Land Use Policy xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Decision-making by farmers regarding ecosystem services: Factors affecting soil conservation efforts in Costa Rica

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ARTICLE INFO

Article history:
Received 24 August 2009
Received in revised form 11 January 2010
Accepted 6 March 2010

Keywords:
Soil regulation services
Cognitive variables
Farmers
Decision-making
Costa Rica

ABSTRACT

The impact of climate change on farm soils in the tropics is the combined result of short-term soil management decisions and expanding precipitation extremes. This is particularly true for cultivated lands located in steeply sloping areas where bare soil is exposed to extreme rainfall such as the Birris watershed in Costa Rica. Farmers in this watershed are affected by increasing degradation of soil regulation services and respond with different level of efforts to conserve their soils. This paper examines influences on farmers' decisions through a survey involving interviews with a sample of farmers ($n = 56$) to test hypotheses on how a combination of cognitive variables (beliefs, risk perception, values) and socioeconomic variables shape decisions on soil conservation. Results show that farmers' awareness of their exposure level to soil erosion combines with other variables to determine their level of soil conservation. Using discriminant analysis, three groups of farmers were identified based on their soil conservation efforts. ANOVA pairwise-comparison among these groups showed significant differences in respect to levels of awareness, perception of risk, and personal beliefs along with territorial exposure and participation in soil conservation programs. Our results help to understand farmers' complex decision-making on soil conservation and help designing policies to support the provision of soil regulation services especially in areas highly exposed to increasing frequency of extreme precipitation events such as Central America.

1. Introduction

Soil erosion, land use and water management are highly interlinked. In Central America, unsustainable use of marginal lands is widespread and has caused severe soil erosion, which in turn reduces productivity of soils in upstream areas (Pimentel et al., 1995) and, downstream, water quality regulation services (Southgate and Macke, 1989; Lutz et al., 1994a; Guo et al., 2000). In addition to these anthropogenic factors, precipitation distribution plays an important role in erosion. According to the model of Wischmeier and Smith (1978), extreme rainfall events interact with high sloping and unprotected soils, increasing kinetic potential of raindrops to remove soil particles increasing erosion and sedimentation downstream. For Central America a significant increase in intensity and frequency of extreme precipitation events has been observed (Aguilar et al., 2005) and is projected to increase further (Magrin et al., 2007).

Exposure to precipitation extremes and the high susceptibility of soils to erosion due to questionable management make this region highly vulnerable to climate change. The Costa Rican Ministry of Environment estimated that reduced soil fertility and soil erosion, partly due to the human and natural factors described above, caused a 7.7% reduction in agricultural Gross Domestic Product from 1970 to 1989 (MINAE, 2002). Moreover, the National Commission on Land Degradation (CADETI, 2002) estimates that 20% of agricultural land is severely over-utilized due to poor management practices as a result of short-term responses to productive needs of farmers.

Policies and development programs to foster soil conservation in vulnerable watersheds of tropical countries like Costa Rica use tools like direct economic incentives such as the Payment for Ecosystem Services (PES) scheme (Pagiola, 2008; Wunder et al., 2008). However, adoption rates of conservation practices in Costar-

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doi:10.1016/j.landusepol.2010.03.003

ican watersheds where intensive and market-oriented agricultural activities have caused large deforestation and soils are prone to intense erosion are low (Abreu, 1994). This is the case of the Birris watershed where other factors than direct payments are influencing farmers proneness to adopt soil conservation practices. Here, PES schemes need to complement existing direct incentives with other strategies to achieve intended additionality. An analysis of institutional and cognitive aspects associated with soil conservation can give insights to the design of successful programs (SWCS, 2003).

The reason for that is that often the cost-effectiveness of soil conservation programs depends on whether erosion is considered only for its off-site effects or also for on-site effects (i.e. in the latter case farmers might have a direct personal incentive to implement voluntary conservation) (Wossink and Swinton, 2007; Dale and Polansky, 2007). Soil conservation programs should, then, use complementary tools to foster adoption of adequate practices among farmers. This paper intends to provide inputs to the design of appropriate soil conservation program while analyzing the complexity of socioeconomic and cognitive variables that influence farmers' decision-making for soil conservation.

The objective of this paper is to analyze how cognitive and socioeconomic variables influence farmers' decisions regarding their management of soils. More specifically, we test hypotheses, in our case study, concerning the influence of cognitive, exposure, and socioeconomic variables on farmers' adoption of soil conservation practices. We test the following null hypotheses: (i) risk perception of natural and anthropogenic activities, and knowledge of the factors causing erosion; (ii) traditional socioeconomic variables (farm size, tenure, education, economic status); and (iii) land characteristics, such as location in high risk areas, considered individually and together, have no effect on soil conservation decisions.

This paper is organized in the following manner. Section 2 discusses the decision-making processes of farmers related to soil conservation referring to previous literature findings. Section 3 presents the case study, and describes the model and the methods. Section 4 presents the results in terms of a series of analytical steps and the construction of cognitive variables with factor analysis. Section 5 provides discussion, followed by conclusions in Section 6.

2. Farmers' decision-making for soil conservation

A large body of literature has analyzed farmers' decision-making to inform the design of soil conservation programs. Econometric studies based on farmers' monetary utility functions have been widely used to study adoption of soil conservation practices (Featherstone and Goodwin, 1993; Innes and Ardila, 1994; Soule et al., 2000; Illukpitiya and Gopalakrishnan, 2004; Leyva et al., 2007). Neo-classical decision models assuming maximization have been criticized by some writers as inappropriate for modeling behavior in real world decisions since strong assumptions on cognitive aspects are required (e.g. access to perfect information, influence of social context, and individuals' and social psychological characteristics) (Van de Bergh et al., 2000). These authors also suggest that especially in developing countries, a changed behavioral economics that includes ecological and psycho-social dimensions of agriculture is emerging.

Societal response to reduce increasing vulnerability to erosion requires physical assessments of erosion processes but also an analysis of institutional and cognitive aspects associated with the problem and its solution (SWCS, 2003; Grothmann and Patt, 2005; Parry et al., 2007). The reason for that is that often the cost-effectiveness of soil conservation programs depends on whether erosion is perceived only for its off-site effects or also for on-site effects (i.e. in the latter case farmers might have a direct incentive to implement voluntary conservation) (Wossink and Swinton, 2007). Indeed, actions directed to improve soil regulation have the potential to benefit other societal sectors. For example, soil management practices such as using low soil-removal ploughs can reduce soil erosion but also increase water infiltration (Swinton et al., 2007; Dale and Polansky, 2007).

When studying farmers' conservation behavior, the perception of uncertain costs and benefits of conservation practices is also relevant. As prospect theory (Tversky and Kahneman, 1974) and other theories indicate, decision-making under uncertainty is influenced by cognitive aspects such as what is considered a loss or gain, experience, individual values and a series of beliefs about the functioning of the system in which decisions are made.

To study farmers' voluntary conservation efforts, Gould et al. (1989) used a three phase decision model: identifying the problem, deciding on adoption and determining the level of effort. These authors found that, for socioeconomic variables, the effect of farm size on adoption of soil conservation practices was negative while that of income was positive. In the case of cognitive variables, the perception of severity of impacts of soil erosion was positive. Similarly, Lynne et al. (1988) combined psychological variables measuring attitudes, with economic variables, such as income and tenure. In their model, attitudes were used as an expression of expected value attached to a given conservation activity. These authors found that cognitive and psychological variables such as beliefs on conservation of and responsibility on management of soil had a positive effect on adoption of soil conservation practices.

Along the same line, the on-site perceived effects of conservation behavior were analyzed by Traore et al. (1998), who confirmed that perception of environmental problems by farmers was corresponded by a higher adoption degree of environmental-friendly agricultural practices, while socioeconomic variables like tenure and farm size were not significant.

The role of risk perception, beliefs, values and socioeconomic variables in farmers' decision-making on soil conservation has been a concern of environmental policies to address climate change threats. Risk perception, environmental values (cost-benefit expectancy) and beliefs (i.e. knowledge base) have different explanatory power for decisions that address environmental change (O'Connor et al., 1999; Siegrist and Gutscher, 2006). For example, Lee and Zhang (2005) used psychometric measurements to analyze farmers' attitudes and risk perceptions of land degradation along with socioeconomic variables. These authors measured the risk perceptions of farmers for the effects of grazing, opening up farmland, cutting trees for fuel-wood and digging up a local traditional plant on land degradation. Type of occupation and age have a positive effect on awareness of land degradation and on the perception of its impacts. Farmers perceive the existence of different ecological risks associated with land degradation activities although significant misconceptions on land degradation causes and impacts exist among farmers' and experts' knowledge.

Another approach, utilized by Bayard and Jolly (2007), adapted the Health Belief Model as a modified version of Ajzen's theory of Planned Behavior (1991). In their approach, psycho-social, physical and economic constructs were used to measure persons' beliefs about costs and benefits of a given behavior which determine intention and soil conservation behavior. More specifically, four components associated with the risk of soil degradation were included: perceived susceptibility (e.g. exposure); perceived severity (e.g. size of impacts); perceived benefits (private *vs* public), and barriers (e.g. perceived behavioral control). The findings confirm that awareness of the problem has a positive effect on soil conservation behavior, while attitudes had no significant effect. On the

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other side, awareness is positively influenced by farmers' higher perception of severity and susceptibility of soil degradation risk.

Explicitly accounting for climate change risk, Grothmann and Patt (2005) used the Private Proactive Adaptation to Climate Change decision model. In this model, farmers' access to resources, institutional barriers, experience, the perception of probability and severity of climate-related events and, finally, perceived capacity to respond were determinants in farmers' adoption of responsive behavior. These authors applied qualitatively their model to the case of farmers' adoption of climate forecast information in their farming decisions. They could show that there is inconsistency among farmers' and experts' assessment of risk and that low perceived self-adaptive capacity hinder adoption of risk-preventive behavior. In Central America, farmers' soil conservation decisions have been studied mainly from a traditional utilitarian perspective, with some exceptions found in the recompilation of Central America case studies on economic and institutional analysis of soil conservation projects (Lutz et al., 1994a,b).

None of these regional studies analyzed the influence of risk perceptions and beliefs concerning anthropogenic activities and natural events as determinants of preventive behavior of soil erosion control. Considering the concerns of the international community and national policies on reducing the potential impacts of climate change, it is relevant to explore how and whether risk and causes of soil erosion are perceived and whether these influence farmers' conservation efforts in a highly vulnerable region.

3. Methods

3.1. Description of the area

The Birris (coordinates 9.9°N, 83,8°W) is a sub-watershed of the Reventazon River in central Costa Rica flowing into the Caribbean, and is 4800 hectares in size. The watershed is influenced by the Caribbean climate, with 2325 mm average annual rainfall of which about 80% is concentrated in the period from May to December. The topography is characterized by slopes of up to 70%, especially in the upper part of the watershed. The population density is 161 inhabitants per square kilometer (i.e. above the national average; INEC, 2002); most inhabitants are locally born and the majority (61%) are involved in agriculture (ICE, 2000).

Large-scale land conversion of the cloud forest in the Birris watershed started in the 1960s when horticulture and dairy-cattle pastures were established. Intensive soil use for horticulture (217 producers of potato, cabbage and carrots with 2.5 ha average farm size) and dairy-cattle pastures (122 producers with 5–7 ha average farm size), is found mainly in riparian areas. Agriculture and infrastructures have reduced the cover of tropical cloud forest to 28% of the total land area in the watershed. This intense process of forest fragmentation and intensive agricultural production makes this area one of the largest sediment-producers in the country (Sanchez-Azofeifa et al., 2002). Average erosion rates grew from 12 ton/ha/year prior to 1978, when only 15% of the watershed was under horticulture, to 42 ton/ha/year in 1992 (Abreu, 1994). However, the effect of these high levels of erosion is only visible in some areas,[1] since deep andosols are common in the area (Lutz et al., 1994b; Marchamalo and Romero, 2007). To date the National Electricity Institute (ICE) yearly spends more than four million US$ to clean its dams and around three hundred thousand US$ to promote the soil watershed management plan. On the other side the ministry of agriculture provides human and logistic resources to promote soil conservation practices in upstream areas. Here, a recent estimation of the reposition cost of soil nutrients lost with erosion corresponds to ninety-five thousands US$ a year (Vignola et al., 2010).

3.2. Sample and survey instrument design

To develop the survey instrument we conducted two focus groups and interviews with key informants (farmers and agricultural extension officers) to identify aspects to be included in the analysis of farmers' adoption of soil conservation practices in the Birris watershed. Additionally, we also reviewed instruments applied in previous farmers' adoption studies that analyzed attitudes and values related to soil conservation (see Section 3.3). We reviewed questions with agricultural extension officers to ensure that they would be easily understood by farmers. A pilot test was conducted with five farmers to further clarify questions.

Our sample ($n=56$; $N=300$) is covering around 18% of all farmers in the watershed and is similar to that of previous studies similar studies ($n=64$; Bewket, 2007). Three lists of producers available from the local agriculture extension office were used for a strata-proportional selection of farmers corresponding to three categories of producers present in the watershed: horticulture and dairy-cattle ($n=10$), horticulture only ($n=35$) and dairy-cattle only ($n=11$). Producers were visited in the field or at home and were administered by pre-trained interviewers a half-hour structured interview consisting of the following sections: (i) soil conservation practices implemented; (ii) perception of farm soil quality; (iii) risk factors contributing to soil erosion; (iv) values that influence soil conservation decisions; and, finally (v) questions regarding socioeconomic data.

3.3. The decision model

Building on Bayard and Jolly (2007), we propose the following model of farmers' decisions to adopt soil conservation:

$$CD = f(B, RP, V, SE)$$

where soil conservation decisions (CD) depend on three types of independent variables such as their belief/knowledge (B), their risk perceptions (RP), values (V)and a set of socioeconomic characteristics (SE). This model served as the basis of the research design discussed below.

3.3.1. Dependent variables

To measure farmers' soil conservation behavior we used secondary literature and key informants (e.g. agricultural extension officers and members of farmers associations) to build a list of conservation practices that are promoted by existing extension programs or by farmers themselves in the watershed (ICE, 2000; Marchamalo, 2004). The list of conservation practices includes planting of trees, cultivation along contour lines, use of water and soil conservation channels, natural regeneration of vegetation in critical areas, among others. We constructed a binary vector for each practice by asking respondents to mark those practices on the list that they were implementing when the interviews were conducted.

We then constructed for each farmer i the dependent categorical variable *soil conservation effort* $CE(i)=1$ for low effort, $CE(i)=2$ for medium effort, and $CE(i)=3$ for high effort. To do this, we first have to consider that there are different numbers of possible protection practices $P_j(i)$ for each productive category j ($j=1$ for cattle breeding; $j=2$ for horticulture, $j=3$ for both practices). For a farmer i belonging to production category j, we calculate the conservation

[1] That is, probably only some farmers are starting to perceive its direct impacts of erosion.

score:

$$Y^j_{Cons}(i) = \frac{P(i)}{T_j}$$

where $P(i)$ is the total number of practices implemented by the farmer i and T_j is the total number of possible practices for productive category j. The conservation score variable was used to define $CE(i)$ by: $CE(1)$ if less than half of the protection practices are applied (i.e. if $Y^j_{Cons}(i) < 0.5$); $CE(2)$ if more than half and up to 75% of the production practices are applied (i.e. if $0.5 \leq Y^j_{Cons}(i) \leq 0.75$); and $CE(3)$ if more than three-quarters of all possible practices are applied (i.e. if $0.75 < Y^j_{Cons}(i)$).

3.3.2. Independent variables

3.3.2.1. Cognitive variables. We draw on similar studies (Bewket, 2007) that used explanatory variables of farmers' decisions to implement soil conservation, such as awareness and perception of erosion hazard, its causes and controllability. In this section, we explore key concepts underlying these cognitive variables.

Farmers' *beliefs* (*B*) guide their understanding and evaluation of causes and solutions associated with erosion control (D'emden et al., 2008). We followed the approach of Wagner (2007), who used mental model questions to elicit lay-people's beliefs on causes of flash floods, and Bewket (2007) who asked farmers about their beliefs on causes of soil erosion. Rankings on the importance of five degradation activities reported by recent studies (ICE, 2000; Marchamalo, 2004; Ramirez, 2008) were used, namely: deforestation, agricultural practices, extreme precipitation, urbanization, and dairy-cattle pastures. We also asked questions on whether they perceive that the "general health"[2] of their soil has changed from the past and whether they think it will change in the future as a way to measure their judgment on the continuity of the erosion problem over time. Additionally, perceptions on the positive role of trees in erosion control and riparian protection, as recognized in the literature (Tejwani, 1993; Bruijnzeel, 2004) and promoted by soil conservation programs, were measured.

Risk perception (*RP*) was measured following the psychometric paradigm which allows identification of differences in perceptions among groups of individuals (Slovic, 1987). In this paper, risk perception merely denotes the cognitive representation and evaluation of negative impacts resulting from a given activity that changes the environment. Risk of erosion can be defined as consequence-related risk that, using the classification of Slovic (1987), can be judged observable, is relatively well-known to scientists, has immediate effect and, considering the highly exposed context of our study, is a relatively well-known and old problem in the area. In this study, the identification of risk constructs was adapted from previous studies that analyzed the relationship among environmental risk sources and behavioral intentions and responses (McDaniels et al., 1996, 1997; O'Connor et al., 1999; Lee and Zhang, 2005; Bayard and Jolly, 2007).

Farmers' decisions regarding soil conservation are largely driven by short-term perceived risks associated with markets and weather, rather than long-term climate change-related hazards (Grothmann and Patt, 2005). To model this component, and following Bayard and Jolly (2007), we built constructs to measure risk perception using Likert scales from one to seven to measure the individuals' perception of the immediacy and saliency of impacts from drivers of soil erosion such as agriculture, cattle, rainfall, and logging and urbanization. This immediacy was measured by four constructs; namely, severity, uncontrollability, observability and rapidity. Additional questions were intended to measure the extent to which individuals perceive themselves to be living in areas generally exposed to soil erosion risk.

Values (*V*) characterize those standards that individuals judge appropriate and desirable in a given situation, and thus reflect their ordering of preferences for end-states of the environment (Scholz, n.d.). We build, for the value items, on Lee and Zhang (2005) and O'Connor et al. (1999) to formulate questions on how much farmers and public administration should be held responsible for avoiding damage to soil. Finally, all items used to measure all our cognitive variables are presented in Table 1.

3.3.2.2. Socioeconomic variables. As reported in other studies (Grasmuck and Scholz, 2005; Siegrist and Gutscher, 2006) risk perception and its associated responsive behavior is influenced by individuals' exposure. We created a binary variable to discriminate producers by risk areas that were identified by polygons (see Fig. 1) reflecting the boundaries of communities subject to the highest rates of soil erosion (Marchamalo, 2004).

Existing programs promoting soil conservation in the Birris watershed cover a limited extent of the area. To account for their eventual influence on individuals' judgment and conservation behavior, participation in an existing program was measured with a binary variable. Economic welfare level was included, similar to other studies (Lynne et al., 1988; O'Connor et al., 1999; Lee and Zhang, 2005; Bayard and Jolly, 2007), with a ranking variable of monthly household consumption with seven levels. As seen in Section 2, land tenure has widely been used in studying farmers' adoption of soil conservation practices. So, based on our recollected data we constructed an ownership variable ("*owned*") which measures the percentage of total farm land that is owned by the individual producer. Finally, education level (measured by five levels) and age of individuals were included for their important role outlined in previous research on farmers' conservation behavior (Traore et al., 1998; Illukpitiya and Gopalakrishnan, 2004; Lee and Zhang, 2005).

3.4. Statistical analysis

3.4.1. Construction of cognitive variables

In what follows we describe how we used factor analysis in SPSS (2001) on *B*, *RP*, and *V* to create three indexes that were ultimately used, together with socioeconomic variables, to test our hypotheses. The three sets of indexes (*B*,*RP*,*V*) were obtained by conducting the factor analysis with the Kaiser normalization method, varimax rotation, and Principal Component Analysis as the extracting method with the variables under each heading in Table 1. Only factors with an eigenvalue of 1 or above were retained (Kaiser-Gutmann retention criterion; Kinnel et al., 2002). Fitness for factorial analysis was tested with Bartlets' *KMO* and *p*-value. Rotated factor loadings were used to identify relevant variables to be used in the construction of indexes. Variables were retained if their rotated loadings were above the threshold value of 0.5.

In the exploratory analysis, we excluded from further analysis the variable that measured farmers' judgment on "own responsibility not to destroy soil productivity" ($V_{SoilProdNoDestr}$) for its low variance (ratings between 5 and 7), possibly due to strategic answering. Then, a separate factor analysis[3] (i.e. one for each specific cognitive aspect of the decision model) reduced the number

[2] This concept was used by key informants when discussing on soil erosion. Soil erosion is associated by farmers to the concept of decreasing soil health which they perceive associated to several consequences such as decreasing productive capacity and increase in amount of fertilizers needed.

[3] In an attempt to reduce the number of variables, we ran exploratory factor analyses using all variables measuring cognitive aspects. The low fitness-test value ($KMO = 0.352$; $p < 0.0001$), however, did not separate consistent factors out of the 14 loaded, thus suggesting the need for a minor-aggregation analysis.

Table 1
Items and their codes to measure cognitive variables.

Component	Abbreviations	Items
Belief	$B_{ProdInRipAgua}$	Riparian areas are optimal for my productive activities given proximity to water.
	$B_{ProdRipGood}$	Sloping areas are good for my productive activity.
	$B_{SoilConsCostInco}$	Soil conservation measures do not bring much benefit, it is more the investment cost then the returns for my farm.
	$B_{SoilNeverDegr}$	Soil is an inexhaustible resource, which is why it can be exploited continuously.
	$B_{ScienceTech}$	Scientific and technological progress in soil management allows overcoming soil degradation problems
	$B_{SoilHealth}{}^{*}$	How healthy do you think your soil is?
	$B_{SHchange}{}^{**}$	Do you consider that your soil health has changed compared to the past?
	$B_{SHChFut}$	Do you think your soil health might change in the future?
	$B_{ContrPreci}$	How much does rainfall contribute to erosion?
	$B_{ContrAgr}$	How much do agricultural practices contribute to soil erosion?
	$B_{ImpoRain}$	Among deforestation, agriculture, rainfall, roads and cattle breeding, how would you rank precipitation impacts on soil erosion?
	$B_{ImpoAgr}$	Among deforestation, agriculture, rainfall, roads and cattle breeding, how would you rank the impacts of agricultural activities on soil erosion?
	$B_{TreesDecrProd}$	Trees on farm lands decrease production.
	$B_{TreeConsSoil}$	Trees benefit soil conservation.
	$B_{SlopeFor}$	In high sloping areas there should be no productive activity, only forest.
Risk	$R_{PCattleObs}$	How observable is the impact of cattle on soil erosion?
	$RP_{CattleRap}$	How fast is the impact of cattle on soil erosion?
	RP_{AgrRap}	How fast is the impact of agriculture on soil erosion?
	$RP_{CattleSev}$	How large is the impact of cattle on soil erosion?
	RP_{AgrObs}	How observable is the impact of agriculture on soil erosion?
	RP_{AgrSev}	How large is the impact of agricultural activities on soil erosion?
	$RP_{EroPast}$	How much has erosion risk increased in respect to the past?
	RP_{EroFut}	How much will soil erosion risk increase in the future?
	RP_{CrSev}	How large are soil erosion related losses in Costa Rica?
	$RP_{RainObs}$	How observable is the impact of precipitation on soil erosion?
	$RP_{RainSev}$	How large is the impact of precipitation on soil erosion?
	$RP_{RainRap}$	How fast is the impact of precipitation on soil erosion?
	$RP_{CrContr}$	How much can people in Costa Rica control the risk of soil erosion?
	$RP_{RainContr}$	How controllable is the impact of precipitation on soil erosion?
	$RP_{CattleContr}$	How controllable is the impact of cattle on soil erosion?
	$RP_{AgrContr}$	How controllable is the impact of agriculture on soil erosion?
Values	$V_{SoilProdNoDestr}$	Soil productivity should never be destroyed
	$V_{wstrUseCare}$	Downstream users do not care about how we upstream producers manage our farm soils
	$V_{IncomeNow}$	Ensuring maximum return possible for this year is much more important than ensuring soil productivity for future generations
	$V_{ProdPay}$	Producers who are responsible for sedimentation in rivers should pay for removing such sediments from rivers and dams
	$V_{ProdOwnDec}$	Each producer owns his farm soil so that his soil management decisions are strictly personal
	$V_{RespFutGenr}$	For our children, we producers have the responsibility to reduce erosion
	$V_{PublicAdmPay}$	Public administration responsible for roads should pay for removing sediments produced by this infrastructure from rivers and dams

All variables are measured on Likert scales. Beliefs scales are 1 (do not agree) to 7 (very much agree); except * (very unhealthy = 1 to very healthy = 4) and ** (Has worsened = 1, the same as now = 2, has improved = 3); risk perceptions are from 1 (very little) to 7 (very large); values scales are 1 (do not agree) to 7 (very much agree).

of variables from the original 38–9 cognitive indexes. In each factor analysis we utilized standard procedures such as *KMO* values and commonalities to improve the separation of factors. The final results are shown in Table 2.

3.4.1.1. *Beliefs.* The factor analysis on beliefs variables identified 3 underlying factors ($KMO = 0.671$; $p < 0.01$). With factor 1 loadings, we constructed an index B_1 called "*Positive Thinking*" ($B_1 = B_{ProdInRipAgua} + B_{SoilNeverDegr} + B_{ScienceTech}$) composed of items capturing (i) beliefs that soils are resilient to degradation, (ii) that technological progress in soil management practices is sufficient to counter soil degradation and, finally, (iii) that producing in riparian areas (i.e. sloping areas) is good because water is closer. This index thus indicates the triumph of positive thinking about production and technology over worries on soil degradation processes. Items from factor 2 loadings built index B_2 named "*soil critical conditions*" ($B_2 = B_{SoilHealth} + BSHchange$). These items measure beliefs as to how healthy farmers think their farm soil is and whether it has changed. The scales of the two contributory items were structured to measure how strongly they believe their farm soil to be in critical condition (i.e. higher values correspond to higher awareness of critical soil conditions). Factor 3 loadings identified beliefs associated with the importance of rainfall in erosion processes in general and in their farm soil in particular. Index B_3, termed "*Climate extremes*" ($B_3 = B_{ContrPreci} + B_{ImpoRain}$), captures beliefs associated with this component of the erosion problem.

3.4.1.2. *Risk perception.* Factor analysis for risk perception ($KMO = 0.71$; $p < 0.0001$) identified four factors. Factor 1 loadings identified an underlying index RP_1 called "*Agricultural risk*" ($RP_1 = RP_{AgrContr} + RP_{AgrObs} + RP_{AgrSev} + RP_{AgrRap}$), which captures risk perception associated with agricultural activities. More specifically, it measures the immediacy of their impacts on erosion and how controllable they are and tells us about the relevance of these activities for erosion. Based on the loadings of the second factor, we constructed index RP_2, termed *"Pasture risk"*, ($RP_2 = RP_{CattleObs} + RP_{CattleSev} + RP_{CattleRap}$), representing the perception associated with the immediacy and severity of pasture activities on erosion. The index RP_3 ($RP_3 = RP_{EroPast} + RP_{RainObs} + RP_{RainRap}$) is named

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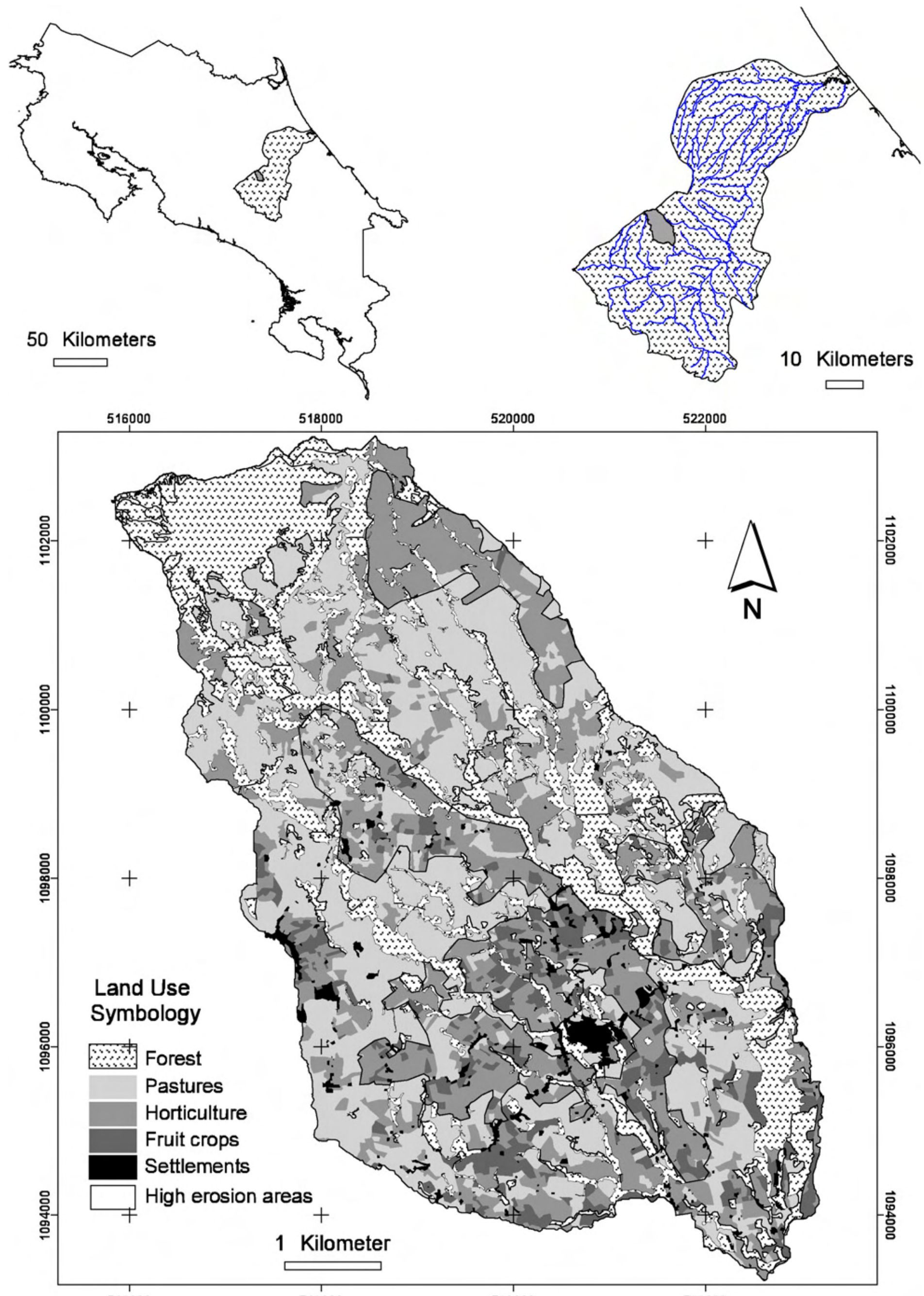

Fig. 1. Location, current land uses and the delimitation of areas with high soil erosion of the Birris watershed (A: Costa Rica; B: Reventazon watershed; C: Birris watershed).

"*Extreme Precipitation*" and clearly complements the first two risk perception indexes, which are directed at anthropogenic activities, by addressing judgment on natural phenomena. This index includes perception of the immediacy of rainfall impacts which, interestingly, is correlated in the same factor with the perception of how strongly erosion has increased in respect to the past. Finally, in the factor analysis of risk perception, the fourth factor loaded items measuring perception of the controllability of erosion effects together with the extent to which individuals perceive that people in the country are able to control this environmental problem. We name index RP_4 *"control perception"* ($RP_4 = RP_{CrContr} + RP_{RainContr}$) since it measures perceptions of how controllable the erosion effects of extreme precipitation are, along with the capacity of Costa Rican people to cope with them

3.4.1.3. Values. Factor analysis on values items identified two underlying factors ($KMO = 0.559$; $p < 0.05$). The first factor loaded items measuring values on private aspects of the erosion problem. Thus, this index called "*private benefits*" ($V_1 = V_{IncomeNow} + V_{ProdOwnDec} + V_{ProdNoPay}$) measures preference for short-term benefits, right to decision on their own farm soil (i.e. erosion is not of public concern) and, finally, the opinion that producers should not be paying for removing sediments from the river. The second factor, in contrast, identified an index ($V_2 = V_{RespFutGenr} + V_{PublicAdminPay}$) that captures the values related more to the public than to the private benefits. This index is built with variables measuring concerns on whether public administration (i.e. and not individual farmers) should be held responsible for removing sediment from rivers and whether soil conservation should be ensured for the benefits of

Table 2
Results of factor analysis with the loadings of the rotated factors for cognitive variables.

Dimension	Variable	Factor 1	Factor 2	Factor 3	Factor 4
Beliefs		Explained variance			
		31.32	15.74	14.85	–
		Rotated loadings			
	$B_{ProdInRipAgua}$	0.82	0.13	0.09	–
	$B_{ScienceTech}$	0.70	−0.05	0.26	–
	$B_{SoilNeverDegr}$	0.67	0.22	−0.16	–
	$B_{SoilHealth}$	−0.04	0.83	0.19	–
	$B_{SHchange}$	0.37	0.7	−0.07	–
	$B_{ContrPreci}$	0.32	−0.001	0.67	–
	$B_{ImpoRain}$	0.11	−0.11	−0.74	–
Risk perception		Explained variance			
		33.18	14.643	10.801	10.459
		Rotated loadings			
	$RP_{AgrContr}$	0.65	0.19	−0.12	0.42
	RP_{AgrObs}	0.85	0.03	0.11	−0.09
	RP_{AgrSev}	0.76	0.22	0.12	−0.10
	RP_{AgrRap}	0.72	0.29	0.39	−0.15
	$RP_{CattleContr}$	0.59	0.31	0.06	0.43
	$RP_{CattleObs}$	0.27	0.81	0.09	0.20
	$RP_{CattleSev}$	0.21	0.92	0.04	0.06
	$RP_{CattleRap}$	0.12	0.92	0.04	0.01
	$RP_{RainObs}$	0.07	0.03	0.72	−0.28
	$RP_{RainRap}$	0.09	0.15	0.63	0.06
	$RP_{EroPast}$	−0.11	0.06	−0.70	−0.15
	$RP_{CrContr}$	0.02	0.04	−0.19	0.74
	$RP_{RainContr}$	−0.12	0.11	0.32	0.75
Values		Explained variance			
		33.82	23.39	–	–
		Rotated loadings			
	$V_{IncomeNow}$	0.71	0.41	–	–
	$V_{ProdNoPay}$	0.75	0.25	–	–
	$V_{ProdOwnDec}$	0.73	0.07	–	–
	$V_{RespFutGenr}$	0.03	0.71	–	–
	$V_{PublicAdmPay}$	0.005	0.70	–	–

future generations (i.e. expressing concerns for longer term benefits of erosion control)

3.4.2. Differentiation of farmers' types

In a second step, following Carlson et al. (1977), we used discriminant analysis, using $CE(i)$ as the dependent variables, to project the socioeconomic and cognitive indexes in a bi-dimensional space allowing for visual representation of the farmers' conservation-efforts groups and the variables characterizing them. Finally, we tested our hypotheses in Section 1 with a pairwise ANOVA to compare groups' means scores on cognitive and socioeconomic variables.

4. Results

4.1. Sample description

Most farmers in our sample are full-time agricultural producers (63%) and have relatively low educational levels (i.e. primary school). The average level of household monthly consumption is between US$ 200 and US$ 400 (Table 3).

The majority of interviewees (71%) do not, at present, participate in conservation programs and the sample shows a relatively even distribution of farmers in and outside (46%) of risk areas. Farmers in the sample, independently from their farm production activity, implement on average about half (55%) of the total soil conservation practices we listed.

4.2. Differentiation of farmers' groups

Combined cognitive and socioeconomic variables clearly differentiate the three groups of farmers based on their conservation efforts (CE). Agriculturalists represent the majority of interviewees in the groups $CE(1)$ and $CE(2)$ (i.e. lower conservation efforts) (Table 4).

Farmers within the group of lowest conservation efforts $CE(1)$ own a smaller percentage of the land they cultivate respect to farm-

Table 3
Socioeconomic variables of the sample ($n = 56$).

Variable	Average	S.D.	Min.	Max.
Age (years)	48.98	14.55	18	80
Farm size (ha)	18.30	11.11	1	38
Education[a]	2.29	0.87	1	5
Income[b]	4.45	1.37	2	8

[a] Education is measured by 5 levels: (1) incomplete primary school; (2) primary school; (3) secondary school; (4) college; (5) university.
[b] Proxied by 10 monthly consumption levels (1 US$ = 480 colones): (1) less than 25,000 colones; (2) 25,001–50,000 colones; (3) 50,001–100,000 colones; (4) 100,001–200,000 colones; (5) 200,001–300,000 colones; (6) 300,001–400,000 colones; (7) 400,001–500,000 colones; (8) 500,001–750,000 colones; (9) 750,001–1,000,000 colones; (10) more than 1,000,000 colones.

Table 4
Distribution of interviewees by farm activity in the different farmers' conservation-effort groups of the sample.

Farm activity	Farmers' groups (n)		
	$CE(1)$	$CE(2)$	$CE(3)$
Agriculture	13	14	8
Dairy-cattle	3	6	2
Agriculture and dairy-cattle	3	1	6
Total	19	21	16

Please cite this article in press as: Vignola, R., et al., Decision-making by farmers regarding ecosystem services: Factors affecting soil conservation efforts in Costa Rica. Land Use Policy (2010), doi:10.1016/j.landusepol.2010.03.003

Table 5
Pairwise ANOVA comparison of the three farmers' groups; $CE(i)$ identifies the Conservation-Effort farmers' group.

	Group averages (standard deviation)			p-Values		
	$CE(1)$	$CE(2)$	$CE(3)$	$CE(1)$ vs $CE(2)$	$CE(1)$ vs $CE(3)$	$CE(2)$ vs $CE(3)$
PartiProgr	0.11 (0.31)	0.14 (0.35)	0.69 (0.47)	0.48	0.0005	0.001
Activity	2 (0.57)	2.24 (0.53)	1.75 (0.68)	0.23	0.29	0.03
Age	48.53 (14.79)	52.57 (16.08)	44.81 (11.50)	0.39	0.39	0.13
Edu	2.37 (0.83)	2 (0.83)	2.56 (0.89)	0.21	0.44	0.08
MonthCons	4.21 (1.18)	4.33 (1.71)	4.88 (1.02)	0.49	0.11	0.28
Owned	0.70 (0.43)	0.83 (0.33)	0.70 (0.40)	0.33	0.50	0.34
RiskArea	0.21 (0.41)	0.48 (0.51)	1 (0)	0.10	0.0001	0.0002
B_1	11.89 (4.93)	14.47 (4.45)	10.50 (4.80)	0.12	0.39	0.02
B_2	4.42 (1.017)	4 (0.94)	3.87 (1.08)	0.22	0.17	0.48
B_3	9.78 (1.81)	10.04 (2.17)	8.81 (2.28)	0.48	0.22	0.14
RP_1	19.84 (3.46)	15.90 (4.08)	15.93 (3.51)	0.003	0.003	0.50
RP_2	9.63 (6.83)	6.42 (4.17)	9.43 (4.76)	0.12	0.49	0.07
RP_3	17.63 (2.31)	16.52 (2.69)	17.56 (2.09)	0.21	0.49	0.24
RP_4	6.47 (3.19)	6.81 (3.22)	5.56 (2.06)	0.49	0.34	0.21
V_1	13.42 (3.99)	8.38 (3.74)	10.25 (4.41)	0.0003	0.05	0.22
V_2	10.78 (3.13)	10.80 (2.37)	12.56 (1.36)	0.50	0.05	0.01

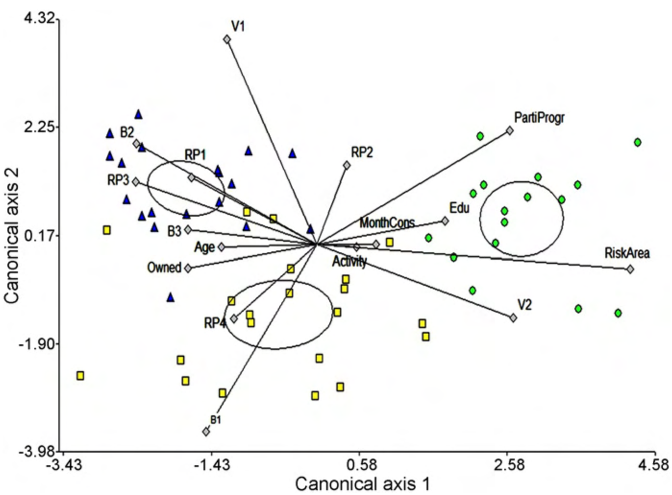

Fig. 2. Discriminant analysis for the three groups of farmers with different soil conservation efforts $CE(i)$. Blue triangles correspond to $CE(1)$, yellow squares to $CE(2)$ and green circles to $CE(3)$. The grey lozenge represents the spatial location of the variable, showing its positive or negative association with farmers groups.

ers in the other two groups. The bi-plot of discriminant analysis[4] (Fig. 2) identifies three separate groups of farmers distinguished using circles built with the confidence interval at p-value lower than 0.05. The first canonical axis explains more than 70% of total variance and allows a clear separation between the group of farmers with greater conservation efforts $CE(3)$ from that of group $CE(1)$. Clearly, group $CE(3)$ is strongly and positively associated with exposure in risk areas, higher education level, more participation in programs and more "*public benefits*" (V_2) concerns. The figure also shows that in this group, given the negative association with socioeconomic variables such as "*age"* and "*own*", we find younger farmers owning a smaller portion of land with respect to total land farmed. Similarly, group $CE(3)$, in contrast to $CE(1)$, is also strongly negatively associated with risk perceptions of "*Agricultural risk*" and of "*extreme precipitation*". The differences between these two groups are also reflected in their contrasting association with beliefs on topics such as "*soil critical conditions*" and "*climate extremes*".

[4] Data are consistent for linear discriminant analysis since the null hypotheses for the homogeneity of variance is accepted (p = 0.4646).

Indexes such as "*positive thinking*" (B_1) beliefs and *"pasture risk"* (RP_2) perceptions are only slightly important with respect to the first canonical axis. In the second canonical axis, it is only cognitive index B_1 which shows a strong and positive association with $CE(2)$. Similarly, it is only with respect to this axis that the index "*private benefits*" (V_1) shows a stronger contribution, being positively associated with $CE(1)$ and negatively with group $CE(2)$.

4.3. Testing hypotheses of differences between farmers' groups

The clear separation among groups of farmers (defined by their conservation effort) resulting from the discriminant analysis rejects our null hypothesis supporting that a combination of socioeconomic and cognitive variables explain significant differences among farmers' conservation efforts. In the following pairwise ANOVA we refine our hypotheses testing to highlight the differential contribution of cognitive and socioeconomic variables by groups of farmers. Results of ANOVA show key contrasting characteristics of the three groups of farmers (Table 5).

Farmers in group $CE(3)$ live in areas more affected by erosion and have greater participation in the soil conservation program than the other two groups showing that technical assistance programs have been having a significant effect on adoption of soil conservation practices. In respect to cognitive variables, higher awareness of the limits of technologies and soil to provide resilience to erosion together with higher perceptions of (i) risks associated to agricultural activities, and (ii) benefits associated to soil conservation and awareness, have a positive effect on adoption. More specifically, farmers in group $CE(3)$ (who are mainly agriculturalists) show significantly higher risk perception of the immediacy of pasture impacts on erosion than do groups $CE(1)$ and $CE(2)$. Similarly, as opposed to the other two groups, group $CE(3)$ is more concerned with the longer term benefits of erosion control (i.e. for future generations) as well as with a perspective that public administration should be paying for removing sediment from rivers. On the other hand, with respect to $CE(2)$, $CE(3)$ farmers show significantly lower values of index B_1 (i.e. positive beliefs on the role of technology and soil resilience to reduce the adverse effects of soil management).

The group with medium conservation effort $CE(2)$ is composed of a significantly larger proportion of farmers dedicated to dairy-farming with a lower participation in soil conservation programs. Farmers in this group show a significantly lower perception of the risk associated with human activities (i.e. agriculture and dairy-cattle farming) than farmers in the other two groups, and generally less concern over the public and private benefits of erosion control (i.e. V_1 and V_2).

Consistent with the findings of the discriminant analysis, risk perception of impacts of agricultural activities on erosion and values regarding short-term benefits of erosion control have an inverse relationship with conservation efforts. Indeed, farmers with the lowest level of conservation effort *CE*(1) showed higher risk perception of the impacts of agricultural activities on erosion (R_1 = *agricultural risk*) than farmers in *CE*(3) and *CE*(2) Farmers in group *CE*(1) also showed higher concern with respect to groups *CE*(2) and *CE*(3) for the private aspects of soil conservation and the importance of short-term benefits of agricultural activities against the longer term benefits of erosion control (V_1 = "*private benefits*"). Deeper analysis of the data on tenure and production activities will help to illustrate this finding. In group *CE*(1) we find mainly horticulturalists as opposed to the other two groups (where horticulturalists and dairy-farmers are more evenly represented). A comparison of the average farmland owned by these two types of producers shows that horticulturalists own smaller plots ($p_{\text{Kruskal-Wallis}} < 0.005$) in which the opportunity cost of soil conservation might be perceived as being higher. Small-scale farmers, dealing with short-term production cycles, such as is the case of horticulture in the area, however, might show awareness of soil degradation but feel that private benefits are more important in the short run.

To further explore these hypotheses we ran a non-parametric test to compare mean values of cognitive indexes accounting for farmers' groups *CE*(i) and also accounting for size of farm owned. We thus categorized the variable "*total farmland*" available to producers into two separate classes; namely, those owning less than 10 ha (n = 16) and the others (n = 40). For smaller landowners, the group with lower conservation efforts *CE*(1) has a significantly higher score for beliefs about "*critical soil conditions*" ($p_{\text{Kruskal-Wallis}} < 0.05$) and "*private benefits*" compared to the other two groups ($p_{\text{Kruskal-Wallis}} < 0.05$). Finally, the producers in group *CE*(3) show greater concerns about "*public benefits*" (V_2) aspects than the other two groups of farmers.

5. Discussion

The results of our analysis reject the hypothesis that farmers' voluntary soil conservation efforts are not influenced by the interaction of cognitive and socioeconomic variables, keeping with the findings of previous research in the region (Forster, 1994). Factor analysis allowed the identification of the most important cognitive aspects that influence soil conservation decisions and the construction of consistent indexes. The multivariate discriminant analysis indicates that the group of farmers with lower conservation effort is positively correlated with cognitive variables. This contrasts with the group showing higher conservation effort (i.e. group *CE*(3)), where there is mainly a positive correlation with socioeconomic variables and exposure to erosion risk. This suggests that, together with the promoted direct payments, a complex set of factors need to be considered in designing conservation programs aimed at promoting adoption of appropriate soil management practices.

Our results indicate that complex interactions among cognitive and socioeconomic dimensions influence significantly farmers' decisions on soil conservation. However, comparison with other studies in the Central American region can only be limited to socioeconomic and some institutional variables (e.g. presence of soil conservation programs) while cognitive variables have been overlooked. More specifically, from an economic perspective, farmers with lower conservation effort are also those cultivating smaller farmlands, which might entail the perception of higher opportunity costs in the implementation of soil conservation practices. This is supported by the results of the economic analysis of soil conservation practices in the close Tierrablanca watershed in Costa Rica (Cuesta, 1994) where results indicate that conservation practices have negative returns also due to the proportion of productive farm land dedicated to conservation (i.e. small farms having higher opportunity cost). Our results also support the finding of Cuesta (1994) and Vasquez and Santamaria (1994) by suggesting that institutional programs promoting technical assistance should be strengthened given their positive effect on adoption of soil conservation practices. Our findings show, however, that cognitive variables also influence the extent to which individual farmers decide to implement soil conservation practices. Farmers' evaluation of the benefits of soil conservation for agricultural production trades off against the costs they attach to erosion control. Their judgment on the costs of soil erosion control and on its benefits appears to be conditioned by their specific context, such as the extent and tenure regime of the land cultivated. Smaller holdings are associated with horticulturalists that have less land available for the implementation of conservation practices and, moreover, are more concerned with short-term income needs, although they score higher on awareness of risks and causes of soil erosion in the area.

Farmers in our sample with lower conservation efforts show a significantly higher perception of the risk of agricultural activities. This finding contrasts with those of Weber et al. (2001), who reported that actual exposure and awareness increase proactive behavior. Additionally, the "availability heuristic" paradigm (Tversky and Kahneman, 1974) may also be playing an important role in farmers' soil conservation behavior. Indeed, the inverse relationship between risk perception of the impacts of agricultural activities on erosion and conservation efforts suggests that farmers may underestimate the consequences of their agricultural activities on erosion. In other words, daily experience with erosion might give the illusion of control and/or smaller losses. Moreover, as discussed Bewket (2007), while awareness of risk and its causes can influence farmers' intentions to implement soil conservation practices, its actual adoption depends on socioeconomic and institutional aspects.

The most educated farmers do not show strong beliefs regarding the soil's capacity to recover or the ability of science and technology to overcome erosion problems (B_2) and they reveal higher conservation efforts. These findings contrast those of Abreu (1994) whom found no significant effect of education on adoption level of farmers in the close watershed of Tierrablanca. Educated farmers in our sample show awareness of the importance of implementing soil conservation practices, understanding that soil productivity can be degraded if appropriate actions are not initiated. These findings confirm those of other authors, in keeping that education is related to knowledge of consequences of soil management practices and of alternative solutions, which in turn influences behavior (Carlson et al., 1977; Ervin and Ervin, 1982; Traore et al., 1998; Mbaga-Semgalawe and Folmer, 2000; Lambert et al., 2007). In line with this same argument, technical assistance programs improving farmers' understanding of erosion causes and alternatives available can improve their chances of adoption (Traore et al., 1998).

6. Conclusions

This article provides new perspectives on the relationship between the perception of climate change risk posed to farm soils and the adoption of conservation practices. The model we used enriches our understanding of the complex interactions among socioeconomic and cognitive variables by showing how these interactions differentiate among specific groups of farmer types. Farmers show a low awareness of the risks posed by climate-change related extremes to their farm soil, although they show high concern with the impacts of human activities. Additionally, our results suggest that soil conservation programs should strategically consider promoting improvement of understanding of the causes, the on-site and off-site consequences, and the limitation of soils and technological solutions to provide resilience to erosion. This might improve understanding on the urgency to take action given the potential intensification of erosion-causing extreme events in vulnerable watersheds and increase the probabilities of larger self-motivated adoption of soil conservation practices.

Acknowledgements

The authors would like to acknowledge Karen Cooke and Julia Brändle for their useful comments on the first draft, Miguel Marchamalo and Marco Otarola for support during this research. This paper was prepared with support from the “Tropical Forests and Climate Change Adaptation” (TroFCCA) research program, executed by CATIE and CIFOR and funded by the European Commission under contract EuropeAid/ENV/2004-81719. The contents of this document are the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the European Union. The efforts of Vignola and McDaniels were supported by the Climate Decision Making Center (CDMC) located in the Department of Engineering and Public Policy, through a cooperative agreement between the National Science Foundation (SES-0345798) and Carnegie Mellon University. The CDMC in turn supports researchers in the Institute for Resources, Environment and Sustainability at the University of British Columbia.

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