DATUM WGS84 Zone 17S.

Knoke T., Calvas B., Aguirre N., Roman-Cuesta R., Günter S., Stimm B., Weber M., Mosandl R. 2009. Can tropical farmers reconcile subsistence demands with forest conservation?. Frontiers in Ecology and the Environment 7(10):548-554.

Kohler U., Kreuter F. 2005. Data analysis using Stata. Stata Corp LP, USA.

Maza B. 2010. Heterogeneity of peasant land use decision as an effect of differences financial and personal capitals in the area of Biosphere Reserve "Podocarpus - El Cóndor", Ecuador. Thesis PhD. Department of Agricultural Economics, Georg-August Universität Göttingen, Germany.

Maza B., Barkmann J., von Walter F., Marggraf. 2010. Efficiency and Distributional impacts of protected area planning using PES schemes in the Biosphere Reserve "Podocarpus-El Cóndor", Ecuador. WCERE, Montreal-Canadá http://www.webmeets.com/files/papers/WCERE/2010/1204/Maza2010WCREE-jb2-Final.pdf

Nicholson W. 1998. Microeconomic theory. Basic principles and extensions. Seventh Edition. Thomson, USA.

Nieto C., Barona N. 2007. El Guarango. Una opción agroindustrial y de exportación para la conservación productiva.

Ogundary K. 2010. Technical efficiency of smallholder farms in Nigeria. PhD Thesis. Faculty of Agricultural Sciences. Georg-August Universität Göttingen, Germany.

Paredes E. 2009. Estudios generales con serie histórica 2000, 2004, 2005, 2006, 2007 y 2008 de la ganadería bovina y raza del Ecuador. Ministerio del Agricultura y ganadería del Ecuador. Quito, Ecuador.

Pearson de Vaccaro, L. 1986. Sistemas de Producción Bovina Predominantes en el Trópico Latinoamericano. "Panorama de la ganadería de doble propósito en la America Tropical, L. Arango-Nieto, A. Charry and R. Vera eds. Bogotá. Colombia: ICA-CIAT Press. In: Ortega L. Ward R., Andrew C. 2007. Technical efficiency of the Dual-purpose cattle system in Venezuela. Journal of Agricultural and Applied Economics 39(3):719-733.

Pohle P. 2008. The People Settled Around Podocarpus National Park. In: E., Bendix J., Kottke I., Makeschin F., Mosandl R. (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:25 – 36.

Rahman S., Kamrul M. 2008. Impact of environmental production conditions on productivity and efficiency: A case study of wheat farmers in Bangladesh. Journal of Environmental Management 88(4):1495–1504.

Rakodi C. 1999. A Capital Assets Framework for Analysing Household Livelihood Strategies: Implications for Policy. Development Policy Review 17: 315–342

Sadoulet E., de Janvry A. 1995. Quantitative Development Policy Analysis. Baltimore (Maryland), Johns Hopkins University Press.

Sherlund S., Barrett C., Adesina A . 2002. Smallholder technical efficiency controlling for environmental production conditions. Journal of Development Economics 69 (1):85-101.

Torracchi S., Tapia M., Valdivieso M. (withoutyear). Spatial and temporal analysis of vegetation from Zamora’s basin. Universidad Tecnica Particular de Loja; powerpoint presentation. In Knoke T., Weber M., Barkmann J., Pohle P., Calvas B., Medina C., Aguirre N., Günter S., Stimm B., Mosandl R., v. Walter F., Maza B., Gerique A. 2009. Effectiveness and distributional impacts of payments for reduced carbon emission from deforestation. Erdkunde 63(4):365–384.

Udry C. 1996. Efficiency and Market Structure: Testing for Profit Maximization in Africa Agriculture. Contributions to Economic Analysis and Policy 242: 363-394.

Universidad Nacional De Loja, CINFA, Herbario Reinaldo Espinosa. 2005. Estado de Conservación de Áreas Protegidas y Bosques Protectores de Loja y Zamora Chinchipe y Perspectivas de Intervención.

Varian H. 1999. Intermediate microeconomics: a modern approach. Fifth Edition W.W.Norton &Company, New York, London.

Wiens E. Production Functions. http://www.egwald.ca/economics/productionfunctions.php (26.11.2009)

Wooldridge J. 2006. Introductory Econometrics: A modern approach. Second Edition. South-Western Cengage Learning. USA.

Wunder S. 1996. Los caminos de la madera. Programa Regional De Bosques Nativos Andinos. UICN, Ecuador.

Wunder S. 2000. The economics of deforestation: the example of Ecuador.

Wunder S. 2005. Payments for Ecosystem services: Some nuts and bolts. CIFOR. Ocasional Paper 42. Jakarta 10065, Indonesia

Zeller M., Schwarze S. 2006. Submodule: Planning methods for agricultural development. Göttingen, Germany.

Zeller M., Diagne A., Mataya C. 1998. Market Access by Smallholder Farmers in Malawi: Implication for Technology Adoption, Agriculture Productivity, and Crop Income. Agricultural Economics 19(1-2):219-229

Zeller M., Schrieder G., von Braun J., Heidhues F. 1997. Rural finance for Food Security for the Poor: Implications for Research and Policy. Washington, D.C.: International Food Policy Research Institute.

Annex

Annex 1: Descriptive statistics of dependent and explanatory variables of arable crop production.

Variable	Observ.	Mean	Std. Dev.	Min	Max
Gross Income (USD/ha/yr)	52	521.14	478.62	51.70	2465.01
Gross Margin (USD/ha/yr)	52	284.66	222.39	-104.79	991.08
Net Profit (USD/ha/yr)	52	-71.45	299.60	-1513.92	510.20
Total Arable crop area (ha)	52	0.51	0.64	0.03	4.00
Total Labor (man-days/yr)	52	28.60	27.85	2.50	116.00
Input Expenses (USD/yr)	52	59.32	59.30	1.37	270.51
Total Area (ha)	52	29.25	32.20	1.52	139.34
Ratio arable crop area/Total Area	52	0.04	0.06	0.001	0.32
Ethnicity (1="mestizo", 0="saraguro")	52	0.81	0.40	0	1
Age of Head-household between (year)	52	53.90	12.09	26	88
Scholarity Head-household (year)	52	4.2	3.37	0	15
Off-Farm Household Income between 1124 - 6000 (USD/Year)	52	0.40	0.50	0	1
Off-Farm Household Income> 6000 (USD/Year)	52	0.10	0.30	0	1
Technical Asisstence (Dummy)	52	0.23	0.43	0	1
Household is part of Organization (Dummy)	52	0.50	0.50	0	1
Access to Credit (Dummy)	52	0.29	0.46	0	1
Logarithm of Gross Income	52	5.84	0.96	3.95	7.81
Logarithm of Arable Crop Area	52	-1.20	1.07	-3.61	1.39
Logarithm of Total Labor	52	2.91	0.98	0.92	4.75
Logarithm of Input Expenses	52	3.45	1.34	0.31	5.60

Annex 2: Descriptive statistics of dependent and explanatory variables of cattle production

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross Income (USD/ha/yr)	130	289.21	197.11	0.10	1149.24
Total Pasture Area (ha)	130	18.34	17.06	0.81	82.81
Total Labor (person-days/yr)	130	159.46	96.84	19.40	647.50
Input Expenses (USD/yr)	130	341.95	607.94	2.50	4178.10
Locality (1 =PACO, 0 = Sabanilla)	130	0.73	0.45	0	1
Total Pasture Area minus Degraded Pasture (ha)	130	17.52	16.79	0.57	82.81
Mequeron Pasture (Dummy)	130	0.46	0.50	0	1
Mequeron Pasture + Morocha Pasture (Dummy)	130	0.07	0.25	0	1
Agroforestry Pasture (Dummy)	130	0.07	0.25	0	1
Other kind of Pastures (Dummy)	130	0.12	0.33	0	1
Morocha Pasture (%)	130	30.41	37.32	0.00	100.00
Mequerón Pasture (%)	130	44.58	37.91	0.00	100.00
Agroforestry Pasture (%)	130	9.88	22.80	0.00	100.00
Degraded Pasture (%)	130	5.24	11.81	0.00	86.50
Melinis Pasture (%)	130	3.12	10.49	0.00	74.70
Penisetum Pasture (%)	130	2.61	11.82	0.00	100.00
Other kind of Pastures (%)	130	4.17	13.56	-0.40	76.10
*Mean Altitude of Pasture (m a.s.l.)	130	1996	263	1261	2668
*Minimun Altitute of Pasture (m a.s.l.)	130	1800	252	1080	2360
*Maximun Altitute of Pasture (m a.s.l.)	130	2190	301	1469	2880
Ethnicity (1="mestizo", 0="saraguro")	130	0.85	0.36	0	1
Age of Head-household between (year)	52	53.90	12.09	26	88

Scholarity Head-household (year)	52	4.2	3.37	0	15
Off-Farm Household Income between 1124 - 6000 (USD/Year)	130	0.39	0.49	0	1
Off-Farm Household Income> 6000 (USD/Year)	130	0.14	0.35	0	1
Technical Asisstence (Dummy)	130	0.22	0.41	0	1
Household is part of Organization (Dummy)	130	0.42	0.49	0	1
Access to Credit (Dummy)	130	0.39	0.49	0	1
**Minimum Cost Distance	130	1013.43	2046.57	0.00	9550.48
**Maximun Cost Distance	130	21520.09	22205.88	1531.87	102541.80
**Mean Cost Distance	130	9418.75	7917.67	681.63	37732.58
Improved Pasture (Years)	130	3.62	9.19	0	58
Logarithm of Gross Income	130	5.37	1.00	-2.30	7.05
Logarithm of Pasture Area	130	2.46	1.01	-0.21	4.42
Logarithm of Total Labor	130	4.89	0.63	2.97	6.47
Logarithm of Input Expenses	130	4.57	1.67	0.92	8.34

*Source: IGM 2003

**Source: Eichhorn 2009

Annex 3: Translog production function of arable crop production

Source	SS	df	MS
Model	37.3118105	9	4.14575672
Residual	9.40174522	42	0.223851077
Total	46.7135557	51	0.915952072

Number of obs = 52
F(9, 42) = 18.52
Prob > F = 0.0000
R^2 = 0.7987
Adj R^2 = 0.7556
Root MSE = .47313

lnYinc	Coef.	Std. Err.	t	P>|t|
Log (Land)	-1.33571	1.214044	-1.1	0.278
Log (Land* Land)	-0.0625	0.136084	-0.46	0.648
Log (Labor)	0.131573	1.473253	0.09	0.929
Log (Labor* Labor)	0.005872	0.210002	0.03	0.978
Log (Input Expenses)	0.087459	0.677766	0.13	0.898
Log (Input Expenses*Input Expenses)	0.059765	0.082034	0.73	0.47
Log (Land *Labor)	0.158951	0.278546	0.57	0.571
Log (Land *Input Expenses)	0.004008	0.163055	0.02	0.981
Log (Labor *Input Expenses)	0.097465	0.150047	0.65	0.52
Cons	2.218222	2.895879	0.77	0.448

MULTICOLLINEARITY TRANSLOG
Mean VIF: 215.10
Rule: VIF greater 10 are generally seem as indicate of severe multicollinearity

Annex 4: Translog production function of cattle production

Source	SS	Df	MS
Model	74.5555651	13	5.73504347
Residual	55.1509653	116	0.475439356
Total	129.70653	129	1.00547698

Number of obs = 130
F(13, 116) = 12.06
Prob > F = 0.0000
R^2 = 0.5748
Adj R^2 = 0.5272
Root MSE = .68952

lnYinc	Coef.	Std. Err.	t	P>|t|
Log (Land)	-2.1157	0.8093	-2.61	0.010
Log (Land * Land)	-0.0521	0.0857	-0.61	0.545
Log (Labor)	6.6835	1.3064	5.12	0.000
Log (Labor * Labor)	-0.6377	0.1583	-4.03	0.000
Log (InputExp)	1.6015	0.4795	3.34	0.001
Log (InputExp * InputExp)	-0.0633	0.0311	-2.03	0.044

Log (Land *Labor)	0.3773	0.1927	1.96	0.053
Log (Land*InputExp)	-0.0264	0.0721	-0.37	0.715
Log (Labor*InputExp)	-0.1438	0.1149	-1.25	0.213
Altitudmin	-0.0011	0.0003	-3.61	0.000
Ethnicity	0.5510	0.1823	3.02	0.003
Technic	0.2993	0.1576	1.90	0.060
Credit	0.1997	0.1299	1.54	0.127
_cons	-11.8086	3.0966	-3.81	0.000

MULTICOLLINEARITY TRANSLOG

Mean VIF: 129.32

Rule: VIF greater 10 are generally seem as indicative of severe multicollinearity

Annex 4. Annual inflation of Ecuador

Year	Annual inflation of Ecuador in %*	Index =100	Net Profit adjusted to inflation (USD/ha/yr)
2000	96.1	196.1	125**
2001	22.4	240.0	153
2002	9.7	263.3	168
2003	9.35	287.9	184
2004	1.95	293.5	187
2005	4.36	306.3	195
2006	3.11	315.9	201
2007	3.32	326.4	208
2008	8.83	355.2	226
2009	4.31	370.5	236
´09.2010	3.44	383.2	**244**

*Source: Banco Central del Ecuador

**Wunder (2000) reports 125 USD/ha/year for cattle ranching in the fourth year of the deforestation cycle, at 5% discount rate

Chapter II

Profitability of smallholder agriculture in the area of the Biosphere Reserve “Podocarpus – El Cóndor”, Ecuador.

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Abstract

The UNESCO Biosphere Reserve “Podocarpus-El Cóndor” is part of the Andes biodiversity “hot spot” suffering from deforestation caused mainly by agricultural production. This paper analyzes the profitability of local arable crops and cattle production systems. The profitability analysis is interesting not only for agricultural development reasons but also because it provides proxies for the opportunity cost of local farmers faced with conservation demands. We use a Cobb-Douglas production function to determine factors that influence farming profitability. The econometric model is based on socio-economic data of 130 peasant households. Arable crops are found in small plots only, designated mainly to subsistence production. A pasture-based cattle production system dominates production. We used an empirically estimated cattle growth equation to predict life weight increments with the explanatory variables race, age and sex of the animals. Cattle production yields an average net income of 160 USD/ha/yr. Determinants of gross income are land ($p<0.001$), labor ($p<0.002$), input expenses ($p<0.001$), altitude ($p=0.013$), ethnicity ($p=0.155$), and access to technical assistance ($p=0.088$) and to credit ($p=0.131$).

1. Introduction

Ecuador is a megadiverse country (Brehm et al. 2008) including the Ecuadorian Andes, one of the global biodiversity hotspots (Meyers et al. 2000; Brummitt & Lughadha 2003, Brehm 2005). One important protected area is “Podocarpus National Park” (PNP) located in the south Ecuadorian Andes (Barthlott et al. 1996). At the same time, the PNP is part of the UNESCO Biosphere Reserve “Podocarpus-El Cóndor”.

The main threat to the biodiversity in the Andes hot spot is deforestation. South America has the largest forest area loss per year (4.3 million ha/yr in the period 2000-2005) as compared to deforestation in other world regions. According to FAO (2006), Ecuador has the highest net deforestation rate 1.7% (198 000 ha/yr) annually in South America. Land use change from natural ecosystems to pastures increased from 2.2 million hectares in 1978 in to 6 million hectares in 1989 (Wunder 2000). The annual deforestation rate in the buffer zone of PNP is calculated as 1.16% (Torracchi et al. quoted by Knoke 2009). Land use change is mainly to pasture land.

Several factors influence deforestation in the Ecuadorian Andes. Wunder (2000) points out that deforestation in the Ecuadorian Andes is the outcome of increasing demand for meat and dairy products. Moreover, deforestation is encouraged by a combination of population growth, improved infrastructure, and urban income. Also, farmers look for short term returns of their agriculture investments. In the research area, cattle production has been the main cause of deforestation (Wunder 1996) with the natural ecosystem being changed by slash and burn processes (Beck et al. 2008a, Beck et al. 2008b). The current land use pattern is an extensive field-pasture-rotation system (Beck et al. 2008a). Adams (2009), comments that the causes of agricultural frontier expansion in the buffer zone of PNP is misguided land-use, poor implantation and enforcement of conservation policies, a desire for cattle production, and the perception by farmers that forest land is abundant. Adams proposes agricultural intensification as a solution to the deforestation problem.

Forest conservation and socio-economic impacts of conservation on concerned peasant households need to be balanced (Bawa & Seidler 1998, Chazdon 1998). Different approaches have been implemented to balance forest conservation and socio-economic demands including forest management (Mosandl et al. 2008), agroforestry systems (Miller

& Nair 2006), payments for ecosystem services (Wunder 2005, Wunder 2007, FAO 2007, Engel et al. 2009), or diversification of land use options (Knoke et al. 2009a).

A central tool to analyze the economic burden of increased conservation land demands is opportunity cost analysis (Naidoo et al. 2006). Opportunity cost is the possible income that is lost by using the next-best choice of using a productive resource (Naidoo et al. 2006). In the context of forest conservation, the opportunity cost of conversion can be approximated by the balance between private gains of deforestation and a private gain from forest uses (Chomitz et al. 2005). Opportunity cost analysis helps policy makers to evaluate environmental protection vs. investment projects (Azzoni & Isai 1994), and to allocate conservation budgets in a cost-effective manner (Chomitz et al. 2005, Naidoo et al. 2006, Bode et al. 2008, Carwardine et al. 2008, Bryan et al. 2009).

There are different approaches to calculate the opportunity costs:

- *Net present value* (NPV) is the present value of future cash flows originated by an investment (Naidoo & Adamowicz 2005, pp. 492). For example:
    - Wunder (2000) uses a NPV approach to calculate the benefits of timber extraction as well as arable crop production and cattle ranching as the opportunity cost of forest conservation of Ecuadorian Andes forests.
    - Naidoo & Adamowicz (2005) use a NPV approach to estimate land values as opportunity costs of land uses in transitional landscapes in Paraguay.
- *A revealed preference approach* revels decision making preferences estimated based on real land use (Bockstael and Freeman 2005, pp.538). For example:
    - Kelsey et al. (2008) used an auction approach to revealed preferences by creating markets for payments for soil erosion control in Indonesia.
    - Chomitz et al. (2005) use the hedonic land value approach to estimate the opportunity cost of biodiversity conservation on South Bahia, Brazil. Land price is a function of climate, soil properties, and market access.
- *Stated preference approaches* reveal decision-making preferences estimates based on hypothetical choices (Bockstael and Freeman 2005, pp.539). One popular stated preference approach is contingent valuation (Carson & Hanemann 2005).

Wunder (2000) and Knoke (2009) calculate the opportunity cost of forest conservation in Ecuador. Wunder (2000) uses the NPV approach to calculate net revenues (profitability) of deforestation over a deforestation cycle of 15 years. He uses cost and revenue data of one-hectare plots obtained by secondary information. The values are net of capital and labor cost (i.e. hired labor, household labor, purchased inputs, loan payments).

During the deforestation cycle, the income for timber extraction, agriculture and cattle production decreases over time. For example, cattle production is valued as 125 USD/ha in the seventh year while profitability decreases to 24.24 USD/ha in the fifteenth year at 5% discount rate. Knoke et al. (2009) calculate NPV of cattle pasture in the buffer zone of PNP. The average NPV is 70 USD/ha/yr (with a range from 20 to 130 USD/ha/yr) with a discount rate of 5% at a 20 year period. The revenue data is derived from local farmer milk production. The cost data are not explained at any detail.

Against this background of pressing conservation problems but scare data, the paper analyzes the profitability of local arable crops and cattle production systems. The profitability analysis is interesting not only for agricultural development reason, but also because it provides proxies for the opportunity cost of local farmers faced with conservation demands.

2. Methodology

2.1. Research area

The research area is located in the south of Ecuador in the Biosphere Reserve "Podocarpus-El Cóndor" located in the provinces of Loja and Zamora-Chinchipe (see Figure 1). The research area is part of the global biodiversity "hot spot" of the Andes Mountains (CIPRB 2005, Brummitt & Lughadha 2003). The majority of rural households are poor smallholders practicing pasture-based cattle ranching (Beck 2008). The protected area "Corazón de Oro" (Area de Bosque y Vegetación Protectora Corazón de Oro; ABVPC) was established to the north of PNP. The protected area "Corazón de Oro" forms a part of the buffer zone of the national park which is the core area of the UNESCO Biosphere Reserve. The annual deforestation rate in the buffer zone of PNP is calculated 1.16% (Torracchi et al. quoted by Knoke 2009), and the land use change is mainly to pasture land. .

The region is inhabited by people with heterogenic ethnic and socio-economic characteristics (Pohle 2009). The majority of rural households are poor smallholders practicing pasture-based cattle ranching (Pohle 2008). The two ethnic groups (“Mestizos” and indigenous group “Saraguros”) are engaged into agricultural activities. Cattle ranching is integrated into the market economy. Arable crop production near homesteads is mainly for subsistence purposes on small plots (Pohle & Gerique 2006, Pohle et. al 2009). Extensive cattle production is the main sources of the income. Peasants use fire as a tool to open new pastures and regenerate old pastures (Pohle and Gerique 2008). Moreover, an additional source of income are small shops, off-farm labor (Pohle and Gerique 2008), and extraction of timber (Pohle 2006).

2.2. Sampling

In the ABVPC and a narrow corridor between ABVPC and PNP, a socio-economic household and farming survey was conducted March to June 2008 (n=130). About 24% of all local households took part in the survey. The primary survey villages were selected randomly and proportional to household numbers. The number of households per village roughly reflects village size. The selection of households in the villages could not be conducted using a random selection. Because of the sensitive economic information to be disclosed during the interview, we relied on snowball sampling and information of key informants in order to approach as much a “representative” sample as possible. The land use on each farm was surveyed by personal interviews; the location of the plots was independently delimited on aerial photographs (IGM 2003), and ground-truthed using GPS measurements.

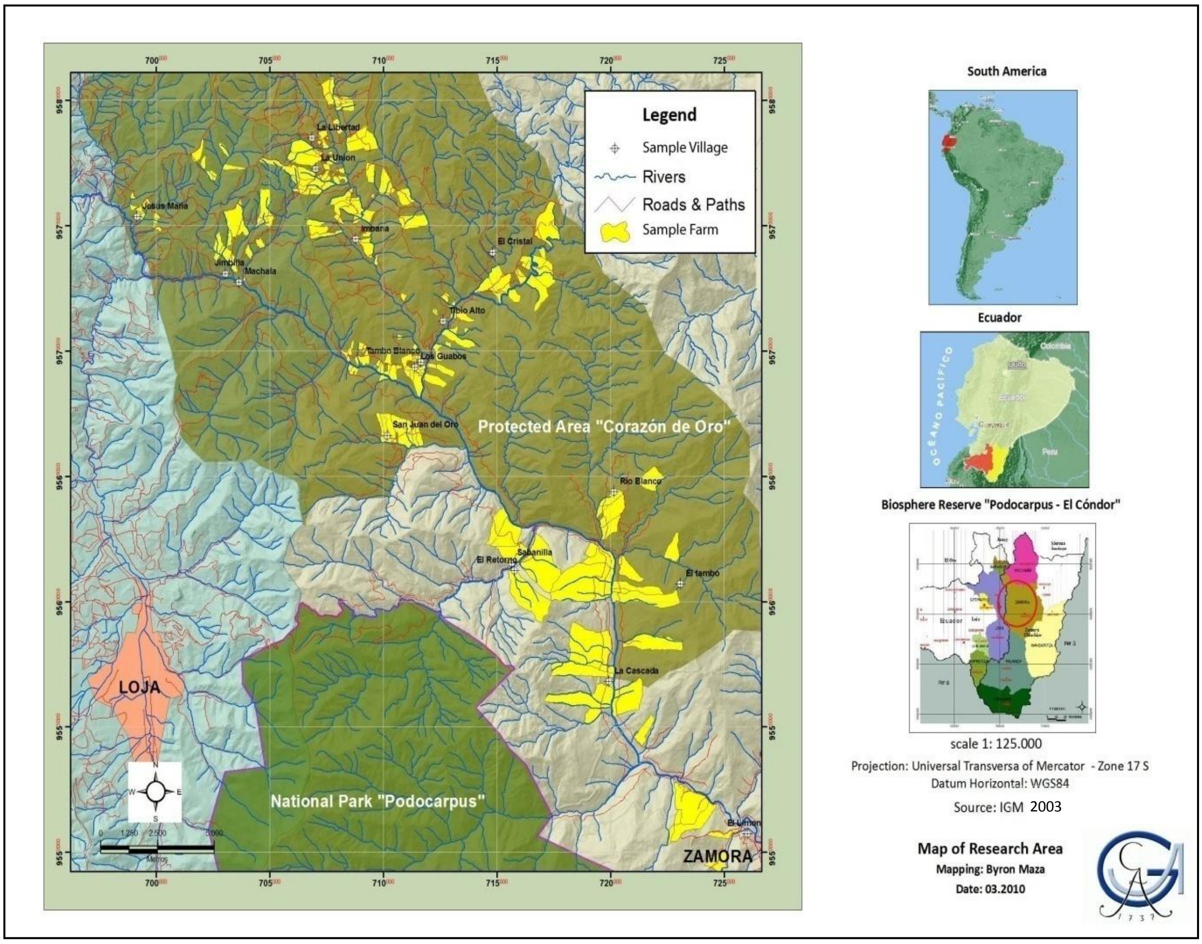

Figure 1: Research area in the Biosphere Reserve “Podocarpus-El Cóndor”, South Ecuador

2.3. Descriptive Statistics

Table 1 shows descriptive values roughly according to the different kinds of household capital. The analysis was made with SPSS version 17.

Table 1: Descriptive statistics of variables

Component	Variables
Personal capital	Family members, age, ethnicity, education level
Financial capital	Access to credit, credit source and reason why farmers do not request formal credit
Social capital	Organization membership, organization meeting attendance, participation in organization decision-making, labor contribution to the organization, money contribution to the organization
Operational capital	• *Land:* tenure regime, farm origin, requested rental price for one hectare of land (cattle or agriculture), farm size per household, land use distribution (forest, pastures, and arable crop), and percent of grass and crops specie, farmer pasture preference

	- *Herd:* structure and stock
Income & Cost sources	d) *Arable crop*: amount sold, amount consumed, labor (hired and family) expenses per hectare e) *Cattle:* dairy production (sold and consumed), animals (sold and consumed), life weight increment, labor (hired and family) and expenses per hectare f) *Off*-farm income Labor and expenses were sampled independently and used in estimation for both production systems

2.4. Profitability of the arable crops and cattle production

First, we calculate gross income/ha/yr[8], gross margin/ha/yr and net profits/ha/yr for each farmer based directly on the empirical survey data. The gross income includes dairy production (consumed and sold), sold and consumed animals, and life weight increments. He selected strategy to represent the inventory changes to the herd as well as income and costs from the commercial and subsistence use of the cattle will require further refinement in future analyses. The used cattle income model assumes that the herd grows in spite of deaths, sales and auto-consumption. The variable cost includes hired labor and cash input cost.

In order to extract summarized information on agricultural production at the single farming household level and to analyse influences in production, we fitted a Cobb-Douglas production function to the gross income, gross margin, and net profit data. A Cobb-Douglas function form was tested against a Translog formulation. Although F-tests indicated that the additional interaction terms of the independent variables in the Translog had an explanatory power, we chose the more simple Cobb-Douglas production function as it yielded more significant predictors, could be more easily interpreted, and avoided the multicollinearity problems in arable crop production (Annex 1) and cattle production (Annex 4) found for the Translog models. Gross income, gross margin and net profit were tested as dependent variables (see in results Tables 24 and 27). Gross income performed best, and the gross income Cobb-Douglas model was accordingly used for econometric analysis.

After the decision for using a Cobb-Douglas functional form we made, gross income was predicted using the empirical gross income data and several explanatory variables. Second,

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[8] Gross Income is the value of the production in monetary terms (Zeller & Schwarze 2006)

surveyed variable costs were subtracted from predicted gross income (= gross margin). Finally, net profits were obtained by subtracting surveyed fixed costs including household labor (Zeller & Schwarze 2006). The formulas are described below in detail for arable crop (Table 2) and cattle production (Table 3).

Land, labor, input expenses, altitude (minimum, maximum and average) of pasture land, ethnicity, technical assistance, access to formal credit, age and education of the household head, membership in organizations, cost distance (minimum, mean and maximum) of farms to markets, and off-farm income were tested as explanatory variables. The analysis also included environmental conditions, i.e., altitude and locality. The topographic factor is represented by altitude. The locality is a representation of soil conditions and market access. Climate variables were not included. The regressions were run with STATA 9.0. Finally, multicollinearity and heteroskedasticity were evaluated.

If we use a production function produced by OLS linear regression in optimization modelling, the standard regression constant poses a problem. With a regression constant, even zero input will result in a certain output. This is a clear violation of the weak essentiality assumption in economic production analysis. Thus, it is the ideal case when the regression constant is near close to zero and not significant. But, if the regression is not close to zero and significant, it may be necessary to use an regression model without a constant term. Alternatively, additional restrictions may need to be imposed to the formulation of the optimization problem to secure that impossible production results can avoided.

Multicollinearity makes it difficult to ascertain the relative and absolute influence of affected variables on the dependent variable. The Variance Inflation Factor (VIF) is used to test for multicollinearity (Stata command VIF). Heteroskedasticity can lead to biased standard errors (Wooldridge 2006). For detecting heteroskedasticity, the Breusch-Pragan/Cook-Weisberg test is used (command “hettest” in Stata version 9). If heteroskedasticity is detected, we use *Robust Standard Errors* that address the problem of biased standard errors (Kohler & Kreuter 2005, Wooldridge 2006).

a) Arable crop production

Gross income/ha/yr includes consumed and sold arable crop production. We did not include the production from the small "home gardens". Variable cost includes hired labor and cash input cost. Fixed costs include family labor and depreciation of (rudimentary) tools. Variable cost was subtracted from gross income to calculate gross margin. Next, fixed cost was subtracted from gross margin to calculate net profits of each household (See Table 2).

Table 2: Formulas used to calculate net-profit in arable crop production per year (n=130)

Variable	Formula
Empirical Gross Income	$\mathrm{GI_i} = (Amount\ Sold_i * \ Market\ Price_i) + (Amount\ Consumed_i * \ Market\ Price\ \ )$ i:number of household Market prices for consumed amount are the average prices of all households of sold production
Gross Margin	$GM_{\ i} = \ Predicted\ GI_i - \ Empirical\ Variable\ Cost_i$ i:number of household
Empirical Variable Cost	$VC_i = (Hired\ Labor_i * \ \ Wage_i) + (Input\ Cost_i * Market\ Price_i)$ i:number of household
Empirical Fixed Costs	$FC_i = (Family\ Labor_i * \ Average\ Wage\ \ \ ) + Depreciation\ of\ Rudimentary\ Tools_i$ i:number of household The Off-farm agricultural wage is used as average wage in fixed cost
Net Profit	$NP_i = \ GM_i\text{-}\ FC_i$ i:number of household

b) Cattle production

Gross income/ha/yr includes dairy production (consumed and sold), sold and consumed animals, and life weight increment (see Herd section Chapter I). The variable cost includes hired labor and cash input cost. The fixed costs include family labor and depreciation of (rudimentary) tools. Next, the variable cost was subtracted from gross income to calculate to gross margin and fixed cost was subtracted from gross margin to calculate the net-profit of each household. The formulas used are shown in Table 3.

Table 3: Formulas used to calculate net-profit in cattle production per year (n=130)

Variable	Formula
Empirical Gross Income	$GI_i = \left[\begin{pmatrix} Amount\_Sold\_and\_ \\ Consumed\_Dairy_i * \\ Market\_Price \end{pmatrix} + \begin{pmatrix} Amount\_Sold\_and \\ Consumed\_Animals_i \\ * Market\_Price \end{pmatrix} + \begin{pmatrix} Life\_Weight\_Increment_i * \\ Market\_Price \end{pmatrix}\right]$ i:number of household Dairy includes sold and consumed dairy products Market prices for consumed amount are the average prices of all households of sold production
Gross Margin	$GM_i = Predicted\ GI_i - Empirical\ Variable\ Cost_i$ i:number of household
Empirical Variable Cost	$VC_i = (Hired\ Labor_i * Wage_i) + (Input\ Cost_i * Market\ Price_i)$ i:number of household
Empirical Fixed Costs	$FC_i = (Family\ Labor_i * Average\ Wage\ ) + Depreciation\ of\ Rudimentary\ Tools_i$ i:number of household The average Off-farm agricultural wage is used as average wage in fixed cost
Net Profit	$NP_i = GM_i$- FC_i i:number of household

Finally, we calculated the marginal effect of inputs on gross income. To calculate the marginal effect of each input, we used the average of the output and inputs in order to represent the average farm characteristics on arable crop and cattle production. Using the coefficients of the Cobb-Douglas production function and the average of the explanatory variables, we calculated the average gross income of the average farm. The marginal effect of land, labor and input expenses was calculated with the difference between the gross income of this mean farm, and the incorporation of one unit more of the input withj keeping all other inputs constant ("*ceteris paribus*").

3. Results

3.1. Personal, financial and social capitals

The sample consist of 85% "Mestizo" and 15% "Saraguro" (indigenous group) ethnic households. The average number of household members is the 4.1 (see Table 4), mean age is 29.5 years, 30.2 years for male and 28.6 years for female household members. The self-reported illiteracy rate in the region is 12.5%, and 7.7% for the household head. 36.5% of all individuals and 46.9% of household heads completed at least primary school. 3.7 % of all household members and 3.1% of the household heads completed secondary school.

In the sample, 88% of the households have off-farm income. The mean and median off-farm income per household are 227 and 122 USD/month respectively. The average off-farm income per member of the household is 55 USD/person/month. The average off-farm agricultural wage is 4.75 USD/day.

The most frequent source of off-farm income is the national social security payment “Bono de Desarrollo humano” (35%). The payment is a conditional cash subsidy of $ 30 per month per each very poor family. The payment can be received by people who are over 65 years old, disabled, or poor single mother. It is conditional because the beneficiaries must have vaccination certificates and certificates of study in the case of single mothers. Substantial of off-farm income also comes from off-farm work (17%), and owned merchant businesses (11%).

In reference to financial capital, 39% of the households had taken out formal credit. There is an informal credit market not covered because informal credit is illegal under Ecuadorian law. With respect to social capital, only 40% of the households take part in farmer organizations.

Table 4: Statistics of personal, financial and social capitals

Personal capital	**Average**	**Standard Deviation**	**Percent**
Number of household members	4.1	2.4	
Age of household members	29.5	21	
Off-farm income	227	288	
Off-farm income source:			
- “Bono Desarrollo Humano”			35
- Agricultural temporary work.			17
Ethnicity:			85
- “Mestizo”			15
- “Saraguro”			
Education level of the members of the household:			
- Without education			12.5
- Completed primary school			36.5
- Completed secondary school			3.7
Financial Capital			
Access to credit:			
- less on year	1425	985	
- more on year	4102	1770	
Interet rate to access to credit:			
- less on year	4.8	3.3	
- more on year	7.3	3.4	
Reason why farmers do not request formal credit:			
- - High interest rate			25
- - Expenses come agricultural			23
- - Adverse to loss their properties			17

Social capital			
Organization membership			44
Meeting attendance			40
Labor contribution to the farmer organization (man-days/yr)	8.2		
Money contribution farmer organization (USD/yr)	10		

3.2. Operational capital

Tenure and land use

Of the 175 farms[9] owned by 130 sampled households, 75% (132 farms) have a legal ownership title and 25% (43 farms) have not such title. Moreover, respondents reported that 76% of the farms were bought, 17% obtained by heritage, 4% obtained by donation, and only 1.1% obtained by forest cleaning. Furthermore, the respondents were asked: What is the value to rent one hectare of your farm? The mean value stated was 67 USD/month. The higher values were reported from the Sabanilla region. Sabanilla village is at rather low altitude close to the main road Loja-Zamora, where the farms are designated mainly to commercial milk production. Farmers have 40.4 ha land on average, the median is 23.4 ha. The minimum area reported is 1.7 ha and the maximum 260.6 ha. 28% of households have less than 10 ha and only 12% more than 80 ha (Figure 2).

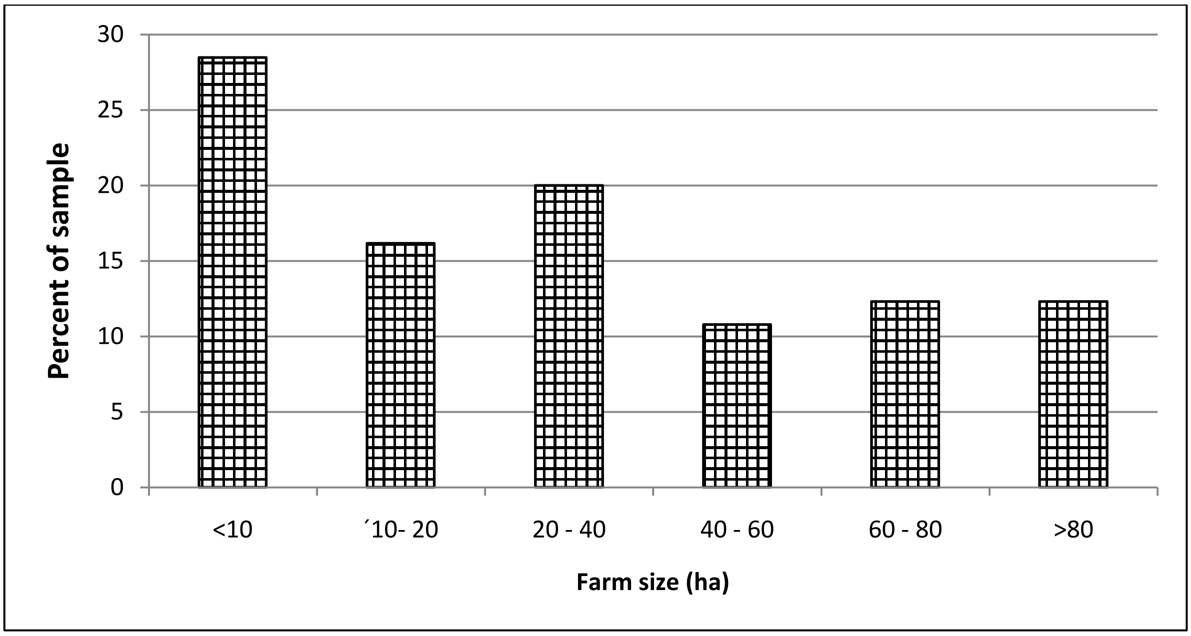

Figure 2: Distribution of farm size per household

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[9] Some households (n=130) have more one farm (175 farms). In some cases, the farms have different land tenure regimes.

In our sample, 54.0% (2820 ha) of the farm land surveyed is forest land, 45.3% (2398 ha) is pasture land. Arable crops only represent 0.6% of the area (Figure 3 and Table 5). Arable crop land use is dominated by an association of *Zea mays* and *Phaseolus vulgaris* (56.5%), which is used for subsistence purposes (see Table 5). The forest land is dominated by native forest 97.8% (2757 ha). There are a few plantations of exotics such as *Eucalyptus globulus* (0.2%) or *Pinnus patula* (0.2%). The pasture land is planted mainly to the grass species *Setaria sphacelata* "Mequerón" (53.2%) or *Sporobulus indicus* "Morocha" (20.1%). More than 12% of the pastures are stocked with at least some trees so that they could be called an agroforestry system (Bhagwat et al. 2008).

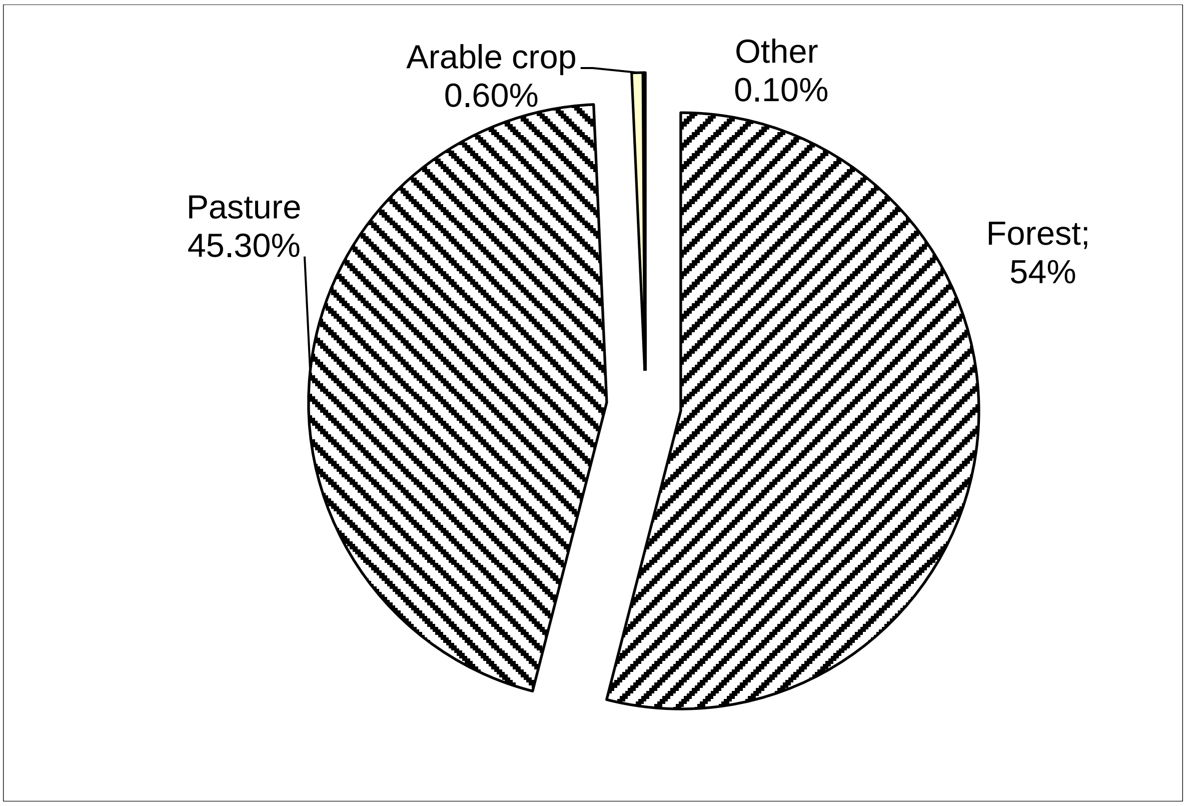

Figure 3: Land use distribution

Herd

The animal stocking in the research area is 0.37 Animal Units/ha (0.6 TLU/ha). This value is below the average of 1.4 AU/ha reported for dual-purpose cattle (milk and meat) production systems in Tropical America (Pearson de Vaccaro, 1986). In the herd structure (Figure 4), the predominant race is "Criolla" with 47%. The race "Holstein" (17.5%), is predominant in the "Sabanilla" region. Most cattle is over 3 years old (36%). 61% of the cattle is female.

Table 5: Land use distribution by category

Land use	Area (ha)	Percent
Arable crop		
Association *Zea mays* & *Phaseolus vulgaris*	17.33	56.5
Home garden	3.35	10.9
Zea mays	2.78	9.1
Musa sp.	2.63	8.6
Saccharum officinarum	2.60	8.5
Prunus sp.	0.90	2.9
Other crops	1.10	3.6
Total Area Arable crop	30.69	100.0
Forest		
Native Forest	2757.20	97.8
Natural regeneration	53.82	1.9
Forest plantation *Eucalyptus globules*	4.73	0.2
Forest plantation *Pinus patula*	4.70	0.2
Total Area Forest	2820.45	100.0
Pasture		
Setaria sphacelata	1275.90	53.2
Sporobulus indicus	481.36	20.1
Pasture associate with trees	296.28	12.4
Degraded pasture dominated by *Pteridium aquilinum* (bracken fern)	102.86	4.3
Melinis minutiflora	95.29	4.0
Holcus lanatus, Pennisetum clandestinum, Calamagrostis sp., *Tripsacum laxum,* other pastures	146.67	6.1
Total Area Pasture	2398.36	100.0
Other kind of land use (construction, road, camp)	7.54	100.0

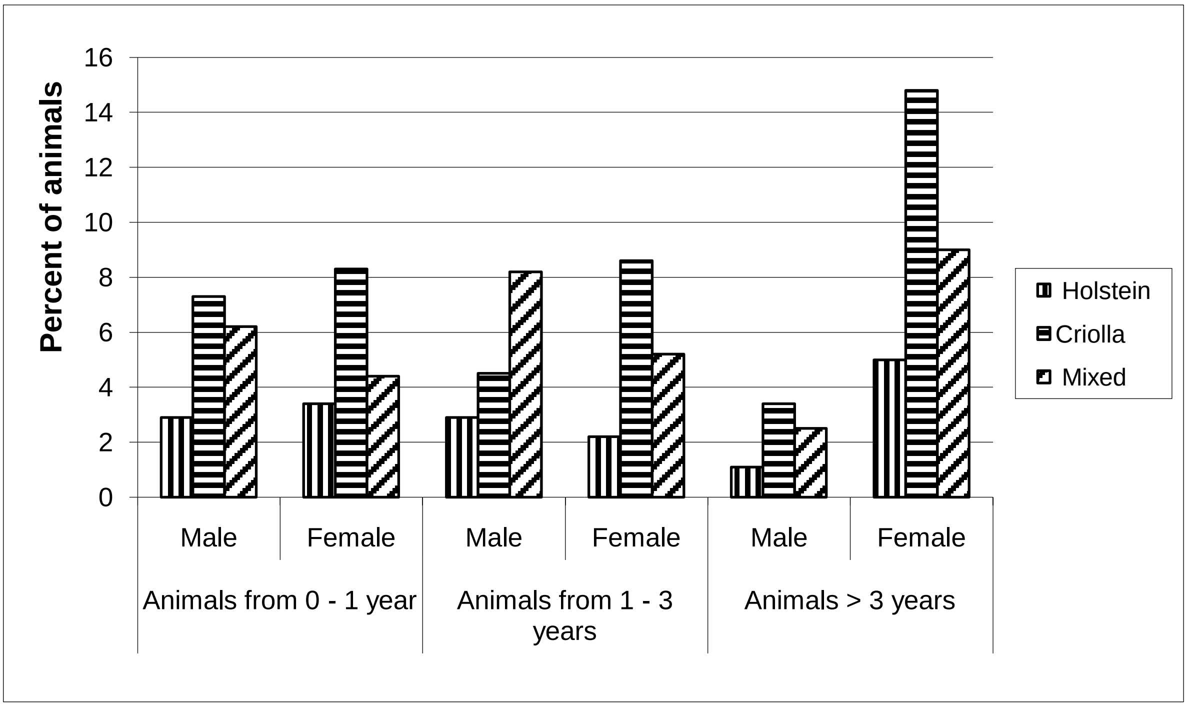

Figure 4: Herd structure per race, age and sex

3.4. Arable crop production function

The best production function obtained is has a Cobb-Douglas functional form with gross income as dependent variable (R^2: 0.94). With gross margin as the dependent variable, a R^2 of only 0.75 is achieved (for Translog results, see Annex 1). There are many negatives net-profit values. For these, it was not possible to estimate the production function as the logarithm could not be taken. The descriptive statistics of dependent and explanatory variables used to calculate the production function are shown in Table 6. The explanatory variables total arable of crop area and input expenses are significant $p<0.05$, total labour of arable crop $p=0.5$ (Table 7). Land, labour and input expenses have a positive effect in the gross income.

Table 6: Descriptive statistics of dependent and explanatory variables of farming households

Variable	Observ.	Mean	Std. Dev.	Min	Max
*Gross Income (USD/yr)	52	94.95	93.07	9.09	386.36
*Gross Margin (USD/yr)	52	39.62	47.59	2.00	274.09
*Net Profit (USD/yr)	52	-100.40	99.33	-399.24	4.84
Total Arable crop area (ha)	52	0.51	0.64	0.03	4.00
Total Labor (man-days/yr)	52	28.60	27.85	2.50	116.00
Input Expenses (USD/yr)	52	59.32	59.30	1.37	270.51
Total Area (ha)	52	29.25	32.20	1.52	139.34
Ratio arable crop area/Total Area	52	0.04	0.06	0.001	0.32
Ethnicity (1="Mestizo", 0="Saraguro")	52	0.81	0.40	0	1
Age of household head (year)	52	53.90	12.09	26	88
Years of schooling household head (year)	52	4.2	3.37	0	15
Total Off-farm household income (USD/yr)	52	2201.77	2920.38	0	12024
Technical Assistance (Dummy), yes =1	52	0.23	0.43	0	1
Household is part of Organization (Dummy), yes =1	52	0.50	0.50	0	1
Access to Credit (Dummy), yes =1	52	0.29	0.46	0	1
Log (Empirical Gross Income)	52	5.84	0.96	3.95	7.81
Log (Arable Crop Area)	52	-1.20	1.07	-3.61	1.39
Log (Total Labor)	52	2.91	0.98	0.92	4.75
Log (Input Expenses)	52	3.45	1.34	0.31	5.60

* The values of gross income, gross margin and net-profit are empirical values.

There is no multicollinearity problem (VIF 3.21<10). There is also no evidence of heteroskedasticity as the Breusch-Pagan/Cook-Weisberg test for linear heteroskedasticity does not reject the null hypothesis of constant error variance (prob>chi^2:0.99). The value of the regression constant is equivalent to 12.79 USD/yr (= log 2.548922). This does not have any substantial impact on gross income prediction (see also Annex 2 for the results of an alternative regression model without constant term).

Table 7: Arable crop production function[10]

Factor	Estimate of population	Std. Error	t value	P>|t|
Intercept	2.548922	0.275024	9.27	0.000
Logarithm Land	0.313634	0.062856	4.99	0.000
Logarithm Labor	0.044776	0.070789	0.63	0.530
Logarithm Input Expenses	0.519201	0.033529	15.48	0.000

SS Model: 47.8883999 (df:3)	Number of observ.: 52	R^2: 0.9434
SS Residual: 2.87243287 (df:48)	F(3, 48): 266.75	Adj R^2: 0.9399
SS Total: 50.7608327 (df: 51)	Prob > F: 0.0000	Root MSE :0.24463

Multicollinearity Test
Mean Variation Inflation Factors VIF independent variables: 3.21
Rule: VIF greater 10 generally seems as indicate of severe multicollinearity

Breusch-Pagan / Cook-Weisberg test for linear heteroskedasticity
Ho: Constant variance
chi^2(1) = 0.00
Prob > chi^2 = 0.9937 Result: no reject Ho: Constant variance

The predicted gross income for arable crops was used to calculate gross margins (subtracting original variable cost) and net profits (subtracting original fixed cost). The average of gross income for arable crop was 243 USD/ha/yr., gross margin 79 USD/ha/yr and net profit -276 USD/ha/yr (Table 8).

Table 8: Profitability of arable crop production function on USD/ha/yr, n=130

Variable	Mean	Standard Deviation
Gross Income Original	251.87	194.99
Gross Income Predicted	243.08	171.23
Gross Margin Original	88.19	42.29
Gross Margin Predicted (subtracted original variable cost)	79.41	38.12
Net Profit Original	-267.91	253.89
Net Profit Predicted (subtracted original fixed cost)	-276.70	262.59

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[10] The null hypothesis of constant return to scale is rejected $F_{calculated}$: 12.04 > $F (1.126)_{critical}$ = 4.04 at α= 0.05

3.5. Cattle production function

The best production function is a Cobb-Douglas production function. Translog results are reported in Annex 4. For the Cobb-Douglas production function with gross income as the dependent variable, $R^{2=}$0.68. For gross margin ($R^{2=}$0.62) and net profit ($R^{2=}$0.34) the values were lower. The coefficient of determination between original and predicted gross income is 0.49. The descriptive statistics used to calculate the Cobb-Douglas production function are shown in Table 9.

Table 9: Descriptive statistics of dependent and explanatory variables of farming households.

Variable	Obs	Mean	Std. Dev.	Min	Max
*Gross Income (USD/yr)	130	4687.84	5527.06	0	29579
*Gross Margin (USD/yr)	130	4236.92	5130.20	0	28210
*Net Profit (USD/yr)	130	3465.15	4914.10	0	27196
Total Pasture Area (ha)	130	18.34	17.06	0.81	82.81
Total Labor (man-days/yr)	130	159.46	96.84	19.40	647.50
Input Expenses (USD/yr)	130	341.95	607.94	2.50	4178.10
Log (Gross Income)	130	5.37	1.00	-2.30	7.05
Log (Pasture Area)	130	2.46	1.01	-0.21	4.42
Log (Total Labor)	130	4.89	0.63	2.97	6.47
Log (Input Expenses)	130	4.57	1.67	0.92	8.34
Locality (1 = high land, 0 = lowland)	130	0.73	0.45	0	1
Mequeron Pasture (Dummy)	130	0.46	0.50	0	1
Mequeron Pasture + Morocha Pasture (Dummy)	130	0.07	0.25	0	1
Agroforestry Pasture (Dummy)	130	0.07	0.25	0	1
Other kind of Pastures (Dummy)	130	0.12	0.33	0	1
Morocha Pasture (%)	130	30.41	37.32	0.00	100.00
Mequerón Pasture (%)	130	44.58	37.91	0.00	100.00
Agroforestry Pasture (%)	130	9.88	22.80	0.00	100.00
Degraded Pasture (%)	130	5.24	11.81	0.00	86.50
Melinis Pasture (%)	130	3.12	10.49	0.00	74.70
Pennisetum Pasture (%)	130	2.61	11.82	0.00	100.00
Other kind of Pastures (%)	130	4.17	13.56	-0.40	76.10
**Mean Altitude of pasture (m a.s.l.)	130	1996	263	1261	2668
**Minimum Altitude of pasture (m a.s.l.)	130	1800	252	1080	2360
**Maximum Altitude of pasture (m a.s.l.)	130	2190	301	1469	2880
Total Area of farm (ha)	130	40.37	44.99	1.52	260
Stocking rate animals (Tropical Livestock Units)	130	9.06	9.19	0.60	50.26
Animal Units/Total Area	130	0.18	0.10	0.01	0.47
Ethnicity (1="Mestizo", 0="Saraguro")	130	0.85	0.36	0	1
Age of Head-household between (year)	130	52.32	13.73	23	88
Years of schooling household head (year)	130	5.51	3.91	0	18
Total Off-farm Household (USD/yr.)	130	2723.69	3468.07	0	19800
Technical Asisstance (Dummy)	130	0.22	0.41	0	1

Household is part of Organization (Dummy)	130	0.42	0.49	0	1
Access to Credit (Dummy)	130	0.39	0.49	0	1
***Minimun Cost Distance	130	1013	2046	0	9550
***Maximun Cost Distance	130	21520	22205	1531	102541
***Mean Cost Distance	130	9418	7917	681	37732

* Based on empirically sample
** Source: IGM 2003
*** Source: Eichhorn 2009

The cattle production function shows a significant relationship between Gross Income and the explanatory variables Total Pasture Area, Total Labor Cattle, Input Expenses Cattle, Minimum Altitude Pasture at $p<0.05$ (Table 10). As expected, land, labor, and input expenses have a positive impact on gross income. Most labor resources came from family labor (78%).

Table 10: Cattle production function[11]

Factor	Estimate of population	Std. Error	t value	P>|t|
Intercept	2.783633	0.8183377	3.40	0.001
Logarithm Land	0.3244224	0.0951863	3.41	0.001
Logarithm Labor	0.9306134	0.1374796	6.77	0.000
Logarithm Input Expenses	0.2174619	0.0549089	3.96	0.000
Minimum altitude	-0.0010468	0.0003115	-3.36	0.001
Ethnicity	0.4829716	0.2054597	2.35	0.020
Technical assistance	0.3541327	0.1825619	1.94	0.055
Access to Credit	0.2579407	0.1491435	1.73	0.086

SS Model: 168.744801 (df: 7)	Numb. of observ.: 130	R^2: 0.6814
SS Residual:78.9144844 (df: 122)	F(7, 122): 37.37	Adj R^2:0.6631
SS Total: 247.659286 (df: 129)	Prob > F : 0.0000	Root MSE: 0.80426

Multicollinearity Test
Mean Variation Inflation Factors VIF independent variables: 1.36
Rule: VIF greater 10 are generally seem as indicate of severe multicollinearity

Breusch-Pagan / Cook-Weisberg test for linear heteroskedasticity
Ho: Constant variance
$chi^2(1) = 171.36$
Prob > chi^2 = 0.0000 Result: reject Ho: Constant variance

Dealing Heteroskedasticity with Robust Standard Error

Factor	Robust Estimate	Robust Std. Error	t value	P>|t|
Intercept	2.783633	1.119741	2.49	0.014
Log (Land)	0.3244224	0.0603147	5.38	0.000
Log (Labor)	0.9306134	0.2997896	3.10	0.002
Log (Input Expenses)	0.2174619	0.0367893	5.91	0.000
Minimum altitude	-0.0010468	0.0004137	-2.53	0.013
Ethnicity	0.4829716	0.3374781	1.43	0.155
Technical assistance	0.3541327	0.2061023	1.72	0.088

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[11] The null hypothesis of constant return to scale is rejected $F_{calculate}$: 19,9 > $F(1,126)_{critical}$ = 3,9 at α 0.05

Access to credit	0.2579407	0.1695159	1.52	0.131

Number of obs.: 130 R^2: 0.6814

F(7, 122): 33.78 Prob > F: 0.0000 Root MSE: 0.80426

Altitude has a negative impact on gross income. It means that farmers located in the lower region “Sabanilla region” are more productive in comparison with farmers located in higher altitudes. This interpretation agrees with a “Local” dummy variable that was also tested but turned to be out to be less significant. The variable “ethnicity” shows a positive impact on gross income. It means there are differences in the production between “Mestizos” and “Saraguros”. A farm owned by “Mestizo” has a higher gross income. Farmers with access to technical assistance have higher production on average. Finally, access to formal credit also has a positive impact on production.

In reference to the value of the intercept, it is equivalent to 16.18 USD/ha/yr (= log 2.783633) which does not have big impact on gross income prediction. A regression model without a constant term is reported in Annex 5.

The predicted gross income of each single household was used to calculate the gross margins and net profits per hectare (Figure 5). The average of predicted gross income is 269 USD/ha/yr, the gross margin is 245 USD/ha/yr and the net profit is 160 USD/ha/yr.

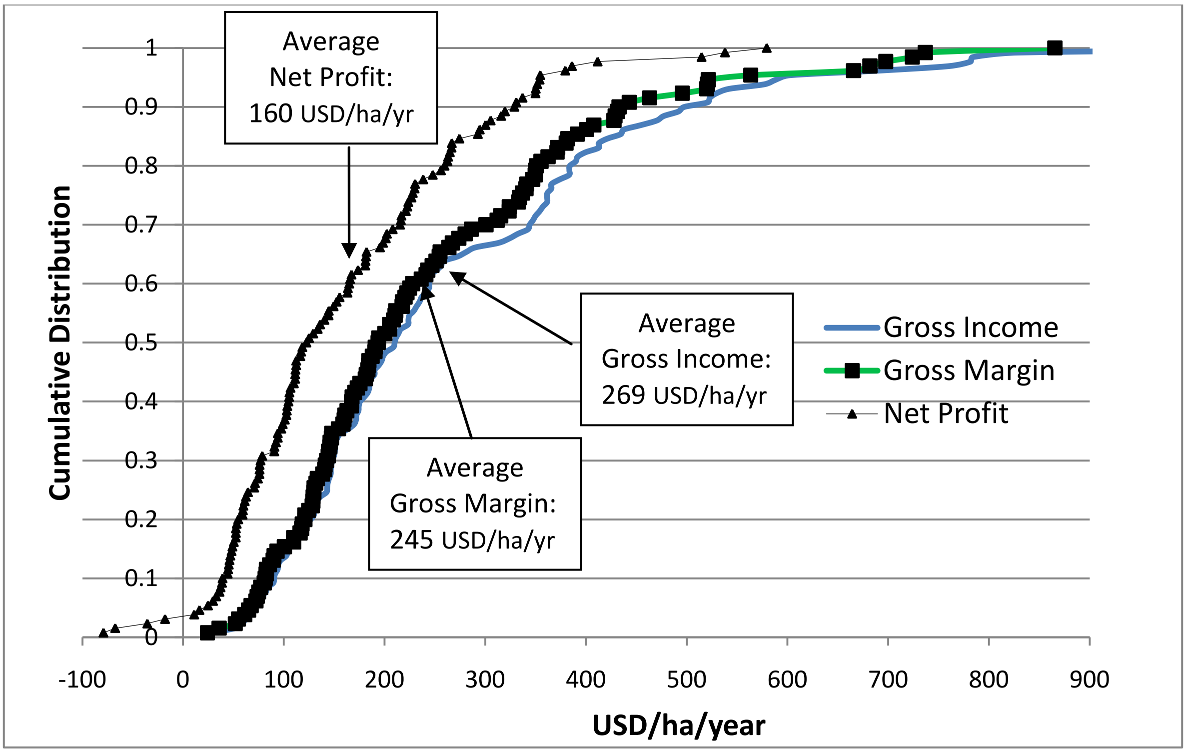

Figure 5: Gross income, gross margin and net profit of cattle production (n=130)

4. Discussion

Studies about profitability of agricultural production are given by Wunder (2000) for the Ecuadorian Andes, and by Knoke et al. (2009) for the local research area. There is a gap of the information about of heterogeneity of farm agricultural profitability, however. In this study, we fill this gap information. We analyze the profitability of local arable crops and cattle production systems.

Given the restricted resources of the study, the snowball sampling approach used has likely performed better than a random sampling approach. Peasant households in the research area tended to exaggerate or understate their farm or production characteristics as a strategy of "personal protection" potentially leading to substantial strategic bias. In this sense, the snowball approach reduces strategic bias likely to be present when sensitivity information or financial information was to be disclosed. Still, statistical representativeness cannot be claimed for the sample. The non-random sampling requires that descriptive statistic presented needs to be treated with caution. Likewise, the representation of cattle income as a function of growth increments and sales of cattle, will need refinements that potentially affect the conclusions presented.

The arable crop production represents 3.9% of the total household income and it is less profitable (-276 USD/ha/yr) on average than cattle production (160 USD/ha/yr). Arable crops are restricted to small plots near to houses mainly for auto-consumption. In other side, pasture-based production accounts for 70.4% of total household income.

Family labour has a strong influence on profitability of arable crop and cattle production. The net profit calculations are reduced drastically when family labour valued at actual agricultural wage rates are included as fixed costs. The gross margin in arable crop switches from 79 USD/ha/yr to -276 USD/ha/yr. The gross margin in cattle switches from 245 USD/ha/yr to 160 USD/ha/yr. As a consequence, some negative values on net profit of cattle production show up. The wage rate applied may have been too high as farmers actually report difficulties in finding off-farm employment.

Our results show that cattle production is the more profitable land use. But it also has a substantial heterogeneity in the net profits. The average cattle ranching net profit is 160

USD/ha/yr. This value is lower than net profit of 208 USD/ha/yr (adjusted for inflation[12]) reported by Wunder[13] (2000) for Ecuadorian Andes. Our values differ from values reported by Wunder (2000) because Wunder values are base on information given by experts in the field. Also, our value (160 USD/ha/yr) is higher than the ~100 USD/ha/yr net profit reported by Knoke[14] et al. (2009) for research area. Our values may differ from values reported by Knoke et al. (2000) because Knoke et al. have a smaller sample, and have used a different algorithm to calculate income.

Our main contribution is to show the huge heterogeneity present in our sample. For instance, 70 USD/ha/yr (percentile 25), 123 USD/ha/yr (percentile 50) and 227 USD/ha/yr (percentile 75). The heterogeneity of profitability of cattle production has biodiversity policy implications, for example in the distributional impacts and efficiency of payments for forest conservation (Details in chapter III) or alternative conservation measures (Wunder 2005).

The cattle production analysis suggests that several factors influence profitability. Cobb-Douglas production function determined significant factors that affect gross income which directly affects profitability. A farmer who lives in lowlands, is of “Mestizo” ethnic, has access to technical assistance and credit has higher gross margin than a farmer who lives in uplands, is of “Saraguro” ethnic, and without access to technical assistance and credit. One reason for differences on profitability may be that the “Mestizos” are more connected with the local markets in Loja and Zamora cities. On the contrary, the ethnic group “Saraguros” is located far from local markets.

One hectare more arable crop land increases gross income by 148.6 USD/yr. Because of the problematic terrain, a substantial extension of arable agriculture may not be possible. One man-day more of labor increases gross income by 0.38 USD/yr. The marginal effect of labor is less that average wage (4 USD/day) reported for our sample. It means that there is too much labor available for arable crop production. One USD/yr of input expenses increases gross income by 2.12 USD/yr. It means that the investment on inputs appears very low.

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[12] The value was adjusted with the formula: Future amount = Present value * (1+ % inflation) ^ number of years. The reference adjusted value is for 2007 (Annex 7). The survey was conducted at the beginning of 2008 and the data information corresponds to 2007. Ecuador adopted the dollar as official currency since 2000.

[13] Wunder (2000) reports 125 USD/ha/year for cattle ranching, at 5% discount rate, in the fourth year of deforestation cycle. It is not explicit how was valued the labor.

[14] It is not explicit how was valued and incorporated the labor.

Marginal effect of one hectare more of pasture land is an increase in gross income by 4.75 USD/yr. This is much less than for arable land. One man-day more of labor increases gross income by 1.56 USD/yr. The marginal effect of labor is still less that the average wage rate paid (4 USD/day) for our sample – but it is much higher than compared to arable agriculture. One USD/yr of input expenses only increases gross income by 0.17 USD/yr. This means that the investment in cash inputs may already be high given the principle constraints of the current production technology.

In the face of severe nature conservation concerns in the area coinciding with severe poverty, it is a challenge to improve the profitability of local peasant households per hectare (intensification). Contrary to the ideas expressed by Adams (2009) who argues for an intensification of the land use system, our results indicate only limited room for successful intensification with the current production technologies. The relatively best results may be achieved if some of the pasture land could be converted to arable agriculture without inducing additional resource conservation concerns. Also a higher cash investment into arable agriculture appears promising with rate of return potentially in excess of 100% p.a. Furthermore, access to technical assistance and to formal credit may improve cattle production. Using robust standard errors, the significance of predictors is closer to and in excess of 0.1 that below 0.05, however.

5. Conclusion

In spite of the two caveats on statistical representativeness and more detailed analyses needed on the representation of cattle income as a function of growth increments and sales of cattle, it is save to say that pasture-based cattle production is a profitable land use in the research area with huge heterogeneity present among the households. The heterogeneity of profitability has biodiversity policy implications with the implementation of conservation instruments in terms of the efficiency and distributive impacts. Our results suggest that the average net profit of cattle production is 160 USD/ha/yr. Factors that influence the gross margin and consequently the profitability on cattle production are land size, labor, input expenses, ethnicity, altitude and access to technical assistance and formal credit. While agricultural intensification in the face of serious conservation and poverty concerns has been suggested to be of high priority, our results indicate only limited scope for short-term improvements in this regard.

References

Adams M. 2009. Pasture Extensification in the Southern Ecuadorian Andes: Appraisal and Recommendations, Journal of Sustainable Forestry 28(6):866 - 887.

Azzoni C., Isai J. 1994. Estimating the cost of environmental protection in Brazil. Ecological Economics 11(2):127 -133.

Barrera V., Grijalva J., León C. 2004. Mejoramiento de los sistemas de producción de leche en la ecorregión andina del Ecuador. Arch. Latinoam. Producción Animal. 12(2):43-51.

Barthlott W., Lauer W., Placke A. 1996. Global distribution of species diversity in vascular plants: towards a world map of phytodiversity. Erdkunde 50:317- 327.

Bawa K., Seidler R. 1998. Natural forest management and conservation of biodiversity in tropical forests. Conservation Biology 12:46–55.

Beck E. 2008. Preface. In: Beck, E.; Bendix, J.; Kottke, I.; Makeschin, F. and Mosandl, R.: Gradients in a tropical mountain ecosystem of Ecuador. Ecological Studies 198:5-7.

Beck E., Makeschin F., Haubrich F., Richter M., Bendix J., Valarezo C. 2008a. The Ecosystem (Reserva Biológica San Francisco). In: E. Beck, J. Bendix, I. Kottke, F. Makeschin, R. Mosandl (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:1-14.

Beck E., Hartig K., Roos K. 2008b. Forest clearing by slash and burn. In: E. Beck, J. Bendix, I. Kottke, F. Makeschin, R. Mosandl (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:371-374.

Benhin J. 2006. Agriculture and deforestation in the Tropics: A Critical Theoretical and Empirical Review. Ambio 35:9-16.

Bode M., Watson J., Iwamura T., Possingham H. 2008. The cost of conservation. Science 321:340.

Bhagwat S., Willis K., Birks H, Whittaker R. 2008. Agroforestry: a refuge for tropical biodiversity? Trends in Ecology & Evolution 23(5):261-267

Brehm G. 2005. A revision of the Acrotomodes clota Druce, 1900 species-group (Lepidoptera: Geometridae, Ennominae). Entomologische Zeitschrift, 115:75–80.

Brehm G., Fiedler K., Häuser C., Dalitz H. 2008. Methodological challenges of a Megadiversity ecosystem. In: E. Beck, J. Bendix, I. Kottke, F. Makeschin, R. Mosandl (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:37-40.

Brooks T., Mittermeier R., Mittermeier C., Da Fonseca G., Rylands A., Konstant W., Flick P., Pilgrim J., Oldfield S., Magin G., Hilton-Taylor C. 2002. Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16:909–923

Bockstael N., Freeman M. 2005 Pages 58-539 in Mäler K. and Vicent J. Editors. Handbook of environmental economics. Volumen 2. Elsevier, Amsterdam, Netherlands.

Brummitt N., Lughadha E. 2003. Biodiversity: Where's Hot and Where's Not. Conservation.Biology 17(55): 442-1448.

Bryan B., King D., Ward J. 2009. Modelling and mapping agricultural opportunity cost to guide landscape planning for natural resources management. Ecological indicators Ecological Indicators doi:DOI: 10.1016/j.ecolind.2009.02.005.

Carson R., Hanemann M. 2005. Contingent Valuation. in Mäler K. and Vicent J. Editors. Handbook of environmental economics 2:821-936.

Carwardine J. Wilson K., Ceballos G., Ehrlich P., Naidoo R., Iwamura T., Hajkowicz S., Possingham. 2008. Cost-effective priorities for global mammal conservation. PNAS 105 (32):11446 – 11450.

Chazdon R. 1998. Tropical forests – log ‘em or leave ‘em? Science 281:1295–1296

Chomitz K., Alger K., Thomas T., Orlando H., Nova P. 2005. Opportunity costs of conservation in a biodiversity hotspot: the case of southern Bahia. Environment and Development Economics 10:293–312.

Coelli T., Rao D., O'Donnell C, Battese G. 2005. An introduction to efficiency and productivity analysis. Second Edition. Springer, New York, USA.

CIPRB (Comisión Interinstitucional Pro Reserva de Biosfera). 2005. Reserva de biósfera Podocarpus – El Cóndor, Loja-Ecuador 145 p.

Costanza R, d'Arge R, de Groot R, et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253–60.

Diewert W. 1971. An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function." Journal of Political Economy 79(3): 481-507.

Engel S., Wünscher T., Wunder S. 2009. Increasing the efficiency of forest conservation: In Palmer, C and Engel, S. (eds). The case of payments for environmental services in Costa Rica in Avoided deforestation 208-216. Routledge.

FAO. 2006. Global forest resources assessment 2005. Progress towards sustainable forest management. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2007. The State of Food and Agriculture. Paying farmers for environmental services. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fiedler K., Beck E. 2008. Investigating gradients in ecosystem analysis. In: E. Beck, J. Bendix, I. Kottke, F. Makeschin, R. Mosandl (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies 198:49-54.

IGM (Instituto Geográfico Militar del Ecuador). 2003. Aerial photographs, scale 1:5000 resolution pixel 1m, pancromaticas, Proyection UTM, DATUM WGS84 Zone 17S.

Kaimowitz D., Angelsen A. 2008. Will Livestock Intensification Help Save Latin America's Tropical Forests?, Journal of Sustainable Forestry, 27 (1): 6-24.

Kelsey J., Leimona B., Ferraro P. 2008. A Revealed preference approach to estimating supply curves for ecosystem services: Use of auctions to set payments for soil erosion control in Indonesia. Conservation Biology, 23 (2): 359 – 367.

Kohler U., Kreuter F. 2005. Data analysis using Stata. Stata Corp LP, USA.

Knoke T., Calvas B., Aguirre N., Roman-Cuesta R.M., Günter S., Stimm B., Weber M., Mosandl R. 2009. Can tropical farmers reconcile subsistence demands with forest conservation?. Frontiers in Ecology and the Environment 7(10): 548-554.

Maza B., Barkmann J., von Walter F., Maggraf R. 2010a. Modelling smallholders production and agricultural income in the area of the Biosphere reserve "Podocarpus – El Cóndor", Ecuador. Internal Discussion paper. Department of Agricultural Economics, Georg-August Universität Göttingen. No. 1009.

Maza B., Barkmann J., von Walter F., Marggraf. 2010b. Efficiency and Distributional impacts of protected area planning using PES schemes in the Biosphere Reserve "Podocarpus-El Cóndor", Ecuador. (Chapter IV).

Maza B., Ogundari K., Barkmann J., Marggraf R 2010c. Technical efficiency of pasture-based agricultural production by indigenous and non-indigenous smallholders in the buffer zone of Podocapus National Park, Ecuador. The journal for submission is Journal of Social and Economical Development. (Chapter III).

Miller R., Nair P. 2006. Indigenous agroforestry systems in Amazonia: from prehistory to today. Agroforestry Systems 66:151–164.

Meyers N., Mittermeier R., Mittermeier C., Da Fonseca G., Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

Mosandl R., Günter S., Stimm B., Weber M. 2008. Ecuador suffers the highest deforestation rate In: E. Beck, J. Bendix, I. Kottke, F. Makeschin, R. Mosandl (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador: Ecological Studies, 198:37-40.

Naidoo R., Adamowicz W. 2005. Modelling opportunity cost of conservation in transitional landscapes. Conservation Biology 20 (2):490-500.

Naidoo R., Balmford A., Ferraro P., Polasky S., Ricketts T., Rouget M. 2006. Integrating economic cost into conservation planning. Trends in Ecology and Evolution 21(12): 681–687.

Nicholson W. 1998. Microeconomic theory. Basic principles and extensions. Seventh Edition. Harcourt Brace College Publishers, USA.

O'Connell M., Young J. 2002. The Role of saltland pastures in the farming system – A whole – Far, Bio-Economic Analysis.

Pohle P., Gerique A. 2006. Traditional ecological knowledge and biodiversity management in the Andes of southern Ecuador. Geographica Helvetica 61(4): 275-285.

Pohle P. 2008. The people settled around Podocarpus National Park. In: Beck, Erwin; Bendix, Jörg; Kottke, Ingrid; Makeschin, Franz; Mosandl, Reinhard (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador. Ecological Studies 198:25-36.

Pohle P., Gerique A. 2008. Sustainable and Non Sustainable Use of Natural Resources by Indigenous and Local Communities. In: Beck, Erwin; Bendix, Jörg; Kottke, Ingrid; Makeschin, Franz; Mosandl, Reinhard (eds.): Gradients in a Tropical Mountain Ecosystem of Ecuador. Ecological Studies 198:347-362.

Pohle P., Gerique A., Park M., Lopez Sandoval M. 2009. Human ecological dimensions in sustainable utilization and conservation of tropical mountain forests under global change in southern Ecuador. In: Tscharntke, T., Leuschner, C., Veldkamp, E., Faust, H., Guhardja, E., Bidin, A. (eds.): Tropical rainforests and agroforests under global change, Springer, Berlin. 198:477-505.

Socio Bosque. 2010. Socio Bosque: Primer Año de implementación 2008-2009. Quito, Ecuador.

Svenning J. 1998. The effect of land-use on the local distribution of palm species in an Andean rain forest fragment in northwestern Ecuador. Biodiversity and Conservation 7:1529-1537

Torracchi S., Tapia M., Valdivieso M. (without year). Spatial and temporal analysis of vegetation from Zamora´s basin. Universidad Tecnica Particular de Loja; power point presentation cited in Knoke T., Weber M., Barkmann J., Pohle P., Calvas B., Medina C., Aguirre N., Günter S., Stimm B., Mosandl R., von Walter F., Maza B., Gerique A. 2009a. Effectiveness and Distributional Impacts of Payments For Reduced Carbon Emissions From Deforestation. 63(4):365–384.

UNL (Universidad Nacional de Loja). 2005. Estado de conservación de áreas protegidas y bosques protectores de Loja y Zamora Chinchipe y perspectivas de intervención. CINFA, Herbario Reinaldo Espinosa. Loja, Ecuador.

Van Houtert M., Sykes A. 1999. Martin F. J. 1999. Enhancing the profitability of pasture-based dairy production in the humid tropics through improved nutrition. Preventive Veterinary Medicine. 38 (2-3):147-157.

Wooldridge J. 2006. Introductory Econometrics: A modern approach. Second Edition. South-Western. USA.

Wunder S. 1996. Los caminos de la madera. Probona-Programa Regional De Bosques Nativos Andinos. Quito, Ecuador.

Wunder S. 2000. The economics of deforestation: the example of Ecuador. St. Martin, New York.

Wunder S. 2005. Payments for Ecosystem services: Some nuts and bolts. CIFOR. Ocasional Paper No. 42. Jakarta 10065, Indonesia.

Wunder S. 2007. The efficiency of payments for environmental services in tropical conservation. Conservation Biology 21:48–58.

Zeller M., Schwarze S. 2006. Submodule: Planning methods for agricultural development. Göttingen Germany

Annex

Annex 1: Translog production function of arable crop production

Source	SS	df	MS	Number of obs = 52
Model	48.7712082	9	5.41902313	F(9, 42) = 114.39
Residual	1.98962458	42	0.047372014	Prob > F = 0.0000
Total	50.7608327	51	0.995310446	R^2 = 0.9608
				Adj R^2 = 0.9524
				Root MSE = 0.21765

lnYinc	Coef.	Std. Err.	T	P>|t|
Log (Land)	1.150176	0.5584907	2.06	0.046
Log (Land* Land)	0.0932267	0.0626022	1.49	0.144
Log (Labor)	-0.102593	0.6777332	-0.15	0.880
Log (Labor*Labor)	0.0282609	0.0966063	0.29	0.771
Log (Input Expenses)	-0.3281227	0.3117892	-1.05	0.299
Log (Input Expenses* Input Expenses)	0.1118358	0.0377375	2.96	0.005
Log (Land*Labor)	-0.0248112	0.1281381	-0.19	0.847
Log (Land* Input Expenses)	-0.1507898	0.0750093	-2.01	0.051
Log (Labor* Input Expenses)	-0.0142654	0.0690254	-0.21	0.837
Cons	4.46646	1.332177	3.35	0.002

Multicollinearity Test
Mean Variation Inflation Factors VIF independent variables: 215.10
Rule: VIF greater 10 are generally seem as indicate of severe multicollinearity

Breusch-Pagan / Cook-Weisberg test for linear heteroskedasticity
Ho: Constant variance
chi^2(1) = 1.22
Prob > chi^2 = 0.2698 Result: no-reject Ho: Constant variance

Annex 2: Cobb-Douglas production function of arable crop production, no-constant

Source	SS	df	MS	Number of obs = 52
Model	915.209161	3	305.06972	F(3, 49) = 1865.60
Residual	8.01263966	49	0.163523258	Prob > F = 0.0000
Total	923.221801	52	17.7542654	R^2 = 0.9913
				Adj R^2 = 0.9908
				Root MSE = 0.40438

lnYinc	Coef.	Std. Err.	t	P>|t|
Log (Land)	-0.2185276	0.0422711	-5.17	0.000
Log (Labor)	0.5961288	0.0634236	9.40	0.000
Log (Input Expenses)	0.5968248	0.0536694	11.12	0.000

Annex 3: Profitability of arable crop production function on USD/ha/yr, n=130

Variable	Mean	Standard Deviation
Gross Income Original	251.87	194.99
Gross Income Predicted	243.08	171.23
Gross Margin Original	88.19	42.29
Gross Margin Predicted	79.41	38.12
Net Profit Original	-267.91	253.89
Net Profit Predicted	-276.70	262.59

Annex 4: Translog production function of cattle production

Source	SS	df	MS	Number of obs = 130
Model	187.473718	13	14.4210601	F(13, 116) = 27.79
Residual	60.1855049	116	0.51884056	Prob > F = 0.0000
Total	247.659286	129	1.91983943	R^2 = 0.7570
				Adj R^2 = 0.7277
				Root MSE = 0.7203

lnYinc	Coef.	Std. Err.	t	P>|t|
Log (Land)	-1.137849	0.8454288	-1.35	0.181
Log (Land * Land)	-0.0532652	0.0895247	-0.59	0.553
Log (Labor)	7.160135	1.364678	5.25	0.000
Log (Labor * Labor)	-0.6773137	0.1653561	-4.10	0.000
Log (Input Expenses)	1.716794	0.5008759	3.43	0.001
Log (Input Expenses * Input Expenses)	-0.0633378	0.0324923	-1.95	0.054
Log (Land * Labor)	0.3858954	0.2013116	1.92	0.058
Log (Land * Input Expenses)	-0.0295603	0.0753097	-0.39	0.695
Log (Labor * Input Expenses)	-0.1650532	0.1199973	-1.38	0.172
Minimum altitude	-0.0010858	0.0003081	-3.52	0.001
Ethnicity	0.5810878	0.19044	3.05	0.003
Technical assistance	0.3120468	0.1646701	1.89	0.061
Access to credit	0.2096489	0.1357097	1.54	0.125
Cons.	-13.22283	3.234814	-4.09	0.000

Multicollinearity Test
Mean Variation Inflation Factors VIF independent variables: 129.32
Rule: VIF greater 10 are generally seem as indicate of severe multicollinearity

Breusch-Pagan / Cook-Weisberg test for linear heteroskedasticity
Ho: Constant variance
chi^2(1) = 148.63 Prob > chi^2 = 0.0000 Result: reject Ho: Constant variance

Annex 5: Cobb-Douglas production function of cattle production, no-constant

Source	SS	df	MS	Number of obs = 130
Model	8131.25346	7	1161.60764	F(7, 123) = 1653.70
Residual	86.3988648	123	0.702429795	Prob > F = 0.0000
Total	8217.65233	130	63.2127102	R^2 = 0.9895
				Adj R^2 = 0.9889
				Root MSE = 0.8381

lnYinc	Coef.	Std. Err.	T	P>|t|
Log (Land)	0.330193	0.0991764	3.33	0.001
Log (Labor)	1.175509	0.1220502	9.36	0.000
Log (Input Expenses)	0.251016	0.0562888	4.46	0.000
Minimum altitude	-0.000350	0.0002446	-1.43	0.155
Ethnicity	0.611408	0.2104598	2.91	0.004
Technical assistance	0.453236	0.1878068	2.41	0.017
Access to credit	0.292064	0.1550682	1.88	0.062

Annex 6: Profitability of cattle production function on USD/ha/yr, n=130

Variable	Mean	Standard Deviation
Gross Income Original	289.25	197.13
Gross Income Predicted	269.17	193.08
Gross Margin Original	265.71	179.01
Gross Margin Predicted	245.69	166.35
Net Profit Original	181.47	150.99
Net Profit Predicted	160.10	124.76

Annex 7. Annual inflation of Ecuador

Year	Annual inflation of Ecuador in %*	Index =100	Net Profit adjusted to inflation (USD/ha/yr)
2000	96.1	196.1	125**
2001	22.4	240.0	153
2002	9.7	263.3	168
2003	9.35	287.9	184
2004	1.95	293.5	187
2005	4.36	306.3	195
2006	3.11	315.9	201
2007	3.32	326.4	208
2008	8.83	355.2	226
2009	4.31	370.5	236
09.2010	3.44	383.2	244

*Source: Banco Central del Ecuador

**Wunder (2000) reports 125 USD/ha/year for cattle ranching in the fourth year of the deforestation cycle, at 5% discount rate

Annex 8. Maginal effects of inputs on gross margin

Input	Agriculture (USD/yr)	Cattle (USD/yr)
Land	148.602	4.759
Labor	0.381	1.570
Input expenses	2.128	0.171

Chapter III

Determinants of the technical efficiency of cattle production in the Biosphere Reserve "Podocarpus-El Cóndor", Ecuador.

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Abstract

Technical efficiency analysis helps to identify policy options for improving rural agricultural livelihoods and, them, may helps to alleviate production conservations conflicts. This paper investigates determinants of the technical efficiency in the Biosphere Reserve "Podocarpus-El Cóndor", South Ecuadorian. The study employs data from 130 farming households obtained by survey carried out in the 2008 farming season. The study employs stochastic frontier production model of pasture-based cattle and dairy production. Our findings reveal that output increased monotonically with size of pasture (p=0.0179), labor (p=0.0001), and costs of input (p=0.0153). An average technical efficiency of about 70% was achieved by local farmers. Technical efficiency was higher for lowland than for upland farms. Lowland farms are more frequently owned by members of the "Mestizo" ethnic group. Upland has high presence of "Saraguro" farms, often receive technical assistance. The policy implication from the findings suggests that the output of cattle production could be increased by 30% provision of technical assistance to the farmers.

1. Introduction

Cattle production is an important sector of the Ecuadorian agricultural economy. According to the last National Agricultural Census (2000) statistics, there are 427,514 production units in the country with a total of 4,486,020 animals. The cattle production sector in Ecuador is characterized by an extensive dual-purpose cattle system of meat (cattle fattening) and milk (dairy) production (National Agricultural Census 2000).

The technological level of cattle production in Ecuador is yet to be increased. In a representative sample of four provinces from the country quoted by Paredes (2009), it is obvious that 86.5% of the production units operate under a traditional or low technology system, 10.1% with intermediate technology and 3.4% by modern technology.

The increase in cattle production in Ecuador has been be associated with the increase in the associated factor inputs such as pasture area, animals, and labor usage, the productivity of cattle production in the selected study area is far below the average national value across most of the regions in the country (Paredes 2009). For example, the average national level of the milk production is about 4.5 liter per cow-day (Paredes 2009).

Zamora (2009) identified several problems related to the pastures and cattle production units in Ecuador. According to the author, the priority problems of pasture management include the following: *i*) genetic material of pasture producing low protein fodder, *ii*) poor agronomic management pastures, *iii*) slow adoption and diffusion of technological improvements. Also the author identified the main problems of priority in cattle production as: *i*) inadequate use of bovine races, *ii*) high prices of veterinary supply, *iii*) poor cattle management, and *iv*) lack of value added to the final product.

In this paper, we investigate determinants of the technical efficiency in Cattle production in the south of Ecuador. The frontier efficiency analysis represents a best practice technology against which the efficiency of production units can be measured producing a production model (Battese, 1992). To the best of our knowledge there is only one study (Bailey et al. 1989) that has investigated technical efficiency in Ecuadorian dairy farm. Bailey et al. (1989) did not the determinants in cattle production. In face of the strategic role of the

Ecuadorian cattle sector as well as its conservation implications, there is more empirical studies are clearly called for.

At Latin American level, studies focus in determining the technical efficiency on farms with high technological level (machinery). Moreira and Bravo (2009) on the meta-analysis of 5 studies with a focus on the technical efficiency of dairy farms in the Latin America determine on 73.2% the average of technical efficiency of the farms. Moreira (2006) in his study of technical efficiency of dairy farms, he found technical efficiency of 87.0%, 84.9%, and 81.1% for Argentina, Chile and Uruguay respectively. Also, Bravo et al. (2007) on the meta-analysis determine 77.9% the technical average efficiency of agricultural sector in the Latin America.

The remaining part of the paper proceeds as follows. Section 2 reviews efficiency measurement techniques. Section 3 describes the methodology including a description of the study area, the sampling technique as well as the variables specifications. Results are presented and discussed in section 4 while section 5 offers concluding remarks and policy implications from the findings.

2. Review of efficiency measurement techniques

Since Farrell's (1957) seminal paper on the measurement of efficiency, there has been a growing interest in the methodology and its applications to real life situations (Thiam et al. 2001). Farrell introduced a method to decompose the overall (economic) efficiency of a production unit into technical and allocative components. The author defined technical efficiency (TE) as the firm's ability to produce maximum output given a set of input bundles and technology. Allocative efficiency (AE) was defined as a measure of the firm's success in choosing the optimal input proportions. Finally, he defined economic efficiency as the product of technical and allocative efficiencies which describes the ability of producers to achieve both technical and allocative efficiencies.

Empirically, two approaches have been developed for measuring the efficiency of production units. The parametric approach uses econometric models such as stochastic frontier analysis (SFA). The non-parametric approach is more widely restricted in form of Data Envelopment Analysis (DEA) based on mathematical programming models. The econometricians' criticism of DEA is based on the fact that DEA cannot differentiate between the random variation and other sources of statistical noise in efficiency unlike SFA. The advantages and limitations of both approaches are extensively discussed in Kumbhakar and Lovell (2000) and Coelli *et al.* (2005). The present study employs SFA because of its frequenty use in the analysis of efficiency and productivity in agricultural development studies. Hence, the subsequent discussion focuses on this methodology.

Stochastic frontier analysis models were independently developed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). The basic SFA function model founded on a cross-sectional data set can be specified as:

$$ln\, y_i \;=\; ln\, f\left(X_i ;\beta\right) + e_i \qquad (1)$$

where, y_i denotes the value of the production of the i-*th* farm (i=1,….N); X_i is a *(1xk, k:columns)* vector of the associated inputs; β is a *(jx1, j=rows)* vector of unknown parameters to be estimated, and f represents the functional form. The error term $e_i = v_i - u_i$ is composed of two components. v_i represents random error (statistical noise/ measurement error) distributed symmetrically. u_i is the asymmetric error term, assumed to be independently and identically distributed (i.i.d.) (u_i >1). u_i captures technical inefficiency, and is independent of v_i.

The technical efficiency of firms could be estimated using the Jondrow *et al.* (1982) approach as

$$E\left[u_i \,|e_i\right] \;=\; \frac{\sigma\lambda}{\left(1+\lambda^2\right)}\left[\frac{\phi\left(e_i\lambda \big/ \sigma\right)}{\Phi\left(-e_i\lambda \big/ \sigma\right)} - \frac{e\lambda}{\sigma}\right] \qquad (2)$$

where $\phi\left(e_i\lambda \big/ \sigma\right)$ is the density of the standard normal distribution, $\Phi\left(-e_i\lambda \big/ \sigma\right)$ is the cumulative distribution function of the standard normal distribution, $e = v_i - u_i$ is as earlier defined and $\sigma = \left(\sigma_u^2 + \sigma_v^2\right)^{\frac{1}{2}}$ is the square root of the sum of the variance of *v* and *u*.

Once conditional estimates of u_i have been obtained, Jondrow *et al.* (1982) calculate the technical efficiency of each producer as:

$$TE_i = 1 - E\left[u_i \middle| e_i\right] \tag{3}$$

The objective of the frontier analysis is not only to serve as a benchmark against which the efficiency of production units is estimated, but also to identify underlying causes of deviation from the frontier technology or determinants of efficiency among the producing units (Kumbhakar and Lovell, 2000).

Earlier approaches to incorporate the determinants of technical efficiency levels in the frontier analysis adopted a two-stage approach (Pitt and Lee 1981; Kalirajan 1981). This approach has been criticized because the i.i.d assumption of u_i is violated in the two-stage approach in which predicted efficiencies are assumed to have a functional relationship with the exogenous variables (Kumbhakar and Lovell 2000; and Coelli *et al.* 2005).

The shortcoming in the two-stage approach led to the development of a single step approach by Kumbhakar *et al.* (1991). The authors proposed the single stage approach model where the determinants of the efficiency levels, the variables in a stochastic production frontier and the technical efficiency scores are estimated simultaneously. The single-stage approach was parameterized such that the mean of the pre-truncated distribution of the inefficiency error term (μ_i) is to be a function of exogenous variables. This model can be implicitly specified as:

$$\mu_i = \delta_0 + \delta_j Z_{ij} \tag{4}$$

where μ_i is the firm-specific mean technical inefficiency, z_{ij} is the matrix of exogenous variables that determines technical inefficiency, and δ_j is a vector of the parameters to be estimated. In this formula, a negative sign of an element of the δ_j -vector indicates a variable with a positive influence on technical efficiency.

Recent studies show that allowing the variance of u_i to be a function of exogenous variables could possibly be explored to investigate technical inefficiency effects while correcting for possible heteroskedasticity in the inefficiency term u_i (Caudill and Ford 1993; Caudill *et al.* 1995; Kumbhakar and Lovell 2000). The heteroskedasticity investigation of technical inefficiency effects according to these authors can be implicitly specified as:

$$\sigma_{ui}^2 = \mathrm{g}\left(Z_{ki};\delta_k\right) \tag{5}$$

where, σ_{ui}^2 denotes the variance of u_i, z_k is the matrix of exogenous variables that determines technical inefficiency and δ_k is a vector of parameters to be estimated. Also in the Eqn.5, a negative sign of an element of the δ_k -vector indicates that the variable has a positive influence on technical efficiency.

3. Methodology

3.1. Study area and Sampling procedure

The research area is located in the south of Ecuador in the UNESCO Biosphere Reserve “Podocarpus-El Cóndor” located in the provinces of Loja and Zamora-Chinchipe (see Figure 1). The research area is part of the global biodiversity “hot spot” of the Andes Mountains (CIPRB 2005, Brummitt & Lughadha 2003). The majority of rural households are poor smallholders practicing pasture-based cattle ranching (Beck 2008). The protected area “Corazón de Oro” (Area de Bosque y Vegetacion Protectora Corazón de Oro; ABVPC) was established to the north of Podocarpus National Park. It forms part of the buffer zone of the national park, which is the core area of the Biosphere Reserve.

In the ABVPC and a narrow corridor between ABVPC and the national park, a socio-economic household and farming survey was conducted in the farming season 2008 (n=130). About 24% of all local households took part in the survey. The survey villages were selected randomly and proportional to household numbers. The number of households per village reflects roughly village size. The selection of households in the villages could not be conducted using a random selection. Because of the sensitive financial information to be disclosed during the interview, we relied on snowball sampling and information of key informants in order to approach as much a 'representative' sample as possible. The land use on each farm was surveyed by personal interviews; the location of the plots was independently delimited on aerial photographs (IGM 2003) and ground-truthed using GPS data.

There is no communal property land in our sample. All land is under private ownership. 53.7% (2795 ha) of the land of the surveyed farms is forest; 45.5% (2391 ha) is pasture. Most farmers produce milk and other dairy products (curd/cheese). Only a small portion produces milk exclusively. Crop production is mainly for subsistence purposes and covers only 0.6% of the area. Arable crop plots are very small or even part of home gardens. Pasture-based production accounts for 70.4% of total household incomes, off-farm income for 25.7% and arable crops for 3.9% of total household incomes.

For some of the households having access to more remote areas of forest, timber also may contribute to household income. As timber felling is an illicit activity in the ABVPC, the extent to which this is the case could not be quantified. The quality of the remaining mountain forest trees is low, however, and indicators for large-scale commercial felling operations could not be found during fieldwork. This suggests that timber felling mainly contributes to subsistence consumption. However, we assume that there is some timber extraction in the villages of the highest, most north-eastern parts of the ABVPC, which were (by chance) not included in the sample. The importance of fuel wood extraction or of other forms of non-timber forest product utilization is small. Most households use domestic gas which is highly subsidized by the state. Against this background, the following focus on pasture-based dairy and cattle production covers the overwhelming share of local income from primary production.

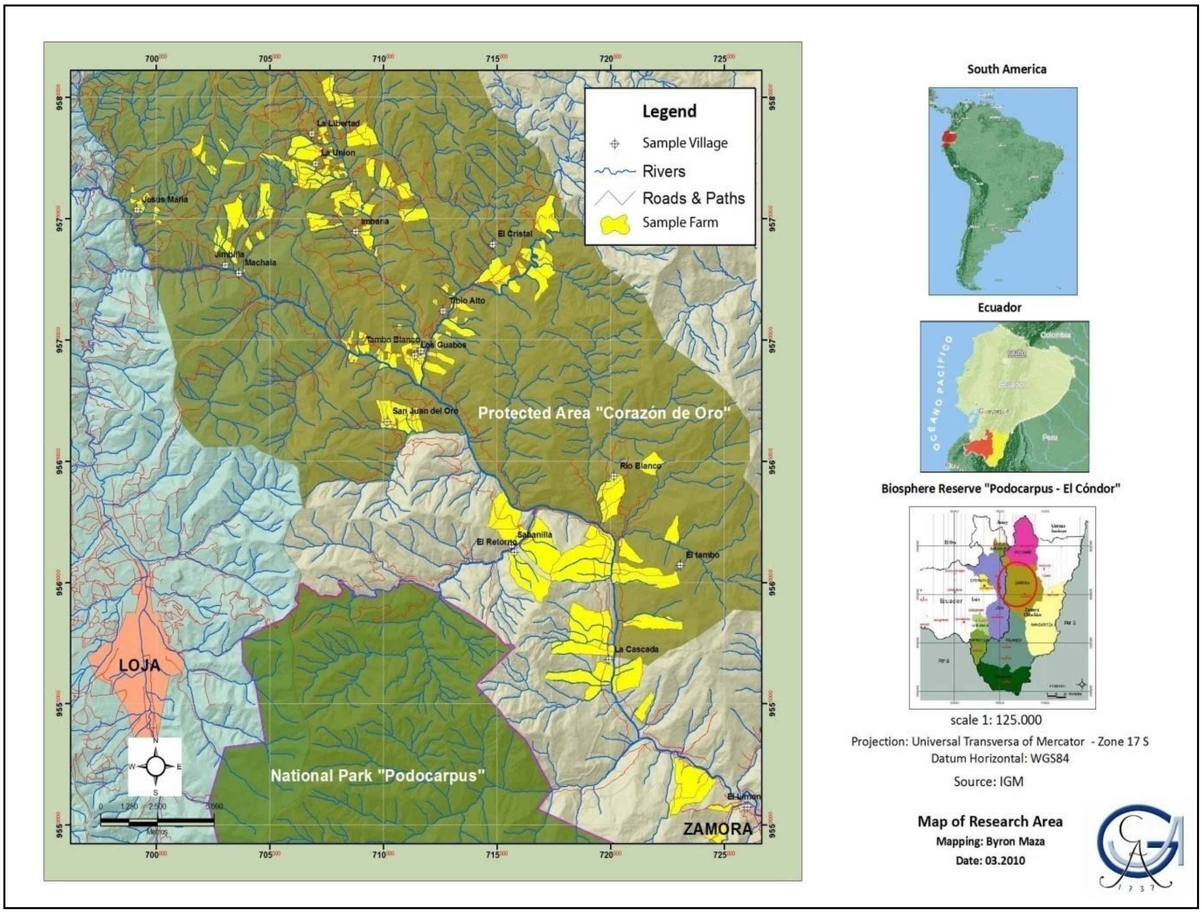

Figure 1: Map showing the study area

3.2. Determinants of technical inefficiency

Determinants of technical inefficiency identify reasons for production differences across production units (farmer/households). SFA quantifies the influence of determinants on the production differences (Battese & Coelli 1995).

Empirical evidence is show by Bravo-Ureta & Pinheiro (1993), they determine socio-economic factors relate to technical efficiency in developing countries in the agriculture sector. They report several factors: income, education, age, literacy, experience, formal and non-formal education, credit, farm size, management policies, extension (visits, hours), irrigation, fertilizer, off-farm income, off-farm employment, region (locality). Alene et al. (2005) in their study in one developing country (Indonesia) point out several determinants that impact on efficiency age, social capital, technical assistance, education, ethnicity, off-farm employment, access to credit. Ortega et al. (2007) reported impact of socio-economic and technical variables on technical efficiency of dual-purpose cattle system in Venezuela.

The factors reported are education, breeding system, land tenure, stocking rate, credit, technical assistance, location, production system, experience, farm size and production, capital investment. More recently, Ogundary (2010) in his meta-analysis of technical efficiency studies in one developing country in agriculture identified policy variables on technical efficiency. He found positive and negative effects of age, experience, credit, extension, household size, education, gender and membership in cooperative societies.

In bases on the above review and our knowledge of research area, and previous analysis presented in the chapters I, II, variables that likely influence in efficiency are: size of pasture, minimum altitude of pasture land, locality, ethnicity, technical assistance and access to formal credit.

3.3. Variable definition

The information collected during the survey includes: gross income from the sale and consumption of dairy products, weight increment[15] of the cattle and sale of cattle (both in USD), size of pastures in hectare, labor usage (family and hired labor) in man-days and costs of production. The cost of production includes cash expenditures on salt, animal vaccination, expenditure on veterinary services, and depreciation on the fixed inputs.

Other information collected includes the number of the farmers receiving technical assistance (dummy variable; respondent has access to a technical assistance from government and non-government organizations), access to formal credit (dummy variable; farmer has access to formal credit), and ethnicity (dummy variable; 1= “Mestizo” ethnic group; 0=“Saraguro” ethnic group), location of the farm (Dummy variable; 1= “upland”; 0=“lowland”). The altitude of pasture land (meters above the sea level) was obtained from digital elevation model. Table A of the appendix contains the summary statistics of variables are subsequently used in SFA.

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[15] The life weight is predicted with a regression where the dependent variable is the life weight and explanatory variables are race, age, and sex. Most of the variables (10 variables) are significant at $\alpha = 0.05$ and the model explain (R^2=0.57) 57% of life weight (see details Chapter II, herd section).

3.4. The empirical model specification

The production technology of the cattle farmers in Ecuador is represented in the present study using a translog functional form for three inputs as:

$$ln(y_i) = \left\{ \delta_0 + \sum_{j=1}^{3} \beta_j \ln X_{ji} + \frac{1}{2} \sum_{j=1}^{3} \sum_{k=1}^{3} \beta_j \ln X_{ji} * \ln X_{ki} \right\} + v_i - u_i \tag{7}$$

where ln: natural logarithm; y_i: gross income from cattle production for the i*th* farmer in USD; X_1: size of pasture in hectares; X_2: both hired and family labour in man-days and X_3: the production costs.

v_{it} is normally distributed with $N\left(0, \sigma_{vi}^2\right)$ while u_i is assumed to be half-normally distributed as $N^+\left(0, \sigma_{ui}^2\right)$ with $\sigma_{ui}^2 = q\left(Z_{is}, D_{pi}; \alpha_i\right)$ following the tradicional assumption of literature.

The heteroskedascity specification of the variance of the inefficiency term (u_i) of Eqn.5 was found to be robust (there is not problem of heteroskedasticity in the inefficiency term) for modeling the determinants of the technical efficiency of cattle production in the study area[16].

Following the traditional technical inefficiency effects model in the literature, the variance of the inefficiency error is modeled as a function of the farms/farmers' socio-economic variables as[17]

$$\sigma_u^2 = exp\left(\omega_0 + \alpha_1 X_{land} + \alpha_2 X_{altitude} + \alpha_3 X_{location} + \alpha_4 X_{ethnicity} + \alpha_5 X_{tec.\ Assistant} + \alpha_6 X_{credit}\right) \tag{7}$$

where $\sigma_u^{\ 2}$ represents the variance of the one-sided error term (u_i).

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[16] Earlier the mean inefficiency specification of Eqn. 4 was employed to relate the farmers/farms specific characteristics to the efficiency level of the respondents. However, most of the parameters were found to be insignificant in this model specification.

[17] We included both altitude and location because dropping one for another affect robustness of the estimates. The location (lowland and upland) captures some information of the altitude of the pasture land. However, the main difference is the excellent market access of lowland farms while are located between on the main inter-provincial road connects the province capitals of Loja and Zamora.

The maximum likelihood estimates of the parameters of Eqn. 3, 6 and 7 are jointly estimated using Ox 4.02 (Doornik, 2006), specifically, the SFAMB package (Brümmer, 2001). The estimation used in this paper Chapter (maximum likelihood) is a different approach than the estimation used (OLS) in the chapter I, II.

Whenever production technology of production units is described by flexible production functions such as the translog functional forms, it is important to check whether the estimated elasticities (coefficients of the inputs) are theoretically consistent (Sauer et al. 2006). A production function is globally consistent when providing regularity conditions for the inputs in the production model (Chamber 1988). One condition is monotonicity (i.e., positive elasticities). Furthermore, the curvature property of the inputs needs to be tested.

Accordingly, a concavity test was constructed using the Hessian matrix (**H**) for each of the inputs at the sample mean as presented in the third row of table 3. The 3 variable inputs were included in the translog frontier function of Eqn.6. It implies that 3 Hessian matrices (**H**) are expected to be constructed with the following conditions ($\mathbf{H_1 \leq 0}$), ($\mathbf{H_2 \geq 0}$), and ($\mathbf{H_3 \leq 0}$) before concavity could be fulfilled (for details see Sauer *et al.* 2006).

3.5. Hypotheses testing

A generalized likelihood ratio test of hypotheses of interest is presented in table 1. The first null hypothesis, which specifies that the Cobb-Douglas frontier functional form is an adequate representation of the data, is rejected. This implies that the translog frontier functional form (Eqn.6) is appropriate for the dataset. Similar results were found by Moreira (2006), translog is the most appropriate functional form for dairy farms of Argentina, Chile and Uruguay. The second null hypothesis of constant returns to scale is rejected. The third null hypothesis which specifies that inefficiency effects are absent from the model is strongly rejected, indicating that OLS is not an adequate representation of the dataset. The fourth hypothesis which specifies that the coefficients of the explanatory variables in the inefficiency model are simultaneously zero is also rejected. The implication of this is that six variables included in the inefficiency component have a joint significant contribution in explaining the inefficiency effects associated with the value of the output for the sampled farmers.

Table 1: Generalized likelihood-ratio tests, n =130

Null hypotheses	LR	Df	$\chi^2_{(0.05)}$	Decision
H_{01}:β_{jk}=0	17.88	6	12.6	Reject
H_{02}:$\sum\beta_{jk}$=1	18.42	4	9.5	Reject
H_{03}:γ_i=0;α_i=0	78.36	7	13.4*	Reject
H_{04}: $\alpha_1 \ldots \alpha_6$=0	52.94	6	12.6	Reject

* This value is obtained from table of Kodde and Palm (1986) with degree of freedom (df) equals q, where q is parameters of inefficiency.

Table 2 presents the result of the maximum likelihood estimates of the parameters of selected translog frontier model of Eqn.6. However, prior to the estimation, the variables of the frontier model were divided by their respective sample mean. The implication of this is that the coefficients of the first order elasticity of the translog frontier directly serve as the measure of the output elasticity of the inputs (Coelli 2005).

We found that the monotonicity condition (i.e., positive elasticities) is fulfilled with greater of cases are not violated. Monotonicity in the inputs at individual sample points is violated in about 7%, 18%, and 9% of the elasticity of pasture, labour and costs of inputs, respectively as presented in the second row of table 3. The percent of cases of monoticity violated are lower than the empiral result reported by Ogundary (2010), it is usumed that monoticity condition is fulfill on great percent. Besides this, the concavity test of curvature of the inputs carried is described below. We found that H_1= -0.124 fulfilled the condition of curvature [due to the way our estimated parameters were arranged in table 2, this value is equal to the first principal minors or simply the second-order derivatives for size of pasture], H_2 = 0.218 (fulfilled), while H_3 = 0.003 (failed to be fulfilled)[18]. Based on these results, we concluded that the curvature property of the inputs required for the sufficient condition in the production function is fulfilled. The condition is fulfill at the sample mean with respect to the size of pasture and labor while this could not be fulfilled in costs of productions in the study. It is means that quasi-concavity condition is achieved.

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[18] Technically, a fulfillment of the concavity condition implies a fulfillment of the quasi-concavity condition (but quasi-concavity does not imply concavity).

4. Results and discussions

4.1. Estimates of production frontier: output elasticity of the inputs

Based on the results presented in the upper panel of table 2, it is obvious that the elasticities of the three considered inputs in the regression were positive and significantly different from zero at least at the 10% level of significance. However, labour was found to have the highest elasticities with a value of 0.653. This is followed by the size of pasture (0.244) and costs of production (0.137). The implication of this is that labour is an important input in the Ecuadorian cattle production. Our results differ from Ortega *et al.* (2007) where veterinary machinery is an important input in the dual-purpose cattle system in Venezuela. This result cleary reflects the low technological machinery level of cattle-based agriculture in our sample even judged against Latin American standars.

The return to scale (RTS) which is the summation of the output elasticity (= 1.034) of the inputs in the regression is presented in the first row of table 3. The null hypothesis of constant returns to scale is rejected (second hypothesis in Table 1). Increasing return to scale was found by Moreira (2006), 1.176 Argentina, 1.100 Chile, 1.09 Uruguay. The extensive system in the local research area is overwhelming the labor (rudimentary technology). It is impossible with a higher technology or higher capital on input to obtain an increment on returns to scale in the same proportion. It means that technical efficiency it is not to much relate with the technology. We expect maybe more substantial returns to scale, which interns suggest that technical efficiency analysis is only one bit of the result.

The result RTS (= 1.034) shows that for an average cattle farm in the study area, increasing returns to scale (IRTS) characterized their production process[19]. The implication of this is that an average cattle farm in the study area is in stage I of the production curve. Hence, at this stage the cattle farm can be expected to increase the use of the inputs in order to reach an optimum point of production since addition to the production inputs would lead to more than proportional addition to the output due to IRTS observed.

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[19] Earlier under the test of hypotheses of interest, we observed that a constant return to scale is rejected.

Table 2: Production frontier estimates

Constant	Parameters	Coefficients	t-value
Frontier estimates			
Constant	ζ_0	0.5557	3.23*
*l*n(size of pasture)	β_1	0.2441	2.40**
*l*n(labour)	β_2	0.6526	5.13*
*l*n(costs of inputs)	β_3	0.1368	2.46**
0.5[*l*n(size of pasture)]^2	β_{11}	-0.1242	1.01
0.5[*l*n(labour)]^2	β_{22}	-0.7468	2.95*
0.5[*l*n(costs of inputs)]^2	β_{33}	-0.1028	2.52**
*l*n(size of pasture)x *l*n(labour)	β_{12}	0.3536	2.49**
*l*n(size of pasture) x *l*n(costs of inputs)	β_{13}	-0.0398	0.72
*l*n(labour) x *l*n(costs of inputs)	β_{23}	0.1121	1.43
Inefficiency estimates			
Constant	ω_0	-0.5926	0.59
*l*n(size of pasture)	α_1	-0.2816	1.25
Altitude (minimum)	α_2	0.2702	0.26
Location	α_3	0.6356	1.71*
Ethnicity	α_4	-0.9443	2.22**
Technical assistance	α_5	-0.4964	1.85*
Credit	α_6	-0.3431	0.97
Variance parameters			
Log likelihood	LL	-103.133	
Gamma	γ	0.755	
Number of parameters	-	18	
Number of observation	-	130	

*,**, and *** indicates that the variables are significant at 10%, 5%, and 1%, respectively.

Table 3: Returns to scale and test of theoretical consistency

Variables	**Size of pasture**	**Labour**	**Costs of inputs**	**RTS**
Elasticities	0.244	0.653	0.137	1.034
Violation of monotonicity	9 (7%)	23 (18%)	11 (9%)	
Concavity tests	-0.124 (fulfilled)	0.218 (fulfilled)	0.003 (failed)	

4.3. Determinants of technical efficiency level

Since the aim of the frontier analysis entails, among other things, the identification of the causes of the technical efficiency among the production units, the lower panel of table 2 presents the estimated coefficients in the explanatory variables in the model for the technical inefficiency effects. The results show that among the six variables considered in the inefficiency model, “location of the farm” significantly increased the variance of the technical efficiency level of the cattle production in the study area. Also, we observed that “ethnicity and technical assistance” significantly decreased the variance of the technical inefficiency level of the cattle production in the study area.

Because of the way these variables are specified, location of the study (upland=1; lowland=0) is interpreted as follows. The significance of this variable implies that farms located in the upland appear to have lower technical efficiency levels in comparison to farms located in the lowland region of the country. This result conforms to observation on the ground in the study area. For example, the upland region is characterized by steep sloping mountain while the lowland region is characterized by less slope which makes the rearing of animal more easy. The steep slope makes it difficult for the farmer to freely graze their animal which might possibly affect their efficiency and productivity level. Moreover, farmers from lowland region have better market access than farmers located in upland region.

The negative impact of ethnicity (Mestizo=1; Saraguro=0) on the variance of technical inefficiency is an indication that technical efficiency of *Mestizo* farmers is higher comparative to *Saraguro* farmers. This observation conforms to the situation on the ground in the sampled area which indicates that Mestizo ethnic farmers because of their location along a major highway and secondary roads in the region have access to the infrastructural facilities. Over the correlation between “Mestizos” & lowland (better market access), there are also coincidences with other “Mestizo” characteristics which are better educated and better land tenure conditions.

The negative coefficient of technical assistance (yes=1; no=0) implies that farmers with technical assistance have higher technical efficiency compared to farmers with no technical assistance.

Although, we observed in the study that size of pasture and access to credit nominally decreased the variance of the technical inefficiency of the farmers, these variables are significantly different from zero.

4.4. Technical efficiencies

Table 4 present the summary statistics of estimated technical efficiency estimates while the histogram of the estimated technical efficiency of the farms is presented in the figure A of appendix to further shed light on the distribution of the estimated efficiencies.

The first row of table 4 shows that the predicted technical efficiencies of the pooled sample differ substantially among the farmers, ranging between 0.0006 and 0.9287, with the mean efficiency of 0.7003. The implication of this substantial difference in the predicted technical efficiencies across the farms implies that there is need for proactive policies to address the low efficiency level in the cattle production.

To give a better indication of the distribution of the technical efficiencies, a histogram which shows the distribution of the predicted technical efficiencies is presented on the left hand side of figure A of the appendix. However, it is obvious from the figure that the sample frequency indicates a clustering of technical efficiencies in the region 0.65-0.75 efficiency range. The average technical efficiency of 70% from the study implies that there is a considerable room for effecting improvement in the technical efficiency level as about 30% level of inefficiency level is observed in the study area. Comparatively, we observed that the average technical efficiency from the present study is below from the 73.2% obtained by Moreira and Bravo (2009) on the meta-analysis of 5 studies with a focus on the technical efficiency of dairy farms in the Latin America. Moreover, Moreira (2006) in his study of technical efficiency of dairy farms, he found technical efficiency of 87.0%, 84.9%, and 81.1% for Argentina, Chile and Uruguay respectively. Also, Bravo et al. (2007) on the meta-analysis determine 77.9% the technical average efficiency of agricultural sector in the Latin America.

Besides this, we also observed that the present average technical efficiency is quite below the average technical efficiency of 78.1% reported by Bailey et al. (1989) on the technical efficiency of the dairy farms in Ecuador. It is only work on technical efficiency on dairy farms reported for Ecuador.

The predicted technical efficiency was related across the location of the study (i.e., upland versus lowland farmers), ethnicity of the farmer's (i.e., Mestizo versus Saraguro farmers), technical assistance (the farmers that received technical assistance versus those that did not), and credit (i.e., farmers that received credit versus those that did not) (Table 4). Such differentiation is essential to further shed light on the performance of the farms across the farms/farmers characteristics from the study.

Table 4: Summary statics of estimated technical efficiency

Statistics	Estimated technical efficiency and sample size	
Pooled sample		
Mean	0.7003	
Standard Deviation	0.1709	
Maximum	0.9287	
Minimum	0.0006	
Sample size	130	
Location	Upland	Lowland
Mean	0.6409	0.8614
Standard Deviation	0.1610	0.0503
Maximum	0.8699	0.9287
Minimum	0.0006	0.6958
Sample size	95	35
Ethnicity	Mestizo	Saraguro
Mean	0.7318	0.5268
Standard Deviation	0.1475	0.1899
Maximum	0.9287	0.7515
Minimum	0.3211	0.0006
Sample size	110	20
Technical assistance	Yes	No
Mean	0.7818	0.6779
Standard Deviation	0.1129	0.1776
Maximum	0.9287	0.9213
Minimum	0.4135	0.0006
Sample size	28	102
Access to credit	Yes	No
Mean	0.7204	0.6873
Standard Deviation	0.1684	0.1722
Maximum	0.9287	0.8971
Minimum	0.3020	0.0006
Sample size	51	79

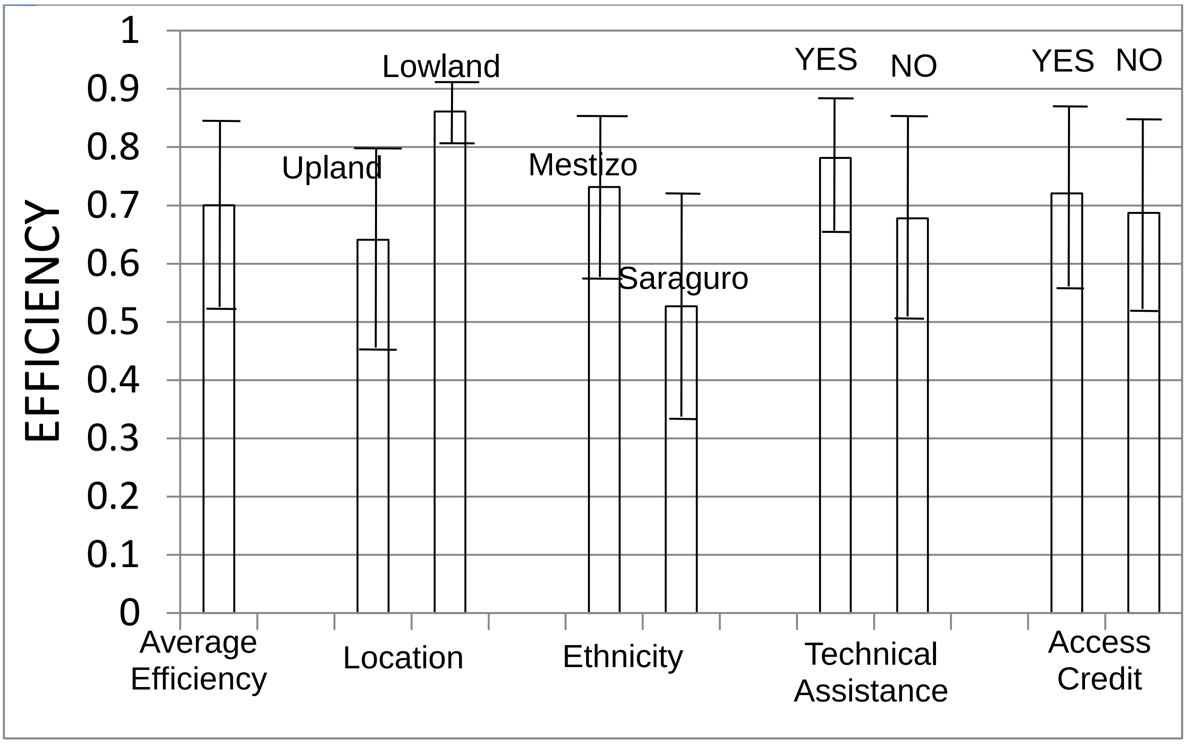

Figure 2: Average of determinants of the technical efficiency

5. Conclusions and policy implications from the findings

This study outlines the technical efficiency level and its determinants in the cattle production based on farm level data sampled in farming season 2008. A total of 130 farming households were considered for the analysis. The translog stochastic frontier production function was found appropriate for the dataset used for the investigation.

The snowball sampling approach is a better than a random sampling approach in the research area. Peasant households exaggerate or minimize their ownership as strategy of “personal protection” (strategic bias). There is a reason: They have unfulfilled promises or bad experiences from politicians, governmental institutions, or past researchers. In this sense, the snowball approach reduces strategic bias likely to be present when sensitivity information or financial information was to be disclosed.

The production frontier models reveal that size of pasture, labour and costs of production monotonically increased cattle production in the sampled farms. Also, the technical inefficiency model shows that location of the farms (lowland), ethnicity (Mestizo ethic) and access to technical assistance increased the technical efficiency of cattle farms in the study area.

The farmer localization has a positive impact on efficiency. The big difference is not capturated with the current variables, that is the market access variable. A road between "Sabanilla" and "Tibio" (inhabitat by Saraguros ethnic) is planned. Saraguros will enable a dramatically market access which is according to our results. In other hand, Eichhorn (2009) suggests that there is high probability of the pasture land increment (deforestation) with the new road.

For the institution of public and private policy design, we suggested that policy relevance of the provision of technical assistance should be seriously looked into in the cattle production. Farmers would like to receive technical assistance mainly on management reproduction cattle, pasture management, and work conservation practices. Although we are aware from our survey that rudimentary (low technology) system characterized cattle production in the sample, nonetheless, increased technical assistance from both public and private stakeholders in the cattle production in Ecuador will go a long way in repositioning the industry in the country and in the Latin American region at large.

References

Aigner D., Lovell A., Schmidt P. 1977. Formation and Estimation of Stochastic frontier production function models. Journal of Econometrics, 6:21-37.

Alene A., Zeller M., Schwartze S., Nuryartono N. 2005. The extent and determinants of production efficiency of farmers in the rainforest margins in Central Sulawesi, Indonesia: implications for land use and support services. Quarterly Journal of International Agriculture 44(4): 335–353.

Bailey D., Biswas B., Kumbhakar S., Schulthies B. 1989. An analysis of technical, allocative, and scale inefficiency: the case of Ecuadorian dairy farms. Western Journal Agricultural Economics 14:30–37

Battese G. 1992. Frontier production functions and technical efficiency: a survey of empirical applications in agricultural economics. Agricultural economics 7:185- 208.

Battese G., Coelli T. 1995. A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics 20(2):325-332.

Beck E. 2008. Preface. In: Beck, E.; Bendix, J.; Kottke, I.; Makeschin, F. and Mosandl, R.: Gradients in a tropical mountain ecosystem of Ecuador. Ecological Studies 198: 5-7.

Bravo B, Pinheiro A.1993. Efficiency analysis of Developing Country Agriculture: A review of Frontier Function Literature. Agricultural and resource economics review 22(1): 88-101.

Bravo B., Solis D., Moreira V., Maripani J., Thiam A., Rivas T. 2007. Technical efficiency in farming: a meta-regression analysis. Journal of Productivity Analysis. 27:57–72.

Binam J., Gockowski J., Nkamleu G. 2008. Technical Efficiency and Productivity Potential of Cocoa Farmers in West African Countries. The Developing Economies 56:242-263.

Brümmer B. 2001. Stochastic frontier analysis using SFAMB for Ox. Department of Agricultural Economics and Rural Development, Georg-August University, Göttingen.

Brummitt N., Lughadha E. 2003. Biodiversity: Where's Hot and Where's Not. Conservation. Biology 17(55):1442-1448.

Caudill S., Ford J. 1993. Biases in Frontier Estimation Due to Heteroscedasticity. Economics Letters 41:17-20.

Caudill S., Ford J., Gropper D. 1995. Frontier Estimation and Firm-specific inefficiency Measures in the presence of Heteroscedasticity. Journal of Business and Economic Statistics, 13:105-111.

Chamber R. 1988. Applied Production Analysis: A Dual Approach, Cambridge University Press, New York.

Coelli T., Rao D., O'Donnell C., Battese G. 2005. An Introduction to efficiency and Productivity Analysis. 2nd Edition. New York. Springer.

Delgado C. 1995. Africa´s Changing Agricultural Development Strategies: Past and Present Paradigms as a Guide to the Future. Food, Agriculture, and Environmental Discussion Paper no 3. Washington D.C.: International Food Policy Research Institute.

Dercon S. 2003. Poverty Traps and Development: The Equity-Efficiency Trade-Off Revisited. First AFD/EUDN Conference on Poverty, Inequality and Growth: What´s at Stake for Development Aid? Oxford: University of Oxford, Department of Economics.

Doornik J.2006. Ox: An object-oriented matrix language. London Timber lake Consultants Press.

Eichhorn S. 2009. Effekte eines Straßenbaus im Biosphärenreservat Podocarpus-El Cóndor auf die Landnutzung und Biodiversität. Diplomarbeit. Georg-August-Universität Göttingen. Germany.

Farrell M. 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society 120:253-281.

Feder G., Murgai R., Quizon J. 2004. Sending Farmers Back to School: The Impact of Farmers Field Schools in Indonesia. Review of Agricultural Economics 26(1):45-62.

IGM (Instituto Geográfico Militar del Ecuador). 2003. Aerial photographs, scale 1:5000 resolution pixel 1m, pancromaticas, Proyection UTM, DATUM WGS84 Zone 17S.

Jondrow J., Lovell C., Materov I., Schmidt P. 1982. On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics 23:269-274.

Kalirajan K.1981. An econometric analysis of yield variability in paddy production. Canadian Journal of Agricultural Economics 29:283-294.

Kodde D., Palm F. 1986. Wald Criteria for Jointly Testing Equity and Inequality Restrictions. Econometrica 54:1243-1248.

Kumbhakar S., Lovell C. 2000. Stochastic frontier Analysis. Cambridge University Press.

Kumbhakar, S., Ghosh S., McGuckin J. 1991. A Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms. Journal of Business and Economic Statistics 9:279-86.

Maza B., J. Barkmann, F. von Walter, R. Marggraf. 2010. Modelling smallholders production and agricultural income in the area of the Biosphere reserve “Podocarpus – El Cóndor”, Ecuador. Internal Discussion paper. Department of Agricultural Economics, Georg-August Universität Göttingen. No. 1009.

Meeusen W., van den Broeck J. 1977. Efficiency Estimation from Cobb- Douglas Production Functions with Composed Error, International Economic Review 18:435-44.

Moreira V., Bravo B. 2009. A study of technical efficiency using meta-regression: An international perspective. Chilean Journal of Agricultural Research 69 (2): 214-223.

Moreira V. 2006. Dairy Farms Efficiency and Milk Total Factor Productivity Growth in Three South American Countries. PhD Thesis.

Ogundary K. 2010. Technical efficiency of smallholder farms in Nigeria. PhD Thesis. Faculty of Agricultural Sciences. Georg-August Universität Göttingen, Germany.

Ortega L, Ward R., Andrew C. 2007. Technical efficiency of the dual-purpose cattle system in Venezuela. Journal of Agricultural and Applied Economics 39 (3): 719-733.

Paredes E. 2009. Estudios generales con serie histórica 2000, 2005, 2006, 2007 y 2008 de la ganadería bovina y raza del Ecuador. Ministerio de Agricultura y Ganadería del Ecuador 86 p.

Pitt M., Lee L. 1981. The measurement and sources of technical inefficiency in the Indonesian weaving industry. Journal of Development Economics 9:43-64.

Sauer J., Fruhberg K., Hockmann H. 2006. Stochastic efficiency measurement: The curse of theoretical consistency. Journal of Applied Economics 9:139-150.

SICA-INEC-MAG. 2002. III Censo Nacional Agropecuario. Resultados Nacionales y Provinciales.

Thiam A., Bravo-Ureta B. E., Rivas T. 2001. Technical Efficiency in Developing Country Agriculture: a meta-analysis. Agricultural Economics 25:235-243.

Wunder S. 2007. The efficiency of payments for environmental services in tropical conservation. In: Conservation Biology 2:48–58.

Udry C. 1996. Efficiency and Market Structure: Testing for Profit Maximization in Africa Agriculture. Northwestern University. http://www.econ.yale.edu/~cru2//pdf/separate.pdf

Zamora 2009. Innovación tecnológica: Rubros y problemas prioritarios. Power point presentation.

Zeller M., Diagne A., Mataya C. 1998. Market Access by Smallholder Farmers in Malawi: Implication for Technology Adoption, Agriculture Productivity, and Crop Income. Agricultural Economics 19(1-2): 219-229

Zeller M., Schrieder G., von Braun J., Heidhues F. 1997. Rural finance for Food Security for the Poor: Implications for Research and Policy. Washington, D.C.: International Food Policy Research Institute.

Appendix

Table A: Summary statics of variables in stochastic frontier model

Variables	Units	Mean	SD	Minimum	Maximum
Gross Income from cattle	USD	4,687.87	5,527.07	0.19	29,578.53
Size of pasture	Hectare	18.34	17.06	0.81	82.81
Labour	Mandays	159.56	96.84	19.4	647.50
Costs of inputs	US	341.95	607.94	2.50	4,178.10
Altitude	Count	1,800.67	252.06	1,080	2,360
Location (upland=1;lowland=0)	Dummy	0.731	0.445	0	1
Ethnicity (Mestizo=1;Saraguro=0)	Dummy	0.846	0.362	0	1
Technical assistance (yes=1;No=0)	Dummy	0.215	0.413	0	1
Credit(yes= 1; No= 0)	Dummy	0.392	0.490	0	1

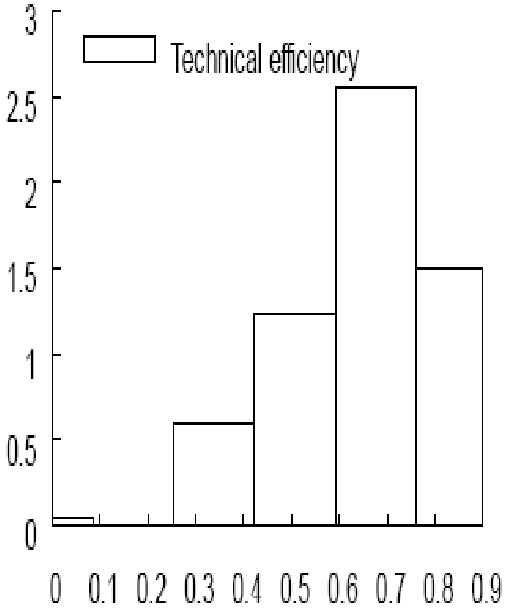

Figure A: Distribution of the estimated technical efficiency

Chapter IV

Efficiency and distributional impacts of protected area planning using PES schemes in the Biosphere Reserve "Podocarpus-El Cóndor", Ecuador.

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Abstract

Ecuador is one of the countries with the richest biodiversity globally. 18% of the national territory are protected areas. Still, Ecuador has the highest annual deforestation rate in South America with much land being converted to pastures and crop land. Payment for Ecosystem Services schemes (PES) are an incentive-based alternative to a "command and control"-type establishment of protected areas. They are voluntary transactions between a buyer and a seller referring to a well defined ecosystem service. PES have been applied in Latin America to biodiversity protection, water supply protection, and carbon sequestration.

This paper investigates the effects of differing conservation instruments fostering a forest conversion ban in mountainous southern Ecuador on cost-efficiency of conservation and on poverty alleviation. The instruments differ with respect to being either mandatory or voluntary, and if all farmers are compensated by the same fixed payment rate per hectare or if the compensation equals individual opportunity cost stipulated to be known by the analyst. Such schemes can be approximated by the auctioning of PES contracts. Additionally, a dedicated 'pro-poor' PES was designed restricting payments at a fixed rate to the poorest households. In all cases, a fixed budget of ~25,000 USD/yr is distributed. Empirical opportunity cost data stem from a sample of 130 local farming households living at the northern edge of the Biosphere Reserve "Podocarpus-El Cóndor" in southern Ecuador.

As expected, a voluntary PES paying just the opportunity costs can cover most of the relevant forest area (305 ha; 36%). In contrast, a mandatory approach covering all farms and compensating at an average opportunity cost of 156 USD/ha/yr only secures 136 ha. This approach also fares worst with respect to poverty alleviation with most payments being dispensed to the relatively least poor farmers and even the GINI coefficient rising slightly to 0.488. Voluntary approaches fare better in this respect with a maximum contribution to household incomes of about 10% for the three poorest household quintiles and GINI coefficients of ~0.477. If payments are restricted to these quintiles at rates between 150 and 300 USD/ha/yr, only 168 to 84 ha forest are covered but the GINI coefficients drops to 0.47-0.462. While mandatory approaches appear worst, we conclude that severe trade-offs between cost efficiency and poverty alleviation are likely to impact PES application in the study area.

1. Introduction

Ecuador is one of the countries with the richest biodiversity in the world (Myers & Mittermeier 2000, Brummitt & Lughadha 2003). Command and control regulation has been the most popular instrument to protect natural ecosystems (Engel et al. 2008). This is also the case in Ecuador where 18.6% of the national territory have been declared protected areas (Rivera 2005). However, command and control instruments have not been effective to stop the conversion from forest to alternative land uses, mainly to pastures and crop land (Wunder 2000): Ecuador has the highest annual deforestation rate in South America with 1.7% (198, 000 ha; FAO 2006).

Among several alternative conservation instruments, Payments for Ecosystem Service (PES) schemes are an attractive option (Wunder 2005). PES are voluntary conservation contracts between a buyer and seller of the service. Under the contract, a provider is required to secure the provisioning of a well-defined ecosystem service (Wunder 2005). If the service - for example forest protection - is not supplied, the payment is withheld. This effect can increase cost-efficiency. Particularly high efficiency is expected in “user financed” PES, where the concerned stakeholders are directly involved. Here, the actual user of the ecosystem service, for example a downstream water utility company, is the buyer.. However, “government financed” PES may at times be the only option as governments can more effectively reduce transaction costs and institute rules to avoid free-riding (Engel et al. 2008).

PES have been recommended not only for potential efficiency gains compared to command and control instruments but also because they can be an instrument of poverty alleviation (Wunder & Albán 2008) For example, PES can provide cash income to poor land holders, and can contribute to income diversification for them (Ferraro & Kiss 2002). In contrast, the mandatory establishment of protected areas without compensation as well as land utilization taxes are likely to have negative distributional consequences for poor people (Engel et al. 2008). In particular, PES may help to alleviate poverty when the poorest potential providers of the ecosystem services have the lowest opportunity cost of ecosystem service supply (Jack et al. 2008a). However, trade-offs may exist between the double goals of increasing conservation efficiency and poverty alleviation (Jack et al. 2008a). Thus, there is the need for studies that shed light on these aspects of a promising, market-based conservation instrument (Engel et al. 2008, Börner et al. 2010).

In the following methodology section, we first review existing literature on the efficiency and on distributional impacts of PES. Next, the case study area is introduced and the calculation of the efficiency and distributional impacts explained. After presenting the main results, the validity and relevance of the results are discussed.

2. Background

2.1. Opportunity cost and efficiency

The integration of cost considerations increases the efficiency of conservation planning (c.f. Naidoo & Adamowicz 2005). For example, the evaluation of a large-scale governmental PES in Costa Rica concluded that the provisioning of ecosystem services could potentially be doubled if more was known about the participation costs of the addressed land owners including opportunity costs (Wünscher et al. 2008). Opportunity cost is that part of an income that is lost if some restriction enforces switching to an alternative, financially second-best course of income generation. With valid and reliable information on the opportunity cost structure of a set of landholders, the principal of a PES scheme could make very cost-efficient individualized offers for participation to the different land owners. In the relevant cases here, opportunity cost is the lost income if regulation or the contractual restrictions of a PES enforce some kind of conservation land use (cf., Azzoni & Isai 1994, Chomitz et al. 2005). In sum, reports based on actual performance data as well as theoretical arguments support the notion that consideration of the opportunity costs of conservation born by participating land holders is a basic and critical element in PES design (cf. Pagiola et al. 2005, Adams et al. 2010).

There are several ways to assess opportunity cost. In the most direct approach, landholders are surveyed and their production economic setting is analyzed. Such surveys are expensive to administer and analyze, however. Furthermore, respondents may answer strategically in order to bias overall survey results or optimize their standing in future contract negotiations (asymmetric information). Finally, a purely financial survey does not include non-market utility components that, nevertheless, may influence land use decisions (Jack et al. 2008b, Wünscher et al. 2008).

An alternative to survey information is the utilization of auctions for allocating conservation contracts to private landholders. Auctions perform well in cases of asymmetric information and can integrate non-financial considerations on part of the land holders which are otherwise difficult to capture (Latacz-Lohmann & Van der Hamsvoort 1997, Latacz-Lohmann & Schilizzi 2005, Jack et al. 2008b). So far, there are no experiences with an auction approach for PES in Ecuador but several international case studies are available. Examples include the “BushTender” and “EcoTender” programs in Australia (Latacz-Lohmann & Schilizzi 2005), or “The Conservation Reserve Program” in the USA (Kirwan et al. 2005). The only published study on a PES offered through an auction in a developing country to date is a soil conservation PES in Indonesia (Jack et al. 2008b). Another paper points out the allocation of tree planting contracts by auction approach in Malawi (Jack Forthcoming).

In contrast to other conservation instruments, PES promise improved efficiency (Wunder 2007). These efficiency gains can, for example, be used to liberate resources for further conservation projects or to scale up existing ones (Engel et al. 2009). From a welfare economics perspective, *additionality* and *conditionality* are preconditions for an economically successful PES. Additionality means that the payment actually increases service provisioning versus a base line (see example below). Conditionality means that the payment is only made if the promised service is actually provided (Wunder 2005).

The most promising scenario for PES application is when the profitability of agricultural land use is only marginally higher than under some desired conservation land use (Wunder

2005, Wunder 2007). In this case, a relatively small payment can induce a shift to conservation land use. If transaction costs of a PES are prohibitively high, however, land purchases may be a better option. Likewise, high opportunity costs may argue for mandatorily established protected areas from a taxpayer perspective (cf. Wunder 2007). From a societal cost-benefit perspective, little is gained in this case, as these opportunity costs must still be born by someone-i.e. the landholder.

PES can either be designed with a fixed rate of payment per unit area (or per unit service provisioning) or with a payment that reflects direct costs and opportunity costs of the service provider. Traditionally, fixed-rate "flat-fee" contracts have been offered. Fixed-rate schemes have efficiency deficits compared to opportunity cost-oriented schemes (Wunder 2007). For example, farmers with high marginal production profits per unit area are difficult to attract although their land may be critically important (Wunder 2005, Engel et al. 2009). Likewise, farmers with low opportunity costs may provide the service even without additional payment (Wunder 2005). However, they may be eager to subscribe these lands to the scheme - and are paid a rather high fixed compensation rate (no additivity). Both problems could be solved if the buyer was able to offer land holders PES contracts that correspond to their opportunity cost. This issue is particularly important if opportunity costs are heterogeneous (Wünscher et al. 2008). Because of the information asymmetry between buyers and service providers, the principal either has to survey and/or estimate opportunity costs very diligently - or offer a competitive auctioning scheme for PES contracts (Latacz-Lohmann & Schilizzi 2005).

In addition to differentiated payments according to landholder opportunity costs, the efficiency of a PES is increased if payments can be differentiated in accordance with the intensity of ecosystem service provisioning per unit area (Engel et al. 2009). Such a spatial "targeting" (Wünscher et al. 2008, Pagiola 2008), however, requires tools and/or procedures to assess the absolute or at least relative importance of an area for service provisioning. This can substantially increase the overall transaction costs of a targeted PES.

Two aspects that can additionally reduce PES efficiency are lack of *permanence* and *leakage* (Wunder 2005). In contrast to buying land or the establishment of a permanently protected area, PES do not regularly establish a permanent protection. Once the payments cease at the end of the contract period, the provision of the service may end. Leakage can occur although the land holder abides to the contract for the land directly covered by the PES. With the additional cash resources paid and/or with saved labour, however, an undesirable land use may be implemented elsewhere compromising overall ecosystem delivery.

2.2. Distributional implications

Distributional impacts of biodiversity policies have relevance when policies impose a cost on people (Bagnoli et al. 2008) or provide potential benefits (Zilberman et al. 2006). Such distributional issues are particularly important if advantages and disadvantages are unevenly distributed among 'rich' and 'poor' people (cf. Bawa et al. 2004).

PES are certainly not a tool for poverty reduction *per se* as they were developed from an economic efficiency perspective (see section above). With PES becoming more and more popular conservation instruments, there is an urgent interest to assess their distributional impacts (Engel et al. 2008). This topic has high relevance for our case study area in southern Ecuador because the Andes are a “hot spot” of high conservation priority which coincides with a high incidence of poverty (Fisher & Christopher 2007). The Convention on Biological Diversity recognizes the potentially problematic conservation-poverty interaction and defined poverty alleviation as one of its goals (SCBD 2009).

Adams et al. (2004) analyze four approaches addressing conservation vis-a-vis poverty alleviation: (*i*) poverty and conservation are separate policy realms, (*ii*) poverty is a critical constraint to conservation, *(iii*) conservation should not compromise poverty reduction, (*iv*) poverty reduction depends on living resources conservation. Given these potential interactions between conservation and poverty alleviation, an integration of these policy realms is highly necessary. In line with point (ii), Wunder (2007) regards the overall "fairness" of a conservation project as a precondition to its long-term success. For many developing countries, the type of interaction between poverty alleviation and conservation is furthermore complicated by weak governance issues (Roe & Elliot 2006).

Several theoretical studies have revealed restricting and facilitating conditions for a "pro-poor" impact of PES (FAO 2007, Zilberman et al. 2006, Wunder 2005, Pagiola et al. 2005). Factors generally influencing the impact are spatial distribution of poor households, property rights structure of the land, agricultural land productivity and spatial as well as the social distribution of the provision of the ecosystem services (FAO 2007). Also PES design itself can induce different distributive effects (Pagiola 2010). Any potentially positive distributive impact can only by realized if poor land holders decide to participate. Participation decisions are influenced not only by mean opportunity costs but also by the transaction costs of participation, price fluctuations, and other production risks as well as insecure or unsuitable type of land tenure (Wunder 2007).

The following phenomenon impacts of participation farmer pro poor is point out with restrictive and positive conditions.The following restricting conditions of a pro-poor impact are frequently cited:

- land diversion programs e.g. enforcing strict no-use (Zilberman et al. 2008, Wunder & Alban 2008),

4. access restrictions to non-agricultural land uses or to illicit agricultural land used by the poor who are not official land holders themselves ("encroachment") (Wunder 2008),
5. Negative local impacts on food prices, employment (Bond et al. 2009, Zilbermann et al. 2008), labor productivity or food supply (Jourdain et al. 2009).
6. exclusion of mixed land use systems, e.g., agroforestry (Wunder 2008),

- small size of eligible land from smallholders resulting in high transaction costs (Kollmair & Rasul 2010, Antle & Stoorvogel 2008, Wunder 2008, Pagiola et al 2008, Lipper & Cavatassi 2004, Gong et al. 2010, Kollmair & Rasul 2010),
- high agricultural opportunity cost of more intensively farming smallholder (Sommerville et al. 2010, Gong et al. 2010, Porras et al. 2008),
- investment constrains such as restricted access to credit or technical assistance when land use change is involved, e.g., to agroforestry, regeneration systems (Pagiola et al. 2008), or afforestation (Lipper & Cavatassi 2004, Kollmair & Rasul 2010),
- institutional preconditions: insecure land tenure (Börner et al. 2010, Gong et al. 2010, Kollmair & Rasul 2010, Wunder 2008), weakness of resources rights/land of communities or indigenous people (Bond et al. 2009), and poor governance (Sommerville et al. 2010),
- risk and uncertaintly to adopt conservation practices (Graff-Zivin & Lipper 2008), e.g. afforestation (Porras et al. 2008),

- weak social capital of smallholders (Gong et al. 2010), or weak collective action (Corbera et al. 2007).

Hypothesized facilitating positive distributional impact conditions include targeting beneficiaries (Bond et al. 2009, Wunder 2008, Uchida et al. 2007): The poor actually need to participate. Analyzing the influence of social targeting is one of the foci of this study as we use social targeting in the design of three of the seven conservation instruments compared (see section 3.4.5).

The following positive conditions of a pro-poor impact are frequently cited:

- non-positive correlation between ecosystem services supply and productivity of alternative land uses. Poor-people may offer high supply of ecosystem services in areas of low agricultural productivity (Zilberman et al. 2008, Pfaff et al. 2008), e.g. PES has significant effect on poor people when they are located in up-land areas, low-density, high supply of ecosystem services, and low opportunity and transaction cost, and high willingness to pay by beneficiaries in some areas of Asia (Leimona et al. 2009),
- PES promotes the employment of smallholder labor (Zilberman et al. 2008), e.g. through agroforestry (Pagiola et al. 2008), or eradication of invasive alien plants to restore ecosystem functions (Turpie et al. 2008),
- equitable land distribution (Zilberman et al. 2008),
- high poverty rate (Pagiola et al. 2008),
- possible low transaction cost as collective smallholder schemes (Wunder 2008, Bracer et al. 2007, Swallow et al. 2005),
- access to credit and to technical information when land use change is involved, e.g. agroforestry systems (Pagiola et al. 2008),
- multiple options of PES contracts (Pagiola et al. 2008, Bracer et al. 2007),
- institutional preconditions: local institutions that empower conservation and reinforce personal motivation (Clements et al. 2010) such as: formal land title (Wunder 2008, Zbinden & Lee 2005), strengthen long term property rights private/communal/indigenous (Gong et al. 2010, Milder et al. 2010, Kollmair & Rasul 2010, Corbera et al. 2007, Bracer et al. 2007), equitable access to land (Kollmair &

Rasul 2010), regulation of power dynamics by state and create scenario for participation process (Bracer et al. 2007),

- reducing risk of payment for ecosystem services (Gong et al. 2010) and equality on payment levels and terms (Bond et al. 2009).
- linking PES other develop programs (Kollmair & Rasul 2010),

A recent review study of PES issues (Engel et al. 2008) indicates that there is little empirical verification for any general poverty alleviation effect of PES. In particular, the results of the few existing studies do not support the notion of a pronounced pro-poor impact. The Ecuadorian government PES “Socio Bosque” was specifically designed to integrate conservation success with poverty alleviation effects (Ministerio de Ambiente 2008, 2009). The program started in 2008, so performance data are not available yet.

With respect to distributional issues, Grieg-Gran et al. (2005) drew some preliminary lessons from an analysis of several Latin American PES. They concluded that the investigated PES did contribute to landholder cash income but that the majority of financial benefits were not accrued by the poor. In fact, the only PES with a clear pro-poor impact had only a small number of participants and was short-lived. However, positive impacts on land tenure status, social capital, training in forest management, and on employment were frequently observed. Also, there was little evidence of negative impacts. To some degree, the lack of poverty alleviation impact could be attributed to PES contract conditions ruling out the participation of smallholders, e.g. because of informal land tenure or 'mixed' land uses (agroforestry, young secondary forest) that prevented participation. An example of a PES successfully addressing both, poverty and ecosystem service provisioning, is the “the working for water program" (WfW), a huge scheme sponsored by the government of the Republic of South Africa (Turpie et al. 2008). WfW generates employment for landowners who restore the land for the provision of water.

With respect to PES design itself (e.g., fixed-rate versus individualized payments), distributive impacts are theoretically expected (Pagiola 2010). Empirically, there are conflicting results regarding the extent to which fixed-rate schemes have pro-poor impacts. Zbinden & Lee (2005) find that the majority of benefits is not conveyed to poor households. In contrast, Wunder & Alban (2008) report a good conveyance of benefits to poor participants.

With respect to determine PES on poverty impact, previous studies use GINI coefficients to show the distributional impact of PES are reported on Pascual et al. 2010, Uchine et al. 2007.

The above cited theoretical and empirical studies show that a high number of factors can influence the efficiency as well as the distributional impacts of different conservation instruments including PES. Three of the factors that can impact both aspects are (i) mandatory vs. voluntary participation, (ii) the level of the granted payments in relation to opportunity costs, and (iii) fixed-rate vs. flexible, opportunity-cost oriented payments. Very few empirical studies are available, however, that empirically assess the influence of these factors, and that investigate potential trade-offs between the two CBD policy targets of conservation and poverty alleviation (Börner et al. 2010).

Unfortunately, the conservation instruments compared (see section 3.4) all use a strict non-use approach. We assume that a deforestation ban for selective logging or Non-wood Forest Products extraction is not possible. Also, transaction costs are not investigated here (Wünscher et al. 2008). Thus, any influence of these factors cannot be investigated here.

In this paper, we analyze the efficiency and distributional impacts of payments for conservation of the native forest in the Biosphere Reserve “Podocarpus - El Condor” in south of Ecuador. We use PES definition given by Wunder (2005), PES is a voluntary transaction, with definied ecosystem service (native forest land use), with buyer (government), with a provider (farmer), and ecosystem service provide secure ecosystem service provision (conditionality). We analyze and compare the efficiency in the forest conservation with “mandatory” versus “voluntary” PES schemes. The schemes are used to assess to which extent distributive impact is affected by how payments are made (Pagiola 2010). Several “pro poor” PES are used to show the potential for PES to act as a tool for poverty reduction (Pagiola et al. 2005). Moreover, we calculate the PES impact on the total household income and discuss the trade-offs between conservation and poverty alleviation.

3. Methods

3.1. Research area

The research area is located in the south of Ecuador in the Biosphere Reserve “Podocarpus-El Cóndor” in the provinces of Loja and Zamora-Chinchipe (see Figure 1). The research area is part of the global biodiversity “hot spot” of the Andes Mountains (CIPRB 2005, Brummitt & Lughadha 2003). The majority of rural households are poor smallholders practicing pasture-based cattle ranching (Beck 2008). The protection area “Corazón de Oro” (Area de Bosque y Vegetación Protectora *Corazón de Oro*; ABVPC) was established to the north of Podocarpus National Park. It forms a part the buffer zone of the national park which is the core area of the biosphere reserve.

In the ABVPC and a narrow corridor between ABVPC and the national park, a socio-economic household and farming survey was conducted in the farming season 2008 (n=130, for details see Maza et al. 2010 Chapter I). About 24% of all local households took part in the survey. The survey villages were selected randomly and proportional to household numbers. The number of households per village roughly reflects village size. The selection of households in the villages could not be conducted using a fully randomized process. Because of the sensitive economic information to be disclosed during the interview, we relied on snowball sampling and information of key informants in order to approach as much a 'representative' sample as possible. The land use on each farm was surveyed by personal interviews; the location of the plots was independently delimited on aerial photographs (IGM 2003), and ground-truthed using GPS data.

There is no communal property land used by the sample farms. All land is privately owned. 53.7% (2795 ha) of the land of the surveyed farms is forest; 45.5% (2391 ha) is pasture. Most farmers produce milk and other dairy products (curd/cheese). Only a small portion of farms produces milk exclusively. Crop production is mainly for subsistence purposes and covers only 0.6% of the area. Arable crop plots are very small; additionally, there are small home gardens. Pasture-based production accounts for 70.4% of total household incomes, *off*-farm income for 25.7% and arable crops for 3.9% of total household income.

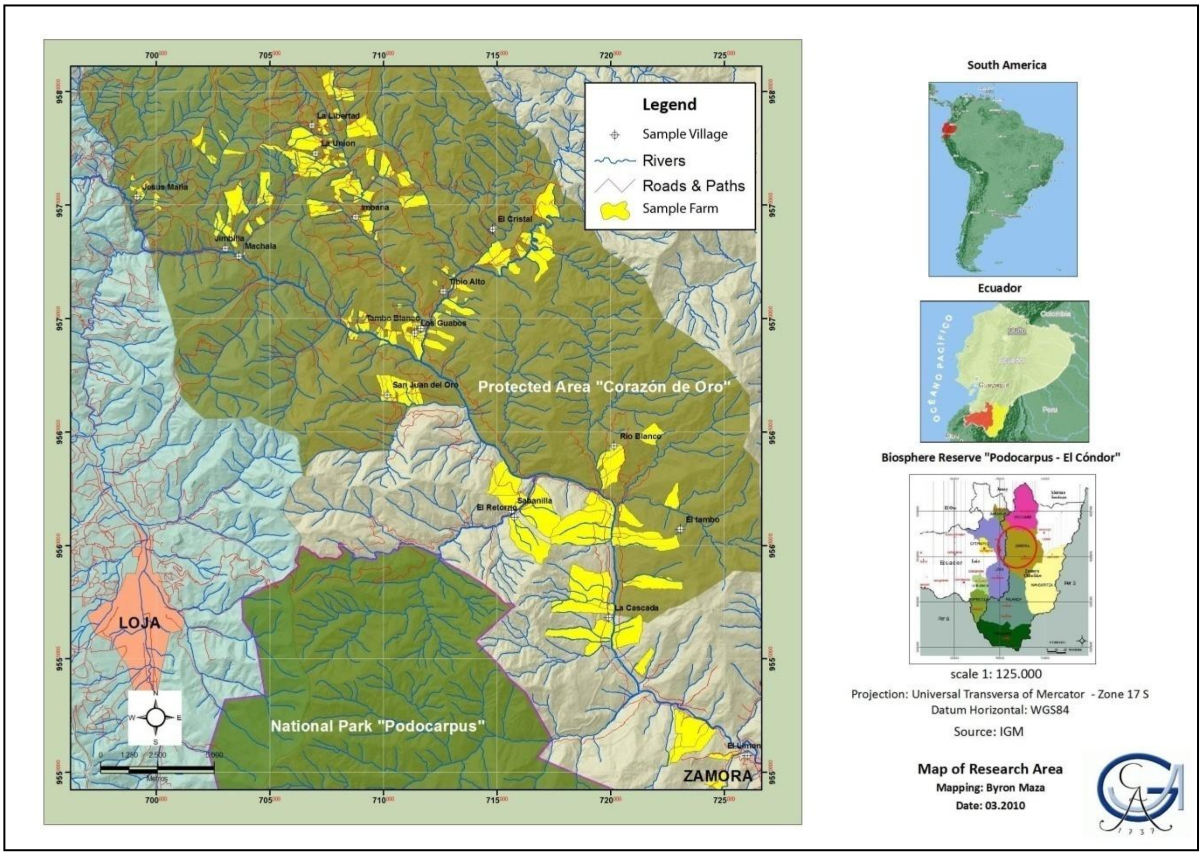

Figure 1: Research area in the Biosphere Reserve "Podocarpus-El Cóndor", southern Ecuador

For some of the households having access to more remote areas of forest, timber may also contribute to household income. As timber felling is an illicit activity in the ABVPC, the extent to which this is the case could not be quantified. The quality of many of the accesible mountain forest trees is low, however, and indicators for any large scale felling operations could not be found during fieldwork. This suggests that timber felling mainly contributes to subsistence consumption in the sample villages. We assume that there is some "commercial" timber extraction in the villages of the highest altitude, most north-eastern parts of the ABVPC, which were (by chance) not included in the sample. The importance of fuel wood extraction or of other forms of non-timber forest product utilization is small. Most households use domestic gas which is highly subsidized by the state.

3.2. Calculation of individual opportunity costs

As a proxy for the opportunity costs of conservation measures to the individual household, we use the net profit of the pasture-based cattle production system. For details, please refer to (Chapter II). The selection of net profits is motivated by the conservation restriction we intend to analyze: A ban on the conversion of forest land households already owning pastures. We assume leveraged upon that the additional land requires additional labor which must be remunerated at a wage rate at which local households work off-farm. Apart from the option to be converted, we assume zero economic value of the forest land. If income come from forest is zero, the opportunity cost of potential pasture is equal to the net profit of cattle production. In effect, we slightly overestimated opportunity cost on some forest utilization is likely to occur (see section 3.1.).

First, we calculated gross income (amount of products sold plus amount of products consumed valued at market prices) for each farmer. In order to be able to project financial effects of PES application, based on stablished agronomic practice, we fitted a Cobb-Douglas production function to predict household gross income. Land, labor, input expenses, altitude, ethnicity, utilization of technical assistance, access to formal credit, membership in local organizations, age as well as education of the household head, cost distance to the provincial capitals (i.e. major markets), and off-farm income were tested as explanatory variables with STATA 9.0. The factors printed in Italics yielded significant ($p<0.1$) predictors in a parsimonious regression model using log-transformed right hand side and left hand side variables (Adj $R^2=0.42$). Because of the heteroskedasticity, the significance of explanatory variables was cheking using robust regression.

Second, surveyed variable costs were subtracted from predicted gross income for each farm to yield gross margins. Finally, net profits were obtained by subtracting fixed costs including household labor atributed to pasture-based production (Zeller & Schwarze 2006).

3.3. Conservation budget

In order to be able to compare conservation effectiveness and distributional impacts of different conservation instruments, each of the instruments (see section 3.4) must be assigned the same amount of money to disburse. For designing a realistic budget scenario, we relied on two sources. First, a previous study had revealed that 30% (839 ha) of the still forested project area are at an immediate land conversion risk to pasture using Landsat ETM data at 30m resolution (Eichhorn 2009). The conversion risk was calculated by multiple logistic regression mainly considering market access and geomorphological aspects such as altitude and slope. For 30% of the forest pixels, the suitability for pasture was higher than for the average pasture pixel actually found in the research region.

Second, the *Socio Bosque* program pays a maximum of 30 USD/ha/yr for existing forest in poor communities placed for 20 years under the a specific PES (*Socio Bosque* 2010a). We use the *Socio Bosque* payment rate to yield the conservation budget by multiplying the 839 ha most endangered forest rate by 30 USD/ha/yr resulting in a budget of 25,170 USD/yr. This budget is assumed to be completely be paid to farmers, i.e. transaction costs are not accounted for (Wunder et al. 2008, Pagiola and Bosquet 2009).

3.4. Conservation instrument options ("PES")

We compare four conservation instruments which are either mandatory or voluntary, either fixed-cost or opportunity cost oriented. The fifth conservation instrument is designed as to provide maximal benefits to the poorest local farming households.

3.4.1. Mandatory PES schemes

The mandatory instruments represent a class of instruments for which the government imposes all rules and also determines the payment to the individual land owner (Engel et al. 2008). In our examples, the crucial characteristic is that all farming households are required to participate in the conservation scheme. In particular, we stipulate that each farming household is required to subject the same proportion of its land to a forest conversion ban. These schemes do not include any form of spatial targeting, e.g., by levying the forest ban only on those 839 ha that were determined as being most in danger of deforestation. In a few cases in which the single household does not have a sufficient amount of forest left, the household is, nevertheless, required to idle the respective proportion of land and to allow for secondary forest development.

For the **mandatory fixed rate scheme**, the compensation rate for land required to be placed under the scheme is set at the mean opportunity cost of the surveyed farming households (at 159 USD/ha/yr). Thus, a conservation budget of 25,170 USD/yr can cover roughly 18.8% of the 839 ha threatened by deforestation. These 18.8% are distributed proportionally among all households according to woodland size.

If we stipulate that the opportunity costs of the individual households are known - and not just an estimate of mean opportunity costs -, individually differing compensation payments could be made to farming households. This gives rise to the **mandatory opportunity cost scheme**. At a given conservation budget, one needs to determine the share of the forest land of the farms that can be placed maximally under the conservation scheme without exceeding the budget. The share was found by a simple calculation: the individual opportunity cost multiplied by forest area under risk and multiplied by proportional share. The proportional share was adjusted until the total payments (n=130) did not exceeding the conservation budget. This share is 16.17%.

3.4.2. Voluntary PES scheme

For the voluntary instruments, we assume that an individual farming household opts to take part in an offered conservation scheme if and only if the payment/ha is higher than its opportunity cost/ha (see section 3.2).

To determine participating households in a **voluntary fixed rate scheme**, first the maximum amount of forest land is determined that can be included while fully compensating land holders for their opportunity costs. If households are ordered according to opportunity cost/ha, participating households are determined by successively selecting more "expensive" land from this list until the budget is exhausted. In a fixed-rate scheme, adding the next household's forest land from the list does not only result in adding the respective costs to the expenditure for the scheme. Additionally, all land already included needs to be multiplied with the opportunity cost of the last added household. If this procedure is followed, the conservation budget of 25,170 USD/yr is exhausted at a fixed-rate of 102 USD/ha/yr.

If a lower fixed rate would be offered, the budget could not be exhausted (reduced conservation effectiveness); if a higher rate was offered, the budget does not suffice to compensate all eligible households (oversubscription). If the analyst determining the rate, at which fixed-rate contracts are offered, does not know the actual distribution of opportunity costs, reduced effectiveness or oversubscription may easily occur.

In a **Voluntary opportunity cost scheme**, the forest land parcels of the farming households are simply included one by one from the ordered list (see above) until the budget is exhausted. Effectively, this selection of households would be the outcome of a competitive auctioning of PES contracts. In such an auction, farming households would have to make bids that exactly equal their opportunity costs.

3.4.3. “Pro-poor” PES

An initial analysis of the above four PES options indicated that their distributional impact is problematic. A very large share of financial resources tends to end up with the relatively least poor households. Thus, we designed a specific "pro-poor" PES. The design process was guided by the consideration that the simplest way of achieving positive distributional impacts would be

(i) to poverty-target payments,

> For 67% of our sample, total farming household income (sum of arable crop, cattle and off-farm income) is below the Ecuadorian minimum income (522 USD/month) necessary to subsist a family of five members in Ecuador (INEC 2009). Only these households should be eligible to participate in the scheme; and even within this large group of households contracts should be assigned in order of decreasing poverty;

(ii) while compensation payments need to exceed opportunity costs.

> If payments do not exceed opportunity costs, participating households cannot be made substantially better off.

A voluntary, poverty-targeted scheme with relatively high, fixed compensation payments is one straight forward way of incorporating both considerations. In particular, we analyse the impacts of three schemes with either 150, 200 or 300 USD/ha/yr as fixed rates. All households with opportunity costs below these rates are assigned contracts in order of poverty status until the budget of 25,170 USD/yr is exhausted. Poverty statement is approximated by total farm net income.

3.5. Distributional Impacts

For an analysis of the distributional impact of the five PES options, several variables were calculated. These variables either apply to the individual households or to the quintiles of the poverty distribution as approximated by the ex-ante total income distribution. The ex-ante income is the total income of the household which includes: agricultural and off-farm. The final income is total ex-ante income plus payments for forest conservation:

- **distribution of the total funds among poverty quintiles** (=average payment received per household poverty quintile).
- **relative income impact** per household and per poverty quintile (=payment received/ ex ante total household income).
- **number of households raised above the poverty line** by the payment.
- **GINI coefficient** measures the degrees of inequality in the distribution of income in a given society.

  The GINI coefficient varies between 0 (full equality; each individual receives the same income), and 1 (full inequality; one individual receive all income and the rest receives nothing). GINI coefficients were calculated with the command “ineqdeco” in the statistical computer package Stata 10. The formula of the GINI coeficient is:

$$Gini = 1 + \frac{1}{N} - \left(\frac{2}{m * N^2}\right) * \sum_{i=1}^{N} (\mathrm{N} - i + 1) * \mathrm{Y}_i$$

  Where N is the number of households, Y_i is the income of household i, and m is the mean total household income.

Previous studies that use GINI coefficients to show the distributional impact of PES are reported on Pascual et al. 2010, Uchine et al. 2007.

3.6. Trade-offs between poverty alleviation and efficiency in forest conservation

Of the above measures of distributional impact, the number of households lifted above the poverty line by the payments as well as the GINI coefficient supply a single value to characterise poverty alleviation and/or distributional impact information. Thus, they are particularly suitable for an aggregated comparison of the trade offs between poverty alleviation and efficiency in forest conservation. As the same budget is used in all cases, efficiency is assumed to be only influenced by the hectares covered by the different schemes.

4. Results

4.1. Distributional Impacts

The explanatory variables used to predict gross income are land ($p<0.001$), labor ($p<0.001$), input expenses ($p<0.001$), altitude ($p<0.009$), ethnicity ($p=0.149$), technical assistance ($p=0.086$), and access to formal credit ($p<0.129$).

The average opportunity cost across all households is 160 USD/ha/yr in the sample, Moreover, the opportunity costs in the income distribution are: first quintile 100 USD/ha/yr, second quintile 131 USD/ha/yr, third quintile 166 USD/ha/yr, fourth quintile 162 USD/ha/yr, and fifth quintile 235 USD/ha/yr.

In terms of total funds spent for the farming households by poverty quintiles, the mandatory opportunity cost scheme results in the worst distributional result (Fig. 3). While the poorest households only receive about 30 USD/yr, the least poor households receive more than 500 USD/yr. The mandatory fixed-rate scheme fares only slightly better. The voluntary fixed rate scheme has the relatively best pro poor performance. Still, for any of these PES options, the poorest quintile of households receives the lowest average payment per household.

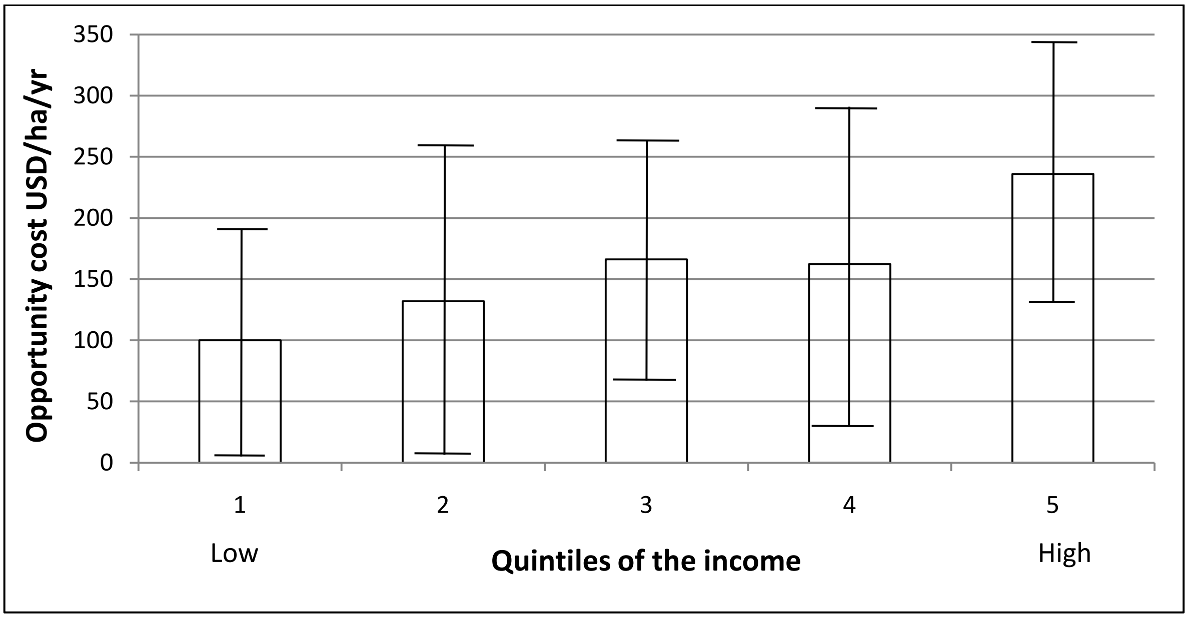

Figure 2: Average of the opportunity cost of forest conservation by quintiles of the income distribution

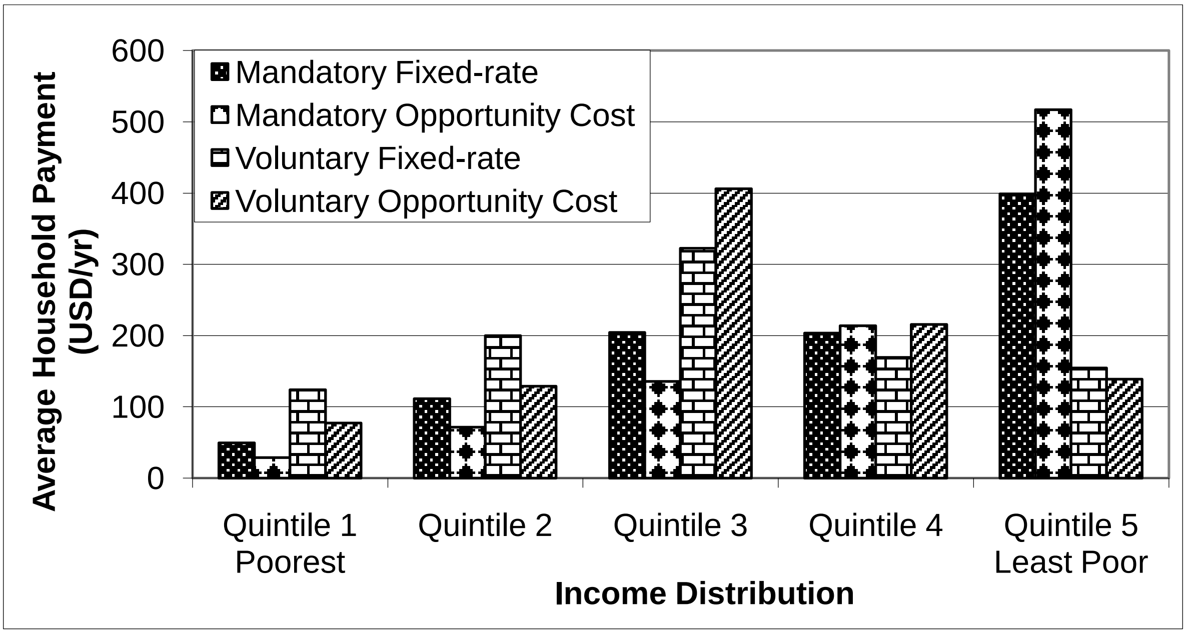

Figure 3: Average payments according to income quintiles

With respect to the impact of the payments in comparison to total household income, exactly the same relative performance of the four schemes emerges (Fig. 4). The mandatory opportunity cost scheme has the worst and the voluntary fixed rate scheme has the best performance. The two voluntary schemes add roughly 6% to 10% to the income of the poorest farming households. They also add more than five percent to the income in the second, and roughly 10% and 8% of the income of the third quintile - the latter still below the official Ecuadorian poverty line.

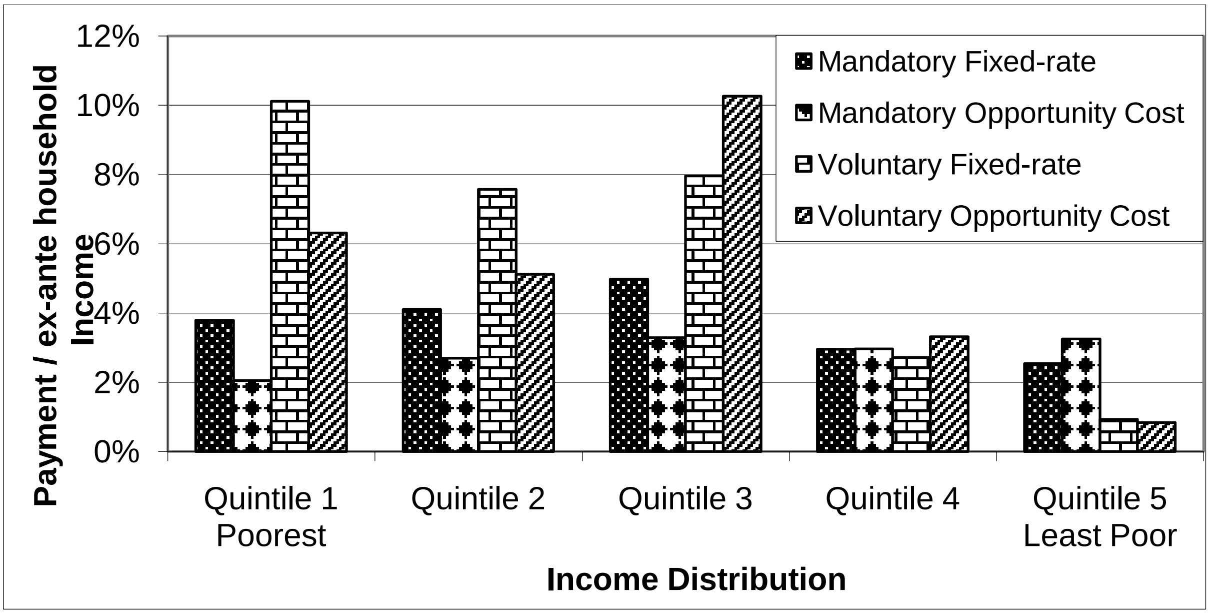

Figure 4: Impact of PES payments relative to ex-ante household income

Clear improvements with respect to distributional impact are evident for the three "pro-poor" PES (Fig.5, and Fig.6). If 300 USD/ha/yr is paid the forest of the poorest households, nearly 500 USD are spent on average in the households of the poorest and second poorest quintiles resulting in an increase of household incomes of 37% and 20% respectively. At 200 USD/ha/yr, average payments are already twice as high for the second quintile while the relative income impact for both quintiles rests at about 22-23%. Very little money is disbursed to the moderately poor third, and no money to the least two quintiles of the income distribution with the 150 USD/ha/yr scheme, already more money ends up with the third then with the first quintile.

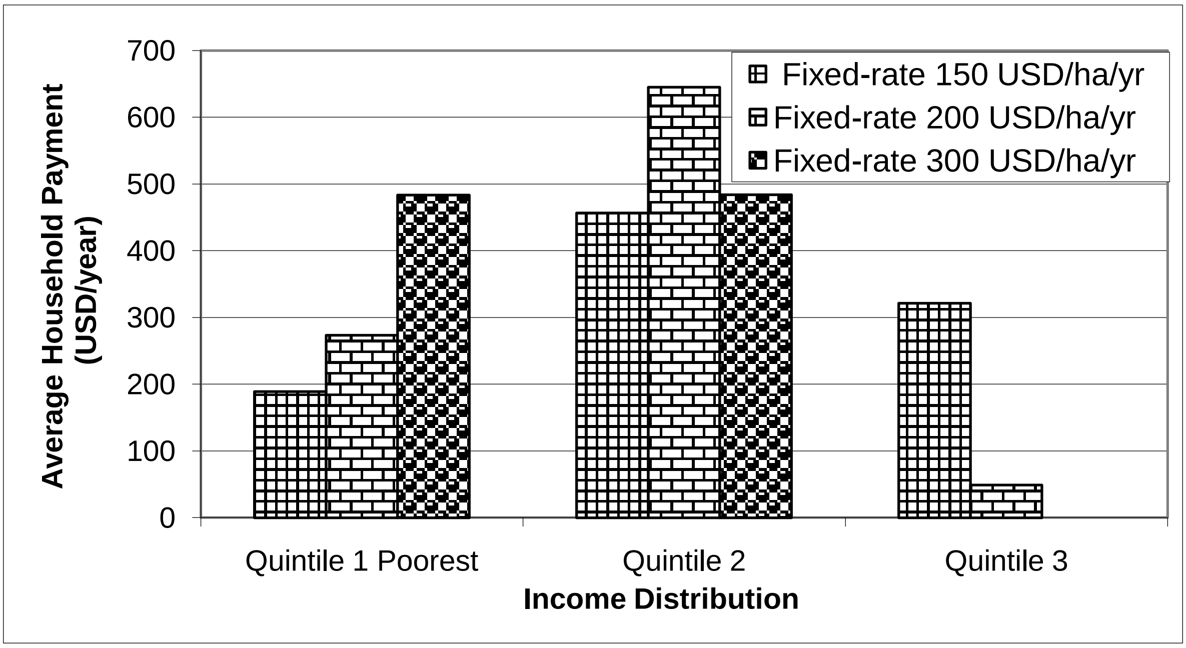

Figure 5: Average payments of the “pro-poor” PES relative to the ex-ante income distribution

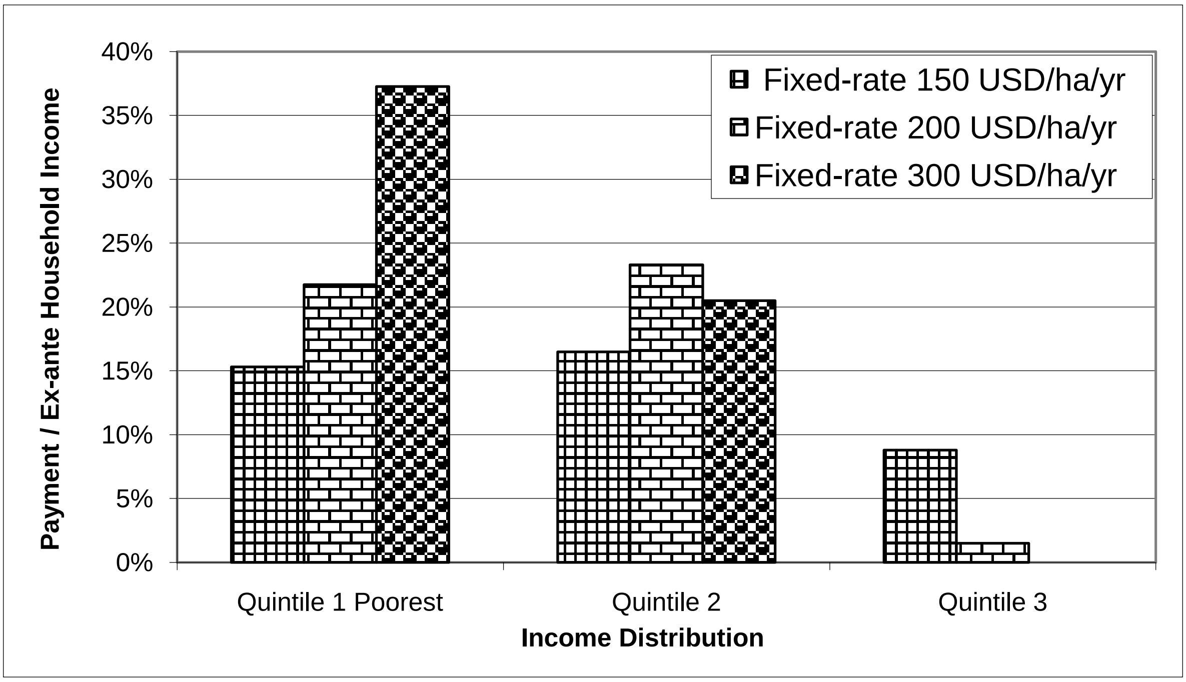

Figure 6: Impact of the “pro-poor” PES payments on relative to ex-ante household income

The numbers of households below the poverty line is not very sensitive to the payment schemes (Fig. 7). In the status quo as well as in the "Pro-Poor 300" PES, only 43 of households are above the poverty line. Even the "best" instrument by this variable-the voluntary opportunity cost scheme-can only lift five additional households above the poverty line.

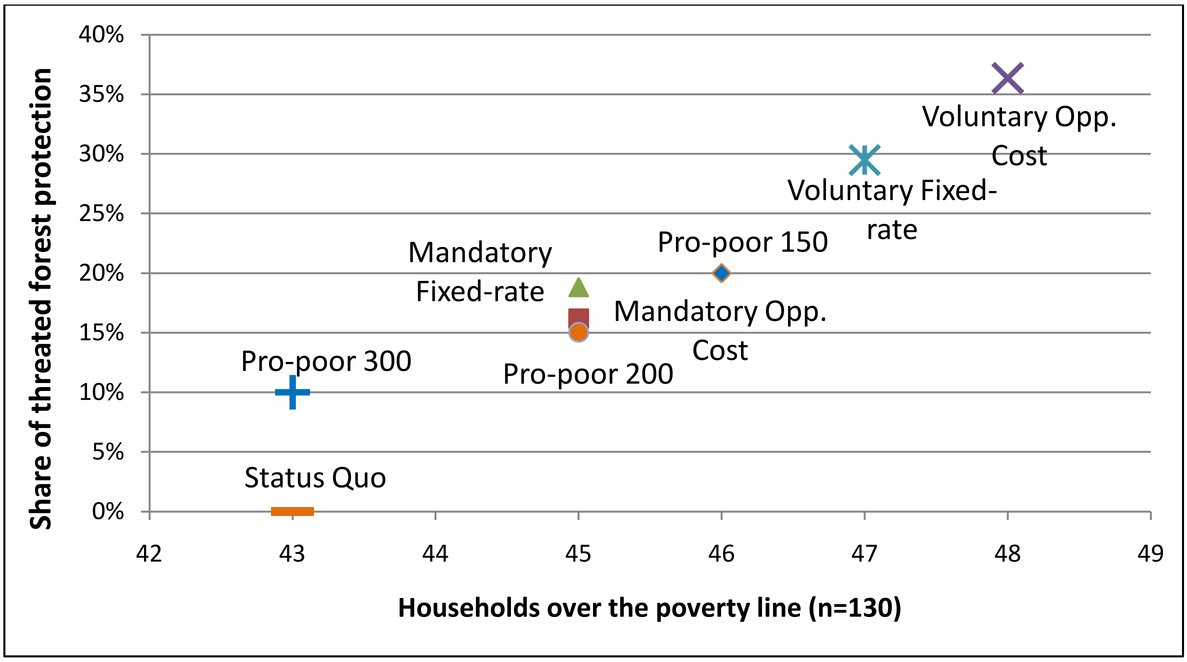

Figure 7: Forest protected versus households over poverty line

The GINI coefficient of the set of sampled households is about 0.487[20] in the status quo (Fig. 8). With a mandatory opportunity cost scheme, the value remains virtually unchanged. Fixing the payment in a mandatory scheme at the average opportunity cost per farm leads to a small improvement (mandatory fixed-rate scheme). Further improvements can be achieved with the voluntary instruments (~0.477), and finally with the "pro-poor" PES. Supporting results from Figures 4 and 5, the "Pro-Poor 300" scheme performs best (0.462) followed by "Pro-Poor 200", and "Pro-Poor 150".

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[20] This is close to the national Ecuadorian average; c.f. GINI coefficients of countries such as: Sweden 0.23, Ecuador: 0.46, Guatemala: 0.50, and Bolivia: 0.60.

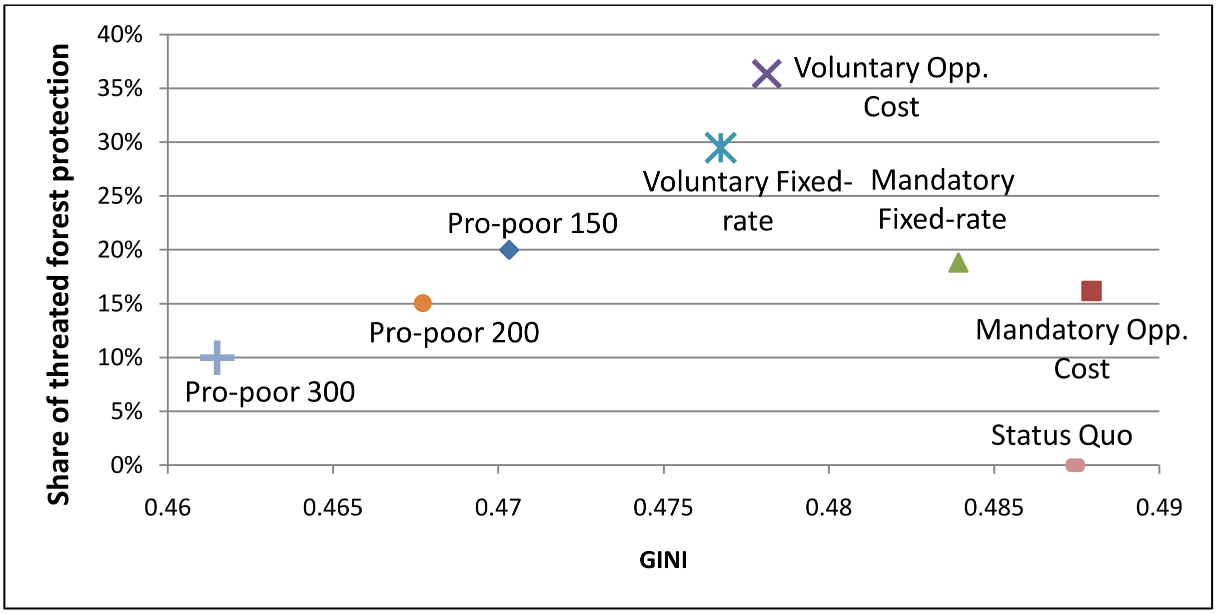

Figure 8: Forest protected versus GINI coefficient

4.2. Conservation efficiency and trade-offs

In table 1, the protected area for each of the PES is listed. The smallest area protected is achieved with the "Pro-Poor300" PES with ~84 ha (10% of the threatened area). The other "Pro-Poor" PES reaches 15-20%. The two mandatory schemes do hardly fare better with 16-19%. In contrast, the voluntary fixed-rate schemes are able to cover nearly 30% to ~36% (305 ha; voluntary opportunity cost scheme).

Table 1: Forest protection and household participation

Scheme	Mean Payment (USD/ha/yr)	Forest area (ha)	Forest area (%)	Households (number)	Households (%)
Mandatory Fixed-rate	159	158.07	18.84	124	95
Mandatory Opportunity Cost	Individual opport. cost	135.67	16.17	124	95
Voluntary Fixed-rate	102	247.34	29.48	53	41
Voluntary Opportunity Cost	Individual opport. cost	304.98	36.35	46	35
Pro-poor Fixed-rate 150	150	167.73	19.99	37	28
Pro-poor Fixed-rate 200	200	126.14	15.03	37	28
Pro-poor Fixed-rate 300	300	83.86	10.00	39	30

Plotting the area protected against the number of households above the poverty line suggests a nearly perfectly linear positive relationship between conservation efficiency and poverty alleviation (Fig. 6). Plotting area protected against the more sensitive Gini coefficients, however, substantial trade-offs become apparent (Fig. 7). Compared to the status quo, there is at least no substantially negative impact of any scheme. However, the two mandatory schemes that achieve 16-19% protection have hardly any positive distributional impact. The two voluntary schemes are highly efficient in terms of forest protection (up to 36%), and in fact, substantially improve the income distribution. Any further improvement in distributional impact is accompanied by a massive decline in conservation efficiency, though.

5. Discussion

Large knowledge gaps exist regarding the conservation effectiveness (Engel et al. 2009). A number of factors is either known or hypothesized to influence the efficiency as well as the distributional impacts of different conservation instruments including PES (section 2.2). In this study, we investigated three of these factors: (i) mandatory vs. voluntary participation, (ii) the level of the payments in relation to opportunity costs, and (iii) fixed-rate vs. flexible, opportunity-cost oriented payments. Before discussing the main results of the study, we briefly summarize a number of methodological issues.

Firstly, we have to point out that study uses empirical data on a sample of typically concerned farms. However, this is a simplified ex-ante assessment (Börner et al. 2010). Real performance of any of the schemes presented will differ as we did not include transaction costs (Wünscher et al. 2008), and use a very simple model of how local farmers decide to participate in any of the voluntary schemes. With the inclusion of the opportunity cost of forest conservation, a critical element of PES performance was included, though. More alternative assumptions on decision making, e.g. including smallholder risk aversion (Fraser 2002, Ozanne & White 2008) as well as the inclusion of (estimates of) transactions costs will improve the results in later analyses.

Second, the sample is certainly only weakly "representative" for the universe of local farming households as a random sampling approach could not be used at household level. In this respect, the quantitative statements, for example on the changes of the precise Gini coefficient values, should be treated with caution. In combination with the background knowledge of the local assistants, the relatively high share of households that was sampled (24%) as well as the much more trustful interview setting somewhat offset the disadvantages of the snowball sampling approach used. All investigated households had at least a small piece of land. If the snowball sampling had missed a number of very poor, landless households, the positive distributional impact of the "Pro Poor" PES would have been overestimated.

Third, no spatial targeting was performed. Most certainly, the forests most in risk of conservation are not evenly distributed among all sampled households. A spatially-explicit treatment of the farming households to facilitate targeting is possible later-on, however, as the precise location of all households was surveyed. It is highly likely that spatial targeting will substantially improve on-the ground conservation efficiency. If spatial targeting would have an effect on distributional aspects, is difficult to prognosticate without a full-fledged investigation into the ownership of threatened forest along the household income distribution.

Fourth, several further aspects that impact the performance of PES (property rights, payment to local communities vs. individuals, labour effects, and impact on the cost of living; Engel et al. 2008, Zilberman et al. 2006) are not included. Likewise, differences in compliance between different schemes have neither been analyzed nor potential leakage (Wunder 2005).

Finally, we do approach the issue exclusively from a financial cost-effectiveness perspective ignoring wider environmental costs and benefits for the time being (Naidoo & Adamowiz 2005). If such information was incorporated (see e.g., Hillmann & Barkmann 2009), it would allow (i) for the determination of an economically optimised conservation budget, and (ii) for additional spatial targeting options.

This brief methodological discussion suggests that quite some room for improvement remains. Still, for no single issue it is apparent that it would - either alone or in combination - invalidate the following overall results.

In discussing the following main results, we focus on a comparison of the PES instrument variants. Our two mandatory schemes are less cost efficient than the two voluntary schemes. This effect is caused by the fact that the mandatory instruments are designed as PES that provide a compensation payment for enforcing conservation land use. As all farming households are required to participate in the schemes regardless of their opportunity costs, many very "expensive" forest lands are included driving up average per ha cost at a fixed budget.

With respect to cost efficiency, opportunity cost-oriented schemes do not have a clear advantage if participation is mandatory. In fact, the mandatory opportunity cost-scheme could enlist 3% less forest area than the fixed-rate scheme using the average opportunity cost per hectare across all farms as the compensation rate. At a slightly lower rate, it would have outperformed the opportunity cost-oriented variant. For the voluntary schemes, the advantage of an opportunity cost-oriented scheme is clearly apparent (Böner et al. 2010), though. In this combination, by far the highest amount of forest (36%) could be conserved with the given conservation budget. As predicted by a consolidated body of literature, this scheme results in exceptional cost effectiveness and can be approximated in a real application by an auctioning of conservation contracts (see Latacz-Lohmann & Achimilizzi 2005, Jack et al. 2008b, Engel et al. 2007, Wooldridge 2009).

Increasingly more expensive voluntary fixed-rate schemes (including the three "Pro-Poor" PES) become less and less cost efficient. Offering voluntary fixed rate schemes with a lower payment rate that used in the "traditional" voluntary fixed rate scheme (102 USD/ha/yr) is no solution, however. In this case of under-compensation (Jack et al. 2008a), so few farmers would accept the contract that the conservation budget was not fully spent. While relative cost efficiency could be boosted, the overall conservation effect would drop.

With respect to distributional implications, a number of results could be obtained. Most importantly, the poverty alleviation impact of any scheme not assigning contracts according to poverty status is small. This supports recent review results that pronounced pro-poor impacts are rarely observed (Engel et al. 2008). This is true, for example for the otherwise much lauded PES in Costa Rica where most of the payments goes to better off households (Grieg-Gran et al. 2005, Zbinden & Lee 2005) or potential high transference of economic benefits to large landholders in the Brazilian Amazon (Böner et al. 2010).

Jack et al. (2008a) as well as Zilberman et al. (2006) had suggested that PES may help to alleviate poverty when poorest potential providers have the lowest opportunity cost of ecosystem services supply. Interestingly, this is the case in our sample with an average opportunity cost of the poorest poverty quintile of 100 USD/ha/yr as opposed to 236

USD/ha/yr for the least poor quintile. Still, none of the PES was able to generate more than about 10% of additional income for the households below the poverty line; often substantially worse results were obtained. In terms of the absolute amounts of money disbursed, all schemes allotted the least amount to the poorest quintile. For the mandatory schemes, this holds even for the poorest two quintiles. This observation stresses the second requirement mentioned by (Jack et al. 2008a): The poorest providers must also be those with a high service provision potential. Along these lines, our results show the poorest households simply own critically little forest land that can be placed under any scheme in the first place. While the average forest size of the poorest quintile is 1.65 ha, the least poor quintile owns 13.3 ha on average.

In addition to traditional efficiency-oriented PES, this study also investigates the likely performance of PES that have explicitly been designed to be an instrument to reduce poverty. At payment rates of 150-300 USD/ha/yr, income increases of 15-37% could be achieved for the poorest quintile of households, and increases of 16-23% for the second poorest quintile. In absolute terms, the scheme with a fixed rate of 300 USD/ha/yr disburses an equal amount of money to both quintiles. Already for the Pro-Poor PES with 200 USD/ha/yr, twice as much money ends up with the second quintile, with the situation worsening for the pro-poor PES with 150 with 200 USD/ha/yr. For the Pro-Poor PES with 150 USD/ha/yr. Still, by employing a voluntary mechanism that offers contracts to the poorest households first (cf. Ministerio del Ambiente 2009), a near perfect social targeting could be achieved by all three "Pro-Poor" PES if compared to the efficiency-oriented PES: The entire conservation budget ends up with households below the poverty line. Many households are so far below the poverty line, however, that even for the Pro-Poor PES, the number of households additionally moving above the poverty line is small. Still, the improveness achieved by the pro-poor PES appears substantial.

The fixed-rate offer of the Pro-Poor300 PES is ten times as high per ha as the maximum payments allowed under the *Socio Bosque* project of the Ecuadorian government. The 30 USD/ha/yr are roughly five times lower than average opportunity cost of the sample and roughly three times lower than the average opportunity cost of the poorest quintile. Still, several thousand hectares could be placed under *Socio Bosque* already (Ministerio de Ambiente 2009). This discrepency may stems from the fact that we used the actual net profit of pasture based agriculture as a opportunity costs of forest land actually under conversion threat (30% of the total forest land). If we had 'allowed' also the other 70% without imminent deforestation threat to be entered into the schemes, local farmers would likely have accepted much lower offers as the expected opportunity costs are close to zero for the next few years. In this case, if the situation describes also the situation of much of the land under Socio Bosque program, its additively may be very low.

Trade-offs between the double objectives of conservation efficiency and poverty alleviation were expected (Jack et al. 2008a). With the exception of the mandatory schemes that perform badly in both respects, such trade-offs are also apparent in our results. Specifically, very pronounced trade-offs exist among the five different voluntary instruments. Moving from "traditional" voluntary schemes (fixed rate or opportunity cost-oriented) to the "Pro-poor" schemes by offering very high fixed payments to the poorest households, comes at high losses of cost efficiency. The amount of forest covered drops from 36% to 10% while the relatively worst distributional impact is traded for the best. In technical terms, the mandatory schemes are clearly suboptimal while the voluntary schemes represent members of a set of instruments with nearly Pareto-optimal performance.

The two mandatory conservation instruments were designed to include a compensation payment. So the risk to actually impose direct cost in terms of overall income losses on the poor was lower than in other forms of 'command and control' conservation that do only impose land use restrictions (see, Engel et al. 2008). The amount of such costs can easily be assessed from our dataset, though. Because the opportunity costs of forest conversion were calculated from actual net profit data of local pasture-based agriculture, the payment data per farm approximate also the long-term loss per farm if no compensation was paid - or the immediate financial loss in case of a mandatory afforestation program with no subsequent forest use.

6. Conclusion

In sum, we found that the design of payment and contract attributes has a pronounced impact on the efficiency (cost-effectiveness) as well as on the distributional impact of PES-type conservation instruments (cf. Pagiola 2010). Voluntary instruments tend to be more cost efficient than mandatory ones if competitively low payments are offered. Such low offers - for example as aimed at though the auctioning of PES contracts – were found to be incompatible with poverty alleviation goals. Pronounced pro-poor distributional impacts are possible, however, but the PES contracts will need rather high payments per unit area (up to 300 USD/ha/yr) and will have to be offered exclusively to the poorest households. At the community level, the Ecuadorian *Socio Bosque* program achieves such a form of social targeting because the program is only implemented in particularly poor communities. Its acceptance in spite of its very low fixed payment offer of 30 USD/ha/yr suggests that forest lands with a low agricultural potential, i.e. with a low deforestation risk, may have been placed under the program. Thus, issues of additionality and spatial targeting should urgently be investigated here. With respect to the massive trade-offs between the goals of conservation efficiency and positive distribution impacts reported, it appears unlikely that these trade-offs can be avoided by additional 'innovative' forms of PES. In landscapes dominated by agricultural smallholders but also populated by a substantial share of larger farms, excluding larger, less poor farming households from participation is in many cases likely to exclude areas with low per area costs.

References

Adams W., Aveling R., Brockington D., Dickson B., Elliott J., Hutton J., Roe D, Vira B., Wolmer W. 2004. Biodiversity Conservation and the Eradication of Poverty. Science 306(5699):1146 - 1149.

Adams V., Pressey R., Naidoo R. 2010. Opportunity costs: Who really pays for conservation?. Biological Conservation 143(2):439-448.

Antle J., Stoorvogel J. 2008. Agricultural carbon sequestration, poverty and sustainability. Environmental and Development Economics 13:327-352.

Azzoni C., Isai J. 1994. Estimating the cost of environmental protection in Brazil. Ecological Economics 11(2):127-133.

Bagnoli P., Goeschl T., Kovács E. 2008. People and Biodiversity Policies. Impacts, Issues and Strategies for policy action. OECD, Paris.

Bawa K., Kress J., Nadkarni N, Lele S., Raven P., Janzen D., Lugo A., Ashton P., Lovejoy T. 2004. Tropical Ecosystems into the 21st Century. Science 306(5694):227-228

Beck E. 2008. Preface. In: Beck, E.; Bendix, J.; Kottke, I.; Makeschin, F. and Mosandl, R.: Gradients in a tropical mountain ecosystem of Ecuador. Ecological Studies 198:5-7

Bond I., Grieg-Gran M., Wertz S., Hazlewood P.,Wunder S., Angelsen A. 2009. Incentives to sustain forest ecosystem services. A review and lessons for REDD. Natural Resources Issues No. 16. International Institute for Environmental and Development, London, UK, with CIFOR, Bogor, Indonesia, and World Resources Institute, Washington D.C., USA.

Börner J., Wunder S., Wertz-Kanounnikoff S., Tito M., Pereira L., Nascimento N. 2010. Direct conservation payments in the Brazilian Amazon: Scope and equity implications. Ecological Economics 69(6):1272-1282.

Bracer S., Scherr S., Molnar A., Sekher M., Ochieng BO., Sriskanthan G. 2007. Organization and Governance for Fostering Pro-Poor Compensation for Environmental Services: CES Scoping Study Issue Paper no. 4. ICRAF Working paper no.39, Nairobi, Kenya: World Agroforestry Center.

Brummitt N., Lughadha E. 2003. Biodiversity: where’s hot and where’s not. In: Conservation Biology 17:1442–1448.

Chomitz K., Alger K., Thomas T., Orlando H., Nova P. 2005. Opportunity costs of conservation in a biodiversity hotspot: the case of southern Bahia. Environment and Development Economics 10: 293–312.

Clements T., John A., Nielsen K., An D., Tan S., Milner J. Payments for biodiversity conservation in the context of weak institutions: Comparison of three programs from Cambodia. Ecological Economics 69 (6):1283-1291.

CIPRB (Comisión Inter-institucional Pro-Reserva de Biosfera). 2005. Propuesta para la declaratoria de la Reserva de la Biosfera Podocarpus- El Cóndor. UNESCO Programa El Hombre y La Biosfera (MAB). Formulario de la propuesta de Reservas de la Biosfera – SC-98/WS/9.

Corbera E., Kosoy N., Martínez M. 2007. Equity implications of marketing ecosystem services in protected areas and rural communities: Case studies from Meso-America. Global Environmental Change 17(3-4):365-380.

Corbera E., Brown K., Adger W. 2007. The equity and legitimacy of markets for ecosystem services. Development and Change 38:587–613.

Engel S., Pagiola S., Wunder S. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. Ecological Economics. 65:663-674.

Engel S., Wünscher T., Wunder S. 2009. Increasing the efficiency of forest conservation: The case of payments for environmental services in Costa Rica in Avoided deforestation. Palmer, C and Engel, S. (eds) 208-216. Routledge.

Eichhorn S. 2009. Effekte eines Straßenbaus im Biosphärenreservat Podocarpus-El Cóndor auf die Landnutzung und Biodiversität. Diplomarbeit. Georg-August-Universität Göttingen. Germany.

FAO. 2006. Global forest resources assessment 2005. Progress towards sustainable forest management. Food and Agriculture Organization of the United Nations, Rome-Italy

FAO. 2007. The State of Food and Agriculture. Paying farmers for environmental services. Food and Agriculture Organization of the United Nations, Rome-Italy

Ferraro P., Kiss A. 2002. Direct Payments to Conserve Biodiversity. Science 29 (5599):1718 – 1719.

Fisher B., Christopher T. 2007. Poverty and biodiversity: Measuring the overlap of human poverty and the biodiversity hotspots. Ecological Economics 62(1):93-101.

Fraser R. 2002. Moral Hazard and Risk Management in Agri-environmental Policy. Journal of Agricultural Economics 53(3): 475-487.

Gong Y., Bull G., Baylis K. 2010. Participation in the world's first clean development mechanism forest project: The role of property rights, social capital and contractual rules. Ecological Economics 69(6):1292 – 1302.

Graff-Zivin J., Lipper L. 2008. Poverty, risk, and the supply of soil carbon sequestration. Environmental and Development Economics 13:353-373.

Grieg-Gran M., Porras I., Wunder S. 2005. How can market mechanisms for forest Ecosystem services help the poor? Preliminary lessons from Latin America. World Development 33(9):1511-1527.

Hillmann, B., Barkmann, J. 2009. Conservation: a small price for long-term economic well-being. Nature 461:37

IGM (Instituto Geográfico Militar del Ecuador). 2003. Aerial photographs, scale 1:5000 resolution pixel 1m, pancromaticas, Proyection UTM, DATUM WGS84 Zone 17S.

INEC. 2009. IPC Canasta Básica Nacional Ciudades

Jack J., Kousky C., Sims K. 2008a. Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. PNAS 105(28):9465-9478.

Jack J., Leimona B., Ferraro P. 2008b. A Revealed preference approach to estimating supply curves for ecosystem services: Use of auctions to set payments for soil erosion control in Indonesia. Conservation Biology 23(2):359 – 367.

Jack J. Allocation in environmental markets: A field experiment with tree planting contracts. Forthcoming.

Jourdain D., Pandey S., Tai D., Quang D. 2009. Payments for environmental services in upper-catchments of Vietnam: will it help the poorest?. International Journal of the Commons 3(1).

Kirwan B., Lubowski R., Roberts M. 2005. How cost-effective are land retirement auctions? Estimating the difference between payments and willingness to accept in the Conservation reserve program American Journal Agricultural Economics. 87 (5):1239–1247

Kollmair M., Rasul G. 2010. Addressing equity and poverty concerns in payments for environmental services. Mountain Forum Bulletin. 10(1):12-14.

Latacz-Lohmann U., Van der Hamsvoort C. 1997. Auctioning Conservation Contracts: A Theoretical Analysis and an Application American Journal Agricultural Economics 79(2) 407-418.

Latacz-Lohmann U., Schilizzi S. 2005. Auctions for Conservation Contracts: A Review of The Theoretical and Empirical Literature. PROJECT No. UKL/001/05)

Leimona B., Joshi L., van Noodwijk M. 2009. Can rewards for environmental services benefit the por? Lessons from Asia. International Journal of the Commons 3(1).

Lipper L., Cavatassi R. 2004. Land-Use Change, Carbon Sequestration and Poverty alleviation. Environmental Management 33(1):374 -387

Maza B., Barkmann J., von Walter F., Maggraf. 2010. Modelling smallholders production and agricultural income in the area of the Biosphere reserve “Podocarpus – El Cóndor”, Ecuador. Internal Discussion Paper. Department of Agricultural Economics. Georg-August Universität Göttingen. No. 1009.

Milder J., Scherr S, Bracer C. 2010. Trend and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. Ecological and Society 15(2):4

Ministerio de Ambiente. 2008. Acuerdo 169 Creación del Programa Socio Bosque. Quito, Ecuador

Ministerio de Ambiente. 2009. Programa Socio Bosque. Quito, Ecuador

Myers N., Mittermeier R. 2000. Biodiversity hotspots for conservation priorities. Nature 403(6772):853.

Naidoo R., Adamowicz W. 2005 Modelling opportunity cost of conservation in transitional landscapes. Conservation Biology 20(2):490 – 500.

Naidoo R., Balmford A., Ferraro P., Polasky S., Ricketts T., Rouget M. 2006. Integrating economic cost into conservation planning. TRENDS in Ecology and Evolution 21(12):681 – 687.

Ozanne A., White B. 2008. Hidden action, risk aversion and variable fines in agri-environmental schemes. The Australian Journal of Agricultural and Resource Economics 52:203–212.

Pagiola S., Arcenas A., Platais G. 2005. Can Payments for Ecosystem Services Help Reduce Poverty? An Exploration of the Issues and the Evidence to Date from Latin America. World Development 33(2):237-253.

Pagiola S. 2008. Payments for environmental services in Costa Rica. Ecological Economics 65(4):712-724.

Pagiola S., Rios A., Arcenas A. 2008. Can the poor participate in payments for environmental services? Lessons from the Silvopastoral Project in Nicaragua. Environmental and development Economics 13:299-325.

Pagiola S., Bosquet B. 2009. Estimating the costs of REDD at the country level. Washington: Forest Carbon Partnership Facility.

Pagiola S. 2010. Using PES to implement REDD. Forthcoming.

Pascual U., Muradian R., Rodríguez L., Duraiappah A. 2010. Exploring the links between equity and effciency in payments for environmental services: A conceptual approach. Ecological Economics 69 (6):1237-1244.

Pfaff A., Kerr S., Lipper L., Cavatassi R., Davis B., Hendy J., Sanchez-Azofeifa. 2007. Will buying tropical carbon benefit the poor? Evidence from Costa Rica. Land Use Policy 24(3):600-610.

Porras I, Gring-Gran M, Neves N. 2008. All that glitters: A review of payments for watershed services in developing countries. Natural Resources Issues No 11. International Institute for Environmental and Development. London, UK.

Rivera 2005. El Sistema Nacional de Áreas Protegidas del Ecuador –SNAP. Power point presentation.

Roe D., Elliot J. 2006. Pro-poor conservation: the elusive win-win for conservation and poverty reduction. Policy Matters 14:53-63.

SCBD (Secretariat of the Convention on Biological Diversity). 2009. Biodiversity, Development and Poverty Alleviation: Recognizing the Role of Biodiversity for Human Well-being. Montreal.

Socio Bosque Program. 2010. Data Base.Quito, Ecuador.

Socio Bosque Program. 2010a. Conceptualización y avances al segundo año de implementación. Ministerio del Ambiente. Quito, Ecuador.

Sommerville M., Jones J., Rahajaharison M, Milner-Gullan E. 2010. The role of fairness and benefit distribution in community-based Payment for Environmental Services interventions: A case study from Menabe, Madagascar. Ecological Economics 69 (6):1262-1271.

Swallow B, Meinzen-Dick R., van Noordwijk M. 2005. Localizing demand and supply of environmental services: Interactions with property rights, collective action and the welfare of the poor. CAPRi Working Paper # 42.

Turpie J., Marais C., Blignaut J. 2008. The working for water programme: Evolution of a payments for ecosystem services mechanism that addresses both poverty and ecosystem service delivery in South Africa. Ecological Economics 65(4):788-798.

Uchida E., Xu J., Xu Z., Rozelle S. 2007. Are the poor benefiting from China´s Land conservation programs? Environmental and Development Economics 12:593-620.

Wunder S. 2008. Payments for environmental services and the poor: concepts and preliminary evidence. Environmental and Development Economics 13:279-297.

Wunder S., Alban M. 2008. Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador. Ecological Economics 65(4):685-698.

Wooldridge M. 2009. An Introduction to MultiAgent System. Second Edition. John Wiley & Sons Ltd.

Wunder S. 2000. The economics of deforestation: the example of Ecuador. St. Martin, New York.

Wunder S. 2005. Payments for Ecosystem services: Some nuts and bolts. CIFOR. Ocasional Paper No. 42. Jakarta 10065, Indonesia.

Wunder S. 2007. The efficiency of payments for environmental services in tropical conservation. Conservation Biology 21.48–58.

Wunder S., Albán M. 2008. Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador. Ecological Economics 13:279-297.

Wunder S., Engel S., Pagiola S. 2008. Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. Ecological Economics 65(4):834-852.

Wünscher T., Engel S., Wunder S. 2008. Spatial targeting for environmental services: A tool for boosting conservation benefits. Ecological Economics 65(4):822-833.

Zeller M., Schwarze S. 2006. Submodule: Planning methods for agricultural development. Georg August Universität, Göttingen-Germany.

Zbinden S., Lee D. 2005. Paying for environmental services: An analysis of participation in Costa Rica´s PSA program. World development 33(2):255-272.

Zilberman D., Lipper L., Mccarthy N. 2006. When could payments for environmental services benefit the poor?. Environment and Development Economics. 13:255-278.

Chapter V

General Discussion

Ecuador is one of the countries with the richest biodiversity globally (Brummitt and Lughada 2003). 18% of the national territory is below protected area. Still, Ecuador has the highest annual deforestation rate (FAO 2005) in South America (1.7%; 198 000 ha/yr) with much land being converted to pastures and crop land. Land use change from natural ecosystem to agricultural land is one main threat of biodiversity in Ecuador (Wunder 2000). Sustainable forest protection versus alternatives land uses needs a deep knowledge of the ecosystem and socio-economic conditions of the users. In this way, DFG Research Unit (RU) 816 promotes the research of tropical mountain rain forest and its anthropogenic replacement systems in the south of Ecuador. Inside RU, the project “Human Drivers and land use system” focus in different sustainable management options in mountain rainforest, by investigating in the ecological and economic consequences of the different land use systems. Also, sub-project “Spatial explicit and institutional extended of ecosystem services C3.2” considers that the design and valuation of biodiversity conservation strategies (afforestation scenarios, biosphere reserve zoning, payments for ecological services) needs following elements: (i) empirical data on the global, regional and local benefits of conservation (demand side of ecosystem services) and (ii) financial data on smallholder production options (supply side ecosystem services).

This study focus in the heterogeneity of different land use options of the peasant household in the area of Biosphere Reserve “Podocarpus-El Condor”. The research has three research questions *i*) What are opportunity costs of the farmers to conserve the native Andean forest?. One way to reduce negative externalities of land use conversion is to increment the technical efficiency. In this sense, the second question: *ii*) Is current agricultural production working efficient?. Finally one special interest is: *ii*) What is the best conservation instrument in order to reach cost-efficiency and poverty alleviation?, The main findings with the research are:

Profitability of smallholder agriculture

Studies about profitability of agricultural production are given by Wunder (2000) for the Ecuadorian Andes, and by Knoke et al. (2009) for the local research area. There is a gap of the information about of heterogeneity of farm agricultural profitability, however. In this study, we fill this gap information. We analyze the profitability of local arable crops and cattle production systems.

Given the restricted resources of the study, the snowball sampling approach used has likely performed better than a random sampling approach. Peasant households in the research area tended to exaggerate or understate their farm or production characteristics as a strategy of "personal protection" potentially leading to substantial strategic bias. In this sense, the snowball approach reduces strategic bias likely to be present when sensitivity information or financial information was to be disclosed. Still, statistical representativeness cannot be claimed for the sample. The non-random sampling requires that descriptive statistic presented needs to be treated with caution. Likewise, the representation of cattle income as a function of growth increments and sales of cattle, will need refinements that potentially affect the conclusions presented.

The arable crop production represents 3.9% of the total household income and it is less profitable (-276 USD/ha/yr) on average than cattle production (160 USD/ha/yr). Arable crops are restricted to small plots near to houses mainly for auto-consumption. In other side, pasture-based production accounts for 70.4% of total household income.

Family labour has a strong influence on profitability of arable crop and cattle production. The net profit calculations are reduced drastically when family labour valued at actual agricultural wage rates are included as fixed costs. The gross margin in arable crop switches from 79 USD/ha/yr to -276 USD/ha/yr. The gross margin in cattle switches from 245 USD/ha/yr to 160 USD/ha/yr. As a consequence, some negative values on net profit of cattle production show up. The wage rate applied may have been too high as farmers actually report difficulties in finding off-farm employment.

Our results show that cattle production is the more profitable land use. But it also has a substantial heterogeneity in the net profits. The average cattle ranching net profit is 160 USD/ha/yr. This value is lower than net profit of 208 USD/ha/yr (adjusted for inflation[21])

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[21] The value was adjusted with the formula: Future amount = Present value * (1+ % inflation) ^ number of years. The reference adjusted value is for 2007 (Annex 7). The survey was conducted at the beginning of 2008 and the data information corresponds to 2007. Ecuador adopted the dollar as official currency since 2000.

reported by Wunder[22] (2000) for Ecuadorian Andes. Our values differ from values reported by Wunder (2000) because Wunder values are base on information given by experts in the field. Also, our value (160 USD/ha/yr) is higher than the ~100 USD/ha/yr net profit reported by Knoke[23] et al. (2009) for research area. Our values may differ from values reported by Knoke et al. (2000) because Knoke et al. have a smaller sample, and have used a different algorithm to calculate income.

Our main contribution is to show the huge heterogeneity present in our sample. For instance, 70 USD/ha/yr (percentile 25), 123 USD/ha/yr (percentile 50) and 227 USD/ha/yr (percentile 75). The heterogeneity of profitability of cattle production has biodiversity policy implications, for example in the distributional impacts and efficiency of payments for forest conservation (Details in chapter III) or alternative conservation measures (Wunder 2005).

The cattle production analysis suggests that several factors influence profitability. Cobb-Douglas production function determined significant factors that affect gross income which directly affects profitability. A farmer who lives in lowlands, is of “Mestizo” ethnic, has access to technical assistance and credit has higher gross margin than a farmer who lives in uplands, is of “Saraguro” ethnic, and without access to technical assistance and credit. One reason for differences on profitability may be that the “Mestizos” are more connected with the local markets in Loja and Zamora cities. On the contrary, the ethnic group “Saraguros” is located far from local markets.

One hectare more arable crop land increases gross income by 148.6 USD/yr. Because of the problematic terrain, a substantial extension of arable agriculture may not be possible. One man-day more of labor increases gross income by 0.38 USD/yr. The marginal effect of labor is less that average wage (4 USD/day) reported for our sample. It means that there is too much labor available for arable crop production. One USD/yr of input expenses increases gross income by 2.12 USD/yr. It means that the investment on inputs appears very low.

Marginal effect of one hectare more of pasture land is an increase in gross income by 4.75 USD/yr. This is much less than for arable land. One man-day more of labor increases gross

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[22] Wunder (2000) reports 125 USD/ha/year for cattle ranching, at 5% discount rate, in the fourth year of deforestation cycle. It is not explicit how was valued the labor.

[23] It is not explicit how was valued and incorporated the labor.

income by 1.56 USD/yr. The marginal effect of labor is still less that the average wage rate paid (4 USD/day) for our sample – but it is much higher than compared to arable agriculture. One USD/yr of input expenses only increases gross income by 0.17 USD/yr. This means that the investment in cash inputs may already be high given the principle constraints of the current production technology.

In the face of severe nature conservation concerns in the area coinciding with severe poverty, it is a challenge to improve the profitability of local peasant households per hectare (intensification). Contrary to the ideas expressed by Adams (2009) who argues for an intensification of the land use system, our results indicate only limited room for successful intensification with the current production technologies. The relatively best results may be achieved if some of the pasture land could be converted to arable agriculture without inducing additional resource conservation concerns. Also a higher cash investment into arable agriculture appears promising with rate of return potentially in excess of 100% p.a. Furthermore, access to technical assistance and to formal credit may improve cattle production. Using robust standard errors, the significance of predictors is closer to and in excess of 0.1 that below 0.05, however.

Technical efficiency and determinants of cattle production

This study outlines the technical efficiency level and its determinants in the cattle production based on farm level data sampled in farming season 2008. A total of 130 farming households were considered for the analysis. The translog stochastic frontier production function was found appropriate for the dataset used for the investigation.

The snowball sampling approach is a better than a random sampling approach in the research area. Peasant households exaggerate or minimize their ownership as strategy of “personal protection” (strategic bias). There is a reason: They have unfulfilled promises or bad experiences from politicians, governmental institutions, or past researchers. In this sense, the snowball approach reduces strategic bias likely to be present when sensitivity information or financial information was to be disclosed.

The production frontier models reveal that size of pasture, labour and costs of production monotonically increased cattle production in the sampled farms. Also, the technical inefficiency model shows that location of the farms (lowland), ethnicity (Mestizo ethic) and access to technical assistance increased the technical efficiency of cattle farms in the study area.

The farmer localization has a positive impact on efficiency. The big difference is not capturated with the current variables, that is the market access variable. A road between “Sabanilla” and “Tibio” (inhabitat by Saraguros ethnic) is planned. Saraguros will enable a dramatically market access which is according to our results. In other hand, Eichhorn (2009) suggests that there is high probability of the pasture land increment (deforestation) with the new road.

For the institution of public and private policy design, we suggested that policy relevance of the provision of technical assistance should be seriously looked into in the cattle production. Farmers would like to receive technical assistance mainly on management reproduction cattle, pasture management, and work conservation practices. Although we are aware from our survey that rudimentary (low technology) system characterized cattle production in the sample, nonetheless, increased technical assistance from both public and private stakeholders in the cattle production in Ecuador will go a long way in repositioning the industry in the country and in the Latin American region at large.

Efficiency and distributional impacts of Payments for Ecosystem Services (PES)

Large knowledge gaps exist regarding the conservation effectiveness (Engel et al. 2009). A number of factors is either known or hypothesized to influence the efficiency as well as the distributional impacts of different conservation instruments including PES (section 2.2). In this study, we investigated three of these factors: (i) mandatory vs. voluntary participation, (ii) the level of the payments in relation to opportunity costs, and (iii) fixed-rate vs. flexible, opportunity-cost oriented payments. Before discussing the main results of the study, we briefly summarize a number of methodological issues.

Firstly, we have to point out that study uses empirical data on a sample of typically concerned farms. However, this is a simplified ex-ante assessment. Real performance of any of the schemes presented will differ as we did not include transaction costs (Wünscher et al. 2008), and use a very simple model of how local farmers decide to participate in any of the voluntary schemes. With the inclusion of the opportunity cost of forest conservation, a critical element of PES performance was included, though. More alternative assumptions on decision making, e.g. including smallholder risk aversion (Fraser 2002, Ozanne & White 2008) as well as the inclusion of (estimates of) transactions costs will improve the results in later analyses.

Second, the sample is certainly only weakly "representative" for the universe of local farming households as a random sampling approach could not be used at household level. In this respect, the quantitative statements, for example on the changes of the precise Gini coefficient values, should be treated with caution. In combination with the background knowledge of the local assistants, the relatively high share of households that was sampled (24%) as well as the much more trustful interview setting somewhat offset the disadvantages of the snowball sampling approach used. All investigated households had at least a small piece of land. If the snowball sampling had missed a number of very poor, landless households, the positive distributional impact of the "Pro Poor" PES would have been overestimated.

Third, no spatial targeting was performed. Most certainly, the forests most in risk of conservation are not evenly distributed among all sampled households. A spatially-explicit treatment of the farming households to facilitate targeting is possible later-on, however, as the precise location of all households was surveyed. It is highly likely that spatial targeting will substantially improve on-the ground conservation efficiency. If spatial targeting would have an effect on distributional aspects, is difficult to prognosticate without a full-fledged investigation into the ownership of threatened forest along the household income distribution.

Fourth, several further aspects that impact the performance of PES (property rights, payment to local communities vs. individuals, labour effects, and impact on the cost of living; Engel et al. 2008, Zilberman et al. 2006) are not included. Likewise, differences in compliance between different schemes have neither been analyzed nor potential leakage (Wunder 2005).

Finally, we do approach the issue exclusively from a financial cost-effectiveness perspective ignoring wider environmental costs and benefits for the time being (Naidoo & Adamowiz 2005). If such information was incorporated (see e.g., Hillmann & Barkmann 2009), it would allow (i) for the determination of an economically optimised conservation budget, and (ii) for additional spatial targeting options.

This brief methodological discussion suggests that quite some room for improvement remains. Still, for no single issue it is apparent that it would - either alone or in combination - invalidate the following overall results.

In discussing the following main results, we focus on a comparison of the PES instrument variants. Our two mandatory schemes are less cost efficient than the two voluntary schemes. This effect is caused by the fact that the mandatory instruments are designed as PES that provide a compensation payment for enforcing conservation land use. As all farming households are required to participate in the schemes regardless of their opportunity costs, many very "expensive" forest lands are included driving up average per ha cost at a fixed budget.

With respect to cost efficiency, opportunity cost-oriented schemes do not have a clear advantage if participation is mandatory. In fact, the mandatory opportunity cost-scheme could enlist 3% less forest area than the fixed-rate scheme using the average opportunity cost per hectare across all farms as the compensation rate. At a slightly lower rate, it would have outperformed the opportunity cost-oriented variant. For the voluntary schemes, the advantage of an opportunity cost-oriented scheme is clearly apparent, though. In this combination, by far the highest amount of forest (36%) could be conserved with the given conservation budget. As predicted by a consolidated body of literature, this scheme results in exceptional cost effectiveness and can be approximated in a real application by an auctioning of conservation contracts (see Latacz-Lohmann & Achimilizzi 2005, Jack et al. 2008b, Engel et al. 2007, Wooldridge 2009).

Increasingly more expensive voluntary fixed-rate schemes (including the three "Pro-Poor" PES) become less and less cost efficient. Offering voluntary fixed rate schemes with a lower payment rate that used in the "traditional" voluntary fixed rate scheme (102 USD/ha/yr) is no solution, however. In this case of under-compensation (Jack et al. 2008a), so few farmers would accept the contract that the conservation budget was not fully spent. While relative cost efficiency could be boosted, the overall conservation effect would drop.

With respect to distributional implications, a number of results could be obtained. Most importantly, the poverty alleviation impact of any scheme not assigning contracts according to poverty status is small. This supports recent review results that pronounced pro-poor impacts are rarely observed (Engel et al. 2008). This is true, for example for the otherwise much lauded PES in Costa Rica where most of the payments goes to better off households (Grieg-Gran et al. 2005, Zbinden & Lee 2005).

Jack et al. (2008a) as well as Zilberman et al. (2006) had suggested that PES may help to alleviate poverty when poorest potential providers have the lowest opportunity cost of ecosystem services supply. Interestingly, this is the case in our sample with an average opportunity cost of the poorest poverty quintile of 100 USD/ha/yr as opposed to 236 USD/ha/yr for the least poor quintile. Still, none of the PES was able to generate more than about 10% of additional income for the households below the poverty line; often substantially worse results were obtained. In terms of the absolute amounts of money disbursed, all schemes allotted the least amount to the poorest quintile. For the mandatory schemes, this holds even for the poorest two quintiles. This observation stresses the second requirement mentioned by (Jack et al. 2008a): The poorest providers must also be those with a high service provision potential. Along these lines, our results show the poorest households simply own critically little forest land that can be placed under any scheme in the first place. While the average forest size of the poorest quintile is 1.65 ha, the least poor quintile owns 13.3 ha on average.

In addition to traditional efficiency-oriented PES, this study also investigates the likely performance of PES that have explicitly been designed to be an instrument to reduce poverty. At payment rates of 150-300 USD/ha/yr, income increases of 15-37% could be achieved for the poorest quintile of households, and increases of 16-23% for the second poorest quintile. In absolute terms, the scheme with a fixed rate of 300 USD/ha/yr disburses an equal amount of money to both quintiles. Already for the Pro-Poor PES with 200 USD/ha/yr, twice as much money ends up with the second quintile, with the situation worsening for the pro-poor PES with 150 with 200 USD/ha/yr. For the Pro-Poor PES with 150 USD/ha/yr. Still, by employing a voluntary mechanism that offers contracts to the poorest households first (cf. Ministerio del Ambiente 2009), a near perfect social targeting could be achieved by all three "Pro-Poor" PES if compared to the efficiency-oriented PES: The entire conservation budget ends up with households below the poverty line. Many households are so far below the poverty line, however, that even for the Pro-Poor PES, the number of households additionally moving above the poverty line is small. Still, the improveness achieved by the pro-poor PES appears substantial.

The fixed-rate offer of the Pro-Poor300 PES is ten times as high per ha as the maximum payments allowed under the *Socio Bosque* project of the Ecuadorian government. The 30 USD/ha/yr are roughly five times lower than average opportunity cost of the sample and roughly three times lower than the average opportunity cost of the poorest quintile. Still, several thousand hectares could be placed under *Socio Bosque* already (Ministerio de Ambiente 2009). This discrepency may stems from the fact that we used the actual net profit of pasture based agriculture as a opportunity costs of forest land actually under conversion threat (30% of the total forest land). If we had 'allowed' also the other 70% without imminent deforestation threat to be entered into the schemes, local farmers would likely have accepted much lower offers as the expected opportunity costs are close to zero for the next few years. In this case, if the situation describes also the situation of much of the land under Socio Bosque program, its additively may be very low.

Trade-offs between the double objectives of conservation efficiency and poverty alleviation were expected (Jack et al. 2008a). With the exception of the mandatory schemes that perform badly in both respects, such trade-offs are also apparent in our results. Specifically, very pronounced trade-offs exist among the five different voluntary instruments. Moving from "traditional" voluntary schemes (fixed rate or opportunity cost-oriented) to the "Pro-poor" schemes by offering very high fixed payments to the poorest households, comes at high losses of cost efficiency. The amount of forest covered drops from 36% to 10% while the relatively worst distributional impact is traded for the best. In technical terms, the mandatory schemes are clearly suboptimal while the voluntary schemes represent members of a set of instruments with nearly Pareto-optimal performance.

The two mandatory conservation instruments were designed to include a compensation payment. So the risk to actually impose direct cost in terms of overall income losses on the poor was lower than in other forms of 'command and control' conservation that do only impose land use restrictions (see, Engel et al. 2008). The amount of such costs can easily be assessed from our dataset, though. Because the opportunity costs of forest conversion were calculated from actual net profit data of local pasture-based agriculture, the payment data per farm approximate also the long-term loss per farm if no compensation was paid - or the immediate financial loss in case of a mandatory afforestation program with no subsequent forest use.

In sum, we found that the design of payment and contract attributes has a pronounced impact on the efficiency (cost-effectiveness) as well as on the distributional impact of PES-type conservation instruments (cf. Pagiola 2010). Voluntary instruments tend to be more cost efficient than mandatory ones if competitively low payments are offered. Such low offers - for example as aimed at though the auctioning of PES contracts – were found to be incompatible with poverty alleviation goals. Pronounced pro-poor distributional impacts are possible, however, but the PES contracts will need rather high payments per unit area (up to 300 USD/ha/yr) and will have to be offered exclusively to the poorest households. At the community level, the Ecuadorian *Socio Bosque* program achieves such a form of social targeting because the program is only implemented in particularly poor communities. Its acceptance in spite of its very low fixed payment offer of 30 USD/ha/yr suggests that forest lands with a low agricultural potential, i.e. with a low deforestation risk, may have been placed under the program. Thus, issues of additionality and spatial targeting should urgently be investigated here. With respect to the massive trade-offs between the goals of conservation efficiency and positive distribution impacts reported, it appears unlikely that these trade-offs can be avoided by additional 'innovative' forms of PES. In landscapes dominated by agricultural smallholders but also populated by a substantial share of larger farms, excluding larger, less poor farming households from participation is in many cases likely to exclude areas with low per area costs.