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The Impact of Socio-Economic Land Use Decisions on the Provision of Ecosystem Services in Small Catchments

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Abstract: Human land-use activities induce substantial changes to the biophysical attributes of earth's land cover, thereby modifying structures and functions of terrestrial ecosystems (Vitousek et al. 1997). Their present manner led to significant decreases in ecosystems' functionalities, which entails major losses of goods and services for human needs on local scales (MA 2005). Furthermore, given ecosystems' global importance for biogeochemical and energy fluxes, land use is a key driver of global change issues. It contributes considerably to climate change (Chase et al. 1999), loss of biodiversity (Sala et al. 2000), as well as soil degradation (Lambin et al. 2001). The project's main goal is to model land-use decisions with respect to ecosystem services, which will provide a tool for optimizing landscape management applied to a case study region in South Korea. As land-use decision making is part of a multilayered human-environment system, the model will incorporate social, economic and ecological considerations of local actors.

Keywords: *ecosystem services, land use decision-making, theory of planned behavior*

1. Introduction

The project evolves from findings stating that over the last 50 years humans have changed ecosystems to an extent unparalleled by any other period of time in human history. According to the Millennium Ecosystem Assessment (MA), nearly two thirds of the world's ecosystems are declining in productivity due to unsustainable land use and degradation (MA 2005), which implies potentially high costs to society and diminishes the ability to benefit from ecosystem services for the present and future generations. The direct and indirect benefits important to people include provisioning services, such as food and timber production, regulating services, such as water and climate regulation, cultural services, such as recreation and scenic beauty, and supporting services, such as nutrient cycling (MA 2003, 2005).

In order to successfully address the issue of deteriorating ecosystems, there are several difficulties to overcome. Thus, it is necessary to improve the understanding of the relationship between human land use decision-making and the provision of specific ecosystem services (Wunder et al. 2008). Especially important in this context is the consideration of spatial interdependencies, since actions always affect multiple ecosystem services simultaneously in accordance to their locus of implementation (Daily et al. 2009). Furthermore, ecosystem management and different ecosystem services are tied to trade-offs, but a systematic planning framework that may identify synergies is mostly lacking (Daily and Matson 2008). The value of these trade-offs to society is often unknown, and particularly in the case of not marketed ecosystem services, no monetary data is available that would allow for the assessment of their demand (DEFRA 2007).

In the end, substantial interventions will be required to address the above given reasons for declining ecosystem services. They have to be implemented considering given limits in budgets, political constraints as well as concerns of social equity. Thus, decision makers are reliant on comprehensive high-quality information, as well as on appropriate tools for selecting between applicant sites that process complex information on interacting ecosystem services in a practical manner. A promising approach in that context is the development of land use models such as Bayesian Belief Networks (BBN). The advantage of BBNs is that land use decisions can be modeled in a realistic way based on a probabilistic approach, e.g. changes in market prices for agricultural goods or implementation of a policy instrument like payments for ecosystem services which influence the probability of land use change for a specific land management unit. As BBNs are based on multivariate probability distributions of model variables and define relations between different variables in terms of their conditional distributions (Haas 1991), they allow reasoning under the uncertainties associated with the conditional distributions (Hornberger 2001). In addition, conditional probability distributions in BBNs can be derived from both qualitative and quantitative information, which makes them highly recommendable for working interdisciplinary. Another explicit advantage is the BBN's ability to learn from newly-available data, i.e. the probability distributions in the model can be updated as soon as improved evidence is found.

The potential of Bayesian methods has been explored in a number of contexts concerning land use and land use change (e.g. Marcot et al. 2001). Rather few publications, however, dwell on the capabilities of BBNs in investigating spatially-explicit land use decision-making (Aalders 2008), let alone linking it with the provision of ecosystem services (Grêt-Regamey 2007). Thus, the objectives of this study are (a) analysis of local farmers' land use decision-making with respect to ecosystem services, (b) development of a Bayesian belief network to model land use decisions, which serves as a support tool for improved landscape management, and (c) spatially-explicit illustration of the impacts of land use decisions on the provision of ecosystem services.

The analysis of land use decision-making examines the role of four services, namely biomass production, soil erosion, water purification and biodiversity with respect to their influence on farmers' decision to plant rice, annual dryland crops, or perennial crops, respectively. The approach is implemented in a watershed dominated by agricultural land use in South Korea, where most policy measures to mitigate environmental degradation show little success. In this light, the attempt to elucidate determinants of farmers' decision-making is based on following hypotheses: farmers' attitudes towards the aforementioned ecosystem services are more positive for (a) those cultivating perennial crops in comparison to rice and annual crops, (b) organic farmers in comparison to conventional farmers, and (c) those owning the land they cultivate in comparison to those that lease the land. Although studies from the same field of investigation underline the importance of these variables (e.g. Locke 2006, Zubair 2006), the ecosystem services, crop types and cultivation methods of the research design were above all chosen in accordance to the characteristics of the study area, which will be described in detail hereafter.

2. Research Area

Data for analyzing land use decision-making is gathered in Haean watershed, South Korea, a basin designated as a pollution hot spot by the Korean government (longitude 128° 5' to 128° 11' East and latitude 38° 13' to 38° 20' North). This catchment in Yanggu County, Gangwon Province, contributes to the Soyang River, which feeds one of the two main tributaries of the Han River. The kettle-like topography of the Haean Basin has a range in altitude from 500 to 1,100 m a.s.l. and the area's appearance can best be described by its local name the 'Punch Bowl'. Land use is dominated by agricultural production, which accounts for approximately 40% of the area. Another 55% are forests while the rest is mainly residential area. Crop choice roughly follows the terrain's gradient: from rice paddies in the flat core areas to dryland crops and some sites of perennial crops in the steeper outskirts, until finally land cover changes to forest on the rims of the catchment where steepness precludes agricultural activities. Besides rice, the main dryland crops are radish, cabbage and potato, whereas perennial crops are mostly Ginseng, various fruit tree varieties and Bonnet Bellflowers (*Codonopsis* spec.).

With Haean's lower tree line being continuously pushed uphill to make room for agricultural land uses, former forest soils on the slopes are rendered vulnerable to erosion processes. Especially during heavy rain events in the monsoon season, soil loss can be tremendous and streams become heavily loaded with eroded sediment. To compensate the loss from their fields farmers often add sandy soil as new top layer, since it is especially well suited for growing root crops. At the same time, however, it is very prone to abrasion, hence the cycle of soil loss and renewal starts over again. Although farmers are aware of their large contribution to water pollution and the associated consequences, initiatives by the Korean government to change their behavior or mitigate the consequences show little success. Policy programs are often considered useless, legal prohibition of soil addition is widely disregarded, and officially endorsed soil loss prevention facilities seldom built (Environment, Culture and Tourism Bureau of Gangwon Province 2006). Most recent governmental endeavors aim at fostering organic farming as well as introducing perennial crops, since both are deemed less environmental harmful.

3. Methods

It is against this background that we implement an interview-based behavioral study to gain better insight into farmers' decision-making. We use the term behavioral in the sense of Burton (2004), who defines studies following this approach as those that (a) seek to understand the behavior of individual farmers directly responsible for the land, (b) focus on psychological constructs such as attitudes, values and goals, but also commonly gather additional relevant data on farm structure, economic situation, etc., and (c) employ largely quantitative methodologies, in particular psychometric scales such as Likert-type scaling procedures for investigating psychological constructs. General questions of our interview comprise information about place of residence, farming experience, age, gender, yearly household income (divided into six classes covering <10M, 10-20M, 20-30M, 30-40M, 40-50M, >50M Korean Won), education as well as several items referring to the particular crops cultivated.

Psychological questions about decision-making are based on the Theory of Planned Behavior (TPB) (Ajzen 1991), which postulates intention as proximate antecedent for the decision whether to engage in a behavior or not. It measures intentions based on three components: attitudes towards the behavior (A), subjective norms (SN), and perceived behavioral control (PBC). A strong intention thus depends on a positive outcome evaluation of performing the behavior, the appreciation of important reference persons, and volitional control over the behavior's performance. The magnitude of these components, in turn, follows an expectancy-value calculus consisting of one belief based and one direct measure. Thus, attitudes are determined by the belief strength (b) about the subjective probability that a given behavior will produce a certain outcome, and the outcome evaluation (e) which reflects the utility derived from the occurrence of that outcome. Both measures are multiplied and the result summed up over all attitudes under consideration (i). In a similar fashion subjective norms are obtained from the summed products of normative belief strength (n) and motivation to comply (m). Finally, perceived behavioral control consists of control belief strength (c) multiplied by perceived power of control (p) and summing the results (Figure 1).

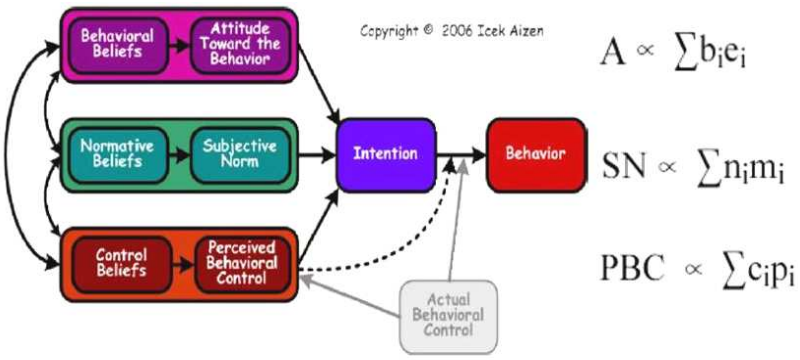

Figure 1. Components of the Theory of Planned Behavior (Ajzen 1991)

Following recommendations by Ajzen (2006) salient beliefs associated with the behaviours under consideration were elicited during a pre-survey field trip. Interviews with five government officials and twelve farmers were used to identify the four most important attitudes, control factors, and reference groups in terms of cultivating rice, annual and perennial crops, respectively. The most frequently named attitudes associated with farmers' crop choice were summarised under the topics (a) biomass production, (b) soil erosion, (c) water quality, and (d) plant and animal conservation. Social reference groups identified as having stakes in crop choice behaviour turned out to be (a) household members, (b) fellow farmers, (c) people living further down the river outside Haean, and (d) environmental protection agencies. Finally, the most influential control factors were (a) availability of money, (b) skills and knowledge, (c) plot characteristics, and (d) given legislation.

All questions following the TPB were measured on fully anchored 5-point unipolar Likert-type scales with a range from 1 to 5. Thus, maximum value for the product of belief based and direct measure is 25. Scale anchors gave a verbal description of the possible response options. The belief based question about the effect of planting rice on soil loss, for instance, was 'Does planting rice in Haean lead to a reduction of soil loss?'. The corresponding response options were described as: 1) very unlikely, 2) rather unlikely, 3) not sure, 4) rather likely, and 5) very likely. The direct measure for the same topic was formulated as 'How important is the effect of planting rice in Haean on the reduction of soil loss for you personally?'. Wording for the scale anchors were: 1) very unimportant, 2) unimportant, 3) irrelevant, 4) rather important, and 5) very important. Due to the non-parametric, ordinal nature of the interview data, Wilcoxon rank-sum tests were used for statistical analysis of group differences. Furthermore, latent class regression modelling was applied to reveal underlying, unobserved latent variables that explain patterns among observed manifest data. Latent class models probabilistically group observations into latent classes, in order to subsequently calculate expectations about the response of that observation on each manifest variable.

Programming of the Bayesian belief network will be done with the help of Hugin, a decision support tool using a graphical interface to display probabilistic relationships between variables. Finally, the spatially-explicit illustration will be implemented with InVEST; an ArcGIS toolbox to spatially map and value changes in the provision of ES under varying scenarios of land use change.

4. Results

Although every interviewee was asked the behavioural questions about all crop types, most were only willing to answer with respect to the specific crops they currently cultivate. Thus, behavioural data exists for 125 rice farmers, 143 dryland crop farmers, and 87 perennial crop farmers. As a result, medians of stated intentions to plant the respective crop type in the following year are very high, with the maximum of 5 for rice and annuals, and 4 for perennial crops. Significant differences exist between farmers with respect to their attitudes towards ecosystem services. Biomass production is ranked lowest for rice cultivation, followed closely by annuals dryland crops with medians of 10 and 12, respectively. Perennials, in contrast, are deemed most productive with a behavioural score median of 16. Annuals are evaluated as least capable of reducing soil loss (median = 5), followed by rice with a median of 12 and perennials rank highest at 16. The pattern of attitudes towards improvement of water quality is similar as far as the ranking is concerned; the median of 6 for annuals is significantly lower than the ones of rice and perennials (10 and 12, respectively). None of the crops is ranked high for conservation of plants and animals with medians of 4 for rice and annuals and a slightly higher value of 5 for perennials (Figure 2 A).

Farmers feel tremendously restricted by their financial capacities when it comes to cultivating perennial and annual crops, which is reflected by medians of 25 and 20. Although still high with a median of 16, money is perceived as a smaller obstacle for rice cultivation. With respect to required skills and knowledge, perennials are seen as most complicated with the highest median of 16 in comparison to the low values of 4 for annuals and 2 for rice. Demands about plot characteristics are deemed equal for rice and annual crops with medians of 9, which are lower than for perennials with a value of 12. No significant differences exist

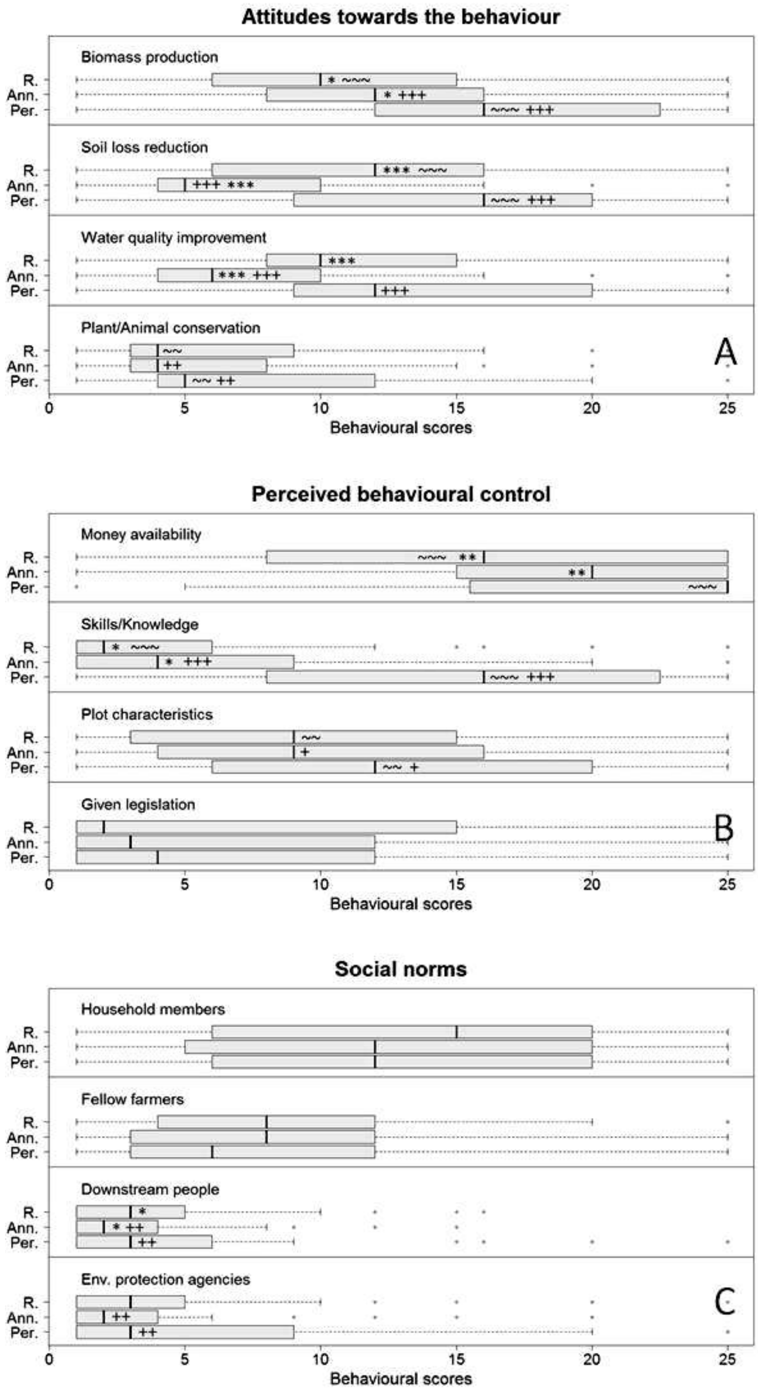

Figure 2. Medians of behavioral scores for AttB (A), PBC (B) and SN (C). Number of symbols indicates significance level (1, 2 and 3 symbols for p<5%, <1% and <0.1%, respectively)

** Statistical difference between rice and annual crops*

+ Statistical difference between annual and perennial crops

~ Statistical difference between rice and perennial crops

in terms of perceived legislative restrictions, which rank low between medians of 2 and 4 for all crop types (Figure 2 B).Household members play the most important role of all investigated social referents with medians ranging from 12 to 15, followed by fellow farmers with values between 6 and 8. None of these variations differ significantly. People living further down the stream outside Haean as well as environmental protection agencies, in contrast, matter very little to the farmers. Both groups were evaluated by the same scores: a median of 3 by rice and perennial, and 4 by annual crop farmers. While this divergence was significant with respect to downstream people, this only holds for annual crop farmers in comparison to perennial crop farmers in terms of environmental protection agencies (Figure 2 C).

Juxtaposing organic and conventional farmers, as well as owners and leasers very much reflects the patterns of comparisons between crop types. Biomass production ranks highest in the category of attitudes, money availability is the most restricting obstacle of the control factors, and household members are the most influential social referents. Significant differences between organic and conventional farmers are only found with respect to availability of money, where organic farmers feel more restricted than conventional farmers. More significant results are present between the groups of owners and leasers. Biomass production is less important to owners, which to a smaller extent is also true for the conservation of plants and animals. This relation holds for the other significant divergences, too. Owners feel less restricted by money availability as well as by skills and knowledge. Also, they care slightly less about downstream people and environmental protection agencies (Table1).

Table 1. Medians of behavioral scores divided by organic vs. conventional farmers and owners vs. leasers Number of asterixes indicates significance level (1, 2 and 3 symbols for p<5%, <1% and <0.1%, respectively).

Attitudes tow. behaviour				
Biomass production	12	12	10**	15**
Soil loss reduction	7	8	8	9
Water qual. improvement	9	9	9	10
Plant and animal conserv.	4	4	4**	5.5**
Perceived beh. control				
Money availability	25*	20*	20*	25*
Skills and knowledge	4	4	3**	6**
Plot characteristics	6	9	9	8.5
Given legislation	4	2	2	4
Social norms				
Household members	12	13.5	12	15
Fellow farmers	6	8	6	9.5
Downstream people	3	3	2***	4***
Env. prot. agencies	3	3	2***	4***

Latent class modelling of attitudes towards the ecosystem services of soil erosion, water quality and plant and animal conservation reveals a clear distinction when divided by 2 classes. Class 1 summarizes observations having a high probability of loading low on the behavioural scores, thus indicating a negative attitude towards the considered ecosystem services. Class 2 groups together those likely to hold a positive attitude. Probabilities of respective class membership are 0.67 for class 1 and 0.33 for the second class (Figure 3). In Figure 3, behavioural scores were collapsed to a range of 1 to 5 in order to ease visual interpretation.

In addition to merely differentiating groups, latent class regression modelling reveals factors that explain divergences. Using income level as regression factor yields a possible explanation for the differences between farmers with negative and those with a positive attitude to the ecosystem services displayed in Figure 3. Plotting the probabilities of class memberships over the investigated income levels shows that with increasing income the probability of belonging to class 1 decreases, while it increases for class 2 (Figure 4). This effect even makes membership to class 2 more likely after a point between income levels 5 and 6 where probabilities equal approximately 50%.

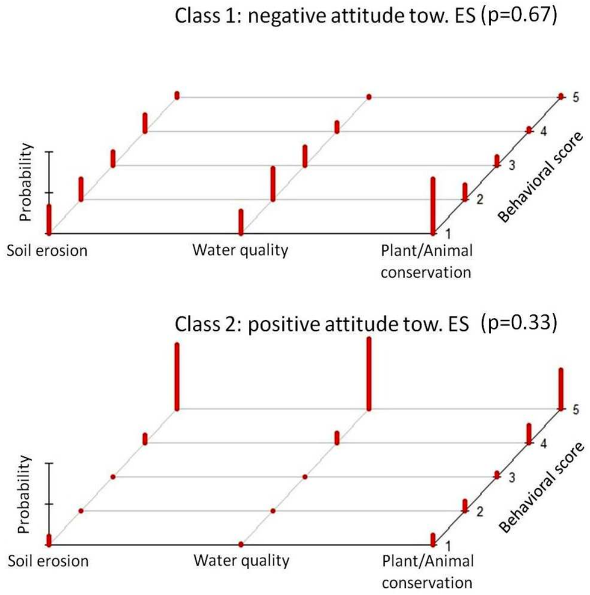

Figure 4. Latent class regression model with income level as predictor of attitudes towards ecosystem services

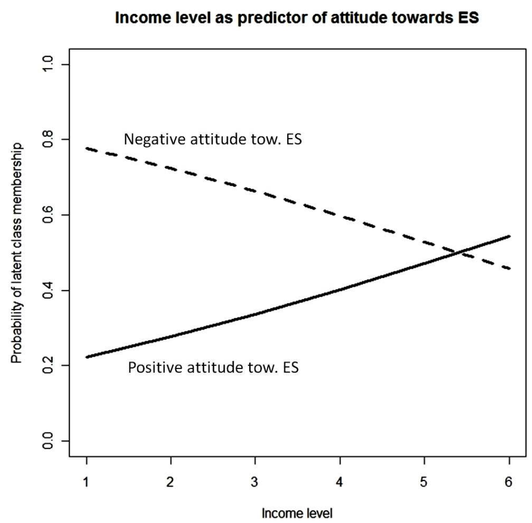

Figure 3. Probability distributions for the latent classes of 1) negative and 2) positive attitudes towards ES

5. Discussion

Missing data for farmers with low intentions due to the unwillingness of respondents to answer behavioral questions about crops they do not cultivate does not allow the usual way of analyzing Ajzen’s TPB, i.e. conducting a regression analysis of attitudes, control factors and social norms over intentions. This shortcoming forbids proving the TPB’s supposition that intentions act as proximate antecedent of a behavior’s performance. However, Ajzen’s theory has been confirmed in a vast body of literature, which is why we deem it reasonable to assume its applicability for our study. The significant differences between farmers of the three different crop types confirm our first hypothesis. Perennial crop farmers have the highest attitudes towards all ecosystem services considered. This is especially striking in comparison to annual crops, which except for biomass production are ranked lowest on all other services. Indication why perennial crops are not yet cultivated more extensively comes from the results for farmers’ perceived behavioral control. Perennials score highest with respect to restrictions by money availability as well as plot characteristics, and are by far perceived as most demanding in terms of required skills and knowledge.

No significant differences turned out between the attitudes of organic and conventional farmers, which disproves our second hypothesis. Organic farmers do not seem to choose this cultivation method out of an environmental concern. What rather seems to influence farmers' attitude is their income level, as shown in the latent class regression analysis. Only the wealthiest farmers seem to be able to afford considering environmental issues. This idea is further supported by the higher financial restrictions that organic farmers indicated (Table 1). Also hypothesis 3 was not approved as expected. In contrast - it was not the farmers that own their agricultural land who care more about ecosystem services, but the ones that lease it. At least this holds for the attitudes towards biomass production, which might be explained by the additional costs leasers have to pay as land rent. Underpinning this argument is again the obstacle of money availability, which leasing farmers perceived as more restrictive (Table 1).

In the end, it seems to be mainly finances and knowledge that decide about farmers' attitudes towards ecosystem services and their choice of crop type. As soon as there is a sufficient monetary foundation, farmers can start considering environmental effects of their agricultural production, rather than first and foremost caring about their monetary returns. Moreover, even if financial means allow choosing more environmentally friendly cultivations schemes, there is still the barrier of necessary expertise that has to be overcome. Thus, intentions to foster the cultivation of perennial crops would require both financial support as well as capacity building measures. Results so far are encouraging with respect to the planned steps of our project, since differences in crop choice will allow a meaningful decision-modeling under varying scenarios.

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