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Analysis

Mediating factors of land use change among coffee farmers in a biological corridor

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ABSTRACT

Trees in agricultural landscapes are important for the provision of environmental services. This study assesses the loss of shade coffee during a 9 year period in a biological corridor in Costa Rica, and investigates the mediating factors of land use change. Following a conceptual framework that presents how household and farm characteristics mediate the interplay between underlying and proximate causes of land use change, the effect of the mediating factors is determined by applying an ordered probit model to household and land use data for 2000 and 2009 from 217 former and present coffee farmers. Additional 224 telephone interviews supplement the data on land use change. Results show a 50% reduction in the coffee area and a corresponding loss of trees. Family labor, age of household head, coffee prices, and use of shade tree products significantly reduce the probability of converting the coffee field, while the number of family members engaged in other agriculture and non-farm work increases the probability. A stronger tie to coffee farming is found to abate the influence of underlying drivers, whereas the younger generation downgrades the labor intensive coffee farming. Payments for environmental services are proposed as a policy instrument that may influence land use.

1. Introduction

The estimated 24–38% of the Earth's land area that is devoted to agricultural use is projected to increase by 18% by 2050 (MEA, 2005; Tilman et al., 2001). In the period 1980–2000, 55% of new agricultural land in the tropical world came from intact forests and another 28% from disturbed forests (Gibbs et al., 2010). If this trend continues, the expected expansion of agricultural land will lead to further destruction of forests and loss of environmental services from natural ecosystems. In return, this will increase the pressure on agricultural areas to provide a larger part of the provisioning, supporting, cultural, and regulating ecosystem services deemed important for human well-being (MEA, 2005). This calls for a land-use management that aims both for agricultural production and the conservation of environmental services; a dual objective which may be met through 'ecoagriculture' management (McNeely and Scherr, 2003). Trees are widely recognized as essential for the provision of several important environmental services in agricultural landscapes. This is recognized in the Costa Rican national program of payments for environmental services (PES), where coffee farmers are among those eligible to receive payments for planting and conserving trees in agroforestry systems (Cole, 2010; Pagiola, 2008). Coffee growing has been among the main culprits of forest conversion in Central America during the first half of the twentieth century and still is in some areas of Asia (Kinnaird et al., 2003). However, shade coffee systems are generally perceived as being ecologically important in terms of watershed functions, carbon sequestration, and habitat for fauna and flora (Correia et al., 2010; Dossa et al., 2008; Perfecto et al., 1996; Verbist et al., 2005). As such, coffee farmers are important actors in ecoagriculture landscapes such as buffer zones and biological corridors (McNeely and Scherr, 2003; Pagiola and Ruthenberg, 2002; Perfecto et al., 2009). Conversion to other land uses may have implications that go beyond the household and cultivated fields if a reduced tree cover results in loss of environmental services.

As other landowners, coffee farmers face multiple factors that influence land use decision making, such as changing markets, policy interventions, cultural change, poverty, as well as synergies among factors (Lambin et al., 2001, 2003). A decade ago historical low coffee prices was the main driver of land use change in coffee producing areas, especially in the tropical America (Eakin et al., 2006; Varangis et al., 2003). Fluctuating prices and costs of production continue to influence the profitability of coffee production (ICO, 2009) and thus land use decision making. Among the few studies of clearing of coffee systems, Blackman et al. (2008, 2012) apply classic land rent models to determine the drivers of clearing. In both studies, they find that coffee plots closer to towns with coffee markets are less likely to be cleared, highlighting the importance of cost advantages. The cultural context of land use choices is also important, as concluded by Ponette-Gonzáles (2007), who found that households maintain coffee production even when it is not economically viable. Agroindustrial

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intensification is another driver for change in coffee landscapes, as traditional small scale coffee agroforests are transformed into industrial plantations with higher dependence on inputs and mechanization (Perfecto et al., 1996). Agricultural intensification often occurs concomitantly with the expansion of non-farm income opportunities through increased mobility of labor and higher levels of education (Rigg, 2006). This is the core of the deagrarianization process, which manifests itself in a declining farm/non-farm labor ratio and decreased dependence on farm income among rural households (Bryceson, 1996).

Understanding the drivers of land use change is necessary in order to manage trees and forested areas in agricultural landscapes. The objective of this study is to assess the rate at which coffee fields are converted to other land uses, and investigate household and farm characteristics as determinants for land use change among coffee farmers. Based on a survey of 217 coffee producing households in a biological corridor in Costa Rica, the changes in the coffee area during the period 2000 to 2009 are analyzed using re-call data on household and farm characteristics corresponding to the year 2000. The nine year time span allows for sufficient data on land use changes, but also presents challenges in data collection as described in Section 4. Further, the temporal difference in household and land use data aims to avoid endogeneity, which is a potential issue in land use studies that model independent and dependent variables based on contemporary data. Temporal priority only reduces the risk of endogeneity that may also arise from other problems in the sampling or data collection. The study contributes to the micro-level (household) subsystem of the substantial land change science as argued for in Section 2, where the background and a conceptual framework for land use change are presented. In Section 3 the study area is described, while Section 4 presents data collection, the development of an ordered probit model, and variables. The results and the discussion are presented in Sections 5 and 6, while Section 7 concludes the article.

2. Land Use Change Framework

Land use change science has developed into an interdisciplinary field that seeks to understand land use and land cover changes based on the human and environment dynamics as a coupled system (Rindfuss et al., 2004; Turner et al., 2007). Integrative approaches are often applied, where different theories, modeling techniques, data collection methods, and levels of data aggregation are integrated, e.g. Castella et al. (2007) and Manson and Evans (2007). Other studies contribute with increased understanding of specific outcomes in subsystems of land change science, which helps to improve the components of the more holistic approaches. Examples of the latter are presented in the synthesis of research efforts by Lambin and Geist (2006). This study aims to increase the understanding of how micro-level (household) factors influence land use decisions, in this case among coffee farmers. Manson and Evans (2007) call for a better understanding of decision making at the micro-level in order to develop the integrated approaches. To do so, the level of data aggregation on both sides of the equation, i.e. the land change variable and the explanatory variables, should be at the micro-level, not least to avoid ecological fallacy (Brown et al., 2004). Relationships found at the aggregate level (e.g. aggregate census data) do not necessarily reflect relationships at the micro-level (e.g. household demographic data) (Rindfuss et al., 2004).

In this study, a conceptual framework is developed that illustrates the linkage between underlying causes, mediating factors, and proximate causes of land use change among coffee farmers (Fig. 1). In their synthesis of land use and land cover change research, Geist et al. (2006) summarize the main underlying causes of change and arrange them in five broad categories of factors that have been widely used in land change studies — biophysical, economic and technological, demographic, institutional, and cultural factors. Fig. 1 includes a modified version of the five categories, adapted to this study. A category of societal factors replace and encompass the cultural factors as well as social processes such as deagrarianization. The categorization of factors is not clear-cut, e.g. urbanization is often categorized as an economic factor but may also represent a societal factor if focus is on the related changes in social structures. The underlying causes are mostly exogenous to coffee farmers, but underpin the proximate causes of land use and land cover change, i.e. human activities or immediate actions at the local level such as agricultural expansion (Geist and Lambin, 2002). The proximate causes are often the focus of land change studies, especially regarding the dominant topic of land change science; deforestation (e.g. Margulis, 2004; Marquette, 1998; Serneels and Lambin, 2001). This study focuses on the conversion of coffee fields to other land uses that are either more or less intensive. As such, attention is not solely directed to processes of agricultural intensification, another dominant land change topic since Malthus and Boserup (Turner and Ali, 1996).

In-between the underlying and proximate causes are the mediating factors that can be described as the characteristics and attributes of the land use agent and of the resources to which the agent has access, that shape and modify the interplay between underlying drivers and proximate causes of land use change. This is a modified version of the definition given by Geist and Lambin (2004), as it specifically group household characteristics and farm characteristics within the mediating factors. Furthermore, it encompass the biophysical factors of the farm, such as soil and topography, that Geist and Lambin (2001) describe as pre-disposing environmental factors. The choice of mediating factors is based on observations from the field and on reviews of studies of land use change affected by or related to household income and assets (e.g. Chowdhury, 2006; Pacheco, 2009), household life cycles (Perz, 2001; Walker et al., 2002), household demographics and educational level (Caviglia-Harris, 2005; Pan and Bilsborrow, 2005; Pichon, 1997), duration of residence and land ownership type (Chowdhury, 2010; Pichon, 1996), and land availability (Ponette-Gonzáles, 2007). The explanatory variables in the econometric model developed in Section 4.2 comprise the mediating factors, which are presented in Section 4.4.

With notable exceptions, the majority of studies on land use of individual households are based on contemporaneous land use and household/farm data (e.g. Blackman et al., 2008; Ponette-Gonzáles, 2007) or use land change data that predates the explanatory variables (Wyman and Stein, 2010). This makes it difficult to demonstrate the direction of possible causation; whether land use is a result of household characteristics or vice-versa. Furthermore, static analyses do not take path-dependencies into account (Verburg et al., 2006). If, for example, a coffee farmer regrets a decision to clear the coffee area, there is a substantial investment and loss of income associated with a re-introduction of coffee and the time lag before the first coffee harvest. Many households will not have the economic capacity to assume such costs, and will therefore find themselves locked to their new land use. The influence of land management and existing land use on future land use decisions is represented by the 'Land use/cover' box in Fig. 1.

3. Study Area

The study was carried out in the Volcan Central Talamanca Biological Corridor (VCTBC) located in the Cartago and Limón provinces in Costa Rica. The corridor covers an area of approximately 115,000 ha with altitudes ranging from 160 to 3340 masl at the top of the Turrialba Volcano. No less than nine protected areas are connected by the biological corridor, emphasizing its importance in the regional conservation network. The climate is very humid with annual rainfall exceeding 2600 mm, most of which falls in the period from June to December.

Agriculture has been practiced for at least 3000 years in the area, on fertile soils mainly of volcanic and alluvial origins. Coffee production was introduced in the beginning of the 19th century and quickly became one of the dominant land uses. Dairy and cattle farming

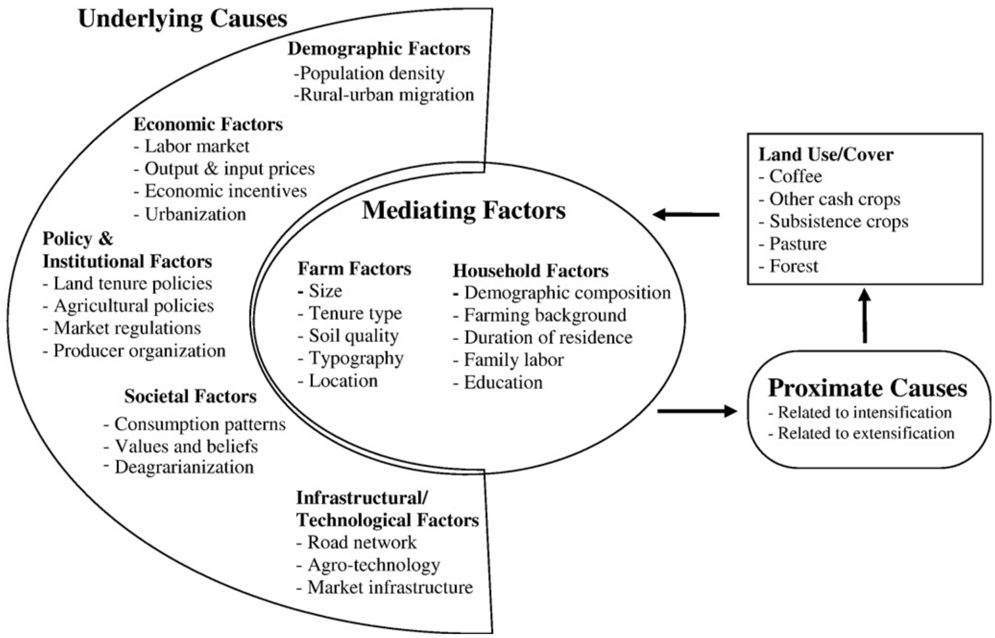

Fig. 1. Conceptual framework of land use change among coffee farmers. Household and farm characteristics mediate the interplay of underlying and proximate causes of land use change and thus influence land use decision making.

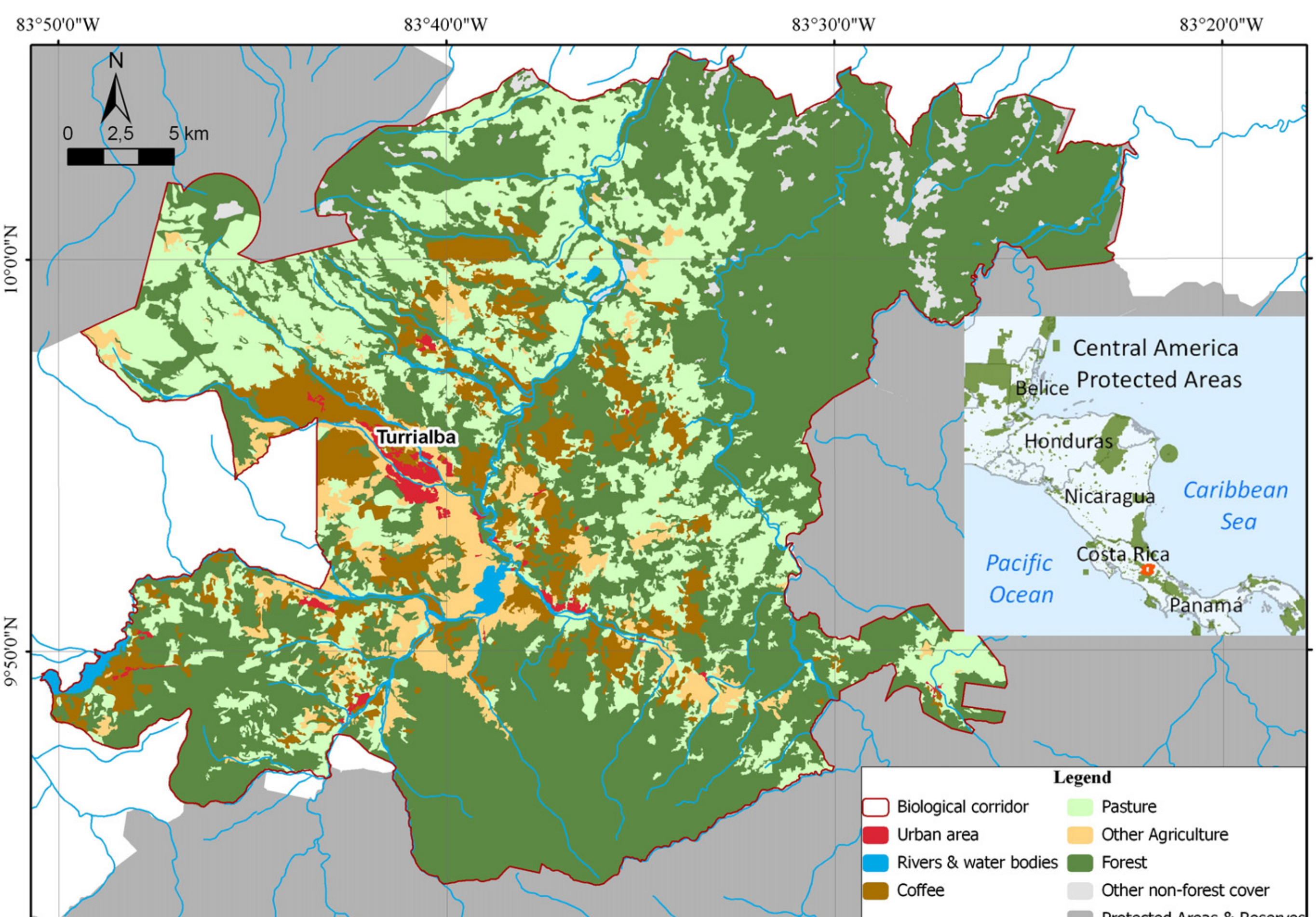

Fig. 2. Map of land use and land cover in the Volcan Central Talamanca Biological Corridor.
Adapted from Brenes (2009) and Estrada Carmona and DeClerck (2012).

followed suit and pasture became widespread, especially on steeper slopes (Kass et al., 1995; Nygren, 1995). A land use classification of the corridor based on Aster images from 2008 shows that the landscape mosaic is made up of three main agricultural practices; pasture (24%), coffee (8.5%) and sugar cane (4%) (Brenes, 2009; Estrada Carmona and DeClerck, 2012). The fields are set amidst forested areas that cover 52% of the corridor, though highly concentrated in the southern and north-eastern part (Fig. 2). There is only one urban area of substantial size, the town of Turrialba with 80,000 inhabitants. The rest of the area is made up of water bodies, scattered urban areas, roads and less common agricultural practices such as vegetable production. According to a coffee census carried out by the Costa Rican national coffee institute ICAFE (2003) there were approximately 2000 coffee farms inside the corridor in 2001, of which 75% were less than 5 ha including areas for other crops. Four years after the coffee census was made, the coffee area in the corridor had declined from 11,912 ha to 10,006 ha (ICAFE, 2006). More than 90% of the coffee area is shaded, often with a shade tree system consisting of two to five dominating tree species, where nitrogen fixating trees are pruned regularly. The corridor is a priority area in the national PES program, but only one contract involves tree planting in coffee systems (as of 2010, FONAFIFO[1] database).

After a long period with decreasing prices, the last cooperative in the VCBCT closed in 2002. Several coffee buyers collect coffee from farmers in the VCTBC, but the majority of farmers sell to a local buyer near Turrialba. ICAFE has enforced a law (no. 2762) that regulates the margins at different stages of the coffee value chain and ensures the producers a minimum price relative to the profit made by coffee processors (Mosheim, 2002; Obando, pers. com.). However, prices do vary according to quality, which is influenced by the altitude of the farm. Since the peak of the coffee crisis in 2002, prices have been rising steadily.

Primary schools are found throughout the VCBCT, and ten years of schooling is mandatory and free in Costa Rica. However, the average years of schooling of the adult population is just six, indicating differences among the younger and older generations (CIA World Factbook, 2010). With the industrial areas mainly concentrated around the provisional capital of Cartago, the demand for employment around Turrialba is still much lower than the supply. There is a saying among people living in the Turrialba region that 'the main alternative to farming is a job as a night watch man in Cartago'. This was true for several of the sons of interviewed coffee farmers.

4. Methods

4.1. Data Collection

A survey of former and present coffee producing households across the biological corridor contributed quantitative data for a statistical analysis as well as qualitative information regarding life as a coffee farmer. Additional contextual information was obtained during a focus group meeting with five coffee farmers and interviews with key informants such as ICAFE personnel, coffee buyers, and former cooperative executives. A data base of 1976 coffee farmers, produced by ICAFE during a census in 2001, was used to randomly select households for the survey. The selected households were grouped according to districts, which were visited on at least two occasions. Farms were located by asking local residents, often at small shops and eateries. Most of the selected farmers, who had sold their farm land, were still living in the same homes. It is therefore believed that the exclusion of farmers who have moved away since 2000 is only a minor issue. The omission of some households may nevertheless underestimate the reported change in coffee area. A total of 217 households participated in the final survey following a pilot study of 20 households.

[1] The National Forestry Financing Fund administers the PES program.

Farmers were asked about household and farm characteristics for the years 2000 and 2009, as well as changes to the coffee area during the period 2000 to 2009. Asking retrospective questions presents methodological challenges and problems, not least uncertainty (Nakata et al., 2009). Important events, such as the closure of local cooperatives, were used as temporal reference during the interviews, and certain pieces of information, e.g. regarding assets and income generating activities, were cross-checked with multiple questions. The variables for the econometric model developed in Section 4.2 are mainly binary, fixed in time, or to a lesser degree subject to uncertainty such as number of adults. The advantages of surveys over remotely sensed images in land use change studies are that even small changes within individual farms are identified and the time frame for the study is not subject to the availability of satellite images or aerial photographs. As the availability and quality of remotely sensed imagery increase, the possibilities of integrating survey data with imagery analysis improve.

In order to get a better picture of the changes made to the coffee area, short telephone interviews were made with an additional 224 households, likewise randomly selected from the ICAFE data base. Questions concerned their land use and use of shade trees from 2000 to 2009. The additional information only serve the purpose of further documenting changes in the coffee area and tree cover, as well as new land use practices. Households that have begun coffee farming after 2001 are not included in the study. It is believed to be a minor issue, as ICAFE (2006) reports a general decrease in the coffee area in the region. Furthermore, only 15 of the 461 interviewed and surveyed households have increased their coffee area during the studied period.

4.2. A Model of Coffee Area Change

A coffee farming household's decision to maintain the coffee area or reduce it in favor of another land use or income generating activity is modeled based on the notion of random utility maximization. The underlying assumption of the study is that given a set of household and farm specific characteristics, i.e. the mediating factors, coffee farming households react to underlying drivers and choose a future land use that will maximize their utility. Following Johnson et al. (1997), a sample of N households is each presented with a set of M discrete, alternative choices of land use. The utility that household i (i = 1,..., N) derives from alternative m (m = 1,..., M) is assumed to be a linear function of various household specific characteristics and can be expressed as:

$$U_{im} = \beta_1 H_{im} + \beta_2 F_{im} + \beta_3 CP_{im} + \beta_4 IA_{im} + \xi_{im}, \tag{1}$$

where U_{im} is the maximum utility attainable when choosing alternative m, β_1 to β_4 are vectors of unknown parameters associated with variables influencing utility levels of alternative m and representing characteristics of household i related to household characteristics H_{im}, farm characteristics F_{im}, characteristics of the coffee production CP_{im}, and income and assets IA_{im}. ξ_{im} is a random disturbance that may reflect random choice behavior or measurement error. Underlying factors, cf. Fig. 1, are assumed to be similar for all households and are not part of the model.

A household is assumed to evaluate each alternative in terms of utility and choose alternative j if, and only if, it results in the highest utility:

$$U_{ij} \geq \max(U_{im} | m = 1, \ldots, M;\ j \neq m), \tag{2}$$

Households' utility U_{ij} represents a latent variable that is unobservable. Only the outcome of their land use decision can be observed, i.e. the maintenance, reduction or full conversion of the coffee area. Let Y represent the observed change in coffee area, which is ordinal in nature, and let Y = j if coffee area change j is observed. Implied by Eqs. (1) and (2), a regression model can be specified and estimated in the following manner:

$$Y_i = \beta_1 H_i + \beta_2 F_i + \beta_3 CP_i + \beta_4 IA_i + \varepsilon_i, \quad (3)$$

where

$$Y_i = j \text{ if } u_{j-1} < Y_i \leq u_j \rightarrow U_{ij} \geq U_{i,j-1};\ j = 2, \ldots, M \quad (4)$$

and

$$\Pr(Y_i = j | U_{ij} \geq U_{i,j-1}) = \Phi\left(u_j - G_i\beta\right) - \Phi\left(u_{j-1} - G_i\beta\right), \quad (5)$$

where $G_i\beta = \beta_1 H_i + \beta_2 F_i + \beta_3 CP_i + \beta_4 F_i$, $\varepsilon_i \sim N(0,\sigma^2)$ is an error term, $u_1, \ldots, u_m$ are category thresholds for the underlying latent variable with $u_1 \leq \ldots u_m$, and $\Phi(.)$ is the cumulative standard normal distribution. Other notations are as previously described. The parameters to be estimated are the β_1 to β_4 vectors and the u values.

The model is estimated with maximum likelihood estimation and the log-likelihood function is given by:

$$\ln \ell = \sum_{i=1}^{N} \sum_{j=2}^{M} Z_{ij} \ln\left[\Phi\left(u_j - G_i\beta\right) - \Phi\left(u_{j-1} - G_i\beta\right)\right], \quad (6)$$

where Z_{ij} is a binary indicator for Y_i being equal to the jth level of the discrete ordinal variable for change in coffee area, so that $Z_{ij} = 1$if $Y_i = j$ and 0 otherwise. This is the specification of the ordered probit model as described by McKelvey and Zavoina (1975).

The estimation of model (3) was done in STATA 11.1 with Huber–White estimator for standard errors, which is robust to heteroscedasticity (StataCorp, 2009). Average partial effects for the independent variables were estimated using the user written Stata command Margeff (Bartus, 2005). Finally, the independent variables were tested for multicollinearity following Hendrickx (2004). A condition number of 35.2 suggested potential problems of collinearity (Belsley et al., 1980; Hendrickx, 2004) caused by a variable measuring altitude, which was subsequently excluded from the model.

4.3. The Effect of Location

The surveyed households were often clustered around small towns or settlements located in different parts of the corridor. Spatial autocorrelation may therefore be present, arising from neighbor or spillover effects, i.e. a farmer's land use decision being influenced by that of the neighbor farmer, and from spatial errors, i.e. correlations in unobserved factors determining land use choice such as geophysical land characteristics. A Moran's I test, carried out in Stata following Pisati (2001), rejected the null hypothesis of zero autocorrelation (p-value 0.02). There are ways to come around different sources of spatial autocorrelation, such as spatial lag models (neighbor effects) and spatial error models that are based on Bayesian estimation (e.g. Anselin, 2002; LeSage and Pace, 2009). Blackman et al. (2012) provide a good example of a Bayesian spatial autoregressive model for a probit to correct for spatial lag dependence. These models are not within the scope of this study. A coarser measure is taken by expanding Eq. (3) with a random effect of location k (k = 1,…,K), thereby taking into account correlations of observations within locations. The variable consists of 26 locations, within which a cluster of households may influence each other and be part of the same social networks.[2] The resulting model is estimated as:

$$Y_{ik} = \beta_1 H_{ik} + \beta_2 F_{ik} + \beta_3 CP_{ik} + \beta_4 IA_{ik} + \gamma_k + \varepsilon_{ik}, \quad (7)$$

where $\gamma_k \sim N(0,\sigma_\gamma^2)$ is the random component. Other notations remain the same. Estimation of model (7) was done with the user-written program Reoprob in Stata (Frechette, 2001).

4.4. Dependent Variable

The percentage change in coffee area from 2000 to 2009 represents the dependent variable, with a negative percentage corresponding to a reduction in coffee area. As the variable is based on data from the survey, the ICAFE database was used to verify the recall data regarding land sizes in 2000, though with one year discrepancy in reference year. Many households either fully converted or maintained their coffee area, resulting in the variable having two peaks; one at zero and one at −100%. In-between are approximately a third of the households; those who partially reduced the coffee area. Nine of the surveyed households had increased the coffee area, only two with more than one ha and only one with more than 100%. As the non-normal distribution of the variable does not allow an OLS regression, a discrete ordinal variable was created by assigning the value 0 (zero) to a 'no change' group of 86 households; the value 1 to a 'partial conversion' group of 72 households, and the value 2 to a 'total conversion' group with 61 households. The new variable is suitable for the described ordered probit model, as the different scale points (m = 0, 1, 2) have a natural order.[3]

4.5. Independent Variables

With the exception of distance to the nearest town, all independent variables are derived from the household survey and correspond to year 2000, e.g. prior to any change in coffee area. In accordance with the framework in Section 2, the variables represent mediating factors that are influenced by categories of underlying drivers. These are assumed to constitute a common context for the coffee farming households that are all located in a geographically limited study area. Four categories of variables are described below and in Table 1, which also contains summary statistics for all 217 households.

'Household characteristics' contain seven variables. The variables *Age* and *Age2*, the age of the household head squared, enable an estimation of the age at which the effect on the probability of land use change is greatest (or lowest). Together with *Age*, the children-to-adults ratio is used to assess the household lifecycle stages, where a higher ratio indicates an earlier 'household lifecycle' (Barbieri et al., 2005). *Adults* is an often used indicator for family labor. Though it may not be their main occupation, all family members usually take part in the coffee production. *Residence* refers to the number of years the family has been living on the farm, and is highly correlated with years of coffee farming experience. Together with *Organization*, a binary variable for membership of a coffee cooperative or producer association, it is a possible proxy for a traditional or at least stronger tie to coffee farming. As explained by several respondents, producer associations, as well as coffee cooperatives that buy, process and market coffee from cooperative members, are centers for social networking, exchange of labor services, and knowledge sharing on coffee production.

'Farm characteristics' include the weighted *Distance* in kilometers on road between farms and the closest, larger town, which for the majority of farmers is Turrialba. Distance on gravel or dirt roads is given a weight of two. *Reform* and *Inheritance* are binary variables indicating the form of acquisition. In the land reform, which was enacted in 1961, landless families are allocated land for living and farming in settlements established by the Agrarian Development

[2] The minimum distance between any two farms in different locations is 700 m birds eye. The identification of locations is based on an incomplete set of GPS coordinates, Google Earth, and observations made in the field.

[3] The original dependent variable, percentage change in coffee area, with observations censored at 0 and 100%, is suitable for a double bounded Tobit. Regression results of a Tobit model with the same explanatory variables as in the ordered probit, showed that all parameter estimates had the same signs and significance level as in the ordered probit. The latter was preferred due to the opportunity of estimating average partial effects for each group of households.

Table 1
Description of variables used in the ordered probit model. The dependent variable, coffee change, is based on the percentage change in coffee area from 2000 to 2009. Mean values, with standard deviations (S.D.) for continuous variables, are based on observations from all 217 surveyed households.

Variables	Description	Mean	S.D.
Coffee change	Percentage change in coffee area from 2000 to 2009	−42.1	(52.5)
Household characteristics			
Age	Age in years of household head	49.4	(12.6)
Educ	Years of schooling of household head	5.00	(2.49)
C/A-ratio	Children to adults ratio	0.48	(0.60)
Adults	Number of adults in age class 16–59	2.93	(1.67)
Organization	Membership of organization or association (0/1)	0.13	–
Residence	Number of years of residence at farm	27.3	(15.0)
Farm characteristics			
Farm size	Size in hectares of farm	3.53	(2.52)
Altitude[a]	Location of farm in meters above sea level	832	(169)
Distance	Weighted distance to nearest larger town	17.2	(5.71)
Reform	Farm received during agrarian reform (0/1)	0.17	–
Inheritance	Farm inherited (0/1)	0.34	–
Coffee production			
Coffee area[a]	Coffee area in ha	2.05	(1.39)
Labor	Use of hired labour during harvest season (0/1)	0.67	-
Ha/adult	Coffee area in ha per adult in the household	0.88	(0.06)
Price	Price of coffee received from buyer, in '000 colones	18.5	(5.91)
Tree product	Sale or consumption of products from shade trees (0/1)	0.72	–
Income and assets			
Income sources	Number of income sources	2.32	(0.84)
Farmers	Number of family members with farming as main occupancy	1.07	(0.86)
Non-farmers	Family members with non-farm activities as main occupancy	0.75	(1.12)
Remittances	Remittances received, in '000 colones	48.3	(229)
Livestock	Livestock score based on local market values	1.57	(4.24)
Asset	Standardized score based on ownership of 12 different assets	0	(1.30)
Loan	Outstanding loan with credit institution (0/1)	0.22	–
Savings	Savings in a bank (0/1)	0.29	–

[a] Not included in the statistical model.

Institute. Households that have bought their farms are considered the base group. *Ha/adult* in the 'Coffee production' category is calculated as ha of coffee field per adult household member. It is a measure for the required work load per household member, and need for hired labor, in order to maintain a certain coffee production per area.

The variable *Income sources* counts all income generating activities as one, except for non-coffee agricultural activities that only count as one activity. Many families cultivated one or more crops beside coffee, and often these crops were in the same category, e.g. two types of vegetables. *Farmers* and *Non-farmers* are numbers of household members who stated that their main occupation was farming their own land, or day laboring, formal employee or business owner, respectively. Though subject to large uncertainty, data from 159 households, who were able to base income estimates on production quantities, average prices, monthly salary levels etc., shows that *Farmers* and *Non-farmers* are highly correlated with other agricultural and non-farm income.[4] The two variables are therefore suitable as proxies for the two types of income activities. *Livestock* is a score based on livestock value on the market in Turrialba in 2000. A score of one is given for each cattle-value equivalent. *Assets* is included as an indicator for accumulated wealth, which may provide a better picture of household wealth than income data for one period. The variable is constructed by assigning weights, derived from a standardized principal component analysis, to binary indictors of ownership of 12 different household assets, from a radio to a truck (Filmer and Pritchett, 2001).

[4] Binary variables for non-coffee agricultural incomes and non-farm incomes were not useful, as most of the households reported some income from these activities. Households with more than one member with main occupation in farming (almost all households had one member in coffee farming), and households with members with main occupation in non-farm activities, reported the highest estimates of income from these activities compared with other households.

5. Results

5.1. Changes in the Coffee Area

Fig. 3 shows the accumulated coffee area among the 441 interviewed and surveyed households from 2000 to 2009. The reduction in coffee area reported by ICAFE in 2006 continues unabated. The area decreases steadily from 904 ha in 2000 to 461 ha in 2009, corresponding to an annual reduction of approximately 7%. The dominant replacement for coffee is pasture, which covers more than 40% (186 ha) of the total converted area. Silvopastoral practices, the use of shade trees on pasture, are found throughout Costa Rica, but it is not widespread in the VCTBC. Another 29% (132 ha) has been replaced with vegetable production, sugar cane, or no crops, while 14% (64 ha) has been converted to fields of fruit trees and banana. The latter is often the result of the removal of coffee plants only, while the existing fruit trees and banana plants, formerly used to shade the coffee, are left in the field. Of the approximately 100 ha of coffee area that were sold, only 14 ha remain in coffee production, while the rest is accounted for in other uses.

As the coffee area decreases, so does the use of shade trees. Shade tree density is maintained on the farms that do not reduce the coffee area, but households that either reduce or eliminate their coffee fields remove an estimated 40,000 shade trees, including both surveyed and interviewed households. As the data is based on self-reported numbers, this figure is not without uncertainties and should be considered a rough estimate. However, it does indicate a substantial loss of trees in the landscape.

5.2. Descriptive Analysis and Summary Statistics

The following sections refer to the 217 households that participated in the survey. Table 2 contains summary statistics for the variables where one group of households is significantly different from at least one of the other groups based on a group-wise t-test. It is worth noticing that *Assets* is not different among the groups, which suggests a similar level of wealth among households in the three groups, even if farm sizes do vary. As could be expected, the largest differences are most often found between households in the 'no change' group and the 'total conversion' group. Households in the 'total conversion' group less often sell or use shade tree products, they have more often acquired their farms through the reform, and they are located at lower altitudes, which may be part of the reason they receive lower prices for their coffee. The 'total conversion' group also has significantly more persons occupied with farming and non-farming activities than the two other groups. This indicates that households who fully convert their coffee fields, already in 2000 were more involved in other agriculture and non-farm activities than the two other groups.

5.3. Results of the Statistical Analyses

The results from the ordered probit models are presented in Table 3. The magnitude and sign of the structural coefficients have no direct interpretation; only that an increase in a variable with a positive coefficient increases the probability in the highest category (full conversion) and decreases in the lowest category (no change) (Greene and Henscher, 2010). The average partial effects are estimated in order to provide an indication of the relative magnitude of a unit increase in the explanatory variables on the probability of being in

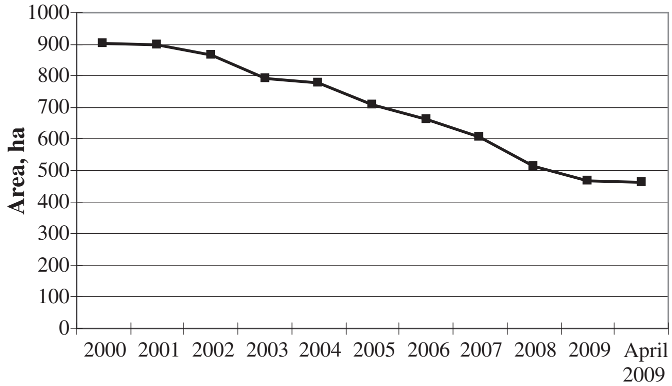

Fig. 3. The accumulated coffee area among 441 farmers from 2000 to 2009. Each point of observation is for the beginning of the year, with the exception of the last point, which is for April 2009.

Table 2
Summary statistics of variables that are significantly different among at least two groups of households. Standard deviation is shown in parenthesis. Significance for mean differences between household groups as found in a group-wise t-test is given in the last column.

Variables	No change		Partial conversion		Total conversion		t-test[a]
	(84 obs)		(72 obs)		(61 obs)		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Change in coffee area	8.9	(39.5)	−52.6	(22.5)	−100	(0.00)	
Household characteristics							
Organization	0.18	(0.39)	0.11	(0.32)	0.08	(0.28)	a,ab,b†
Residence	29.4	(14.4)	28.3	(16.0)	23.3	(14.0)	a,a†,b
Farm characteristics							
Farm size	2.82	(2.25)	4.38	(2.93)	3.51	(2.02)	a,b,c†
Altitude	871	(176)	821	(143)	791	(178)	a,b†,b
Reform	0.07	(0.26)	0.21	(0.41)	0.25	(0.43)	a,b,b
Inheritance	0.44	(0.50)	0.28	(0.45)	0.26	(0.44)	a,b,b
Coffee production							
Labor	0.60	(0.49)	0.79	(0.41)	0.62	(0.49)	a,b,a
Ha/adult	0.63	(0.61)	1.14	(0.96)	0.92	(0.89)	a,b,b
Price	20.0	(6.69)	18.6	(4.96)	16.2	(5.12)	a,a,b
Tree product	0.80	(0.40)	0.75	(0.44)	0.59	(0.50)	a,a,b
Income and assets							
Farmers	0.96	(0.90)	0.96	(0.86)	1.34	(0.75)	a,a,b
Non-farmers	0.60	(0.91)	0.75	(1.36)	0.97	(1.05)	a,ab,b

[a] Group-wise t-test for mean differences. Different letters indicate significant difference at 0.05 level († if 0.1 level).

either group.[5] Table 3 reports significance levels for structural coefficients and APE, though Greene and Henscher (2010) recommend limiting inference to the former. The random effect model generally estimates lower significance levels, a result of the location specific effects. However, only organizational affiliation and *C/A-ratio* becomes insignificant as a result of the random effect, indicating that their effect cannot be isolated from location effects. Besides the insignificant variables *Labor* and *Livestock*, none of the other parameters changes signs.

Among the household characteristics *Age* and *Adults* have significant effects on land use change at the 0.05 level.[6] The probability of partially or fully converting the coffee area is largest among households with younger household heads and increases until age 41, where after it decreases. This stands in contrast to the effect of *C/A-ratio*. The ratio is generally highest among younger households but none the less decreases the probability of reducing the coffee area, though insignificantly when location is accounted for. An increase in *Adults* also decreases the probabilities of either reducing or fully converting the coffee area. The is expected as all adults, women and men, help to fulfill labor requirements during e.g. coffee harvests, thereby reducing the need for hired labor and ensuring a full harvest. The effect of *Organization* is of a larger magnitude, and increases the probability of maintaining coffee, though not significant in the random effect model. None of the farm characteristics has significant effects. However, as expected, if altitude is reinstated in the model, it shows a significant and positive effect on 'no change' when *Price*, a correlated variable, is left out of the model. Two variables associated with income and benefits from the coffee fields, *Price* and *Tree product*, significantly reduce the probability of reducing or removing the coffee field, while *Ha/adult* increase the probability. The latter could be expected as a household with less family labor per area is more inclined to shift to less labor demanding land uses.

The significant effects of *Farmers* and *Non-farmers* show that households that are more engaged in non-coffee activities, and likely derive a smaller share of their income from coffee, have a higher probability of reducing the coffee area than families that are less engaged in non-coffee activities. The magnitude of the APE associated with *Farmers* is larger than for *Non-farmers*, indicating that being substantially engaged in other agriculture is a more important factor for reduction of coffee area than non-farm activities. This may be because other agriculture not only takes up time, as does non-farm activities, but also requires land. Thus, an increase in other agriculture would be at the expense of coffee areas, while an increase in other activities would likely result in a reduced coffee production but not area, at least in the short run. *Remittances* significantly increase the probability of shifting to another land use. This is partly due to a few households in the 'total conversion' group that receive relatively large remittances.

Though not significant in the regressions, *Inheritance* and *Reform* show positive and negative effects on the probability of maintaining the coffee field, respectively, just as households in the 'no change' group are significantly different from the other groups in form of farm acquisition. These opposing effects prompted a comparison between households with different forms of farm acquisition (Table 4). Households that have received their farm through the farm reform stand out. They have on average been in the area only half as long as other households, are younger, and have a higher ratio of dependent household members. Reform households show the largest propensity to fully convert their coffee area, while the majority of households, that have inherited their farm, do not make changes in the area. Further, the last two columns in Table 4 show that reform households that reduce the coffee area, most often shift to more labor intensive practices (sugar cane, vegetables[7]), contrary to households outside the reform-group that more often change to labor extensive land uses (pasture, no crops, sale or lease).

6. Discussion

6.1. The Economic Aspect

Not far from the assumptions underlying classic Ricardian land rent models (Hardie et al., 2000), households with larger benefits from their coffee fields are also those who maintain the production. Both coffee prices and use of shade tree products significantly increase the probability of maintaining the coffee field. All coffee buyers mentioned a pricing policy, i.e. an underlying driver, that

[5] So far, it is not possible to estimate APE for random effects ordered probit models in Stata. The APE from the ordered probit model are suitable, though they do ignore the effect of location.

[6] When *Age2* is left out of the model, *Age* is significant at $p > 0.05$.

[7] Fruit plantations are not included as it may be either more or less intensive than coffee farming, depending on the production system.

Table 3
Results from the econometric regressions. Parameter coefficients and standard errors (in brackets) are given for the random effect (RE) ordered probit and the ordered probit with average partial effects for changes in continuous and discrete variables.

Variables	RE ordered probit		Ordered probit		Ordered probit average partial effects					
	Coef.	st.err.	Coef.	st.err.	No change		Partial conversion		Total conversion	
Household characteristics										
Age	0.095	(0.057)†	0.090	(0.052)†	−0.028	(0.016)†	0.003	(0.002)	0.024	(0.014)†
Age2	−0.113	(0.058)†	−0.113	(0.053)*	0.035	(0.016)*	−0.004	(0.003)	−0.030	(0.014)*
Educ	−0.034	(0.038)	−0.049	(0.037)	0.015	(0.011)	−0.002	(0.002)	−0.013	(0.010)
C/A-ratio	−0.197	(0.166)	−0.263	(0.156)†	0.080	(0.048)†	−0.010	(0.008)	−0.071	(0.042)†
Adults	−0.162	(0.079)*	−0.179	(0.068)*	0.055	(0.020)**	−0.007	(0.004)†	−0.048	(0.018)**
Organization	−0.291	(0.282)	−0.425	(0.254)†	0.134	(0.082)	−0.029	(0.027)	−0.106	(0.056)†
Residence	−0.004	(0.007)	−0.005	(0.007)	0.001	(0.002)	0.000	(0.000)	−0.001	(0.002)
Farm characteristics										
Farm size	0.028	(0.041)	0.032	(0.039)	−0.010	(0.012)	0.001	(0.002)	0.009	(0.010)
Distance	0.033	(0.022)	0.020	(0.015)	−0.006	(0.005)	0.001	(0.001)	0.005	(0.004)
Reform	0.103	(0.288)	0.291	(0.223)	−0.086	(0.063)	0.001	(0.007)	0.085	(0.068)
Inheritance	−0.180	(0.204)	−0.180	(0.203)	0.057	(0.066)	−0.009	(0.015)	−0.048	(0.051)
Coffee production										
Labor	0.052	(0.207)	−0.024	(0.201)	0.007	(0.062)	−0.001	(0.008)	−0.007	(0.054)
Ha/adult	0.217	(0.127) †	0.237	(0.109)*	−0.073	(0.033)*	0.009	(0.006)	0.064	(0.029)*
Price	−0.057	(0.017)**	−0.055	(0.015)***	0.017	(0.004)***	−0.002	(0.001)*	−0.015	(0.004)***
Tree product	−0.383	(0.203) †	−0.406	(0.185)*	0.122	(0.059)*	−0.007	(0.014)	−0.116	(0.047)*
Income and assets										
Income sources	−0.093	(0.108)	−0.095	(0.109)	0.029	(0.033)	−0.004	(0.004)	−0.026	(0.029)
Farmers	0.495	(0.123)***	0.435	(0.109)***	−0.131	(0.029)***	0.015	(0.008)*	0.115	(0.027)***
Non-farmers	0.215	(0.101)*	0.227	(0.097)*	−0.069	(0.028)*	0.008	(0.005)	0.061	(0.025)*
Remittances	0.099	(0.046)*	0.100	(0.034)**	−0.031	(0.010)**	0.004	(0.002)	0.027	(0.009)**
Livestock	−0.008	(0.022)	0.002	(0.026)	−0.001	(0.008)	0.000	(0.001)	0.001	(0.007)
Asset	0.055	(0.070)	0.043	(0.065)	−0.013	(0.020)	0.002	(0.002)	0.012	(0.018)
Loan	−0.102	(0.216)	−0.065	(0.220)	0.020	(0.068)	−0.003	(0.010)	−0.017	(0.058)
Savings	−0.230	(0.192)	−0.242	(0.182)	0.075	(0.058)	−0.011	(0.013)	−0.064	(0.046)
Threshold 1	0.407	(1.527)	−0.217	(1.329)						
Threshold 2	1.567	(1.534)	0.867	(1.336)						

Log likelihood: random ordered probit −197.9 and the ordered probit −199.9. Significance levels: †$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$.

differentiated prices based on quality using altitude, a mediating factor, as the main indicator of quality. As could be expected, farms in the 'no change' group are generally located at higher altitudes (Table 2), but altitude is not the only factor affecting quality and price; coffee field maintenance and selective harvesting are also important factors, as explained by both surveyed farmers and local buyers. The 'no change' group is associated with more adults and less coffee area per adult, both indicating better opportunities for a well-managed coffee field. Further, the same group had significantly more income from coffee per ha in 2000 than the other groups (t-test, not shown), though the production in bags/ha did not vary between groups. This may likely be the result of a generally larger focus on coffee production among these households, something that is further supported by 'no change' households having fewer family members occupied by non-coffee activities.

Likewise associated with land rent maximization, the effect of prior engagement in other agricultural practices, increasing the probability of reducing or fully replacing coffee, may be related to the cost of conversion. Households with more members in other farming activities may find it less costly to convert to an already known land use, also in relation to the need for new agricultural knowhow. The available income data shows that households that replaced coffee with more labor intensive practices already in 2000 derived a substantial part of their income from other agriculture (18%) compared with households that shifted to less intensive practices (4%). Periods of low coffee prices, which especially characterize the first half of the studied period, and increasing costs of inputs, present an incentive to look for non-farm alternative income sources. This has been identified as a common strategy for coffee exit or reduced dependence on coffee among Costa Rican coffee farmers (Samper, 2010). Households with existing non-farm occupation, particularly formal employment and business, will find it easier, and may be more inclined, to expand non-farm activities as indicated by the effect of *Non-farmers*.

Distance to towns, and thereby coffee buyers, does not show an effect on land use decisions, likely because all farmers in the VCTBC have their coffee collected by the buyers, reportedly at only minor distance-related costs. Blackman et al. (2008, 2012) found that proximity to coffee buyers decreased coffee clearing due to costs advantages, following the assumption in von Thünen-like models that agricultural land use is determined by market proximity and transportation costs (Serneels and Lambin, 2001).

The conversion of coffee fields has taken place during a period with increasing coffee prices. The price paid to Costa Rican coffee producers rose from 44.4 US cents/lb in 2001 to 150 US cents/lb in mid 2009 (ICO, 2010). In spite of this, the main problem in coffee production mentioned by farmers was fluctuating and low coffee prices. This view is partly a result of increasing costs of labor and agrochemicals, which was the second main problem mentioned by farmers, and may explain why the coffee area does not follow the coffee prices. Another explanation is the substantial investment required to revert to coffee once it has been removed, and the three to four years without income from the coffee field after establishment. This clarifies why none of the households increased the coffee area after an initial reduction.

Table 4
Comparison of households (HH) with different farm acquisitions. Number of households and mean values for selected variables are shown. The last five columns show percentages of households in the three levels of land change (m), and the percentages of households with reduced or fully converted coffee area that have shifted to either more extensive or intensive land uses.

Acquisition	No. of HH	Residence	Age	Child/adult	$m=0/1/2$			Ex-/intensive	
Reform	36	14.7	45	0.78	16.7	41.7	41.7	35	65
Bought	101	28.3	51.4	0.42	38.6	31.7	29.7	84	16
Inherited	73	32.8	48.6	0.44	50.7	27.4	21.9	81	19

6.2. The Household Lifecycle and Cultural Change

Often, all family members are involved in the coffee growing, even when laborers are hired. When family labor becomes scarce it affects land use decision making as seen by the effect of *Adults* and *Ha/adult* in the regressions. Two frequent reasons for replacing coffee with less intensive land uses were given by several farmers. First, by converting to e.g. pasture, family labor is freed and can be put to use elsewhere, often as day-laboring, thereby adding an activity to the income portfolio. Second, and this was often stated by older household heads, the younger members of the family had no intention of continuing labor intensive farming, resulting in the household head deciding for less labor intensive land uses. The latter statement by farmers fits the household lifecycle approach, where reduced family labor in the last stage of the cycle leads to contraction of intensive land uses (Barbieri et al., 2005). Contrary to the household lifecycle, which stipulates that the grown up children establish their own farms, the children of the surveyed coffee farmers get an education and look for jobs and a living in the city. Compared to their parents, the younger generations in Costa Rica have more opportunities of schooling and higher education (Mendiola, 1989). Many farmers expressed that the young generations' stay at educational institutions in urban areas makes them reluctant to return to a life as a farmer.

The conversion to more intensive land uses by some farmers, diversification of income sources by others, increased level of education, and changed perception of farming among the young generation are elements of a deagrarianization process (Rigg, 2006). This process is also characterized by a higher non-farm to farm income ratio, increased mobilization, rising average age of farmers, and an increasing role of remittances; all of which can be seen among coffee farmers in the VCTBC. However, not all households are similarly influenced by these processes. Households that are more likely to maintain their coffee area have more years of residence, which is highly correlated with years of coffee experience, have a low child to adult ratio, use shade tree products, and are more often members of producer associations. The latter was also found by Blackman et al. (2008, 2012). These characteristics are indicators of a stronger tie to coffee farming, likely through family traditions. Many farmers explained that they were coffee farmers in their hearts, and were reluctant to change land use even if the economic rationale argued for it. Ponette-Gonzáles (2007) came to a similar conclusion in her study of coffee farmers; production choices should be seen within a cultural context.

6.3. Implications for Ecoagriculture Management

Nearly 50% of the original coffee area has been converted to other land uses, with a considerable loss of shade trees. Such changes to land use and land cover are expected to have adverse impacts on the provision of environmental services. The predominant coffee shade system in Costa Rica is rather simple, but local studies in the VCTBC have documented higher bird diversity in coffee fields compared to other land uses, and even great cats are observed using coffee farms as passageway (F. DeClerck, pers. com). Significant forest loss in buffer zones around National Parks during the last four decades of the 20th century has put the network function of the protected areas in jeopardy (Sánchez-Azofeifa et al., 2003). This augments the role of biological corridors such as the VCTBC and the farmers who live in the corridors. Elsewhere in Costa Rica, the national PES scheme has halted deforestation and increased forest cover on former agricultural lands (Arriagada et al., unpublished; Daniels et al., 2010 [mimeo]). A new PES modality, targeting shade coffee farmers, is under development and currently in a trial phase in Costa Rica (E. de Melo, pers. com.). It could potentially improve the economic aspects of shade coffee farming, also in the VCTBC that is a PES priority area. Other PES modalities may divert coffee areas cleared for lack of labor to reforestation instead of other extensive and tree-less land uses. However, awareness raising is needed; less than 10% of the surveyed farmers had heard of the national PES program. Transferring experiences from other parts of Costa Rica, where local cooperatives and agricultural centers are facilitating PES contracts to small landowners (Bosselmann and Lund, unpublished), will add value to policies aimed at conserving the ecoagriculture landscape in the VCTBC.

7. Conclusions

The coffee area in the Volcan Central Talamanca Biological Corridor is reduced by nearly 50% among the investigated farmers in the period from 2000 to 2009. Underlying drivers, such as coffee price policies and changes in production costs, are found to affect land use decision making of coffee farming households differently, contingent upon certain household and farm characteristics that take on a mediating role. In accordance with conventional land rent models, higher coffee prices and tangible benefits in the form of shade tree products are associated with the retention of coffee areas, whereas coffee conversion is more likely to take place among households without sufficient labor or that are engaged in other agricultural practices and non-farm activities. The influence of economic factors is buffered by non-economic factors in ambiguous ways. A change in perception of agriculture among the younger generation and an increased emphasis on non-farm activities seem to hinder the continuation of coffee farming, while a stronger tie to coffee farming is found to reduce the probability of coffee farm conversions. Payments for environmental services, aimed at retaining shade coffee areas and influencing the choice of alternative land uses, are proposed as a policy instrument that may conserve the services of the biological corridor.

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