Economic Valuation, Land Use Change and Ecosystem Services in the Nicoya Peninsula of Costa Rica

A Dissertation

Presented in Partial Fulfillment of the requirements for the

Degree of Doctorate in Philosophy

with a

Major in Environmental Sciences

in the

College of Graduate Studies

University of Idaho

and in the

Escuela Posgrado

Centro Agronómico Tropical de Investigación y Enseñanza

by

Héctor S. Tavárez Vargas

Major Professor: Levan Elbakidze, Ph.D.

Co-Major Professor: Adriana Chacón, Ph.D.

Committee Members: Nilsa A. Bosque Pérez, Ph.D.; Jodi Johnson-Maynard, Ph.D.

Department Administrator: Robert L. Mahler, Ph.D.

May 2016

Authorization to Submit Dissertation

This dissertation of Héctor S. Tavárez Vargas, submitted for the degree of Doctorate of Philosophy with a Major in Environmental Sciences and titled "**Economic Valuation, Land Use Change and Ecosystem Services in the Nicoya Peninsula of Costa Rica**," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor: ________________________________ Date: __________
Levan Elbakidze, Ph.D.

Co-Major Professor: ________________________________ Date: __________
Adriana Chacón, Ph.D.

Committee Members: ________________________________ Date: __________
Nilsa A. Bosque Pérez, Ph.D.

________________________________ Date: __________
Jodi Johnson-Maynard, Ph.D.

Department Administrator: ________________________________ Date: __________
Robert L. Mahler, Ph.D.

Abstract

Anthropogenic land use change affects the provision of ecosystem services (ES), including water provisioning and habitat for pollinators. Understanding the value of benefits provided by forests is crucial for the design of current and future water provisioning and ES conservation policies. However, special attention should be devoted to understanding the validity of the methods widely used for the estimation of benefit-value. The first chapter of this dissertation provides an overview of the social-ecological system in the Nicoya Peninsula of Costa Rica and the rationale for the research I conducted. The second chapter of this dissertation examines the value of water for household uses, obtained from two different water-provisioning projects: well construction and reforestation. Results from contingent valuation and choice experiments methods show that residents are willing to pay a considerable amount for household water and that water generated from reforestation has a higher value than water generated from well construction. The third chapter of this dissertation examines the effects of incorporating risk as a separate attribute in choice experiments, and the effects of positive or negative framing on estimates of willingness to pay. We found that residents are willing to pay more for reforestation and additional water when information about risk is provided as a separate attribute and when risk is presented positively (e.g., probability of success vs. probability of failure) in choice experiments. The last chapter presents an interdisciplinary mixed-methods approach for using local ecological knowledge to generate practical information for the valuation of ES. We used beekeepers as a case study, as they have been working in the Nicoya Peninsula region for many years and their livelihoods are impacted by land use change. Results from a questionnaire showed that participants prefer forests for beekeeping, and rank native trees as their most important floral resources. In interviews, beekeepers reported a loss of floral resources over time, which is often due to land use changes that have been incentivized by policies at the national level. This research provides insights into resource changes from the species to landscape scale and recommendations for improving ES management and conservation policies.

Acknowledgements

I would like to thank first and foremost my major professor, Levan Elbakidze, for guidance and many wonderful discussions and experiences throughout the last five years. His advice on this work was fundamental to my success and inspires me to continue advising other students in the future. I would also like to thank my committee members (Nilsa A. Bosque Pérez, Jodi Johnson-Maynard, and Adriana Chacón Cascante) for their valuable feedback. Special recognition goes to Nilsa A. Bosque Pérez for being proactive in organizing both professional meetings and international trips related to this project. Her devotion to this project is outstanding and the evidence of her sacrifices is reflected in the enormous body of literature produced from the scientific research from different cohorts of students. This work could not have beeen possible without the financial support provided by NSF-IGERT and USAID-Borlaug. I am very grateful for the opportunity that both agencies offered me. Finally, I want to thank the people of the Nicoya Peninsula of Costa Rica who hosted my family and me for two years and provided invaluable information and support that made my research possible.

Dedication

To Lizbeth and Naylea for their support and sacrifice during the last years

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

Anthropogenic land use change can produce positive outcomes; however, such change can also produce negative outcomes for ecosystem services (ES)[1]. Anthropogenic land use change is responsible for disturbances in social-ecological systems in Mesoamerica, causing poverty, migrations, and food insecurity throughout the region. Social-ecological systems are regularly quite complex (Anderies et al. 2004; Ostrom 2009) and difficult to investigate from a single perspective, requiring the integration of multiple disciplines to better assist decision makers (Graybill et al. 2006; Morse et al. 2009). Thus, researchers worldwide have shown a growing interest in conducting interdisciplinary studies to address social-ecological systems-related concerns. An example of a complex social-ecological system (SES) is the Nicoya Peninsula of Costa Rica, which has experienced dramatic land use change during the last decades, altering the ES provided by forests and, in turn, the livelihoods of local residents. This study integrated the perspectives from multiple disciplines such as economics, ecology, landscape ecology, and entomology to develop research questions, objectives, and methods that better address the needs of the region.

Forests provide and support many services from which humans obtain benefits (MEA, 2005). These benefits, or ES, can be divided into four main categories (Daily et al. 1997; MEA 2005): provisioning services (e.g., production of food), supporting services (e.g., carbon storage), regulating services (e.g., pollination services), and

[1] ES are the benefits humans obtain from nature (MEA, 2005).

cultural services (e.g., opportunities for recreation). Thus, humans derive direct and indirect benefits from ES. For instance, people often enjoy the aesthetic beauty of the landscape formed by patches of forests, or they might use forested areas for recreational purposes. These are two examples of direct benefits humans derive from forests. Additionally, forests can confer indirect benefits. For example, when forest cover provides floral resources and habitat for pollinators, farmers receive indirect benefits, as pollinators can increase agricultural production (Ricketts 2004). Forests also provide indirect benefits to communities via water provisioning, as forests play a critical role in hydrological processes (Sandström 1998; Ilstedt et al. 2007; Krishnaswamy et al. 2013). Forests are thus, an integral part of social-ecological systems throughout the world.

The SES in the Nicoya Peninsula of Costa Rica experiences disturbances every year due to environmental factors and anthropogenic land use change. The region is affected annually by a dry season causing extreme droughts in local communities, which can be worsened by El Niño-Southern Oscillation (Vega-Garcia 2005). These droughts affect local residents in different ways. For example, they increase the vulnerability to food insecurity by reducing the capabilities of self-sustainability through home gardening, which, in these communities, is critical for the production of food and medicines at household levels. The drought also affects farmers such as beekeepers, as bees rely on floral resources and water accessibility for honey production.

These communities are also impacted by conservation policies at the national level and actions by community leaders at the local level. One well known policy-type used to encourage land use change and ES protection is payment for ecosystem services (PES). Costa Rica has one of the most widely studied PES policies worldwide (Pagiola 2008; Pattanayak et al. 2010). The PES program pays landowners who help to protect ES through land management, including reforestation and forest conservation (FONAFIFO 2013). However, a large amount of area is reforested with monoculture tree plantations, mainly teak (*Tectona grandis*), which is regarded as one of the drivers of water scarcity and reduction of floral resources by locals (Community leaders, personal communication). The effects of land management on ES and residents' livelihoods provide feedback to stakeholders that can be used in the future to design policies. A conceptual model of the SES in the Nicoya Peninsula of Costa Rica is shown in Figure 1.1.

In a changing climate with anthropogenic land use change it is critical to understand how variations in the provision of ES affect social welfare in different sectors of society. Understanding the value different sectors of society assign to different land uses and their services can provide useful information about the impact of current and future water provisioning and ES policies, such as PES. Additionally, information about the value of different ES can be used to evaluate the feasibility of projects as alternatives for ES provision. However, debates about validity of non-market valuation techniques are ongoing in the economic literature (Hausman 2012; Kling et al. 2012). Biased estimates of value may drive researchers to arrive at inaccurate conclusions. As a result, policy designs may be inefficient in allocating limited resources in terms of failing to achieve social welfare maximization. Consequently, researchers have devoted a substantial amount of time to studying the accuracy of current valuation methods and how results may be affected when survey designs lack relevant information (Brown & Gregory 1999; Brown 2005; Roberts et al. 2008; Howard et al. 2009; Wielgus et al. 2009; Glenk & Colombo 2011; Harrison et al. 2014).

Economic valuation' studies regularly assume that project outcomes are certain. However, this assumption may not be realistic in environmental settings as the final outcome of projects often depends on stochastic events such as precipitation, temperature, etc. For this reason, researchers have shown an increasing interest in including risk of project outcomes in choice experiments (CE) methods (Roberts et al. 2008; Wielgus et al. 2009; Glenk & Colombo 2011). Although significant progress has been made in this regard in the economic valuation literature, significant gaps remain. For example, respondents are likely to make choices depending on how information is presented, leading to potential framing effects (Howard et al. 2009; Harrison et al. 2014). In the CE literature, framing effects have not been widely examined in instances when risk is considered as a separate factor in environmental settings.

This study focused primarily on two ES that may have been affected by land use change: water provisioning and habitat for supporting biodiversity, including pollinators. The general objectives of this study were to: (1) understand how different stakeholder groups value the ES provided by forests, and (2) make a methodological contribution to the valuation literature by assessing the accuracy of the CE method and reliability of values using risk as a separate attribute in an environmental setting. The value economic agents assign to ES were assessed using multiple methods.

References

Anderies, J.M, Janssen, M.A., & Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. Ecology and Society, 9(1), 18.

Brown, T.C. (2005). Loss aversion without the endowment effect, and other explanations for the WTA-WTP disparity. Journal of Economic Behavior and Organization, 57, 367-379.

Brown, T.C., & Gregory, R. (1999). Why the WTA-WTP disparity matters? Ecological Economics, 28, 323-335.

Daily, G., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J. & Shallenberger, R. (2009). Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment, 7, 21-28.

Fondo Nacional de Financiamiento Forestal (FONAFIFO). (2013). Poder ejecutivo: decretos y acuerdos. FONAFIFO, San José, Costa Rica.

Glenk, K., & Colombo, S. (2011). How sure can you be? A framework for considering delivery uncertainty in benefit assessments based on stated preference methods. Journal of Agricultural Economics, 62, 25-46.

Graybill, J.K., Dooling, S., Shandas, V., Withery, J., Greve, A., & Simon, G.L. (2006). A rough guide to interdisciplinarity: graduate student perspectives. BioScience, 56(9), 757-763.

Ilstedt, U., Malmer, A., Verbeeten, E., & Murdiyarso, D. (2007). The effects of afforestation on water infiltration in the tropics: a systematic review and meta-analysis. Forest Ecology and Management, 251, 45-51.

Harrison, M., Rigby, D., Vass, C., Flynn, T., Louviere, J., & Payne, K. (2014). Risk as an attribute in discrete choice experiments: a systematic review of the literature. Patient, 7, 151-170.

Hausman J. (2012). Contingent valuation: from dubious to hopeless. Journal of Economic Perspectives, 26(4), 43-56.

Howard, K., & Salked, G. (2009). Does attribute framing in discrete choice experiments influence willingness to pay? Results from a discrete choice experiment in screening for colorectal cancer. Value in Health, 12(2), 354-363.

Kling, C.L., Phaneuf, D.J., & Zhao, J. (2012). From Exxon to BP: has some number become better than no number? Journal of Economic Perspectives, 26(4), 3–26.

Krishnaswamy, J., Bonell, M., Venkatesh, B., Purandara, B.K., Rakesh, K.N., Lele, S., Kiran, M.C., Reddy, V., & Badiger, S. (2013). The groundwater recharge response and hydrologic services of tropical humid forest ecosystems to use and reforestation: support for the ‘‘infiltration-evapotranspiration trade-off hypothesis.” Journal of Hydrology, 498,191-209.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and human well-being: synthesis. Island press, Washington, DC.

Morse, W.C., Nielsen-Pincus, M., Force, J.E., & Wulfhorst, J.D. (2007). Bridges and barriers to developing and conducting interdisciplinary graduate-student team research. Ecology and Society, 12(2), 8.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. Science, 325, 419-422.

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

Pattanayak, S.K., Wunder, S., & Ferraro, P. (2010). Show me the money: do payments supply environmental services in developing countries? Review of Environmental Economics and Policy,4, 254-274.

Ricketts, T.H. (2004). Tropical forest fragments enhance pollinator activityin nearby coffee crops. Conservation Biology, 18(5), 1262-1271.

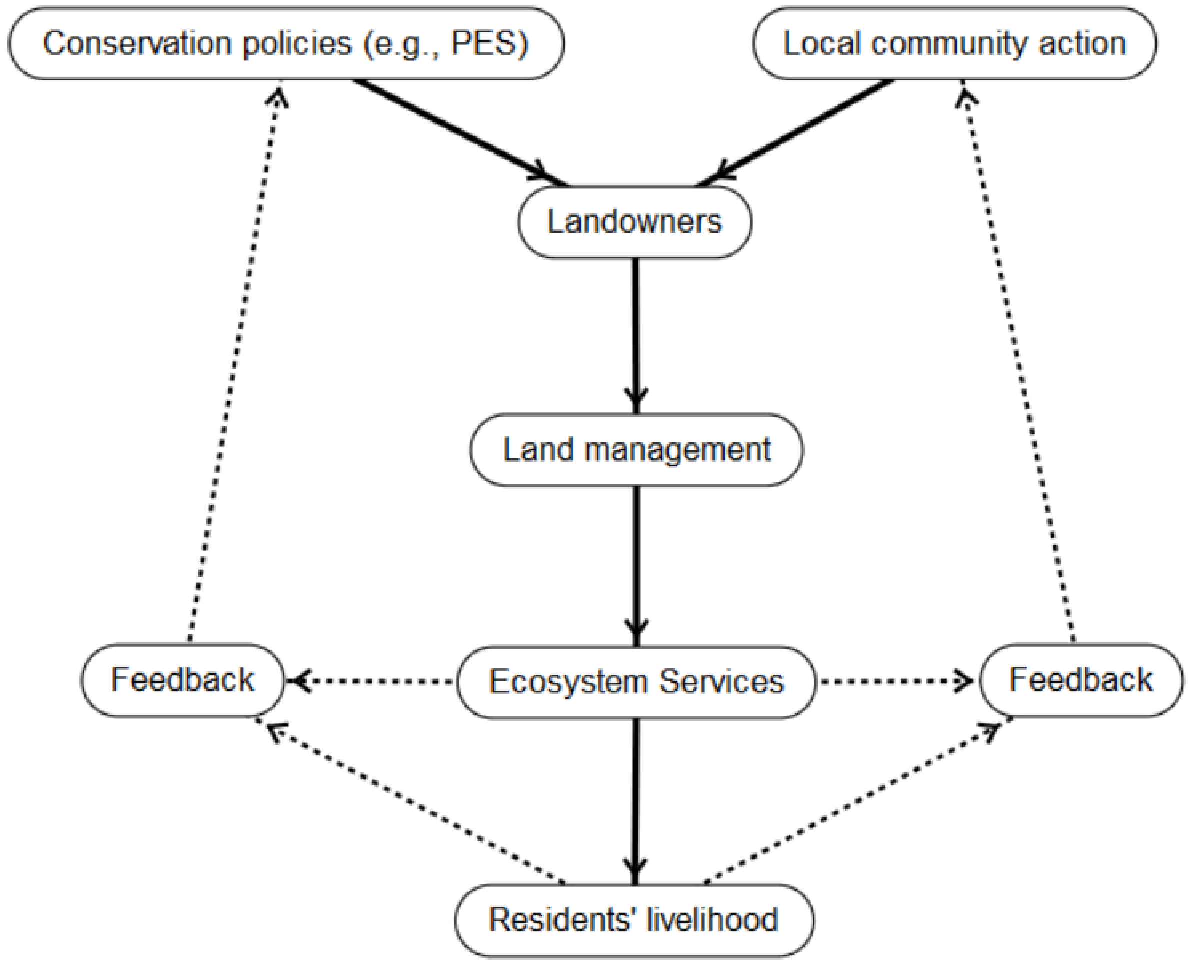
Roberts, D.C., Boyer, T.A., & Lusk, J.L. (2008). Preference under environmental quality under uncertainty. Ecological Economics, 66, 584-593.

Sandström, K. (1998). Can forests "provide" water: widespread myth or scientific reality? Ambio, 27(2), 132-138.

Vega-García, H. (2005). Migración ambiental inducida por variabilidad climática: el caso del Corredor Centroamericano del la sequía. CEMEDE, San José, Costa Rica.

Wielgus, J., Gerber, L.R., Sala, E., & Bennett, J. (2009). Including risk in stated-preference economic valuation: experiments of choices for marine recreation. Journal of Environmental Management, 90, 3401-3409.

Figure 1.1: A conceptual model of the Nicoya Peninsula social-ecological system. Conservation policies, local community actions, and landowners determine changes in land management that ultimately affect the provision of ecosystem services. Local residents receive direct and indirect benefits from ecosystem services. Thus, changes in the provision of ecosystem services affect residents' livelihoods, or social welfare. The provision of ecosystem services and changes in residents' livelihoods provide feedback to stakeholders for the design of future policies that better suit their goals.



Chapter 2. Alleviating Water Scarcity in Seasonally-Dry Rural Costa Rica: The Value of Ecosystem Services Co-benefits from Reforestation

Abstract

Droughts are responsible for significant socio-economic impacts in Mesoamerica, causing poverty and migrations throughout the region. Investments in infrastructure and land management have the potential to mitigate water shortage and provide other benefits in the form of ecosystem services. We used single-bounded dichotomous choice and choice experiment methods to assess residents' preferences and willingness to pay for two alternative water-provisioning policies, well construction and reforestation, in the seasonally-dry Nicoya Peninsula of Costa Rica. Based on a single-bounded dichotomous choice method, respondents were on average willing to pay $5.97 per household per month for 168 additional water-hours obtained annually from well construction. Based on the choice experiment method, respondents were willing to pay on average $14.93 per household per month for 168 additional water-hours obtained annually from reforestation. Residents' willingness to pay for improvements in water service provisioning depended on age, home gardening practices, and household income.

Introduction

Rural communities around the world suffer from periodic or permanent water shortages, resulting in decreased capabilities for self-sustainability through agriculture and associated activities (Falkenmark 1997). Access to 20 liters of clean water per person per day has been recognized as a minimum requirement to fulfill basic human needs (UNDP 2006). However, many communities around the world still have limited access to water. This is particularly acute in rural communities in developing countries where water is often managed and distributed by non-governmental organizations that lack resources to provide an adequate service. To address this concern, researchers have dedicated substantial efforts to understanding the factors that influence water provisioning, including household preferences and willingness to pay (WTP) for water supply (Raje et al. 2002; Casey et al. 2006; Hensher et al. 2005, Hensher et al. 2006; Genius et al. 2008; MacDonald et al. 2010) and water quality (Barton 2002; Akram & Olmstead 2011). The value of improved water systems for domestic consumption varies across countries and depends on various aspects of water provisioning projects and individual profiles. In this study, we evaluated local residents' WTP for water obtained from well construction and from reforestation[2].

In some regions, reforestation has the potential to increase water supply and mitigate water scarcity due to its effect on hydrological processes (Sandström 1998;

[2] Reforestation by definition is planting trees in lands that were previously covered by forest. However, we use the term for increases in forest cover in general.

Brujinzeel 2004; Ilstedt et al. 2007; Krishnaswamy et al. 2013). Reforestation not only affects water yield, stream flow seasonality, and groundwater recharge, but also provides scenic beauty, carbon sequestration, and other ecosystem services (ES) (MEA 2005). Investments in infrastructure such as wells can also potentially mitigate water scarcity. Well construction can provide a more certain water supply, at least in the short term. In addition, well construction can increase water availability more immediately, whereas benefits provided by reforestation suffer from spatio-temporal lags (Fremier et al. 2013). On the other hand, well construction does not provide the ES that reforestation provides, and wells may dry out permanently after some years of use, or periodically due to extended droughts or overexploitation (Nyholm et al. 2002; Konikow & Kendy 2004).

Many communities worldwide experience severe water shortages that may be exacerbated by land use change, particularly in dry tropical regions (Vega-Garcia 2005). Payment for Ecosystem Services (PES) is one of the policies used to encourage land uses that secure ES provision. Costa Rica has been a pioneer in PES schemes (Pagiola 2008; Pattanayak, et al. 2010). In Costa Rica, PES cover a bundle of ES including water resource protection, biodiversity conservation, carbon sequestration, and scenic beauty (FONAFIFO 2014). Different land cover types, including reforestation and forest protection, can qualify for PES. Forest cover has increased in Costa Rica in recent decades, due in part to the PES program and other conservation policies (Calvo-Alvarado et al. 2009).

More than 60% of the population in rural areas of Costa Rica receives water from non-governmental, Community-Based Drinking Water Organizations (CBDWO). CBDWOs are in charge of managing and distributing water to users. On a national level, 22% of the Costa Rican population receives water from CBDWOs (Madrigal et al. 2011). Non-CBDWO water users typically receive water from the government and do not experience notable water shortages. CBDWOs often lack water during dry seasons, which can be worsened by droughts related to El Niño-Southern Oscillation (Vega-García 2005).

Understanding the value that residents place on alleviating water shortages and on other ES is important for the design of PES policy. However, different land cover types provide different ES to varying degrees (Daly et al. 2009). This makes it difficult to estimate the real value of each ES as perceived by end-users because it compounds the selection of options such as land management policy or improvements in infrastructure. For example, residents may place more value on resolving water shortages as soon as possible through infrastructure improvements rather that waiting for the slower long-term effects of reforestation. However, residents may place more value on the positive effects that reforestation has on mitigating water shortages in the long-term if they consider other ES co-benefits provided by reforestation, such as biodiversity conservation or scenic beauty. Understanding the value that residents assign to alleviating water shortage and to ES is necessary for cost-benefit analyses by policymakers and for evaluating projects aimed at improving access to water (Daly et al. 2009; Pattanayak et al. 2010).

The benefits of ES provided by forests to end-users are often uncertain because environmental processes are very complex in space and time. For instance, ground water availability depends on stochastic events such as precipitation, temperature, evapo-transpiration, and infiltration rates (Sandström 1998; Brujinzeel 2004; Ilstedt et al. 2007; Krishnaswamy et al. 2013). Ground water availability also depends on water management at a watershed level. As a consequence, it is difficult to make accurate predictions about project outcomes. This may be why previous studies estimating households' WTP to avoid interruptions in water service (Hensher et al. 2005; Hensher et al. 2006; MacDonald et al. 2010) have not included land use change as an option. However, studies that integrate land use change and estimate corresponding economic values are increasingly needed to inform ES-related policy analysis (Jackson et al. 2005; Pattanakak et al. 2010).

To address these knowledge gaps, the objectives of this study were to: (1) estimate the value of additional water from well construction for household uses, (2) estimate the value of additional water from reforestation for household uses, (3) identify the factors that affect the value of additional water for household uses, and (4) assess if other ES provided by reforestation are valued by CBDWO water recipients in the Nicoya Peninsula of Costa Rica. A single-bounded dichotomous choice contingent valuation method (CVM) was used to estimate the value of additional water generated from well construction and a choice experiment (CE) method was used to estimate the value of additional water and ES generated from reforestation.

Methods

Study area

The study was conducted in the Nandayure, Nicoya, and Hojancha counties of the Nicoya Peninsula of Costa Rica (Figure 2.1). These counties have similar biophysical characteristics with seasonally dry tropical weather. Typically, there is zero to minimal precipitation from December to May, and most communities experience water scarcity between March and May. Because this region is vulnerable to climate change (McCarthy et al. 2001), water shortage may intensify in the future. Population growth in this region is expected to increase over the next years (INEC 2015), which can increase demand for water.

The region has experienced dramatic land use change during the last five decades, with significant implications for the provision of ES. Substantial deforestation occurred during the 1950's and 1960’s to expand both livestock and coffee production (Vallejo et al. 2006). Between 1970 and 2005, government policies and local stakeholder action increased forest cover in some counties between 14% and 52% (Serrano 2005). Agricultural lands have decreased, whereas monoculture tree plantations, mainly of teak (*Tectona grandis*), have increased over the same time period (Serrano 2005). Currently the main land uses in the region are pasture, tree plantations, and primary and secondary forest.

In the Nicoya Peninsula, CBDWOs distribute water to approximately 50% of the population (personal communication, Regional Coordinator of Forestry Development). This study focused on households serviced by the Administrative Associations for Aqueducts and Sewers (ASADAS, the Spanish acronym), which are types of CBDWOs, for two main reasons. First, contact information was available for many of the ASADAS administrators, which made the study logistically feasible. Second, and perhaps more importantly, ASADAS represent the vast majority of CBDWOs in the region.

Survey and study design

Thirty-four semi-structured interviews were conducted via telephone with ASADAS' presidents from December 2013 to January 2014. Information gathered from these interviews was used to understand water-related issues and the relationships between water scarcity and forest cover across ASADAS in the Nicoya Peninsula. We used the results from these interviews to develop the CVM and CE instruments. We asked whether the ASADAS suffered from water scarcity that was not attributable to damaged existing infrastructure. We also estimated the percentage of forest cover in watersheds where ASADAS were located using Geographic Information Systems (GIS) to evaluate the relationship between forest cover and water scarcity. We estimated the difference in the mean percentage of forest cover found in watersheds where ASADAS did not experience water scarcity and watersheds where ASADAS did experience water scarcity. This difference in mean percentages was multiplied by the average number of hectares per watershed. The resulting figure was used as a rough estimate for the amount of land that would be needed to be converted to forest in watersheds of ASADAS suffering from water scarcity in order to alleviate water shortages. All watersheds had sufficient available land that could be reforested, making this a feasible strategy. Following this survey and data analysis, we assumed that forest cover can reduce peak runoff during the rainy season and release stored groundwater during the dry season, resulting in more water availability during droughts (Sandström 1998; Bruijinzeel 2004; Krishnaswamy et al. 2013).

Information gathered from interviews with ASADAS' presidents was also useful for deciding on the payment vehicle in both CVM and CE. It has been documented that in the case of water supply improvements, the most appropriate payment vehicle is through increases in the water bill (Genius et al. 2008). However, most of the ASADAS' presidents indicated that current water bills are considered very high by many water recipients, and water recipients regularly express disapproval of attempts to increase the water fees. Thus, there is a chance that participants may protest if this payment vehicle is used, which may in turn affect WTP estimates (Georgiou et al. 1998). Another payment vehicle that has been widely cited in the valuation literature is that of increasing annual taxes, but the vast majority of ASADAS' water recipients are not required to pay taxes due to low yearly income. Providing no information about the payment vehicle, or failing to select the appropriate one, may affect estimates (Bateman et al. 2002; Ivehammar 2009). However, it has been argued that in cases where the use of a proposed payment vehicle is considered not feasible, credible, or desirable, it may be beneficial to use a more vague definition of the payment vehicle in order to increase the accuracy of responses and reduce the number of protest responses (Bateman et al. 2002). For these reasons, the payment vehicle was not specified in the CVM or CE.

To collect data from residents, a questionnaire was developed that consisted of two main sections. One section included a single-bounded dichotomous choice CVM for WTP for water obtained from well construction, and a CE for WTP for water obtained from reforestation[3]. CVM and CE subsections were presented in random order to account for potential ordering bias. A maximum of 168 hours of increased water was used for both well construction and reforestation. This value was selected as all ASADAS examined in the region had at least 168 hours of water shortage per year. The second section included questions about socio-economic and demographic characteristics (SDC) of individuals and perceptions about benefits received from forest functions. This information was gathered to better understand respondents' preferences and choices. Respondents were allowed to make comments and provide feedback about the valuation exercise at the end of the questionnaire.

[3] Although CE design could have been used for estimation of WTP for water from well construction, the dichotomous choice method was chosen for the sake of survey simplicity to reduce the burden on the participants. Based on input received from ASADAS' presidents during interviews, it was decided that two levels of water availability in a single-bounded dichotomous CVM format would provide the appropriate balance of complexity and efficiency to measure WTP for additional water from well construction. On the other hand, a CE format was chosen for estimating WTP for additional water from reforestation to assure the appropriate balance between complexity, length of the survey, and variability in levels of multiple attributes (forest cover area, water availability, and cost) of interest.

The questionnaire was tested in two different focus group sessions held at the National System of Conservation Areas (SINAC, Spanish acronym) regional office located in the Hojancha county. Local residents with different levels of education attended the meeting. This allowed assessing the instrument for relevance, comprehension, and length. After gathering information provided by members of the focus groups, the questionnaire was modified accordingly.

Single-bounded dichotomous choice CVM

Single-bounded dichotomous CVM has been recommended over other elicitation formats (Arrow et al. 1993; Bateman et al. 2002) because it avoids outliers and minimizes non-responses (for a more detailed comparison of elicitation formats see Bateman et al. 2002). In this format, the contingent valuation question takes the form of a proposition that the respondents can either support or not support (i.e., binary response; Bateman et al. 2002). In this study, each respondent was asked whether he/she would support a well construction project that would increase water availability by 168 hours and would cost ₡500, ₡1,000, ₡2,000, ₡3,000, ₡4,000 or ₡5,000[4] per household per month for as long as the well was functional. All price scenarios were equally distributed within and across ASADAS. Only one contingent valuation question was included per questionnaire. We used a structure commonly employed in CVM (Loomis & White 1996; Zhongmin et al. 2003; Akram & Olmstead 2011): (1) the good or service under consideration is described, (2) the payment vehicle and

[4]The currency exchange rate was 1 USD = 537 colones at the time of the survey.

provision rule is established, and (3) the WTP question is presented. An example of the contingent valuation question is shown in Figure 2.2.

Choice experiment

CE was used to estimate WTP for increments in water availability and forest cover. Contrary to the single-bounded dichotomous choice method, in which participants are asked to choose between a status quo and a specific alternative, CE respondents are asked to choose between two or more alternatives that differ in one or more attributes. Thus, the CE method can be seen as an extension of the dichotomous choice CVM (Boxall et al. 1996; Adamowicz et al. 1998). In this study, an introductory paragraph was used to explain to participants the potential advantages and disadvantages of reforestation, such as time lags in water provisioning. Afterward, participants were given the CE exercise, which was carefully explained by the interviewer.

Attributes and levels

Table 2.1 shows the attributes and levels used in the CE tables. One of the attributes was *Forest cover in watershed surrounding the ASADA*. Participants were told that forest cover in the study context did not consider teak plantations. Forest cover levels were based on the interviews made to ASADAS' presidents from which we obtained a statistical relationship between forest cover at the watershed level and water scarcity. This attribute had two levels in addition to the status quo: (1) between 140-

180 more hectares than the current situation, and (2) between 300-340 more hectares than the current situation. Given that respondents might not have a comprehensive understanding of the current amount of forest cover in the region, which varies across ASADAS, respondents were given a map of the region showing the current amount of forest cover in the watershed surrounding their ASADA, and the area that was available for reforestation. Respondents were told that increases in forest cover would take place in the mapped watershed area. Figure 2.3 illustrates one of the maps used in the questionnaire. Because each ASADA is located in a different watershed, 8 different maps were developed.

The other attribute was *water availability*, defined as water provision from reforestation. Respondents made choices involving increases in water availability due to reforestation. Based on the information provided by the ASADAS' presidents, 24, 72, 144, and 168 hours of additional water for household consumption were used as attribute levels. The attribute levels were presented in terms of hours and corresponding number of additional days of water availability. Previous to the CE exercise, participants received a paragraph in which they were informed about current water scarcity levels in their communities as reported by ASADAS' presidents. See Figure 2.4 for an example of a choice set, including the paragraph each respondent received.

To elicit WTP estimates, a *cost* attribute was included. Cost attribute levels were selected based on input from ASADAS' presidents as well as information gathered in focus groups. The levels were set at ₡500, ₡1,000, ₡2,000, or ₡3,000 per household per month for as long as the additional forest remains, and for additional days with water due to reforestation.

Experimental design for the choice experiment

The CE design included two attributes, one with four levels and one with two levels. The complete factorial design including all possible combinations of attributes, and levels amounted to 32 possible alternatives ($4^2 * 2^1 = 32$). Each choice set had two alternatives plus a status quo option in which all attribute levels reflected the current situation. A complete randomized design would include 1,024 different choice sets. We used an orthogonal fractional factorial design to select 32 choice sets (Louviere et al. 2000). Each participant filled out 8 randomly selected choice sets from the 32 choice sets, ensuring that each choice set was evenly repeated in the entire CE. In addition, a "warm-up" choice set was used before the choice exercise to help respondents become familiar with the method and gather information that reflects respondents' preferences and WTP (Carlsson & Martinsson 2001; Ladenburg & Olsen 2008).

An additional choice set was included in all treatments to assess respondent comprehension of the valuation exercise. In this choice set, the levels of forest cover were identical in alternatives A and B. The other attributes were unquestionably dominant in alternative B. Thus, alternative B was dominant over alternative A.

Although alternative C had no environmental improvements, respondents did not incur extra costs if this option was selected. Thus, alternative B was not dominant over alternative C. Respondents had no incentives to select alternative A. If respondents selected alternative A, it was assumed he/she did not understand the choice task and would be removed from the statistical analysis.

Theoretical model

Both single-bounded dichotomous CVM and CE are based on random utility theory, which states that individual utility is unknown, but can be decomposed into deterministic and unobserved components (McFadden 1974). Respondents analyze and compare available alternatives, and the alternative providing the highest utility will be the preferred choice. The utility function of respondent n for each alternative can be denoted as:

$$U_{ni} = V_{ni} + \varepsilon_{ni} \tag{1}$$

where U_{ni} is the total utility derived from alternative i; V_{ni} is the indirect utility, which is specified as a function of the attributes; and ε_{ni} is the error term capturing the effect of unobserved attributes. It is assumed that participants will select alternative i over alternative j if (and only if) the utility of alternative i is higher than the utility of alternative$j$ ($U_i > U_j$). Then the probability of respondent n selecting alternative i is:

$P_n(i) = \left(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}\right) \, for \; all \; j \in C, i \neq j$(2)

The inclusion of the error term combined with the assumption that they are independently and identically distributed allows estimating the parameters of utility via maximum likelihood procedures in logit models. Assuming the utility function is linear and additively separable (Louviere et al. 2000; Jin et al. 2006), the indirect utility function can be expressed as follows:

$$V_{ni} = \alpha_i + \boldsymbol{\beta} X_i + \boldsymbol{\gamma} Z_n + \delta C_i \quad (3)$$

where α_i is a constant term capturing the preference for alternative i**;** $\boldsymbol{\beta}$**,** $\boldsymbol{\gamma}$ and δ are coefficients; X_i is a vector of all attributes, Z_n is a vector of SDC, and C_i is the cost of alternative i.

Welfare estimates

Maximum WTP in single-bounded dichotomous choice CVM can be estimated parametrically (Hanemann 1984) using results from a logistic regression. Assuming logistic distribution of utility difference, median WTP for additional water from well construction is estimated using the following equation (Loomis et al. 1997):

$$WTP = \frac{\alpha + \sum_{k=1}^{K} \gamma_k S_k}{\delta} \quad (4)$$

where α is the coefficient for the constant term, γ_k are coefficients, S_k is the sample mean of the associated k SDC, and δ is the cost coefficient. All coefficients are obtained from the logistic regression. Subscript i drops from the constant term because in single-bounded dichotomous choice CVM there is only one alternative in addition to the status quo.

In the CE literature, researchers are usually interested in measuring the compensating variation (CV) to estimate the value of an improvement where more than one attribute is changing (e.g., Alpízar et al. 2003; Jin et al. 2006; Wielgus et al. 2009). The CV is the amount of money that must be given to or taken from a person to make him/her as well off after the change as they were before the change (Champ et al. 2003). Thus, CV is used as the WTP for an improvement. Whether CV is similar to WTP depends on the income effect (Ward 2006). However, for most ES, the income effect is small, thus the WTP is close to CV (Ward 2006). When income effect is zero, WTP is identical to CV. Equation 5 was used to value a change in forest cover with an associated increase in water hours (Alpízar et al. 2003; Champ et al. 2003):

$$CV = -\frac{1}{\delta}(V^0 - V^1) \tag{5}$$

where V^0 and V^1 are the indirect utilities before (i.e., of current situation) and after the change under consideration, respectively. In equation 5, the utility associated with the current situation (status quo) is used as the reference and, consequently, set equal to zero (Lancsar & Savage 2004). The utility of a new situation (V^1) is calculated using the parameters from conditional and mixed logit models.

With a linear utility function, and only one attribute changing, equation 5 reduces to the negative ratio of the coefficient of the attribute of interest and the coefficient of the cost (Alpízar et al. 2003; Green 2012). The resulting figure is known as the marginal WTP for a change in attribute, holding all else equal.

Data and Estimation Models

We used a logit model for the estimation of coefficients in the CVM. In addition to the cost variable, our model in the CVM included three types of explanatory variables: the characteristics of the respondents, attitudes towards water scarcity, and the features in the household. The explanatory variables associated with characteristics of respondents included variables such as gender, age, education, and number of dependents. The explanatory variable associated with attitudes toward water scarcity included variables like respondent satisfaction with regard to water supply. The explanatory variables associated with the features of the household included variables such as household income and presence of home gardens. The description of all the variables used in the model specification is reported in Table 2.2. All these variables were included in the initial model specification in the CVM.

Two approaches were used in CE to circumvent singularity when specifying both water and forest attributes in terms of dummy variables. One approach used two dummy variables for the three levels of the forest cover attribute, and continuous variables for the water and cost attributes (data codification 1). The other approach used four dummy variables for the five levels of the water availability attribute, and continuous variables for the forest cover and cost attributes (data codification 2)[5]. For the first approach, three different models were run: a conditional logit model (CLM) with main effects only (model specification 1), a CLM including SDC of individuals as interaction terms with the water attribute (model specification 2), and a mixed logit (ML) model (model specification 3)[6]. For the second approach, a CLM was run with main effects only (model specification 4). Model specification 2 allowed evaluation of whether respondent SDC influenced attitude towards water improvements. Other model specifications where the SDC of individuals interacted with the status quo alternative or forest attribute were also tested, but the model presented here had a better goodness of fit.

The CLM is based on the IIA property, which states that the probability of choosing alternative i over alternative j is unaffected by the presence or absence of alternative k (Louviere et al. 2000). Although CLM has some disadvantages, such as

[5] An example of a study specifying choice attributes as continuous or categorical across different model specifications can be found in Glenk and Colombo (2011).
[6] To account for preference heterogeneity across respondents a ML model was used that addresses some of the limitations of the CLM model (Hoyos 2012). The log-likelihood for ML models cannot be solved analytically and has to be approximated using simulation methods (Train, 2009). The ML model was run with random parameters for all variables except for the cost using 500 Halton draws. It is a common practice and recommended to hold the cost coefficient fixed to facilitate the calculation of marginal WTP for the attributes in mixed logit models (Train 2009; Wielgus et al. 2009). Econometrics of ML models are discussed by Train (2009).

homogenous preferences and the IIA assumption (Alpízar et al. 2003; Hoyos 2012) relative to other econometric models, it provides an initial assessment of whether the selected attributes are important determinants of choice. The basic CLM assumes homogenous preferences across respondents, which may not hold in practice. Thus, model specification 3 (i.e., ML model) was used to account for preference heterogeneity and examine coefficient results when the IIA assumption is relaxed.

Results

Results from preliminary interviews

Interviews with ASADAS' presidents showed that approximately 30% of the ASADAS in the study region had water shortage problems not related to damaged infrastructure. In all of these cases, water shortages occurred yearly during the dry season, mostly between March and May. Some of the ASADAS experienced an equivalent of up to 90 days of water shortage[7] per year during the dry season. Hours of water interruption did not vary notably among water recipients within ASADAS. Only a few water recipients who live at higher elevations had longer interruptions of water service. The water catchment methods are springs or wells, indicating that all water distributed in these communities is groundwater. All ASADAS' presidents highlighted that water supplied by the organization can be used only for domestic consumption and that irrigation is only allowed for maintenance of home gardens.

[7] One day of water shortage is equivalent to twenty-four hours with no water. For instance, a total of twenty-four hours of water shortage within seventy-two hours (3 days) is equivalent to one day of water shortage.

Intensive irrigation for commercial agriculture is not allowed by ASADAS. The majority of ASADAS' water recipients were households, which varied from 30 to 300 per ASADA.

The watersheds of ASADAS that suffered water scarcity had 50% (N = 10; S.D. = 8.5) forest cover compared to 58% (N = 24; S.D. = 13.4) forest cover in watersheds of ASADAS with no water scarcity. To test for a difference in the amount of forest cover between communities with and without water scarcity, a Kruskal-Wallis test was performed on the set of forest cover percentages for the 34 communities. The Kruskal-Wallis Chi-squared statistic (corrected for ties) equaled 3.867 on 1 degree of freedom, with a P-value of 0.049. Thus, using an alpha value of 0.05, we rejected the null hypothesis of equal average percent forest cover between the two groups. The difference between these two percentages, 8%, represents hundreds of hectares of more forest cover in ASADAS watersheds that are not suffering from water scarcity. The average number of hectares per watershed (4,025 ha) multiplied by 8% equals 322 hectares.

Respondents' socio-demographic characteristics

Face-to-face survey interviews were conducted at every other household in eight different ASADAS across the study region. Interviews were conducted from December 2014 to March 2015. A total of 248 respondents completed the survey with CVM and CE sections. In this analysis, the CVM data from all 248 surveys and

CE data from 84 surveys were used[8]. Because each participant faced 8 choice sets as part of the CE, 672 choice sets were completed in total (2,016 observations). There were no differences in respondent gender, age, household income, education, presence of a home garden, perceived satisfaction of water supply and number of dependents between the group who completed CE and the group that did not (Table 2.2).

Based on follow-up questions, we identified several factors related to perception of water obtained from well construction versus reforestation and attitudes towards the valuation exercise that help us understand the choices made in CVM and CE. Seventy-two percent of respondents believed there was a high probability that a well construction project would fail to increase water availability. Conversely, only thirty-three percent of respondents believed that increasing forest cover would fail to increase water availability. Ninety-six percent of respondents believed that, in a changing climate, increasing forest cover is a better option for increasing water availability in the long run. Seventy-two and seventy-four percent of respondents believed that a project based on reforestation provides more water and a better water quality than well construction, respectively. As mentioned above, in order to avoid protest answers, we did not provide information about the payment vehicle. Disclosing no information about the payment vehicle was easily understood and accepted by respondents, as they did not mention this as an issue in either focus groups or follow-up questions in the questionnaire.

[8] The other respondents (164) filled out CEs which are used in a different study.

Most respondents believed that ES are either important or very important, and a small portion of respondents stated not knowing the importance of the ES in the area. The three most important ES to respondents were increase in groundwater yield, climate change mitigation, and biodiversity protection (Table 2.3). The least important were wood production and flood control. Flood and soil erosion control were the least known of all ES.

Results from single-bounded dichotomous choice contingent valuation

All explanatory variables in the logit model are significant (Table 2.4). The model fits the data well with a Pseudo R^2 of 0.43, which is reasonable for logit models (Hoyos 2010). The likelihood ratio test suggests that the model does well in terms of overall model fit ($Prob>\chi^2 = 0.000$). The COST coefficient is negative, which indicates that the probability that a resident is willing to pay for a well construction project to alleviate water scarcity decreases as the cost increases. The AGE coefficient is negative, which indicates that younger residents are more likely to pay for well construction. The GARDEN coefficient is positive, indicating that residents with home gardens (i.e., subsistence agriculture) are more likely to be willing to pay for well construction. The INCOME coefficient is positive, suggesting that respondents with a higher household income are more likely to be willing to pay for the project. Other variables that may affect choices were also analyzed, including those presented in Table 2.2. However, these variables were not significant.

Each of the selected ASADAS in our study suffers from different levels of water scarcity. Therefore, in addition to the characteristics of individuals, respondents WTP may be affected by current water availability. To account for this, dummy variables were generated for each ASADA to evaluate if respondent choices were influenced by current water scarcity. The logit model was re-estimated with these variables as regressors. None of the dummy variables for ASADAS were significant. To verify these findings, a different logit model was run using a continuous variable corresponding to current levels of water scarcity as reported by ASADAS' presidents and as presented to respondents in the surveys. This variable was not significant, suggesting that respondent choices were not driven by current water scarcity within the range currently observed in the ASADAS sampled.

Two approaches were used to test for bias due to the ordering effect of CVM and CE sections. First, a dummy variable was created that had the value of 1 if the questionnaire had the CE followed by the contingent valuation question, and a value of zero otherwise. The logit model for the contingent valuation question was re-estimated including the dummy variable as a regressor. If this variable was significant, the order of the valuation questions may have influenced WTP estimates in the contingent valuation section. However, this variable was not significant. Second, WTP for water obtained from well construction was estimated for both instances; then the questionnaire had the CE followed by contingent valuation question and vice-versa. Using the non-overlapping confidence intervals method (Park et al. 1991), no evidence was found of differences in WTP values using results from CVM. These analyses suggest that WTP values were not affected by the order of the valuation questions.

Estimation results from choice experiment

The CLM and ML models fit the data well (Table 2.5), as reported by the pseudo R^2 (Hoyos 2010). Results from the likelihood ratio test suggest that models do well in terms of overall model fit (Model 1, 2, and 4: Prob>χ^2 = 0.000; Model 3: Prob>χ^2 = 0.001). According to the Akaike Information Criterion (AIC), which penalizes for the number of estimated parameters and adjusted pseudo R^2, model 2 has a better fit. All the coefficients were statistically different from zero in all models, which may be a sign of robustness across models. The sign of the coefficients suggests that an increase in forest cover and water availability increase the probability of choosing an alternative. The cost coefficient is negative, which suggests that the higher the cost, the lower the probability of choosing an alternative. Results from model 2 also showed that younger respondents, households with home gardens, and households with higher income are more likely to pay for increases in water availability.

Table 2.6 reports marginal WTP for additional water and reforestation, holding all else constant, and their respective confidence intervals for all models using the Krinsky-Robb method (Krinsky & Robb 1986, 1990). Recall that marginal WTP is given by the negative ratio of the attribute of interest and the coefficient of the cost (Alpízar et al. 2003; Green 2012). Results from model specification 2, which has a better model fit, indicate that respondents are willing to pay on average $3.70 per household per month for increasing forest cover by 300-340 hectares in the watershed, holding the water attribute constant. Similarly, respondents are willing to pay on average $0.07 per household per month for one water-hour, given that the forest attribute is unchanged. Multiplying $0.07 by 24 yields estimates in dollars per water-day (see Calfee & Winston 1998 and Hensher et al. 2005 for similar procedures in other contexts), which results in a WTP estimate of $1.68 per household per month for additional water-days.

Welfare analysis

The value of additional water obtained from well construction was lower than that obtained through reforestation (Table 2.7). The value of increasing water availability by 168 water-hours through well construction, which is the only proposed project in the contingent valuation question, was $5.97 per household per month (based on equation 4). This corresponds to approximately $71.64 per household per year. The value, measured as compensating variation, of additional days with water resulting from an increase in forest cover of 300-340 hectares, which would correspond to an additional 168 hours of water service per year, are reported for each model specification in CE. Assuming a linear relationship between water and utility, the value of increasing forest cover by 300-340 hectares and corresponding increases in water availability by 168 hours is $9.18, $14.93, $10.90, and $10.29 per household per month for model specifications 1, 2, 3, and 4, respectively. This corresponds to $110.16, $179.16, $130.8, and $123.48 per household per year.

Discussion

Respondents are willing to pay more for reforestation, which produces the same amount of water as well construction. In all the estimated CE models, WTP values are higher and statistically different than estimates from CVM (Table 2.7). This difference between value estimates can be explained by several factors. First, results from model 1 in CE show that residents are willing to pay $6.72 for 168 hours of additional water, which is about the same amount they are willing to pay for 168 hours of additional water obtained from well construction. However, results from model 1 also indicate that residents are willing to pay $2.38 and $3.70 per household per month for increasing native forest cover by 140-180 and 300-340 hectares, respectively, holding the water attribute constant. This can be interpreted as the amount of money that respondents are willing to pay for the co-benefits, or ES, they receive from the forest in addition to increased water provisioning. Results from both CE and follow-up questions (Table 2.3) indicate that residents value ES, and differences in WTP values may be a result of co-benefits such as scenic beauty and carbon sequestration that are generated by the forest.

Second, participants may make choices based on their own perceptions about project aspects (Jakus & Shaw 2003; Roberts et al. 2008). For example, as reported above, respondent perceptions about the probability of a well construction project's failure to deliver the expected increase in water availability is different from perception of the probability of successful outcomes from reforestation projects. In addition, most respondents believe reforestation is a better option to reach their water improvement needs. Reforestation is thus perceived as a better solution than well construction for water service improvements.

Third, the source of funding for water scarcity alleviation projects may drive respondents to respond differently. Well construction projects are usually paid by ASADAS residents, whereas reforestation is incentivized by government policies. Thus, ASADAS residents do not pay for reforestation. This may have influenced answers and, consequently, WTP estimates, as respondents may respond strategically, expecting that they may not have to pay for reforestation. In such instances, respondents may give a WTP amount that differs from the true WTP in an attempt to influence results. In this study, respondents were clearly informed that each option in the CE had an associated increase in forest cover, water availability, and cost, which would be paid by ASADAS' water recipients. None of the respondents pointed out that in the end the government will pay for reforestation or mentioned not being willing to pay for reforestation.

Fourth, two different methods were used for the estimation of WTP for additional water obtained from well construction and reforestation to account for complexity and length of the valuation exercise. Although dichotomous choice CVM and CE are based on random utility theory and should provide identical WTP estimates (Adamowicz et al. 1998; Jin et al. 2006), researchers have found different values when comparing WTP estimates from these two methods (Boxall et al. 1996). Thus, differences in WTP for well construction and reforestation, which produce the same amount of additional water, might be due to selected methods.

This study sought to find the factors that affect WTP for additional days of water availability generated from well construction and reforestation. Estimates of WTP for water obtained from well construction and reforestation projects are influenced by respondent household income, age, and the presence of home gardens. The higher the household income, the higher the WTP for additional water. Reporting this variable as significant is particularly important because in the past, income of respondents has been used to assess the validity of the results in CE studies in terms of consistency (Barton 2002; Bateman et al. 2002). Based on economic theory, higher individual income should correspond to greater demand for normal goods.

As age increased, WTP for additional days of water availability decreased. This result is not surprising given the context of the study area. As part of the recent high school curriculum in the study region, students must take environmental science courses and participate in activities related to environmental protection. In some schools, students have the option to obtain a degree in environmental science related subjects (e.g., environmental tourism). In addition, government agencies and schools occasionally work together to develop workshops focused on the benefits of environmental conservation (MSc. Yeimy Cedeño, personal communication). The incorporation of environmental science into the school curriculum is relatively new and has gained more attention in recent years. Therefore, respondents from different age groups may not have been exposed to comparable high school requirements relevant to environmental science issues, and younger respondents may be more aware of ES provided by forests than older respondents. This may influence WTP for additional days of water availability obtained from reforestation across age groups.

There are other factors that may have influenced WTP for additional days of water availability across age groups. If younger respondents have greater financial resources than older respondents, one would expect higher WTP for environmental improvements such as increases in water availability. While data from the survey showed that income did not vary significantly across age groups (Spearman correlation test; $P = 0.11$), younger respondents have fewer dependents than older respondents, resulting in more financial resources. We rejected the null hypothesis of equal number of dependents between younger and older respondents (Kruskal-Wallis test; $P = 0.004$).

The presence of home gardens was also found to affect WTP for additional days of water availability from well construction and from reforestation projects with potential to increase water availability. Respondents with home gardens were willing to pay more for increases in water availability. Home gardens play an important role in these rural communities, as they reduce household food expenditures, and residents in the study region rely on home gardens to produce some of their food and medicines. Similar findings have been reported in other countries where home gardens play a role in the diets of people living in rural areas (Birol et al. 2006). In addition, some people in the study region live far away from the nearest grocery store and have limited access to the market. Home gardens thus are important for everyone, but critical for the food security of the poorest residents.

Conclusion

Residents of the Nicoya Peninsula of Costa Rica suffer from periodic water shortage that occurs annually from December to May. Investments in infrastructure and land cover change have the potential to mitigate water shortage. However, land cover change such as reforestation provides other co-benefits, or ES, in addition to potential water shortage mitigation. Reforestation in this region has been possible, in part, due to existing environmental conservation policies at the national level (Serrano 2005). Contingent valuation and choice experiments methods were used to estimate resident WTP for additional water that may be obtained from well construction or reforestation. Results from CVM and CE show that residents on average are willing to pay $5.97 and $14.93 per household per month for well construction and increases in native forest cover with identical increases in water supply, respectively.

Previous studies have estimated household WTP to avoid interruptions in the water service in other regions using choice experiments (e.g., see Hensher et al. 2005; Hensher et al. 2006; MacDonald et al. 2010). This study contributes to the literature by integrating land use change such as reforestation as an integrated part of the CE design, as this may help to increase water provisioning. In addition, value estimates were obtained for two types of projects, which should help policymakers and stakeholders identify projects that better suit their needs.

An assumption of the study based on literature review, inputs from water managers, and current forest cover trends at the watershed level is that reforestation in this area will increase water supply. It is important to keep in mind that the effectiveness of increased forest cover in increasing water supply in this region has not been documented in the scientific literature. The results of this study should not be interpreted as indication of increased water provisioning from reforestation projects. Nevertheless, the negative relationship between forest cover and water scarcity was used as an assumption to estimate WTP for additional water hours and reforestation. If future biophysical studies find that increasing forest cover in the study region can in fact increase water supply, then the benefits of such projects estimated in this study can be used in cost-benefit analyses to assess the relative merits of forest cover enhancement projects.

This research can be combined with future studies to better assist decision makers. Additional studies are needed to assess how land cover and land use changes, particularly reforestation, affect water provisioning at the household level in this region. Research can be directed towards evaluating the effects of forest functional trait composition on hydrological processes. Results from such studies can be combined with this research to assess the socio-economic effects of land cover change and aid in the development of land cover policies to mitigate water shortages that consider these effects (Daly et al. 2009; Abelleira 2015; Naeem et al. 2015; Abelleira et al. in review). Survey respondents in some communities indicated that water quality is a concern. Studying respondent willingness to pay for water quality improvements can also help to support decision makers.

Acknowledgements

This study was funded by NSF-IGERT grant # 0903479 and the USAID Borlaug Fellowship in Food Security grant # A1102.2. This project was approved by the University of Idaho Internal Review Board for work with human subjects (project 14-279). We are grateful to ASADAS' presidents and residents of the region for their participation in this study. We are grateful to officials of the SINAC regional office in Hojancha for their support in this research.

References

Abelleira-Martínez, O.J., Fremier, A.K., Günter, S., Ramos-Bendaña, Z., Vierling, L., Galbraith, S.M., Bosque-Pérez, N.A., & Ordoñez, J.C., *In Review*. Scaling-up functional traits for ecosystem services with remote sensing: Concepts and methods. Ecology and Evolution.

Abelleira-Martínez, O.J. (2015). Water use of reforested lands in dry tropical Costa Rica: A functional traits and ecosystem services approach. PhD dissertation. University of Idaho and CATIE.

Adamowicz, W., Boxall, P., Williams, M., & Louviere, J. (1998). Stated preference approach for measuring passive use values: choice experiments and contingent valuation. American Journal of Agricultural Economics, 80, 64-75.

Akram, A.A., & Olmstead, S.M. (2011). The value of household water service quality in Lahore, Pakistan. Environmental and Resource Economics, 49, 173-198.

Alpízar, F., Carlsson, F., & Martinsson, P. (2003). Using choice experiments for non-market valuation. Economic Issues, 8, 83-110.

Arrow, K., Solow, R., Portney, R.P.R., Leamer, E.E., Radner, R., & Shuman, H. (1993). Report of the NOAA Panel on contingent valuation. National Oceanic and Atmospheric Administration (U.S. Department of Commerce).

Barton, D.N. (2002). The transferability of benefit transfer: contingent valuation of water quality improvements in Costa Rica. Ecological Economics, 42, 147-164.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R., & Swanson, S. (2002). Economic valuation with stated preference techniques: a manual. Edward Elgar, Massachusetts, USA.

Birol, E., Smale, M., & Gyovai, A. (2006). Using a choice experiment to estimate farmers' valuation of agrobiodiversity on Hungarian small farms. Environmental and Resource Economics, 34, 439-469.

Boxall, P., Adamowicz, W.L., Swait, J., Williams, M., & Louviere, J. (1996). A comparison of stated preference methods for environmental valuation. Ecological Economics, 18, 243-253.

Bruijnzeel, L.A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems, and Environment, 104, 185-228.

Calfee, J., & Winston, C. (1998). The value of automobile travel time: implications for congestion policy. Journal of Public Economics, 69, 83-102.

Calvo-Alvarado, J., McLennan, B., Sánchez-Azofeifa, A., & Garvin, T. (2009). Deforestation and forest restoration in Guanacaste, Costa Rica: putting conservation policies in context. Forest Ecology and Management, 258, 931-940.

Carlsson, F., & Martinsson, P. (2001). Do hypothetical and actual willingness to pay differ in choice experiments. Journal of Environmental Economics and Management, 41, 179-192.

Casey, J.F., Kahn, J.R., & Rivas, A. (2006). Willingness to pay for improved water service Manaus, Amazonas, Brazil. Ecological Economics, 58, 365-372.

Champ, P.A., Boyle, K.J., & Brown, T.C. (2003). A primer on nonmarket valuation. Kluwer Academic Publishers, Norwell MA.

Daily, G., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J. & Shallenberger, R., 2009. Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment, 7, 21-28.

Falkenmark, M. (1997). Meeting water requirements for an expanding world population. Philosophical Transaction of the Royal Society of London, 352, 929-936.

Fremier, A.K., DeClerck, F.A.J., Bosque-Pérez, N.A., Estrada Carmona, N., Hill, R., Joyal, T., Keesecker, L., Klos, P.Z., Martinez-Salinas, A., Niemeyer, R., Sanfiorenzo, A., Welsh, K., & Wulfhorst, J.D. (2013). Understanding spatial-temporal lags in ecosystem services to improve incentive mechanisms and governance. BioScience, 63, 472-482.

Fondo Nacional de Financiamiento Forestal (FONAFIFO). (2014). Datos históricos de las presolicitudes recibidas: periodo 2003-2013. www.fonafifo.cr.gov

Genius, M., Hatzaki, E., Kouromichelaki, E.M., Kouvakis, G., Nikiforaki, S., & Tsagarakis, K.P. (2008). Evaluating consumers' willingness to pay for improved potable water quality and quantity. Water Resource Management, 22, 1825-1834.

Georgiou, S., Langford, I.H., Bateman, I.J., & Turner, R.K. (1998). Determinants of individuals' willingness to pay for perceived reductions in environmental health risks: a case study of bathing water quality. Environment and Planning A, 30, 577-594.

Glenk, K., & Colombo, S. (2011). How sure can you be? A framework for considering delivery uncertainty in benefit assessments based on stated preference methods. Journal of Agricultural Economics, 62, 25-46.

Greene, W.H. (2012). Econometric analysis (7th ed.). Prentice Hall, NJ, USA.

Hanemann, M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. American Journal of Agricultural Economics, 66(3), 332-341.

Hensher, D.A., Rose, J.M., & Green, W.H. (2005). Applied choice analysis: A primer. Cambridge University Press, NY, USA.

Hensher, D., Shore, N., & Train, K. (2005). Households' willingness to pay for water service attributes. Environmental and Resource Economics, 32, 509-531.

Hensher, D., Shore, N., & Train, K. (2006). Water supply security and willingness to pay to avoid drought restrictions. The Economic Record, 82, 56-66.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. Ecological Economics, 69, 1595-1603.

Ivehammar., P. (2009). The payment vehicle used in CV studies of environmental goods does matter. Journal of Agricultural and Resource Economics, 34(3), 450-463.

Ilstedt, U., Malmer, A., Verbeeten, E., & Murdiyarso, D. (2007). The effects of afforestation on water infiltration in the tropics: a systematic review and meta-analysis. Forest Ecology and Management, 251, 45-51.

INEC (Instituto Nacional de Estadísticas y Censo). (2015). Población total por grupos de edades, según provincia y cantón: 2011-2025. Instituto Nacional de Estadísticas y Censo, San José, Costa Rica.

Jackson, R.B., Jobbágy, E.G., Avissar, R., Roy, S.B., Barrett, D.J., Cook, C.W., Farley, K.A., le maitre, D.C., McCarl, B.A., & Murray, B.C. (2005). Trading water for carbon with biological carbon sequestration. Science, 310, 1944-1947.

Jin, J., Wang, Z., & Ran, S. (2006). Comparison of contingent valuation and choice experiment in solid waste management programs in Macao. Ecological Economics, 57, 430-441.

Konikow, L.F., & Kendy, E. (2005). Ground water depletion: A global problem. Hydrogeology Journal, 13, 317-320.

Krinsky, I, & Robb, A.L. (1986). On approximating the statistical properties of elasticities. The Review of Economics and Statistics, 68, 715-719.

Krinsky, I., & Robb, A.L. (1990). On approximating the statistical properties of elasticities: a correction. The Review of Economics and Statistics, 72(1), 189-190.

Krishnaswamy, J., Bonell, M., Venkatesh, B., Purandara, B.K., Rakesh, K.N., Lele, S., Kiran, M.C., Reddy, V., & Badiger, S. (2013). The groundwater recharge response and hydrologic services of tropical humid forest ecosystems to use and reforestation: support for the ‘‘infiltration-evapotranspiration trade-off hypothesis. Journal of Hydrology, 498,191-209.

Ladenburg, J., & Olsen, S.B. (2008). Gender-specific starting point bias in choice experiments: evidence from an empirical study. Journal of Environmental Economics and Management, 56, 275-285.

Lancsar, E., & Savage, E. (2004). Deriving welfare measures from discrete choice experiments: inconsistency between current methods and random utility and welfare theory. Health Economics, 13, 901-907.

Loomis, J., Brown, T., Lucero, B., & Peterson, G. (1997). Evaluating the validity of the dichotomous choice question format in contingent valuation. Environmental and Resource Economics, 10, 109-123.

Loomis, J., & White, D.S. (1996). Economic benefits of rare and endangered species: summary and meta-analysis. Ecological Economics, 18, 197-206.

Louviere, J., Hensher, D., &Swait, J. (2000). Stated choice methods. Analysis and application. Cambridge: Cambridge University Press.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., & White, K.S. (2001). Latin America. In: Climate change 2011: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Basso, E., Compagnucci, R., Fearnside, P., Magrin, G., Marengo, J., Moreno, A.R., Suárez, A., Solman, S., Villamizar, A., and Villers, L.]. Cambridge University Press, Cambridge, United Kingdom and New York, USA, pp. 693-734.

McDonald, D.H., Morrison, M.D., & Barnes, M.B. (2010). Willingness to pay and willingness to accept compensation for changes in urban water customer service standards. Water Resource Management, 24, 3145-3158.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. Frontiers in Econometrics. Academic Press, New York.

Madrigal, R., Alpízar, F., & Schlüter, A. (2011). Determinants of performance of community-based drinking water organizations. World Development, 9, 1663-1675.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and human well-being: synthesis. Island press, Washington, DC.

Naeem, S., Ingram, J.C., Varga, A., Agardy, T., Barten, P., Bennett,G., Bloomgarden, E., Bremer, L.L., Burkill, P., Cattau, M., Ching, C., Colby, M.,Cook, D.C., Costanza, R., DeClerck,F., Freund, C., Gartner, T., Goldman-Benner, R., Gunderson, J., Jarrett, D., Kinzig, A.P., Kiss, A., Koontz, A., Kumar, P., Lasky, J.R., Masozera, M., Meyers, D., Milano, F., Naughton-Treves, L., Nichols, E., Olander, L., Olmsted, P., Perge, E., Perrings, C., Polasky, S., Potent, J., Prager, C., Quétier, F., Redford, K., Saterson, K., Thoumi, G., Vargas, M.T., Vickerman, S., Weisser, W., Wilkie, D., & Wunder, S. (2015). Get the science right when paying for nature's services. Science, 347(6227), 1206-1207.

Nyholm, T., Christensen, S., & Rasmussen, K. R. (2002). Flow depletion in a small stream caused by ground water abstraction from wells. Ground Water, 40(4), 425-437.

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

Park, T., Loomis, J.B., & Creel, M. (1991). Confidence intervals for evaluating benefits from dichotomous choice contingent valuation studies. Land Economics, 67,64-73.

Pattanayak, S.K., Wunder, S., & Ferraro, P. (2010). Show me the money: do payments supply environmental services in developing countries? Review of Environmental Economics and Policy, 4, 254-274.

Raje, D.V., Dhobe, P.S., & Deshpande, A.W. (2002). Consumer’s willingness to pay more for municipal supplied water: a case study. Ecological Economics, 42, 391-400.

Roberts, D.C., Boyer, T.A., & Lusk, J.L. (2008). Preference under environmental quality under uncertainty. Ecological Economics, 66, 584-593.

Sandström, K. (1998). Can forests "provide" water: widespread myth or scientific reality? Ambio, 27(2), 132-138.

Serrano-Dávila, M.E. (2005). Evaluación y planificación del manejo forestal sostenible en escala de paisaje en Hojancha, Costa Rica. M.S. Thesis, CATIE, Costa Rica.

Train, K.E. (2009). Discrete choice methods with simulations (2nd edition). Cambridge University Press, NY, USA.

UNDP (United Nations Development Programme). (2006). Beyond scarcity: Power, poverty and the global water crisis. Human development report, N.Y., USA.

Vallejo, A., Gutierrez, I., Chacon, M.L., Rooij, W.V., Davila, M.S., Arce, J.J.C., & Villalobos, R. (2006). Biodiversity - human well-being linkages for teak farms in Hojancha, Nicoya Peninsula, Costa Rica. Case study commissioned by Netherlands Environmental Assessment Agency.

Vega-García, H. (2005). Migración ambiental inducida por variabilidad climática: el caso del Corredor Centroamericano del la sequía. CEMEDE, San José, Costa Rica.

Ward, F. (2006). Environmental and natural resource economics. Pearson education inc., New Jersey, USA.

Wielgus, J., Gerber, L.R., Sala, E., & Bennett, J. (2009). Including risk in stated preference economic valuation: experiments of choices for marine recreation. Journal of Environmental Management, 90, 3401-3409.

Zhongmin, X., Guodong, C., Zhiqiang, Z., Zhiyong, S., & Loomis, J. (2003). Applying contingent valuation in China to measure the total economic value of restoring ecosystem services in Ejina region. Ecological Economics, 44, 345-358.

Table 2.1: Attributes and levels for the choice experiment

Attributes	Levels
Forest cover in the watershed surrounding the ASADA	Same as current situation (Status quo), Between 140-180 more hectares than the current situation, Between 300-340 more hectares than the current situation
Water availability	Same as current situation (Status quo), 24, 72, 144, or 168 hours of additional water supply
Cost per household per month	₡0 (Status quo), ₡500, ₡1,000, ₡2,000, ₡3,000

Table 2.2 Socio-economic and demographic characteristics of individuals across groups

Variables	Description	CE Mean (SD)	CVM Mean (SD)
Number of participants		84	248
Gender	1=male, 0=female	0.43 (0.50)	0.40 (0.49)
Age	Age of respondents	46.42 (17.38)	47.03 (17.80)
Household income	Total household income per month (1= less than or equal to ₡200,000, 5= more than ₡800,000)	1.4756 (0.88)	1.5319 (0.94)
Education[a]	Education of respondents (1= none, 5= graduate school)	2.45 (0.77)	2.35 (0.89)
Garden	Respondents with a home garden (for their own consumption; 1=yes, 0=no)	0.2195 (0.42)	0.2678 (0.44)
Water yield	Respondents satisfaction with regard to water supply (1=very satisfied, 4= not satisfied)	2.6145 (0.81)	2.7054 (0.82)
Number of dependents	Number of household dependents	1.8846 (1.59)	1.9736 (1.51)

CE= Choice experiment, CVM= Contingent valuation method, SD= Standard deviation
[a]The description of categories for education is as follows: 1= None, 2= Primary school, 3= High school, 4= University, 5= Graduate school

Table 2.3: Residents perception of some forest functions*

Forest functions	Mean	SD	Don't know (N= 248)
Recreation opportunities	1.73	0.78	10
Water purification	1.44	0.63	9
Soil erosion reduction	1.58	0.66	23
Biodiversity protection	1.39	0.54	7
Contribution to scenic beauty	1.48	0.6	2
Climate change mitigation	1.33	0.53	10
Increase in ground water yield	1.29	0.49	9
Flood control	2.07	1.22	32
Habitat for pollinators (e.g., bees)	1.58	0.73	11
Wood production	2.15	1.29	5

* Likert scale: 1= very important, 5= not important; SD= standard deviation

Table 2.4: Result from logit model for contingent valuation method

Variables	Coefficient	Standard error	p-value
Constant	3.6017	0.75	0.000**
COST	-0.6424	0.08	0.000**
AGE	-0.0195	0.02	0.052*
GARDEN	0.8040	0.42	0.055*
INCOME	0.6030	0.21	0.004**
Observations	239		
Pseudo R^2	0.39		
Prob>χ^2	0.000		

* Significant at 0.10, ** Significant at 0.01

Table 2.5: Results from conditional and mixed logit models for choice experiments

Variables	CLM (model 1) Coefficient (SE)[a]	CLM (model 2) Coefficient (SE)	ML (model 3) Coefficient (SE)	CLM (model 4) Coefficient (SE)
Forest	-	-	-	0.4352(0.10)**
140-180 hectares	0.7596(0.20)**	1.0601(0.22)**	1.4229(0.39)**	-
300-340 hectares	1.2251(0.19)**	1.6477(0.22)**	2.0529 (0.47)**	-
Water (cont.)	0.0131(0.001)**	0.0297(0.004)**	0.0195(.01)**	-
* age[b]	-	0.0004(0.0001)**	-	-
* garden	-	0.0087(0.003)**	-	-
* Income	-	0.0028(0.001)*	-	-
Water (discrete)	-	-	-	-
24	-	-	-	0.5011(0.25)*
72	-	-	-	1.5556(0.25)**
144	-	-	-	2.0816(0.24)**
168	-	-	-	2.6138(0.25)**
Cost	-0.3727(0.04)**	-0.4452(0.04)**	-0.4888(0.13)**	-0.3807(0.04)**
Number of choice	664	648	664	664
Pseudo R^2	0.31	0.39	0.25	0.32
Prob>X^2	0	0	0.001	0
AIC	1015.21	878.3	1004.17	1010.18

* Significant at 0.05; ** Significant at 0.01
[a] Standard errors (SE) in parentheses
[b] Interaction effects between water and AGE, GARDEN and INCOME, respectively

Table 2.6: Marginal WTP[a] ($) per household per month for reforestation and water based on choice experiments

Variables	CLM (model 1)	CLM (model 2)	ML (model 3)	CLM (model4)
Forest	-	-	-	1.14 (0.58-1.71)
140-180 hectares	2.04 (1.00-3.11)	2.38 (1.45-3.31)	2.91 (1.75-4.07)	-
300-340 hectares	3.29 (2.27-4.38)	3.70 (2.77-4.63)	4.20 (2.91-5.49)	-
Water (for one water-hour)	0.04 (0.03-.04)	0.07 (0.05-0.09)	0.04 (-0.03-0.05)	-
24	-	-	-	1.32 (0.08-2.60)
72	-	-	-	4.09 (2.90-5.37)
144	-	-	-	5.47 (4.31-6.91)
168	-	-	-	6.87 (5.63-8.53)

[a] Marginal WTP were calculated dividing the coefficient of the attribute of interest by the cost attribute (Champ et al. 2003)
95% confidence intervals (in parenthesis) were estimated using the Krinsky-Robb method (Krinsky and Robb 1986, 1990)

Table 2.7: WTP for 168 hours of additional water per household per month obtained from well construction or reforestation

Methods	WTP ($)	95% Confidence intervals[a] ($)
Well construction	5.97[b]	5.41-6.53
Reforestation (model 1)	9.18[c]	7.79-10.58
Reforestation (model 2)	14.93	11.23-18.62
Reforestation (model 3)	10.90	8.62-13.18
Reforestation (model 4)	10.29	8.54-12.05

[a] 95% confidence intervals were obtained using the Deltha Method (Park et al. 1991)
[b] WTP for an increase of 168 water hours obtained from well construction. WTP is estimated with coefficients from Table 2.4
[c] WTP for an increase of both 300-340 hectares of forest cover and 168 water hours in model specifications 1,2, 3 and 4. WTP is estimated with coefficients from Table 2.5

Figure 2.1: Map illustrating the study region and ASADAS that formed part of the study. Information gathered from the Costa Rican Atlas (2008)

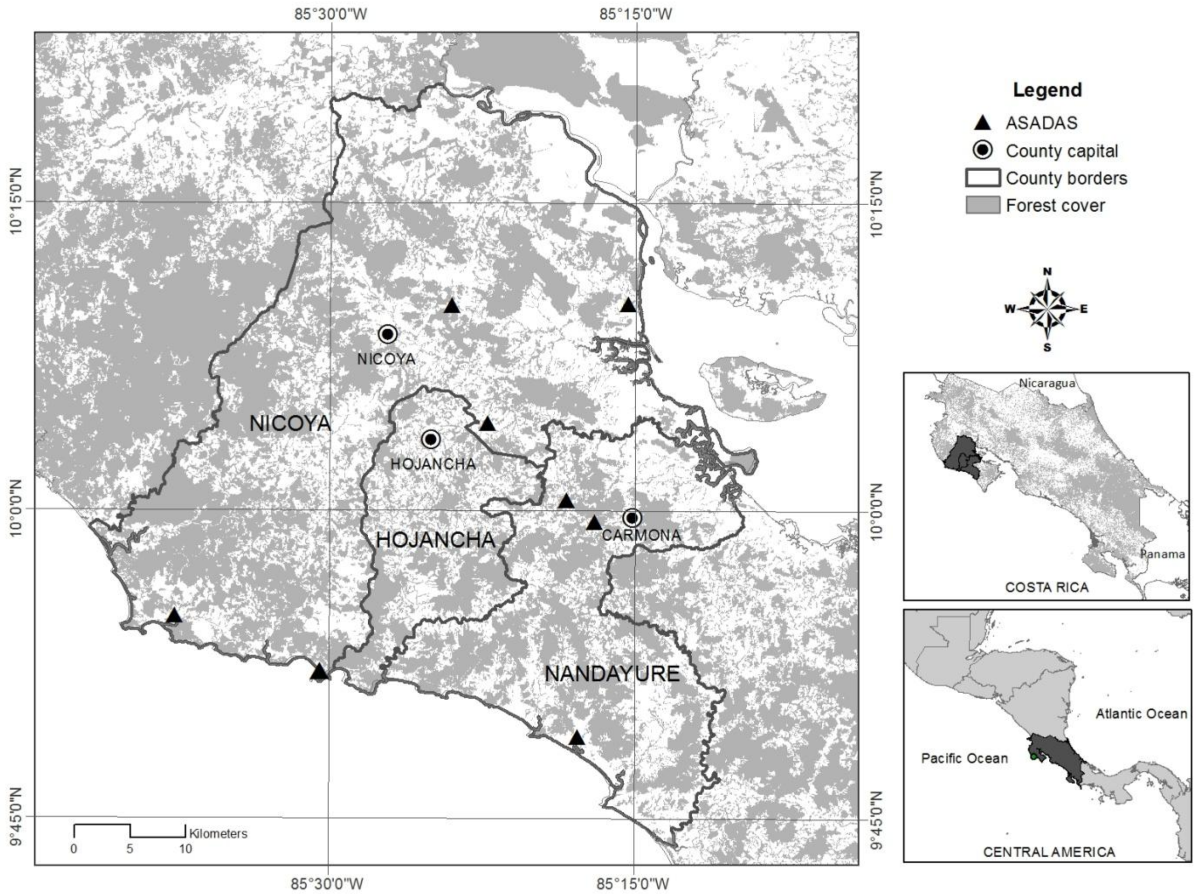


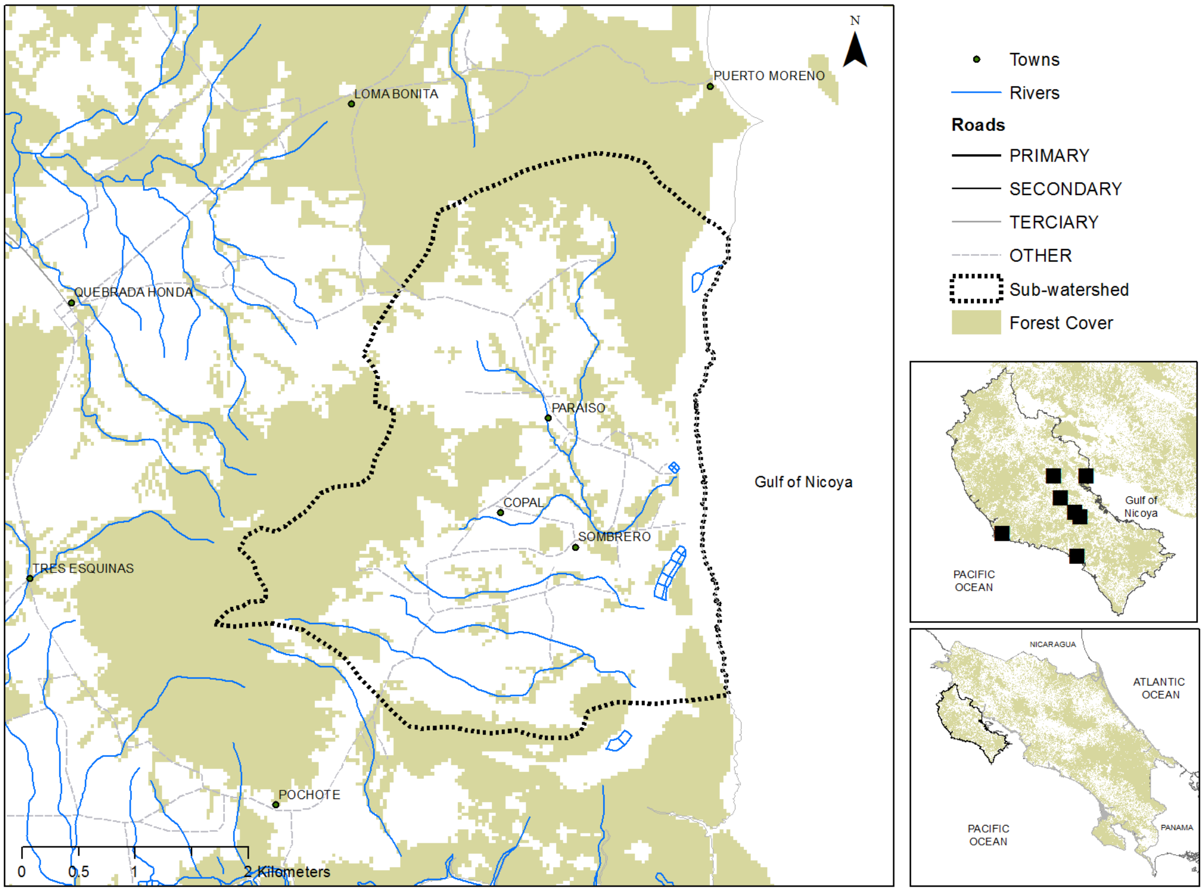
Figure 2.2: Example of the contingent valuation question

The ASADA where you live has 240 hours (equivalent of 10 days) of water scarcity per year. If you disagree with this number, for purpose of this study, please assume that you have 240 hours of water shortage. Suppose that the government or the municipality of your county would be willing to construct a well to increase the amount of water hours for household uses by 168 (equivalent of 7 days) during the dry season. Wells generate water immediately but it has been found that some wells in the past have become dry after several years of being constructed. If this project (well construction) is developed, this will result in a fixed monthly payment. Given the costs, the well will be constructed only if a sufficient number of households are willing to pay the rate. If the well is constructed, then all households benefiting from this well in the region will pay the same rate.

The project implementation will cost you [offer amount colons] monthly for as long as the service is provided. Would you support such project and be willing to pay the said amount for well construction?

Yes _____ No _____

Figure 2.3: An example of one of the maps used to illustrate the region under consideration for increases in forest cover*



* Dotted line represents the watershed surrounding the ASADA

Figure 2.4: Example of the choice experiment exercise

It has been estimated that the ASADA where you live has on average 240 hours (equivalent of 10 days) of water shortage during the whole year. If you disagree with this number, for purpose of this study, please assume that you have 240 hours of water shortage. Reforestation is one of the projects considered to increase water in household. This project will increase forest cover in the ASADA and/or its surrounding areas (see the map at the end of the survey), but it is unknown exactly the lands that will be reforested. With the exception of residential areas, all lands are eligible for reforestation. Notice that in addition to water the forest provides other benefits, such as protection of biodiversity, reduction of climate change, contribution to scenic beauty, etc. However, after reforestation additional water may start to become available only after a few years and it may take up to 15 or more years to generate maximum water and other benefits provided by trees.

An example of a choice set presented to respondents

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 140 and 180 hectares more than current situation	Between 300 and 340 hectares more than current situation	Same as today
Water availability	72 hours more than current situation (equivalent of 3 days)	144 hours more than current situation (equivalent of 6 days)	Same as current situation
Cost	₡2,000	₡3,000	₡0
	□	□	□

Chapter 3. Risk and Framing Effect: Results from a Choice Experiment in a Water Scarcity Context

Abstract

Most economic studies valuing environmental goods and services assume certainty of project outcomes. However, considering uncertainties may help to create better and more realistic research designs. Survey respondents in economic valuation studies are likely to make choices based on the way information is provided, leading to potential framing effects. In this paper a choice experiment (CE) is used to estimate residents' willingness to pay (WTP) for increases in forest cover and water availability. Results from multiple CE treatements are used to assess whether risk influences WTP estimates and to examine potential risk framing effects. We found that residents are willing to pay more for reforestation and additional water when information about risk is provided as a separate attribute and when risk is presented positively (e.g., probability of success vs. probability of failure) in choice experiments. Multiple model specifications are used to verify these findings.

Introduction

In the economic valuation literature, it is common to describe the outcomes arising from a policy alternative as being certain. While this may be true for some goods and services, it is not appropriate to make such assumptions in environmental contexts where processes are quite complex and often uncertain. For instance, groundwater availability not only depends on anthropogenic forces, but also on stochastic factors like precipitation, trade-offs between infiltration and transpiration, temperature, etc. (Sandström 1998; Brujinzeel 2004; Ilstedt et al. 2007). Even in scenarios where stochastic events are considered, lack of scientific knowledge and evidence complicates the predictions of outcomes. These uncertainties should be considered in stated-preference economic valuation studies because they can affect individuals' preferences and behavior (choices), which may influence willingness to pay (WTP) estimates (Roberts et al. 2008; Wielgus et al. 2009; Harrison et al. 2014).

Two main arguments have been put forward to explain what happens when uncertainties associated with project outcomes are not considered in stated-preference based economic valuation studies. First, when information about uncertainties is not provided, economic agents may assign subjectively perceived risk levels for each of the project outcomes based on their own knowledge and interpretation of the context (Jakus & Shaw 2003; Roberts et al. 2008). However, if uncertainties are provided, economic agents will have, at least to some degree, controlled perceptions of project-associated risk. Second, the inclusion of uncertainty could potentially make the valuation exercise more realistic and credible, which has been pointed out as critical in order to consider the results from stated-preference methods valid and applicable (Arrow et al. 1993). Lack of both realism and credibility could drive individuals to choose the status quo option in stated-preference methods, depending on attitudes towards the good in question (e.g., risk aversion) and protest attitude (Meyerhoff & Liebe 2009), which affects WTP.

Choice experiments (CE) are a stated preference method commonly used to elicit individual preferences and WTP for non-market goods and services. In recent years, the inclusion of uncertainty in the CE design in environmental settings has gained more attention. To account for project outcome uncertainties in CE, some researchers have adopted quantitative measures (Roberts et al. 2008; Wielgus et al. 2009; Glenk & Colombo 2011), while others have used qualitative representations of attributes (Lundhele et al. 2013). Those who adopted quantitative measures have defined uncertainty in terms of probabilities (e.g., the probability that a project delivers the expected change). Some researchers have defined uncertainty as probability of failure[9] (Glenk & Colombo 2011), while others have defined it as probability of occurrence (Rolfe & Windle 2010). However, the way projects are described to respondents is likely to affect their choices and potentially WTP estimates (Howard & Salked 2009). Given the growing interest of environmental economists in considering risk as a separate attribute in CE, it is critical to examine

[9] Because almost all of these studies have used probabilities as levels in the stated preference methods, authors have used the term "risk" instead of "uncertainty". This study used risk for the same reason. However, it should be acknowledged that these two terms are not exactly the same. The outcome probabilities in uncertain situations are unknown, while in risky situations probabilities are known (Knight 1921).

how results may be affected by potential framing effects. Previous studies reviewing the incorporation of risk as an attribute in CE have called for further research to test how the process of communicating risk affects results outside health-related topics (Harrison et al. 2014).

The framing effect is observed when respondents' choices depend on how the information is presented. Particularly, people often perceive a problem framed positively as a gain and the identical problem presented negatively as a loss (Kahneman &Tversky 1979), resulting in choices that are contradictory. A classical example of framing effect is the so-called "Asian disease problem" presented by Tversky and Kahneman (1981). Respondents were asked to choose between a certain (i.e., sure) or probabilistic (i.e., risky) alternative to save lives (positively framed) or avoid deaths (negatively framed) from an unusual disease. Framing the question in two different manners led to dramatically different answers. Another example of framing effect is the "fat vs. lean analysis" (Levin & Gaeth 1988). The authors found that ground beef described as 75% lean was given higher ratings in terms of product quality than ground beef described as having 25% fat content.

The framing effect has been studied in the CE literature, and it has been found that respondent decision behavior (choices) is affected by the manner in which attributes and levels are presented (Howard & Salked 2009; Kragt & Bennett 2012). Howard and Salked (2009) used CE to evaluate framing effects in screening for colorectal cancer. They found mixed results in respondent WTP for different attribute levels when attributes are presented as cancers found rather than cancers missed. Kragt and Bennett (2012) studied framing effect using results from a CE of community preferences for natural resource management in the Georgia River catchment, Tasmania. Three environmental attributes were used to describe the condition of the Georgia River Catchment: seagrass area, native riverside vegetation and rare native animals and plant species. The authors presented the attributes as absolute levels or in relative terms, and used positive versus negative description of attribute levels. They found that respondents' WTP is not affected by presenting attributes in relative terms compared to absolute values. However, they found that respondents are willing to pay more for attribute levels when information is presented as a loss.

Respondent choices are also influenced by the content and composition of CE. Researchers may find different answers by varying the choice set complexity, such as changing the number of alternatives per choice set, attributes per alternatives, levels per attributes, or choice sets per questionnaire (Hensher 2006; Rose et al. 2009). For example, some studies have shown that the inclusion of an additional attribute in a CE exercise results in a higher tendency to select the status quo option (Glenk & Colombo 2011), whereas others have found that respondents select less frequently the status quo option when the number of levels in the CE is increased (Mayerhoff & Liebe 2010). Others have found choice inconsistencies and mixed results in terms of the selection of the status quo option when attributes are presented as intervals (i.e., distribution) (Wielgus et al. 2009).

In the CE literature, framing effects have not been widely explored in instances when risk is considered as a separate attribute in environmental settings. With results of CE studies increasingly being used to support policy and project development, it is particularly important to evaluate the validity of the method and reliability of WTP values in the context of uncertainty and risk (Kragt & Bennett 2012). For instance, results from CE are often used as inputs in cost-benefit analysis to evaluate the feasibility of project implementation (Ward 2006). Biased estimates, such as those potentially caused by not including relevant information like uncertainty of project outcomes or framing effects, may lead analysts to arrive at misleading conclusions. As a result, policy designs may be inefficient in allocating limited resources and thereby fail to achieve social welfare maximization.

To address this knowledge gap, the objectives of this study were to: (1) assess if WTP for additional water and reforestation are affected by inclusion of risk as a separate attribute in the CE and, (2) assess if WTP values are affected by the way risk is framed. We used a CE method to estimate WTP for additional water and for reforestation by water recipients of non-governmental community-based drinking water organizations (CBDWO) in the Nicoya Peninsula of Costa Rica.

Methods

Study region

The Nicoya Peninsula of Costa Rica, bordered by the Pacific Ocean to the west and the Gulf of Nicoya to the east, has experienced dramatic land use change in recent decades. For instance, native forest cover in some counties increased from 14% to 52% between 1970 and 2005 (Serrano 2005). Agricultural lands have decreased, whereas monoculture tree plantations, mainly of teak (*Tectona grandis*), have increased over the same time period (Serrano 2005). As a result of land use change, the environmental benefits provided by forests such as scenic beauty, carbon sequestration, and hydrological services can be affected (Daly et al. 2009). Currently the main land uses in the region are pasture, tree plantations, and native forest.

Reforestation in this region has been possible due to governmental policies and local stakeholder action (Calvo-Alvarado et al. 2009). Costa Rica has one of the most studied Payment for Ecosystem Services (PES) programs worldwide (Pagiola 2008; Pattanayak et al. 2010). This program pays landowners who help to protect ecosystem services (ES) through qualifying land use management practices. Different land cover types, including reforestation, can qualify for the PES program. In Costa Rica the PES scheme covers a bundle of ES including water provision, biodiversity conservation, carbon sequestration, and scenic beauty (FONAFIFO 2014).

Many households in this region receive their water service from non-governmental CBDWOs, as the government does not offer water service in all communities. CBDWOs are in charge of managing and distributing the water service to approximately 50% of the population in the Nicoya Peninsula of Costa Rica (Regional Coordinator of Forestry Development, personal communication). However, every year these communities experience water scarcity during the dry season from December to May. We focused on water for household uses by the Administrative Associations for Aqueducts and Sewers (ASADAS, the Spanish acronym), which are types of CBDWOs, for two main reasons. First, contact information was available for many of the ASADAS administrators, which made the study logistically feasible. Second, ASADAS represent the great majority of CBDWOs in the region.

Survey and study design

We conducted thirty-four semi-structured phone interviews with ASADAS' presidents from December 2013 to January 2014. Information gathered from these interviews was used to understand water-related issues and relationships between water scarcity and forest cover across ASADAS. This information was used to develop the questionnaire to be distributed to ASADAS' water recipients. Specifically, percentage of forest cover at the watershed level was calculated for each ASADA. Afterward, we estimated the amount of land that would need to be reforested in watersheds where ASADAS suffering from water scarcity are located in order to have the same percentage of forest cover as those ASADAS not suffering from water scarcity. The estimated amount of land needed for reforestation was used as part of the CE design.

A questionnaire was developed to collect data from ASADAS' water recipients, which consisted of two main sections. One section included the CE to estimate WTP for additional water and reforestation. The second section included questions about socio-economic and demographic characteristics (SDC) of individuals and perception of services received from different forest functions. This information was gathered to understand respondent preferences and decision behavior. At the end of the questionnaire, respondents were allowed to make comments and provide feedback about the questionnaire, including the valuation exercise.

We developed three different treatments (survey versions) to collect data from ASADAS' water recipients. Treatment one did not include any information about risk. For treatment two, risk was framed as "probability of success" and defined as the probability that the project would achieve or exceed the expected increase in water availability. For treatment three, risk was framed as "probability of failure" and defined as the probability that the project would fall short of achieving the expected increase in water availability. We used a between-subject design where each participant randomly received one of the three treatments to avoid both confusion and fatigue. This design is also useful to avoid the problem of familiarity, i.e., that experience gained from one treatment can affect responses in subsequent treatments (e.g., see Lusk & Shroeder 2004).

We tested the questionnaire in two different focus group sessions held at the National System of Conservation Areas (SINAC, Spanish acronym) regional office located in Hojancha county. Local residents with different levels of education attended the meeting. This allowed testing for relevance, comprehension, and length of the survey. After gathering information provided by members of the focus groups, the questionnaire was modified accordingly.

Choice experiments

In CE, respondents are presented with two or more options and associated prices and are asked to state their preferred alternative. A series of choice sets is presented to each surveyed respondent, with choice sets varying among respondents. Respondents WTP for improved service levels are inferred using statistical analysis of their indicated choices.

The attributes used in CE and their respective levels are described in Table 3.1. The first attribute used was *Forest cover in watershed surrounding the ASADA*. Forest cover levels were based on the interviews made to ASADAS' presidents from which we obtained a statistical relationship between forest cover at the watershed level and water scarcity. Given that respondents may not understand the meaning of watershed and current forest cover in the region, each respondent was given a map of the target region showing the current amount of forest cover in the watershed surrounding their ASADA. A representative map for one such watershed is provided in Figure 3.1. Respondents were informed that reforestation would take place in this watershed area and that any land excluding residential areas would be considered for forest conversion. Landowners of private lands would be compensated for changes to forest cover.

The other attribute was *Water availability for household use*. Increases in water availability were restricted to household use, including home gardening, because large-scale irrigation is prohibited in the ASADAS. Respondents made choices involving increases in water availability due to reforestation. A maximum amount of additional water-hours was assumed to be 168 because all ASADAS in the region had at least this level of water shortage per year. Before the CE task, respondents were informed about current water scarcity levels as reported by ASADAS' presidents.

The next attribute was *Probability of success or failure*. We only used this attribute in treatments 2 and 3. The levels for this attribute depended on whether the attribute was presented as probability of success or probability of failure. Participants were told that although reforestation may increase water availability, the increase might not achieve the expected level. Similar procedures for describing risk were used by Glenk and Colombo (2011), where respondents were informed that a soil carbon program might fail to reduce overall greenhouse gases emissions.

Finally, to elicit WTP values, a cost attribute was included. We selected the levels for this attribute based on inputs from ASADAS' presidents and feedback from focus groups. These levels were presented in colones (₡), the Costa Rican currency. Given that current water bills are considered high and participants are not required to pay annual taxes, in order to reduce the number of potential protest responses the payment vehicle was not specified (Georgiou et al. 1998; Bateman et al. 2002). See Figure 3.2 for an example of a choice set presented to respondents.

Experimental design

The CE design for treatment 1 included two attributes (water and cost) with four levels and one attribute (forest cover) with two levels in addition to the status quo. The complete factorial design including all possible combinations of attributes and levels amounted to 32 possible alternatives ($4^2 * 2^1 = 32$). Each choice set had two alternatives plus a status quo option in which all attribute levels reflected the current situation. A complete randomized design would include 1,024 different choice sets. We used an orthogonal fractional factorial design to select 32 choice sets (Louviere et al. 2000). Each participant filled out eight randomly selected choice sets from the 32 choice sets, ensuring that each choice set was evenly repeated in the entire CE. In addition, a practice table, often called a "warm-up" choice set, was used before the choice exercise to help respondents to become familiar with the method (Carlsson & Martinsson 2001; Ladenburg & Olsen 2008).

The CE design was similar for the other two treatments, where two attributes (water and cost) had four levels, and two attributes (forest cover and risk) had two levels each. The complete factorial design, including all possible combinations of attributes and levels, equaled 64 possible alternatives ($4^2 * 2^2 = 64$). Similar to the first treatment, each choice set had two alternatives in addition to the status quo option. Thus, a complete randomized design would include 4,096 different choice sets. Again, we used an orthogonal fractional factorial design to select 32 choice sets (Louviere et al. 2000) and each respondent completed eight randomly selected choice sets from the 32 selected choice sets. In addition, a "warm-up" choice set was also used in these treatments.

In all treatments an additional choice set was included to assess participants' comprehension of the exercise. In this choice set the levels of forest cover were identical for alternative A and B. The other attributes were unquestionably dominant in alternative B. Thus, alternative B was dominant over alternative A (i.e., alternative A is a dominated choice). Although alternative C had no environmental improvements, respondents did not incur extra costs if this option was selected. Thus, alternative B was not dominant over alternative C. While it was perceived as reasonable to select option C, respondents had no incentives to select alternative A. If respondents selected alternative A, we assumed they did not understand the choice task, thereby justifying removal of the respondent from the data set.

Econometric approach

CE is based on random utility theory, which states that the utility function can be decomposed into a deterministic component and an unobserved component

(McFadden 1974). As part of the utility maximization process, it is assumed that respondents analyze and compare available alternatives and will select the one providing the highest utility (Alpízar et al. 2003). The utility function can be denoted as follows:

$$U_i = V_i + \varepsilon_i \quad (1)$$

where U_i is total utility derived from alternative i; V_i is the indirect utility, which is specified as a function of the attributes; and ε_i is the error term capturing the effect of unobserved attributes. It is assumed that participants will select alternative i over alternative j if (and only if) the utility of alternative i is higher than the utility of alternative j ($U_i > U_j$). Then the probability of respondent n selecting alternative i is:

$$P_n(i) = P\left(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}\right)\, for\ all\ i, j \in C, i \neq j \quad (2)$$

The inclusion of the error term combined with the assumption that they are independently and identically distributed allows estimating the parameters of utility via maximum likelihood procedures in logit models (Champ et al. 2003). V_i is a function of x attributes with associated parameters, β_x. In the absence of risk and assuming the utility function is linear and additively separable (Louviere et al. 2000; Glenk & Colombo 2011), the indirect utility function can be expressed as follows:

$$V_{ni} = \beta_{0i} + \beta_{Forest}\, Forest_i + \beta_{Water}\, Water_i + \beta_{Cost}\, Cost_i + \sum_{k=1}^{K} \gamma_k Z_{nk} \quad (3)$$

where β_{0i} is a constant term for alternative i; β_{Forest} , β_{Water} , β_{Cost} and γ_k are coefficients; $Forest_i$, $Water_i$ and $Cost_i$ are choice set attributes; and Z_{nk} are the SDC of respondent n that may affect choices.

Risk was incorporated in two different ways. First, choices involving risk were evaluated assuming that risk directly affects individuals' utility. To take this into account, we analyzed risk as another attribute in the CE. This may be the most common way of considering risk in CE (e.g., Rolfe & Windle 2010; Glenk & Colombo 2011). Then equation 3 becomes:

$$V_{ni} = \beta_{0i} + \beta_{Forest}\, Forest_i + \beta_{Water}\, Water_i + \beta_{risk}\, Risk_i + \beta_{Cost}\, Cost_i + \sum_{k=1}^{K} \gamma_k Z_{nk} \qquad (4)$$

Second, choices involving risk were assessed by drawing on the Expected Utility Theory (Von Neumann & Morgenstern 1944). This theory postulates that respondents derive utility over expected outcomes. Thus, we multiplied changes in water availability by probabilities. This approach has also been previously used in the CE literature (Roberts et al. 2008; Glenk & Colombo 2013). Under this reasoning, equation 3 becomes:

$$V_{ni} = \beta_{0i} + \beta_{Forest}\, Forest_i + \beta_{Water}\, (Risk_i * Water_i) + \beta_{Cost}\, Cost_i + + \sum_{k=1}^{K} \gamma_k Z_{nk} \qquad (5)$$

It should be noted that if the interest of a study is to compare results from survey versions where risk is framed in different ways, as is the case of this study, special attention should be devoted to the manner in which risk enters into equations 4 and 5. That is, for treatments where risk is framed negatively, risk probabilities have to be introduced in a different manner into the model specification in order to compare results with the treatment where risk is framed positively. In this study, for the treatment where risk is framed positively, risk probabilities measure the probability of success; conversely, for the treatment where risk is framed negatively, risk probabilities represent probabilities of failure. Therefore, in treatement 3, where risk was expressed in terms of probabilities of failure, the probabilities were replaced with one minus the probabilities of failure to make sure that the data are consistent across treatement 2 and 3. This allows us to analyze the effect of the probability of achieving the expected change in water availability in treatments 2 and 3 (i.e., for treatment 3, 40% of probability of failure means that there is a 60% of probability of success; $1 - 0.40 = 0.60$)[10]. A similar approach was used by Glenk and Colombo (2013), where $1 - Risk_i$ was used to assess the probability of successfully achieving the expected change in gas emissions as they introduced risk as probability of failure (negatively framed).

The final goal of most CE studies is to estimate the marginal WTP for a change in the level of provision in the attribute. The value of a change in attribute level can be

[10] We also tried a different approach. For treatment 2, where risk was expressed in terms of probabilities of success, the probabilities were replaced with one minus the probabilities of success. Thus, both treatments were expressed in terms of risk of failure. We found no differences in coefficient estimates.

estimated using marginal WTP, or implicit prices, while holding other attributes constant. Marginal WTP are given by the negative ratio of the coefficient of the attribute of interest and the cost coefficient (Green 2012). This can be expressed as:

$$WTP = -\beta_x/\beta_{cost} \quad (6)$$

where β_x is the coefficient of the x attribute and β_{cost} is the coefficient of the cost attribute. This formula represents the marginal rate of substitution between the attribute of interest and the cost attribute.

Data and models

Given our design, inclusion of both forest and water variables as binary variables were not possible due to singularity problems. In running the econometric model, two dummy variables were used for the three levels of the forest cover attribute, and continuous variables were used for the water and cost attributes. Risk was also defined as a continuous variable when used. A different model was also previously examined where the forest attribute was specified as continuous and water was specified as a dummy variable. The reported model in this study has a superior model fit as reported by the adjusted pseudo R^2 and the Akaike information Criterion.

We analyzed data obtained from questionnaires using a conditional logit model (CLM). Different model specifications were evaluated to assess how information about risk and framing affect choices and, consequently, WTP estimates. Figure 3.3 shows all model specifications and treatements for the statistical analysis. Model specification 1 used only data from treatment 1 as respondents in this treatment received no information about risk (equation 3 above). The design of the CE for treatments 2 and 3 did include a risk attribute. For treatment 2, risk was presented as probability of success. For treatment 3, risk was presented as probability of failure. Two different models involving risk probabilities were specified and used for treatments 2 and 3. In model specification 2, risk entered as a standalone independent variable into the utility function (equation 4 above). In model specification 3, water was weighted by the probability of successfully achieving the expected change in water provision (i.e., expected increase in water availability; equation 5 above). We compared results from treatment 1 with results from treatments 2 and 3 to analyze the effect of providing information about risk on respondent choices and WTP estimates. We also compared the results from treatment 2 with the results from treatment 3 to test for potential framing effects. Finally, we compared results from treatment 2 in model specification 2 with results from treatment 2 in model specification 3 to assess how model specifications affect results. The same comparison was done for treatment 3 across model specifications. Specifying two different model specifications for treatments involving risk allows a better examination of the effect of risk and framing on respondent choices than specifying only one model specification, as risk may affect utility in diverse ways.

One may be tempted to compare parameter estimates across models; however, in discrete choice models the estimated parameters are confounded with the scale parameter (Louviere et al. 2000), which is used to normalize utility expressions (Hensher et al. 2005). Therefore, it is unknown whether the observed difference, if any, is the result of differences in scale, true parameters, or both (Louviere et al. 2000). Results across models need to be analyzed using other approaches. Results across models were compared analyzing the estimated WTP values (equation 6 above), as the scale parameter cancels out (Alpízar et al. 2003; Green 2012).

A joint model unifying data from all treatments was run as an alternative approach to evaluate whether respondent choices are influenced by information about risk (joint model 1). For this model, we generated a dichotomous variable taking the value of one for survey versions involving risk, and zero otherwise (i.e., a variable accounting for treatments involving risk). This variable, however, cannot enter directly into CLMs as this variable is invariant within choice sets (Champ et al. 2003; Birol et al. 2006; Colombo & Hanley 2008). In the CE literature, variables that are invariant within choice sets, such as respondents' SDCs, are evaluated in CLMs by interacting them with either the alternative-specific constant (ASC) or attributes (Champ et al. 2003; Alpízar et al. 2003; Birol et al. 2006; Colombo & Hanley 2008; Wielgus et al. 2009). Interaction terms between a variable accounting for treatments with the ASC or attributes are also found in the literature (List et al. 2006; Carlsson et al. 2012). In this study, the variable accounting for treatments involving risk was interacted with the water attribute[11].

The second joint model unifying data only from treatment 2 and 3 was also run to evaluate if respondent choices are affected by risk framing (joint model 2). This joint model was specified as identical to model specification 2. That is, in joint model 2, risk was introduced as another attribute into the utility function. For this joint model, we generated a dichotomous variable taking a value of one for the treatment where risk is framed as probability of success and zero otherwise. Analogously to joint model 1, this variable was interacted with the water attribute.

One last joint model unifying data from treatments 2 and 3 using a different model specification was run to evaluate whether respondents' choices are affected by risk framing (joint model 3). For this joint model, data were specified as identical to model specification 3. The difference between joint models 2 and 3 is that for the latter, water is multiplied by probability of success (expected increase in water availability), and for the former, risk is entered as an additional attribute into the utility function. The variable accounting for the treatment where risk is framed as probability of success is the same as for joint model 2 and so is the interaction term.

Results and discussion

[11] The variable accounting for treatments involving risk was also interacted with the ASC. The model with the interaction we are reporting has a better model fit as reported by the adjusted pseudo R^2 and the AIC. Additionally, we are particularly interested in interactions with the water attribute because water scarcity is the focus of this paper.

Respondents' socio-demographic characteristics and their attitudes

Data collection was completed from December 2014 to March 2015. In-person interviews were conducted at every other household in eight different ASADAS across the study region. A total of 248 participants were interviewed, and most of respondents were heads of households[12] (63%). Because each participant faced eight choice sets as part of the CE, 1,984 choice sets were completed in total (5,952 observations). Table 3.2 reports descriptive statistics of main SDCs of respondents across treatments. Overall, respondents' SDC were similar across treatments, suggesting that differences in choices made and WTP values are not likely due to differences in SDC of individuals across treatments.

Based on follow-up questions, we identified various factors related to perceptions about water obtained from reforestation and attitudes towards the valuation exercise that help to understand choices across treatments. The status quo option was selected 81 times out of 664 (12%) in the treatment not including any information about risk. For treatment 2 (risk framed as probability of success), the status quo option was selected 55 times out of 624 (9%), compared with 94 times out of 640 (15%) in treatment 3 (risk framed as probability of failure). The selection of the status quo option allows assessing for potential inconsistent responses. That is, where the status quo option was selected in choice set X, an inconsistent choice was determined if the respondent selected one of the non-selected alternatives in choice

[12]The person for the most part in charge of making financial decisions in the household.

set X over the status quo option in a different choice set (as per Wielgus et al. 2009). Inconsistent choices were minimal and almost identical across treatments as only three respondents made inconsistent choices in treatment one, one respondent in treatment two, and two respondents in treatment 3. We decided not to drop these respondents from the analyses because coefficient estimates were unaffected when excluding these participants.

The perceived complexity of the valuation exercise across survey versions appears not to be affected by incorporating risk. None of the respondents in treatment 1 perceived that the CE task was either complex or very complex. Two respondents in treatments 2 and 3 each perceived that the valuation exercise was complex. In addition, only one respondent selected a dominated choice in the survey version not including risk, compared with three who selected a dominated choice in treatment 2 and one respondent who selected a dominated choice in treatments 3. Respondents who selected a dominated choice appeared not to understand the CE task and were removed from all statistical analyses.

Estimation results from choice experiments

In all CLM specifications, all coefficients were statistically significant (Tables 3.3 and 3.4). The signs of the forest cover, water availability, and risk attributes are positive, which suggests that the higher the forest cover, water availability, and probability of success, the higher the probability of choosing an alternative in choice sets. The cost coefficient is negative, which suggests that the higher the cost, the lower the probability of choosing an alternative. The signs of all coefficients are invariant across model specifications, which may be a sign of robustness. The values of the adjusted pseudo R^2 indicate that model fit across model specifications is very good for this type of model (Hoyos 2010). The adjusted pseudo R^2 and Akaike Information Criterion (AIC) suggest that model specifications 2 and 3 have a better model fit for the treatment where risk is framed positively than the treatment where risk is framed negatively, suggesting that framing risk negatively leads to more data variability.

All coefficients were also statistically significant in all joint models (Tables 3.3 and 3.4). The signs of the forest cover, water, risk, and cost attributes are similar to those reported from model specifications 1, 2, and 3. This may be interpreted as a sign of robustness across the selected models. Results from joint model 1 indicate that the interaction term between the dichotomous variable accounting for treatments involving risk and water was significant and negative, indicating that the utility derived from water decreases when risk information is provided. These results can be expected, as it has been reported that individuals often prefer sure outcomes over a gamble that has equal or even higher expectation (Kahneman & Tversky 1984). This is particularly true if individuals are risk averse. Our findings indicate that respondent choices are influenced by information about risk.

Results from joint models 2 and 3 indicate that the interaction term between the dichotomous variables accounting for treatments where risk is framed as probability of success and water was significant and positive, indicating that the utility derived from water in survey versions involving risk increases when risk is framed positively. These results can also be expected as individuals often perceive information framed positively as gains and negatively as losses (Kahneman & Tversky 1979). A desirable gain should increase the utility of individuals. Our findings suggest that respondent choices are influenced by risk framing.

Households' WTP for reforestation and additional water-hours across model specifications and treatments are reported in Table 3.5. Results from treatment 1 (which is the only treatment used for model specification 1) indicate that households are willing to pay $2.04 and $3.29 per month for increasing forest cover by 140-180 and 300-340 hectares, respectively, and $0.035 for each additional water-hour. These WTP estimates are smaller than those reported in treatment 2 in model specification 2 where results indicate that households are willing to pay $5.24 and $6.41 for increasing forest cover by 140-180 and 300-340 hectares, respectively, and $0.04 for each additional water-hour. Additionally, WTP estimates from treatment 1 are smaller than those reported in treatment 2 in model specification 3, where results suggest that households are willing to pay $5.16 and $6.34 for increasing forest cover by 140-180 and 300-340 hectares, respectively, and $0.05 for each additional water-hour. WTP estimates from treatment 1 are also generally smaller than those reported in treatment 3 in model specification 2, where results show that households are willing to pay $4.11 and $4.70 for increasing forest cover by 140-180 and 300-340 hectares, respectively, and $0.026 for each additional water-hour. Results from treatment 3 in model specification 3 indicate that households are willing to pay $3.51 and $4.11 for increasing forest cover by 140-180 and 300-340 hectares, respectively, and $0.04 for each additional water-hour. Overall, respondents are willing to pay more for reforestation and additional water-hours when information about risk is provided and when risk is framed positively. With the exception of water from treatment 3 in model specification 2, all WTP estimates are higher in survey versions that include information about risk. Our findings also show that WTP for reforestation and additional water-hours are higher when information is presented positively.

We used the complete combinatorial approach suggested by Poe et al. (2005), which has been widely used to test for differences in WTP values in the CE literature (Carlsson et al. 2005; Rolfe & Bennette 2009; Glenk & Colombo 2011), to examine if value estimates are different across treatments. Results from the Poe et al. test reveal mixed results across model specifications (Table 3.6). We compared results from treatment 1 (model specification 1) with results from treatments 2 and 3 in model specification 2 to evaluate the effects of incorporating risk into the CE. WTP for increasing forest cover by 140-180 hectares in the watershed in model specification 1 is statistically different from treatments 2 (P-value=0.001) and 3 (P-value=0.007) in model specification 2. WTP for increasing forest cover by 300-340 hectares in model specification 1 is also different from those obtained in treatments 2 (P-value=0.001) and 3 (P-value=0.04) under specification 2. In contrast, WTP for additional water-hours in model specification 1 is not statistically different from treatment 2 (P-value=0.21), but statistically different from treatment 3 (P-value=0.10) under specification 2.

The effects of incorporating risk into the CE were also evaluated by comparing results from treatment 1 with results from treatments 2 and 3 in model specification 3. WTP for increasing forest cover by 140-180 hectares in the watershed in treatment 1 is statistically different from treatments 2 (P-value<0.01) and 3 (P-value=0.05) in model specification 3. WTP for increasing forest cover by 300-340 hectares in treatment 1 has statistically different values from treatment 2 (P-value<0.01), but not from treatment 3 (P-value 0.16) in model specification 3. WTP for additional water-hours in treatment 1 was found to be statistically different from treatment 2 (P-value=0.01), but not from treatment 3 (P-value=0.17) in model specification 3. Similar to model specification 2, WTP for reforestation and additional water-hours from the two treatments in model specification 3 are higher than results from treatment 1.

Results from this study demonstrate that WTP for reforestation and additional water-hours are higher when information about risk is provided to respondents[13]. Results from this study are different from those reported by Wielgus et al. (2009), who found higher WTP values for improvements in park recreational attributes in survey versions that do not include information about risk relative to surveys that do. Different reasons may explain the differences in WTP estimates. First, Wielgus et al.

[13] It is possible that differences in WTP values across model specifications may be a result of differences in the econometric method employed. For example, model specification 2 includes an additional variable to the model, relative to model specification 1. The omission of an important variable in the regression model may affect results, regardless of whether is risk or other important variable.

(2009) reported results for scenarios as a whole (i.e., changing in multiple attributes), not marginal WTP for a change in a single attribute as reported in this study. In addition, they used a different approach in the CE design. Risk was incorporated to all attributes in the form of intervals (i.e., distributions), not as a separate attribute as introduced in this study. This may have affected the way respondents processed the information in the two studies. Results from this study are also different from those reported by Glenk and Colombo (2011) who found no differences in WTP values for reducing greenhouse gas emissions in treatments that do not include details about risk relative to surveys that do. However, Glenk and Colombo (2011) adopted a within-subject design in which participants faced the initial CE task without information about risk; this was followed by a second version where risk information was provided. But this design, in which the order of the two was not randomized, may have caused a learning effect: participants may have used information gained from the first choice sets to complete the survey version that included risk information.

Other factors may explain why results from this study are different from those reported in previous literature. To some degree, people in this region have experienced land use change, including reforestation, during the last decades and still experience water scarcity problems. As a result, respondents in treatment 1 may have assigned relatively high perception about risk of project outcomes and made choices accordingly. It is possible that providing information about risk of project outcome in this study might have controlled for those high perceptions, allowing respondents to adjust their WTP for reforestation and additional water-hours.

Roberts et al. (2008) studied average water quality in Tenkiller Lake, Oklahoma, and reported similar results to those reported in this study in terms of higher WTP values in survey versions where risk was incorporated (they introduced risk to all attributes, not as a separate attribute, as designed in this study). The authors argued that differences in WTP estimates may be due to increased choice set complexity. Roberts et al. (2008) argued that when choices are more complex, consumers more critically evaluate the tradeoffs between the attributes that vary among the options. We utilized their arguments to examine results from this study. We examined the length of the survey (in terms of minutes) as a proxy of the effort respondents put toward responding to the valuation exercise (i.e., how much time it took for respondents to complete the surveys across treatments). We found that the length of the survey in this study was almost identical across treatments. Perhaps, respondents in this study did not more critically evaluate the tradeoffs between attributes when risk was incorporated, as argued by Roberts et al. (2008), and this may be because CE complexity did not increase across treatments, as reported in follow-up questions and focus groups.

Comparing results between treatments 2 and 3 in model specifications involving risk provides information about potential framing effects. In model specification 2, WTP for increasing forest cover by 140-180 hectares is not statistically different between treatment 2 and 3 (P-value= 0.17). However, increasing forest cover by 300-340 hectares has statistically different WTP values between the two treatments (P-value=0.07). WTP for additional water-hours was also found to be affected by the way risk is framed (P-value=0.03). In model specification 3, WTP for the two levels of forest cover is statistically different between treatments 2 and 3 (140-180 ha: P-value=0.08; 300-340 ha: P-value=0.03). However, WTP for additional water-hours is not statistically different between treatments 2 and 3 in model specification 3 (P-value=0.17). WTP estimates for reforestation and additional water-hours are smaller in treatment 3, relative to treatment 2.

Results from this study demonstrate that individuals are willing to pay more for different levels of reforestation and additional water-hours when risk is framed as probability of success rather than probability of failure. These results contrast with those reported by Kragt and Bennett (2012), who found lower WTP in survey versions where attributes were positively framed, and Howard and Salked (2009), who found mixed WTP values when risk was presented positively. Therefore, to date, the literature is mixed. We believe that more studies are required in this area of research in order to reach strong conclusions on risk framing in CE. Researchers have shown an increasing interest in the use of risk to describe project outcomes with the intent of improving the CE method (Roberts et al. 2008; Wielgus et al. 2009; Rolfe & Windle 2010; Glenk & Colombo 2011). Results from this study suggest that information about risk should be presented carefully to respondents, as the final goal of many CE studies is to inform decision makers in the implementation of policies or projects. This subject can be discussed in focus groups sessions or meetings with investigators with expertise in this area of research, such as experimental economists, to minimize potential effects caused from framing risk.

Results from model specification 2 allow for estimating risk values in treatments 2 and 3. Our findings show that respondents are willing to pay $4.89 and $6.38 for the risk attribute in treatments 2 and 3, respectively. This may be interpreted as respondents' WTP to reduce risk and increase the probability of success or the accuracy of predictions. Although participants are willing to pay more for reducing risk in survey versions where risk is framed negatively, value estimates are not statistically different from survey versions where risk is framed positively (P-value=0.18). Thus, framing does not affect the value of reducing risk, but it has significant effects on other attributes.

Another approach to understanding how risk affects outcomes is to compare results within treatments when risk enters in a different way into the utility function. WTP estimates from treatment 2 were compared using results from model specifications 2 and 3. WTP for reforestation and additional water-hours were not found to be different across model specifications in treatment 2 (140-180 ha: P-value= 0.45; 300-340 ha: P-value=0.46; water: P-value=0.13). WTP estimates from treatment 3 were compared using results from model specifications 2 and 3. Results from treatment 3 were mixed. Although WTP for reforestation were not statistically different (140-180 ha: P-value=0.25; 300-340 ha: P-value=0.26), WTP for additional water-hours was statistically different (P-value=0.03).

This study confirmed that WTP values can be affected by the manner in which models are specified. Although most WTP values are similar when comparing results from model specification 2 with results from model specification 3, WTP for additional water-hours was found to be affected by the way risk enters into the utility function. Similar results have been reported in the literature in terms of mixed WTP estimates for attribute improvements when specifying models differently (Roberts et al. 2008; Glenk & Colombo 2013). Researchers are often interested in estimating the value of a particular attribute-change to inform policymakers. This highlights the importance of assessing more than one model specification or dedicating considerable effort to identify the potential functional form of variables based on previous literature.

Conclusion

There is evidence that lack of information (Brown 2005), or the way the information is presented (Howard & Salked 2009; Kragt & Bennette 2012), in stated preference methods may drive respondents to behave differently when making choices and result in responses that do not reflect respondents' true preferences and WTP for the goods in question. In an attempt to provide relevant information in CE, researchers have recently included project outcome uncertainties (or risk) as a separate attribute in choice sets (Rolfe & Windle 2010; Glenk & Colombo 2011, 2013). However, the way this information is presented to respondents is likely to affect their responses. With an increasing interest in using CE to inform decision makers, research examining the reliability and accuracy of this method is needed. This study examined the effects of incorporating risk into the valuation exercise in an environmental setting to make the method more realistic and credible. Particularly, the study evaluated how results are affected when risk information is incorporated into the CE and risk is presented in different ways to respondents.

We found that households are willing to pay more for reforestation and additional water-hours when information about risk is presented and risk is framed as probability of success rather than probability of failure. However, given the relatively small sample sizes per treatment, the results of this study cannot be considered conclusive. Nevertheless, our findings highlight the importance of including information about risk of project outcomes as an integrated part of the CE design. When CE practitioners and policymakers do not consider risk of project outcomes in CE design, they may arrive at wrong conclusions. As a result, policy designs may be inefficient in allocating limited resources and fail to achieve social welfare maximization. This is particularly true as results from CE are often used to study the viability of project implementation (Ward 2006).

The economic valuation studies incorporating risk into the CE as a separate attribute in environmental contexts have framed risk in terms of either losses (Glenk & Colombo 2011) or gains (Rolfe & Windle 2010), as presented in this study. However, this information may be presented in other ways to respondents in order to increase the comprehension for this attribute and scenarios presented in choice sets. For example, future research might assess how respondents make choices when risk is presented in terms of both losses and gains (i.e., failure and success). Researchers may also use diagrams or drawings to illustrate information about risk or its corresponding levels.

Acknowledgements

This study was funded by NSF-IGERT grant # 0903479 and the USAID Borlaug Fellowship in Food Security grant # A1102.2. This project was approved by the University of Idaho Internal Review Board for work with human subjects (project 14-279). We are grateful to ASADAS' presidents and residents of the region for their participation in this study. We are grateful to officials of the SINAC regional office in Hojancha for their support in this research.

References

Alpízar, F., Carlsson, F. & Martinsson, P. (2003). Using choice experiments for non-market valuation. Economic Issues, 8, 83-110.

Arrow, K., Solow, R., Portney, R.P.R., Leamer, E.E., Radner, R., & Shuman, H. (1993). Report of the NOAA panel on contingent valuation. National Oceanic and Atmospheric Administration (U.S. Department of Commerce).

Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R., & Swanson, S. (2002). Economic valuation with stated preference techniques: a manual. Edward Elgar, Massachusetts, USA.

Birol, E., Smale, M., & Gyovai, A. (2006). Using a choice experiment to estimate farmers' valuation of agrobiodiversity on Hungarian small farms. Environmental & Resource Economics, 34, 439-469.

Bruijnzeel, L.A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems, and Environment,104, 185-228.

Calvo-Alvarado, J., McLennan, B., Sánchez-Azofeifa, A., & Garvin, T. (2009). Deforestation and forest restoration in Guanacaste, Costa Rica: putting conservation policies in context. Forest Ecology and Management, 258, 931-940.

Carlsson, F., & Martinsson, P. (2001). Do hypothetical and actual willingness to pay differ in choice experiments? Journal of Environmental Economics and Management, 41, 179-192.

Carlsson, F., Mørkbak, M.R., & Olsen, S.B. (2012). The first time is the hardest: a test of ordering effects in choice experiments. Journal of Choice Modelling, 5(2), 19-37.

Carlsson, F., Frykblom, P., & Lagerkvist, C.J. (2005). Using cheap talk as a test of validity in choice experiments. Economic Letters, 89, 147-152.

Champ, P.A., Boyle, K.J., & Brown, T.C. (2003). A primer on nonmarket valuation. Kluwer Academic Publishers, Norwell MA.

Colombo, S., & Hanley N. (2008). How can we reduce the errors from benefits transfer? An investigation using the choice experiment method. Land Economics, 84(1), 128-147.

Daily, G., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J., & Shallenberger, R., 2009. Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment, 7, 21-28.

Georgiou, S., Langford, I.H., Bateman, I.J., & Turner, R.K. (1998). Determinants of individuals' willingness to pay for perceived reductions in environmental health risks: a case study of bathing water quality. Environment and Planning A, 30, 577-594.

Glenk, K., & Colombo, S. (2011). How sure can you be? A framework for considering delivery uncertainty in benefit assessments based on stated preference methods. Journal of Agricultural Economics, 62, 25-46.

Glenk, K., & Colombo, S. (2013). Modelling outcome-related risk in choice experiments. The Austrialian Journal of Agricultural and Resource Economics, 57, 1-20.

Greene, W.H. (2012). Econometric analysis (7th edition). Prentice Hall, NJ USA.

Harrison, M., Rigby, D., Vass, C., Flynn, T., Louviere, J., & Payne, K. (2014). Risk as an attribute in discrete choice experiments: a systematic review of the literature. Patient, 7, 151-170.

Hensher, D.A. (2006). Revealing differences in willingness to pay due to the dimensionality of stated choice designs: an initial assessment. Environmental and Resource Economics, 34(1), 7-44.

Hensher, D.A., Rose, J.M., & Green, W.H. (2005). Applied choice analysis: a primer. Cambridge University Press, NY, USA.

Howard, K., & Salked, G. (2009). Does attribute framing in discrete choice experiments influence willingness to pay? Results from a discrete choice experiment in screening for colorectal cancer. Value in Health, 12(2), 354-363.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. Ecological Economics, 69, 1595-1603.

Ilstedt, U., Malmer, A., Verbeeten, E., & Murdiyarso, D. (2007). The effects of afforestation on water infiltration in the tropics: a systematic review and meta-analysis. Forest Ecology and Management, 251, 45-51.

Jakus, P.M., & Shaw, W.D. (2003). Perceived hazard and product choice: an application to recreational site choice. Journal of Risk and Uncertainty, 26, 77-92.

Kahneman, D., & Tversky, A. (1979). Prospect theory: an analysis of decision under risk. Econometrica, 27, 263-291.

Kahneman, D., & Tversky, A. (1984). Choices, awards, and frames. American Psychologist, 39(4), 341-350.

Knight, F.H. (1921). Risk, uncertainty and profit. Boston: Houghton Mifflin Company.

Kragt, M.E., & Bennett, J.W. (2012). Attribute framing in choice experiments: how do attribute level descriptions affect value estimates? Environmental and Resource Economics, 51, 43-59.

Krishnaswamy, J., Bonell, M., Venkatesh, B., Purandara, B.K., Rakesh, K.N., Lele, S., Kiran, M.C., Reddy, V., & Badiger, S. (2013). The groundwater recharge response and hydrologic services of tropical humid forest ecosystems to use and reforestation: support for the ‘‘infiltration-evapotranspiration trade-off hypothesis. Journal of Hydrology, 498, 191-209.

Ladenburg, J., & Olsen, S.B. (2008). Gender-specific starting point bias in choice experiments: evidence from an empirical study. Journal of Environmental Economics and Management, 56, 275-285.

Levin, I.P., & Gaeth, G.J. (1988). How consumers are affected by the framing of attribute information before and after consuming the product. Journal of Consumer Research, 15(3), 374-378.

List J.A., Sihna, P., & Taylor, M.H. (2006). Using choice experiments to value non-market goods and services: evidence from field experiments. Advances in Economic Analysis and Policy, 6(2), 1-37.

Louviere, J., Hensher, D., & Swait, J. (2000). Stated choice methods. Analysis and Application. Cambridge: Cambridge University Press, New York, USA.

Lundhele, T., Jacobsen, J.B., Strange, N., & Hanley, N. (2013). Incorporating policy outcome uncertainty in choice experiment valuation studies. European Association of Environmental and Resource Economists, 20th Annual Conference, 26-29 June 2013, Toulouse, France

Lusk, J.L., & Schroeder T.C. (2004). Are choice experiments incentive compatible? A test with quality differentiated beef steaks. American Journal of Agricultural Economics, 86(2), 467-482.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press, New York, USA.

Meyerhoff, J., & Liebe, U. (2009). Status quo effect in choice experiments: empirical evidence on attitudes and choice task complexity. Land Economics, 85(3), 515-528.

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

Pattanayak, S.K., Wunder, S., & Ferraro, P. (2010). Show me the money: do payments supply environmental services in developing countries? Review of Environmental Economics and Policy, 4, 254-274.

Poe, G.L., Giraud, K.L., & Loomis, J.B. (2005). Computational methods for measuring the difference of empirical distributions. American Journal of Agricultural Economics, 87(2), 353-365.

Roberts, D.C., Boyer, T.A., & Lusk, J.L. (2008). Preference under environmental quality under uncertainty. Ecological Economics, 66, 584-593.

Rolfe, J., & Bennette, J. (2009). The impact of offering two versus three alternatives in choice modeling experiments. Ecological Economics, 68, 1140-1148.

Rolfe, J., & Windle, J. (2010). Valuing protection of the Great Barrier Reef with choice modelling by managements policy options. Environmental Economics Research Hub: Research report #57.

Rose, J.M., Hensher, D.A., Caussade, S., Ortúzar, J.D., & Jou, R.C. (2009). Identifying differences in willingness to pay due to dimensionality in stated choice experiments: a cross country analysis. Journal of Transport Geography, 17, 21-29.

Sandström, K. (1998). Can forests "provide" water: widespread myth or scientific reality? Ambio, 27(2), 132-138.

Serrano-Dávila, M.E. (2005). Evaluación y planificación del manejo forestal sostenible en escala de paisaje en Hojancha, Costa Rica. M.S. Thesis, CATIE, Costa Rica.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. Science, 211, 453–8.

Von Neaumnn, J., & Morgenstern, O. (1981). Theory of games and economic behaviour. Princeton University Press, Princeton.

Wielgus, J., Gerber, L.R., Sala, E., & Bennett, J. (2009). Including risk in stated-preference economic valuation: experiments of choices for marine recreation. Journal of Environmental Management, 90, 3401-3409.

Table 3.1: Attributes and levels for the choice experiment

Attributes	Levels
Forest cover in the watershed surrounding the ASADA[a]	Same as current situation (Status quo), Between 140-180 more hectares than the current situation, Between 300-340 more hectares than the current situation
Water availability	Same as current situation (Status quo), 24, 72, 144, or 168 hours of additional water supply
Probability of success (failure)[b]	100% (0%), 60% (40%)
Cost per household per month[c]	₡0 (Status quo), ₡500, ₡1,000, ₡2,000, ₡3,000

[a] ASADA = Administrative Associations for Aqueducts and Sewers (Spanish acronym)
[b] This attribute was only included in treatments 2 and 3
[c] The currency exchange rate was 1 USD = 537 colones at the time of the survey

Table 3.2: Socio-economic and demographic characteristics of respondents across treatments

SDC	Description	Treatment 1 Mean (SD)	Treatment 2 Mean (SD)	Treatment 3 Mean (SD)
Observations[a]	Number of participants in each treatment	83	79	79
Gender	1=male, 0=female	0.43 (0.50)	0.35 (0.48)	0.41 (0.49)
Age	Age of respondents	46.42 (17.38)	45.39 (17.44)	49.32 (18.55)
Household income	Total household income per month (1= less than or equal to ₡200,000, 5= more than ₡800,000)	1.48 (0.88)	1.56 (0.93)	1.56 (1.00)
Education[b]	Education of respondents (1= none, 5= graduate school)	2.33 (0.77)	2.57 (1.03)	2.39 (0.85)
Garden	Respondents with a home garden (for their own consumption; 1=yes, 0=no)	0.22 (0.42)	0.35 (0.48)	0.23 (0.42)
Water yield	Respondents satisfaction with regard to water supply (1= very satisfied, 4= not satisfied)	2.61 (0.81)	2.72 (0.78)	2.78 (0.87)
Number of dependents	Number of household dependents	1.88 (0.81)	2.15 (1.49)	1.89 (1.47)
Complexity	Respondents perceived complexity of the CE task (1= very easy, 5= very complex)	2.64 (0.51)	2.62 (0.58)	2.73 (0.55)

SD= Standard deviation

[a] A total of 7 respondents were removed from the analysis as they failed to understand the CE task by selecting a dominated choice

[b] The description of categories for education is as follows: 1= None, 2= Primary school, 3= High school, 4= University, 5= Graduate school)

Table 3.3: Results from conditional logit model for model specifications 1 and 2

	Model 1	Model 2		Joint models	
Variables	Treatment 1 Coefficients (SE)[a]	Treatment 2 Coefficients	Treatment 3 Coefficients (SE)	Joint model 1[b] Coefficients (SE)	Joint model 2[c] Coefficients (SE)
Forest	-	-	-	-	-
140-180 hectares	0.7596** (0.20)	1.2650** (0.21)	1.0595** (0.18)	1.0397** (0.11)	1.1397** (0.14)
300-320 hectares	1.2251** (0.19)	1.5476** (0.20)	1.2129** (0.18)	1.3163** (0.11)	1.3586** (0.13)
Water	0.0131** (0.001)	0.010** (0.001)	0.0069** (0.001)	0.0106** (0.001)	0.0107** (0.001)
Risk	-	1.1805** (0.25)	1.6448** (0.25)	-	1.4196** (0.17)
Cost	-0.3727** (0.04)	-0.2414**	-0.2578** (0.03)	-0.2698** (0.02)	-.2498** (0.02)
Water x d_{risk}	-	-	-	-0.0021* (0.001)	-
Water x $d_{framing}$	-	-	-	-	0.0044** (0.001)
Number of choice	664	624	640	1,928	1,264
Adjusted pseudo	0.3	0.29	0.21	0.25	0.25
Prob>χ^2	0.000	0.000	0.000	0.000	0.000
AIC	1,015.21	969.75	1,116.24	3,194.05	2,082.21

* Significant at 0.05, ** Significant at 0.01
[a] Standard errors (SE) in parentheses
[b] Joint model for all treatments
[c] Joint model for treatments 2 and 3

Table 3.4: Results from conditional logit model for model specification 3

	Model specification 3		Joint model
Variables	Treatment 2 Coefficients (SE)[a]	Treatment 3 Coefficients (SE)	Joint model 3[c] Coefficients (SE)
Forest	-	-	-
140-180 hectares	1.2563*	0.8720*	1.0024*
	(0.20)	(0.18)	(0.13)
300-340 hectares	1.5420*	1.0199*	1.2206*
	(0.20)	(0.18)	(0.13)
Water	0.0127*	0.0106*	0.0102*
	(0.001)	(0.001)	(0.001)
Cost	-0.2434*	-0.2483*	-0.2459*
	(0.03)	(0.03)	(0.02)
Water x $d_{framing}$	-	-	0.0029*
			(0.001)
Number of choice sets	624	640	1,264
Adjusted pseudo R2	0.30	0.21	0.25
Prob>χ^2	0.000	0.000	0.000
AIC	962.71	1,114.31	2,077.7

* Significant at 0.01
[a] Standard errors (SE) in parentheses
[b] Joint model for all treatments
[c] Joint model for treatments 2 and 3

Table 3.5: WTP ($) for increasing forest cover and additional water across treatments and model specifications*

Variables	Model 1	Model 2		Model 3	
	Treatment 1	Treatment 2	Treatment 3	Treatment 2	Treatment 3
Forest	-	-	-	-	-
140-180 ha.	2.04	5.24	4.11	5.16	3.51
	(1.03-3.05)	(3.39-7.09)	(2.74-5.47)	(3.35-6.97)	(2.15-4.87)
300-340 ha.	3.29	6.41	4.70	6.34	4.11
	(2.28-4.29)	(4.48-8.34)	(3.31-6.10)	(4.44-8.23)	(2.73-5.48)
Water[a]	0.035	0.04	0.026	0.05	0.04
	(0.03-0.04)	(0.03-0.05)	(0.02-0.04)	(0.04-0.07)	(0.03-0.06)
Risk	-	4.89	6.38	-	-
		(2.67-7.11)	(4.20-8.56)		

* 95% confidence intervals (in parenthesis) were estimated using the Krinsky-Robb method (Krinsky & Robb 1986, 1990)

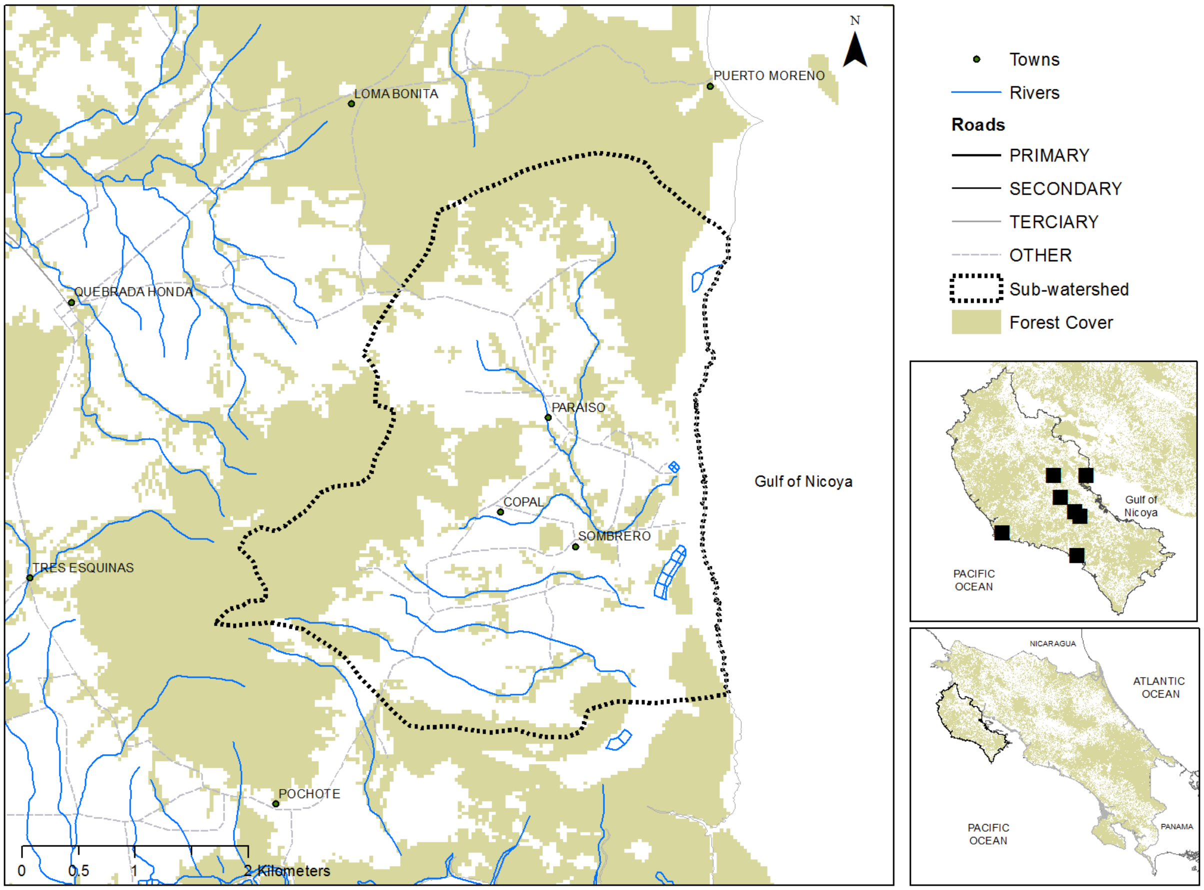
[a] For one water-hour

Table 3.6: Results of differences in WTP value estimates using the Poe et al. test

Model specifications and treatments	140-180 hectares	300-320 hectares	Water Availability	Probability of success
Model specification 1 and model specification 2				
Treatment 1 vs. Treatment 2	***	***	—	
Treatment 1 vs. Treatment 3	***	**	*	
Model specification 1 and model specification 3				
Treatment 1 vs. Treatment 2	***	***	***	
Treatment 1 vs. Treatment 3	**	—	—	
Model specification 2				
Treatment 2 vs. Treatment 3	—	*	**	—
Model specification 3				
Treatment 2 vs. Treatment 3	*	**	—	
Model specification 2 and Model specification 3				
Treatment 2 vs. treatment 2	—	—	—	
Treatment 3 vs. Treatment 3	—	—	**	

* Significant at 0.10, ** Significant at 0.05, *** Significant at 0.01, — not significant

Figure 3.1: An example of one of the maps used to illustrate the region under consideration for increases in forest cover*

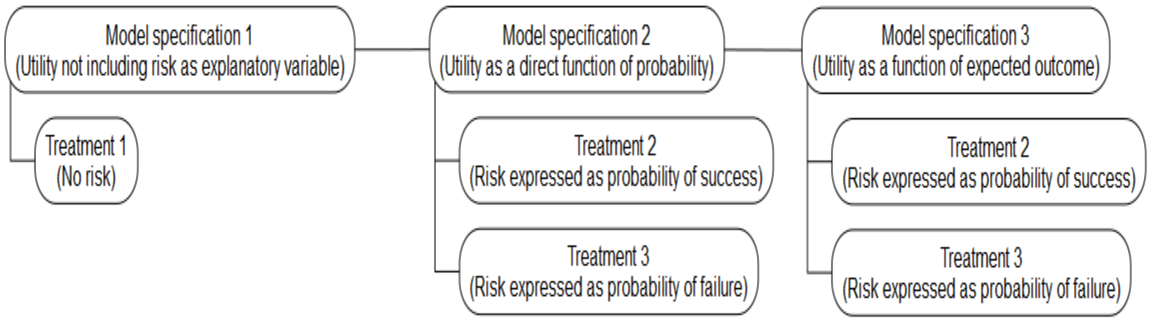


* Dotted line represents the watershed surrounding the ASADA

Figure 3.2: An example of a choice set involving risk presented to respondents

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 140 and 180 hectares more than current situation	Between 300 and 340 hectares more than current situation	Same as today
Water availability	72 hours more than current situation (equivalent of 3 days)	144 hours more than current situation (equivalent of 6 days)	Same as current situation
Probability of success	100%	60%	0%
Cost	₡2,000	₡3,000	₡0
	❑	❑	❑

Figure 3.3: All model specifications and data each model uses



Chapter 4. A Mixed-Methods Approach for Applying Local Ecological Knowledge to Ecosystem Service Valuation

Submitted to the Ecosystem Services Journal

Sara M. Galbraith, Troy E. Hall, Héctor S. Tavárez, Chad M. Kooistra, Jenny C. Ordoñez, and Nilsa A. Bosque-Pérez

Abstract

Attempts to measure the impact of land use change on ecosystem services (ES) typically focus only on landowners or aggregate the social impacts among diverse groups. There is a need for new approaches that focus on the value of ES change, especially for marginalized groups of non-landowners. We illustrate a mixed-methods approach for using local ecological knowledge to generate practical information for the valuation of ES. Our approach included mapping apiary locations (n=215) on a high-resolution land use map of the Nicoya Peninsula of Costa Rica to measure land cover used by beekeepers, then using a questionnaire (n=50) and follow-up interview (n=21) to understand beekeepers' land use preferences and perceptions of how land use change has impacted their provisioning services of honey and other income-generating products. Apiary maps revealed that hives are significantly more likely to be placed in pastures than in other land uses. However, questionnaire results demonstrated that beekeepers would prefer to place apiaries in secondary forest,

native tree plantations, or primary forest for access to floral resources from native tree species. In the interviews, beekeepers reported increased challenges to honey production due to the spatial and temporal change of floral resources, often as a result of land use change incentivized by national conservation policies. They also described adverse changes such as the loss of shade trees in pastures and interactions between land use and climate change. Beekeepers’ long-term observations provided information on resource changes from species to landscape scale and specific recommendations for improving ES management and conservation policies. Our method can be combined with approaches from other disciplines to contribute to more comprehensive ES valuation that includes spatially-explicit non-landowner perspectives.

Introduction

Ecosystem services and valuation

Since the publication of the Millennium Ecosystem Assessment (MEA 2005), scientists have been increasingly interested in understanding how changes in the environment impact the provision of ecosystem services (ES) (Fisher et al. 2009). Ecosystem services, the benefits humans derive from nature, include provisioning services, such as the production of lumber or food; regulating services, such as pollination or pest control; supporting services, such as carbon storage and nutrient cycling; and cultural services, such as recreational or spiritual use (MEA 2005). Many ES that are critical for human well-being are being degraded or used unsustainably worldwide, largely because of land use and cover change and land use intensification to produce food and energy for a growing population (MEA 2005). Growing concern for the negative outcomes from ES loss has resulted in development of diverse methods for the valuation of ES from ecological, economic, and social perspectives.

In this paper, we define valuation as the act of assessing, appraising or measuring the worth or importance of something, in this case ES from different land use and cover types (Gomez-Baggethun et al. 2014). Several ES-related challenges call for interdisciplinary mixed-methods approaches to consider, compare, or combine different valuation perspectives (Fontaine et al. 2014; Gomez-Baggethun et al. 2014). Examples of interdisciplinary ES challenges include ES trade-offs, where one service is increased at the cost of another (Jackson et al. 2005), intangible outcomes due to spatial and temporal mismatch of service production and reception (Brauman et al. 2007; Fremier et al. 2013), and unequal benefits to different stakeholders (Daw et al. 2011; Muradian et al. 2013).

Several conservation strategies worldwide incentivize "favorable" land uses and management for maximizing ES (Milder et al. 2010). These policies are often described as win-win solutions because they are designed to support human livelihoods while protecting ES (Muradian et al. 2013). Various approaches exist for valuation of different types of ES (Martin-Lopez et al. 2014). In terms of social valuation, the most well developed approaches are based in economics. However, some economic valuation methods have been criticized for providing biased estimates of value and not being consistent with economic theory (Hausman 2012; Kling et al. 2012). Furthermore, they often focus on landowners or aggregate values from different social groups, thereby underestimating the impact of small net economic changes for low-income groups (Daw et al. 2011). This can lead to policies that exacerbate inequality for already marginalized groups such as non-landowners.

To improve ES-related strategies, particularly for low-income, rural residents for whom small shifts in income could have the most impact (Milder et al. 2010), we must improve our ability to assess the impacts of land use and cover change from diverse stakeholder perspectives (Gomez-Baggethun et al. 2014; Martin-Lopez et al. 2014). Here, we use a combination of data collection methods (mapping, questionnaire, and interview) and analytical approaches (i.e., GIS analysis and assessment of local ecological knowledge) in a study of beekeepers in the Nicoya Peninsula of Costa Rica to determine how they perceive the value of different land use and cover types to sustain bee populations. Results provide useful insights for improving ES management practices and conservation policies at relatively low cost. These mixed-methods can be combined with other methods, such as economic valuation of non-market goods, for integrated ES valuation.

Local ecological knowledge (LEK) for valuation of ES among land use and cover types

Because of the scope, complexity, and uncertainty of global environmental problems, various types of knowledge are needed tobetter understand ES changes and associated impacts on human well-being (Raymond et al. 2010; Fagerholm et al. 2012). LEK is knowledge held by a specific group of people about their local ecosystems (Barber & Jackson 2015). LEK from geographically distant and ethnically different locations but with a similar agroecological context show strong similarities (Sinclair & Joshi 2000). Traditional Ecological Knowledge (TEK) is a subset of LEK, but while TEK is embedded in long-term culture and practices, LEK comes from more recent, site-specific, contextualized observations and experiments generated by local users over the last few generations (Gadgil et al. 2003). We drew from literature on both LEK and TEK for this study.

Research that considers TEK or LEK has identified different priorities and concerns among local communities than those perceived by external institutions and has shown that LEK can be used to identify gaps in scientific inquiry. Thus, including LEK is important for studies that seek to respond to environmental problems in a way that is both scientifically sound and considers local value systems and priorities (Gómez-Baggethun et al. 2013; Barber & Jackson 2015). There is increasing recognition of the role that LEK can play to inform environmental policy (MEA 2005; Turnhout et al. 2012; Gomez-Baggethun et al. 2013). Some examples include incorporating LEK into wildlife population monitoring (Moller et al. 2004) and marine conservation (Huntington 2000; Drew 2005). It has also been used to improve technical interventions and land management for livestock (Thapa et al. 1995), coffee (Albertin & Nair 2004; Cerdán et al. 2012), plantain (Polidoro et al. 2008) and cocoa agroforestry systems (Dahlquist et al. 2008; Anglaaere et al. 2011).

While Costa Rica has become well known for novel conservation strategies, including payments for ecosystem services (PES), there is still significant potential for research focused on the impacts of land use changes that occurred over the last half century, particularly for local residents who are not receiving payments but are otherwise impacted by land use and cover change. Efforts of ES valuation in Costa Rica have often measured the direct economic outcomes for landowners who have converted land into protected forest or protected existing forest patches, but have failed to consider implications for other stakeholders. For example, Milder et al. (2010) assessed the current status and future potential for PES to alleviate poverty in developing countries, but only suggested solutions for landowners or stewards, who would receive payments and make decisions about land use and management. Similarly, McLennan and Garvin (2012) investigated the impacts of land use and cover change on landowner livelihoods in Northwestern Costa Rica. Their study focused on sustainable rural livelihoods, but did not look at any groups who may utilize ES without receiving payments or making land use decisions. In contrast to these studies, Caceres et al. (2015) conducted a more integrated study of the ES values in a region of Argentina and compared diverse stakeholder perspectives. Their approach showed that diverse stakeholders perceived different ES from the same land uses, and demonstrated the need for methods to capture this diversity as part of ES valuation.

Study objectives

Our objectives were: 1) to illustrate a mixed-methods approach using mapping and LEK to generate practical information applicable to ES valuation; 2) to use this approach to assess and explain changes in ES provision, as perceived by beekeepers in the Nicoya Peninsula, examining how this has been influenced by conservation policies; and 3) to contribute to the discussion of the impact of land use and cover change on ES for non-landowners so as to achieve more integrated valuation of ES by including diverse social groups and perspectives.

Study region

The study was part of an interdisciplinary effort to understand the impact of conservation incentives in the Nicoya Peninsula (Figure 4.1). The peninsula, bordered by the Pacific Ocean to the west and the Gulf of Nicoya to the east, is a mix of seasonally dry and moist tropical ecological life zones (Calvo-Alvarado et al. 2009). Currently, the peninsula is dominated by secondary forest regrowth, pasture, tree plantations, and agricultural crops (Serrano 2005), but in recent history, the region has undergone dramatic changes in land cover. Due to high beef prices and a growing cattle industry, extensive dry tropical forest in the peninsula was converted to pasture from the 1950s to mid-1970s (McLennan & Garvin 2012). However, a drop in the international beef market combined with a severe El Niño-induced drought in the late 1970s resulted in land abandonment and migration from the region. Over subsequent years, supported by landscape stewardship led by local institutions and policy reforms that focused on forest protection, much of the pasture regenerated into secondary forest (Vallejo et al. 2006), and in some counties forest cover increased from 14% to 52% between 1970 and 2005 (Serrano 2005).

Nationally protected areas, regulation of extraction of products from natural forests, forestry incentives, and a national PES scheme were created to incentivize reforestation and protection on private lands (Vallejo et al. 2006). Though PES may have had a role in reforestation of the Nicoya Peninsula, some of the PES-sponsored reforestation has occurred in the form of monoculture plantations of introduced species like teak (*Tectona grandis*) and melina (*Gmelina arborea*). The ownership of these plantations is common among landowners who receive PES in the peninsula (Cárdenas et al. 2014). While the Costa Rican PES plan states goals for decreasing poverty, participation in the program is more common among landowners with larger properties, higher education levels, and absenteeism (Zbinden & Lee 2005) and may in some instances exclude traditional uses and users (Pagiola et al. 2005).

Case study: Beekeeper LEK

Beekeeping is an important rural livelihood strategy in many countries worldwide (Bradbear 2009), with some of the highest honey-producing countries located in Latin America (Vandame & Palacio 2010). There are an estimated 400-500 beekeepers in Costa Rica, and many of the hives are located in the province of Guanacaste (Dr. Johan W. van Veen, personal communication), where the Nicoya Peninsula is located. The global demand for honeybee (*Apis mellifera)* pollination services is outpacing the honeybee stock, with implications for crop production and biodiversity maintenance (Aizen & Harder 2009). With pollinator populations decreasing and increasing rates of colony collapse among honeybees (Potts et al. 2010), it is of pressing importance to understand how human activities influence bee populations (Vanbergen 2013). Therefore, we focused on the perspectives of commercial beekeepers.

Beekeeping occupies a unique niche because it does not require landownership, provides an essential ES for agriculture and biodiversity maintenance and relies on other ES in the form of pollen and nectar resources from flowering plants. Beekeeping takes advantage of existing floral resources without requiring deforestation or competing with other livelihood strategies or conservation efforts in the landscape (Brown 2001; Brown 2009; Ingram & Njikeu 2011). Beekeepers generally have an extensive knowledge of the quantity, quality, and location of floral resources for honeybees based on the production of their colonies and location of successful hives. The potential of using this type of LEK to understand and interpret observations of land use and cover change has been historically underappreciated and largely untapped (Kleinman & Suryanarayanan 2012).

Methods

Data collection

Our mixed-methods approach included a mapping exercise, questionnaire, and semi-structured interview, which were applied to beekeepers in the Nicoya, Hojancha, Nandayure, and peninsular Puntarenas Counties. Data were collected from March to November of 2014. The questionnaire was given to 50 beekeepers whom we located using beekeeping association records (Jicaral Beekeeping Association, n=21; Chorotega Beekeeping Association, n=17), or, in the case of non-members, through chain referrals (n=12). The Jicaral and Chorotega Beekeeping Associations are the only two beekeeping associations within the study region, thus our survey was conducted with the majority of working beekeepers in this area.

The primary purpose of the questionnaire was to collect information on beekeepers' preferences for different land use and cover types. In addition to providing socio-demographic information and information about their business practices, respondents were asked to rate the importance of 12 land use and cover types for beekeeping on a five-point Likert-type scale from one (not important) to five (extremely important). To guide the mapping exercise, we asked respondents to rank the factors used when choosing apiary locations on a five-point Likert-type scale from zero (not important) to four (extremely important). They also listed the five most important floral resources in the region for beekeeping.

For the mapping portion, we obtained hive locations from beekeeping associations and several other participants who had GPS locations in their records. Beekeepers who did not have GPS locations identified the location of their apiaries on a physical map of the region. We used color printed cartographic maps (scale 1:50,000), which included roads, homes, and topography to maximize accuracy in identifying hive locations. Beekeepers also provided information on the number of hives kept at each apiary. In total, we mapped 215 apiaries representing 4,332 hives managed by the 50 beekeepers that responded to the questionnaire.

The semi-structured interview was focused on the Chorotega Beekeeping Association members and non-members within the northern portion of the study region. We restricted this sample to beekeepers with at least five years of experience beekeeping in the region (n=21), because the questions focused on participants' perspectives of land use and cover change over time. There were no interview refusals. We started each interview with the question: "How has land use and cover changed since you began beekeeping in the peninsula, and how has this affected your business?" We then allowed the conversation to continue, focusing on explanations for their questionnaire responses and topics such as characteristics of preferred land use and cover types and the impact of conservation policies on the resources available to beekeepers. We recorded the interviews to be transcribed verbatim and translated them from Spanish to English for later analysis.

Data analysis

We summarized and graphed questionnaire data using R version 3.2.1. Recorded conversations during the questionnaire portion and semi-structured interviews were transcribed and translated, and co-authors discussed material to find sections that were pertinent to our research questions. We then developed a codebook for identifying themes and relationships among themes in the interviews (Weston et al. 2001). Two of the researchers independently applied the codebook to the interviews across five iterations, calculating an inter-rater reliability agreement coefficient after each iteration, until reaching an acceptable reliability coefficient (Cohen's Kappa >0.80; Krippendorff 2004). Then all interviews were uploaded to NVivo, coded using the codebook, and analyzed for overall patterns related to the research objectives. Interviews were semi-structured, so that not every participant was asked the same questions in the same way. Therefore, it is inappropriate to interpret the importance of different themes based solely on the number of participants who included those topics. However, the questionnaires generated mean rankings of land use and hive selection variables and standard error of responses, which provided a quantitative measurement of agreement among participants to use in conjunction with interview data. In presenting results, we included interview excerpts that provide the most insight into the questionnaire results.

We used responses from the questionnaire to inform the mapping analysis, both to determine buffer zone distances for land cover analyses and to understand which variables were possible predictors of hive location. Hive mapping was performed on the Sistema Nacional de Áreas de Conservación (National System of Conservation Areas) land cover classification made through the National Forestry Inventory program, which has a spatial resolution of 10 meters (Ortiz 2013). We overlaid hive points as a feature class in ArcGIS 10, and added buffers of 500-meters and 2-kilometer radii from each point. We then calculated the total area of land cover types within each buffer zone. We chose the 500-meter buffer because studies have shown that this is a typical honeybee foraging range when resources are available (Schneider & Hall 1997). This radius was used to assess the land uses immediately surrounding apiaries. The 2-kilometer buffer was selected because honeybees will also forage at these larger distances (Beekman & Ratnieks 2000).

We recorded the land cover output of area within the 500-meter and 2-kilometer hive buffers to assess the total area of each cover type per apiary. In addition, we combined all apiary buffer zones into a single polygon. We calculated the mean proportion of hive buffer zone overlap by dividing the summed areas for individual hive buffer zone from the combined polygon. We generated a convex hull feature around the two primary regions of usage and generated random points (n=215) within each of these features to compare beekeeper land use to land uses surrounding randomly selected locations.

We compared actual to random hive placement using logistic regression, which is an established method for assessing wildlife resource selection (Keating & Cherry 2004; Baash et al. 2010). This method allows researchers to assess habitat usage of animals by comparing presence-only data to habitat availability within a constrained region. In this case, we determined habitat selection for bees by beekeepers using the standard logistic regression equation:

$$P(i) = \frac{\exp(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3})}{1 + \exp(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3})}$$

Where β values are coefficents that relate the probability of use [i.e., P(i), or in this case probability of hive placement] to the habitat covariates x_{i1} (the proportion of forest), x_{i2} (the proportion of pasture) and x_{i3} (the proportion of forest plantations) for sample *i*. The results show the odds of finding a hive in a particular set of land uses.

We exponentiated the output to determine the odds that a point would be an actual hive versus a “random hive” based on land use proportions.

Results

Socio-demographic information about respondents

Ninety percent of beekeepers who completed the questionnaire were male, and approximately half of the participants had a primary school education only. Participants ranged from 21 to 77 years of age (mean=51). The average beekeeper had 17.4 years of experience beekeeping in the Nicoya Peninsula (range of 1 to more than 50 years of experience). The average participant had 4 to 5 apiaries and about 126 hives. Approximately half (n=24) of the beekeepers made less than $5,000 U.S. dollars gross income annually from beekeeping, and one third of participants (n=15) made over $8,000 annually from beekeeping.

Apiary site selection

When asked the distance they considered around potential apiary sites, the mean response by beekeepers was 2.1 kilometers (SE= 1.3 kilometers) with a range from 100m to 6 -kilometers, bracketing the 500m and 2-kilometer buffers used in our landscape analysis. Output from the mapping exercise showed that: 1) at a 500-meter range from the hives, the mean area around the apiaries is mostly pasture, followed by forest (Figure 4.2); 2) at a 2-kilometer range from the hive, the mean area around the apiaries is mostly forested, followed by pasture lands (Figure 4.2); and 3) there is a substantial overlap of buffer zones, particularly at the 2 kilometer range (38.8%). The overlap of buffer zones is important because questionnaires revealed that beekeepers generally seek to avoid other beekeepers' apiaries, which was indicated in questionnaire results (Figure 4.3).

Results from the logistic regression of land use for actual and random hives revealed that at the 500-meter buffer zone, only the coefficient for pasture was significant, indicating beekeepers actively select apiary locations based on the amount of pasture within 500-meters (Table 4.1). Based on the odds ratios, which is the exponentiated probability function, for each percent increase in pasture within the buffer zone, points are 1.2 percent more likely to be an actual apiary versus a randomly placed apiary (p=0.002). At the 2-kilometer range, the complete coverage of apiary buffer zones within the constrained region prevented statistical analysis because hives could not be randomly located with a different land cover distribution than the existing hives, so results would underestimate beekeeper land use selection.

Beekeeper land use and cover preferences

Questionnaire results demonstrated that beekeepers consider land use and other biophysical factors when choosing where to place their hives (Figure 4.3). On average, the most important variables for determining hive location were proximity to water (3.5/4), surrounding land uses (3.2/4), tree diversity in the region (3.1/4), and distance from other beekeepers' apiaries (3.1/4). During the interviews, respondents explained that proximity to water is important because it decreases the number of trips they have to make to tend the hives, and because high quality water resources improve bee health and production. Water was also related to land use and cover. For example, one beekeeper said, "*The melon farms have another problem: there is no water there. The bees have to spend a certain amount of time searching for water... they die of thirst in the melons because they don't put water there. There are no rivers, no streams, nothing. Just melon farms*." Another beekeeper noted a connection between water resources and floral resources: "*We prefer to put the hives close to rivers because the water is there, but also a higher diversity of plant species*."

The land use types ranked as most preferred for beekeeping were secondary forest (4.5/5), native tree plantations (4.3/5), primary forest (4.2/5), and shade coffee (3.9/5) (Figure 4.4). These were notably different from the locations where hives are actually placed, namely pastures. Native tree plantations are not currently a significant land use in the region, but several beekeepers take their hives to laurel (*Cordia alliodora)* plantations in Upala, which is north of the study region. Shaded native pasture was ranked significantly higher than improved pasture with shade trees (2.4/5), improved pasture species with no shade trees (2.2/5), and native pasture with no shade trees (2.1/5). Beekeepers explained that improved pastures, where new species of grasses have been introduced to improve productivity for livestock, will eventually compete for water with shade trees. One beekeeper noted that "*they removed all of the natural pastures of the region, like the jaraguá and the brama, and put all these improved grasses; brisanta, tanzania, guinea... there used to be some trees in the natural pastures, but those grasses are killing them, and the trees won't survive.*"

Beekeepers were also asked in the questionnaire to list the five most important plants needed for beekeeping in the region. Of the 231 plants listed, 79% were native trees, including the five most common plants mentioned (Table 4.2). In the interviews, 10 beekeepers emphasized the temporal availability of floral resources as the main reason why they value certain plants over others. For example, a common weed in pastures, florecilla, helps beekeepers sustain the harvest during the rainy season: "*The florecilla... it flowers in the rainy months, when no one harvests the honey. It is just for the bees. It is one of the most important flowers because it helps you in the wet season so the hive survives*." The high value of native trees also explains why beekeepers ranked shade coffee (3.9/5) significantly higher than sun coffee (3.1/5) in the questionnaire.

Melina (1.9/5) and teak (1.3/5) had the lowest preference values among the land use types. Several explanations for this trend were revealed during follow-up interviews, all related to the availability of flowers: "*Reforestation with plantations does affect [beekeeping] because teak just flowers once, in the wet season. I have never found it flowering in the dry season. On the other hand, with native species, as there are* *many types, there are always flowers, and everything does not flower at the same time*." Several beekeepers perceived that teak, in particular, does not serve as a floral resource for bees: *"A long time ago, there was more pasture than lumber, but the pasture had trees, shade. So, the pastures had a lot of different trees that gave shade. Now there are no pastures, but there is melina and teak, that doesn't give anything to the bees, nor to the animals... Not even the birds like it*." When comparing plantations to the improved pastures, one beekeeper explained that, "*In the case of Hojancha, when it's October, there is nothing that produces pollen and some farms are empty, so the improved pasture flowers and produces pollen... It's not as if we aren't going to produce without it, but in this season it is useful*."

The questionnaire results, combined with explanation from interviews, support our analysis of hive location trends with regard to land use and cover, as several of the most important factors considered for hive placement are connected to the current land use and cover types in the surrounding area. Although beekeepers prefer forested land uses, they routinely locate their hives around pastures as a strategy to access forested regions that are either logistically difficult to enter or prohibited by law due to their protected status. This is confirmed by the high proportion of pasture at the small buffer distance and high proportion of forest at the large buffer distance.

Perceived changes in location, abundance, and quality of floral resources for honeybees

In the interviews, respondents described trends in land use change and the resulting impact on floral resources for beekeeping. Reforestation with tree plantations was described by seven of the beekeepers as "deforestation," as they lose valuable resources when teak replaces the natural plant succession that might otherwise occur in abandoned pastures. One beekeeper noted that "*the teak and melina plantations affect us a lot because* [prior to planting] *those were young secondary forests and they chopped everything down."* Another beekeeper said*, "everybody cuts when they are going to 'reforest.' They remove everything that is native, which is what gives honey, let's say, flowers, vines, and young forest growth*." Beekeepers also had a long-term perspective on reforestation: "*The thing is that they 'reforested' a bunch of farms here, and when they are 15 years old, they cut everything down and leave things worse off, because they had to cut native trees to plant them*."

Eleven of the beekeepers raised concerns about the loss of preferred tree species due to the introduction of improved pastures in the region. During the interviews, three of the nine most important tree species for beekeeping listed in Table 4.2 were referred to as decreasing due to wood harvest or competition with improved pastures. One beekeeper said, "*People, when they cut trees, go to search for an economic harvest… they cut gallinazo, yes they have cut the pochote, yes they have cut the guanacaste, yes they have cut the cenizaro.... I am mentioning four, but we are talking about cachimbo, laurel... there are many.*" Another beekeeper said, "*Now we are seeing that the improved grasses are having problems like, they are drying the* *trees that are near the grass. So if there was a tree in the middle, a pochote for example, or gallinazo -- which was very good -- now they are dry.*"

There were also several neutral or positive comments about land use change over time in the region. For example, one beekeeper said, "*Before, there was a lot more deforestation...We are talking about 30 years ago... But, many people who have livestock now are leaving a protected area to grow... in this sense, the people have more conscience about leaving natural forest to grow; the changes have been magnificent*."

Impact of conservation policies on beekeeper livelihoods

Beekeepers are prohibited by law from keeping hives within national parks. Of the six beekeepers who explicitly mentioned national parks or reserves in the interviews, four were concerned with the lack of access and two explained that they can easily access the parks by placing hives at the forest edge. Two of the beekeepers in the interviews explicitly mentioned Monte Alto, a reserve in Hojancha County. One beekeeper said, "*There's plenty of forest right now. More forest--Because Monte Alto was protected. It was once a livestock farm and now has become a protected forest*." Another beekeeper mentioned that, "*yes, here [near Monte Alto] there have been good changes for beekeepers. Reforestation. Before, all of this was deforested. Now it is different.*"

PES also have impacted beekeeper livelihoods by encouraging forest conservation, secondary forest regeneration, and the establishment of teak and melina plantations. PES lands contracted for natural forest types are seen favorably by beekeepers, but plantations are seen as poor resources because they are established in place of secondary forest regrowth, they are planted as monocultures, the understory is managed intensively, and they are ultimately harvested completely.

Restrictions on native tree removal protect floral resources for beekeepers, but six participants mentioned the lack of enforcement locally. One beekeeper noted that, "*When you have a family and your family has to eat and you don't have a means to generate resources to get this food and you have property -- you have farms -- what you are going to do is cut a tree, sell it, and eat. That's how it works*." Another beekeeper stated, "*Wood production is a big problem for the bees. The wood harvesters take trees from everywhere. MINAE [a government agency] sometimes prohibits harvesting wood but... the more they try, the more wood people harvest*."

Discussion

Overall, mapping, interview, and questionnaire data combined demonstrate that non-plantation forests, followed by agricultural land uses containing native trees, are preferred for beekeeping. Given that pastures occupy such large portions of the landscape, native trees within pastures are perceived as important floral resources for beekeepers. In addition, pastures provide access to forested areas. Land uses that are mostly monocultures, such as teak and melina plantations, melon, and pastures without shade trees, are less preferred for beekeeping activities.

Methodological insights

Our study demonstrated the importance of mixed methods approaches to properly integrate LEK into ES valuation. Hive mapping was helpful to identify land cover types currently in use by beekeepers, showing that beekeepers mostly place their hives in or near pasture and native forest, and that there is considerable overlap between hive foraging ranges at a 2-kilometer buffer distance. In the questionnaire, beekeepers indicated that they prioritize avoiding other beekeepers' hives, so the overlap suggests that preferred locations are insufficient in the region. By combining map data with the questionnaire and interview results, policymakers could target certain regions of the peninsula, specifically by increasing floral resources in heavily utilized pastures, to increase provisioning services for beekeepers. Mapping, in the right context, also makes findings more appealing for policy applications than questionnaire and interview data alone (Hauck et al. 2012), and we demonstrate here that spatially-explicit descriptions of land use can provide insights into resource availability and use by non-landowners.

Reliance on mapping alone would have given a misleading picture, however. Specifically, questionnaires suggested that pastures are not valued as much as forest. Likewise, hives are sometimes placed near teak or melina, even though these were not highly valued in the questionnaire and interviews. The questionnaires lead us to interpret these mapping results as an effect of lack of access to preferred land uses (agricultural land uses and plantations being more accessible than natural forests). Given the diverse matrix in the landscape, apparently beekeepers still have indirect access to forest resources within 2-kilometer of their hives. The questionnaire also permitted us to explore the level of agreement among beekeepers. Because of the small variation in beekeeper preferences for different land use types, we can say with confidence that the group has relatively homogenous views. The questionnaire also provided the novel opportunity to apply participant-derived feedback towards map analyses, such as specifying the relevant buffer zone distances.

In addition to describing actual behavior (mapping) and explaining the basis for preferences (questionnaire), our study used interviews to reveal LEK related to impacts of land use and cover changes that occurred on multiple spatial and temporal scales. For example, interviews highlighted the use of different floral resources throughout the year, as well as changes in plant species that are valuable for beekeeping. This was particularly important, as there are limited data on the impact of introduced species beyond their economic value for plantation owners and employees. Beekeepers also stressed the adverse impact of teak management on valued ES, including the removal of early successional forests from pastures to establish plantations and the lack of understory plants that would otherwise provide resources for bees and other organisms.

Beekeeper LEK may also be useful in guiding biophysical research for better ES valuation. Biophysical studies of teak farms have found low biodiversity of plants and animals when compared to secondary forest, though some researchers argue that it is more justified to compare biodiversity in plantations with the biodiversity in land use and cover types such as pasture, which the plantations typically replace (Hallet et al. 2011). Beekeeper LEK provides evidence that, in some cases, it is reasonable to make ES comparisons between teak plantations and non-managed regional forests, as early successional secondary forest growth is sometimes removed to establish teak plantations. In addition, beekeepers knowledge demonstrated the value of regional pasture systems that include flowering native tree species.

Actionable insights for policymakers

This study provides practical LEK that can be used by policymakers, particularly because of beekeepers' detailed, long-term observations from the species to landscape scale. The main themes from beekeeper LEK include an emphasis on heterogeneity: they are most concerned about the diversity of flowering native plants both spatially and temporally in the peninsula. Several beekeepers explained that pastures, coffee, and other land use and cover types can be viable for beekeeping if there are shade trees, live fences, or small patches of forest, such as riparian areas. In addition, all of the plants listed by 15 or more of the participants are common trees used for shade or live fences in coffee (Albertin & Nair 2004) and pastures (Esquivel 2007) in the Nicoya Peninsula. This reinforces findings from previous work showing that live fences provide habitat, resources, and connectivity for wildlife in Central America (Harvey et al. 2005). The most valuable forms of reforestation for beekeepers, therefore, may be the PES modalities within the Costa Rica program that incentivize the use of shade trees in certain land uses (FONAFIFO 2013).

In addition, this study identified that access to preferred land use types is a major limitation for beekeepers, despite reforestation trends in the Nicoya Peninsula. At the 500-meter buffer distance, beekeepers are more likely to choose pastures than the random sample of points, although they utilize high proportions of forest at the 2-kilometer buffer zone. Based on questionnaire data, beekeepers clearly prefer native forests and native trees, so the placement of hives in pastures highlights the lack of preferred land uses. Since they are unable to use national forest or reserve areas in the region, some reforestation efforts have not benefitted them, except insofar as they can place hives in other land use and cover types at the periphery of parks and reserves. Policymakers could increase park utility by providing edges around parks and reserves that are accessible for local users.

Since many of the beekeepers rent the land where they place their hives, they are not necessarily eligible to receive PES or make choices about land use, cover, or management practices. Like other rural user groups, beekeepers are heavily impacted by land use change and often by conservation policies that are meant to guide land use and cover change in the region. Some of the PES go to landowners as compensation for adopting practices that adversely affect ES valued by beekeepers.

Conclusions and future research directions

LEK from beekeepers can be useful for policymakers, as beekeepers hold practical information on the impact of land use, land cover and management change on floral resources over long periods of time and across broad landscapes. Beekeeper TEK also provided information on the trade-offs of different conservation policies, such as harvesting regulations, protected national parks, and conservation incentives on private land. Such combination of methods can contribute to integrated valuation in cases where different stakeholder groups depend in different ways on natural resources; certain groups -- like beekeepers -- are impacted by land use and cover change or other policy outcomes but not in power to influence decision-making processes. Actively seeking out and including LEK as part of ES valuation would empower groups of stakeholders that are often marginalized, while providing useful information from species to landscape scales, and over long, sometimes multi-generational, time scales.

Our study revealed several opportunities for novel interdisciplinary study. Beekeeper LEK provided information on the decline of specific tree species due to the use of improved pasture. Additional studies are needed to understand the influence of land management practices on tree species distribution, particularly in improved pastures, and the impact on the biodiversity of organisms that depend on shade trees for landscape connectivity. Furthermore, future research could look at the impact these management changes have on rural livelihoods or cultural practices that depend on native trees, some of which provide additional resources such as edible fruits and seeds.

Beekeeper LEK revealed the need to study the impact of climate change on flowering phenology and distribution of native trees in Costa Rica. Nine of the 21 beekeepers interviewed mentioned seeing shifts in phenology, temperature, and precipitation, consistent with projections in scientific models for the region (Delgado et al. 2012). Such changes compound the impact of land use and cover change to make beekeeping more difficult. For example, one beekeeper said, "*The rain in the wet season prepares the honey harvest for the next year. Land use and the climate are both changing. Under normal conditions the harvest would be low, [and] land use accentuates the problem of the changing climate*." Several beekeepers mentioned the climate becoming drier and hotter. Another beekeeper explained that the timing of the rain is also an issue: "*the thing that is changing lately is the climate -- the rain. It rains [in the dry season] when the trees are already flowering and the flowers are ruined*." Though honeybees are non-native pollinators, they have served worldwide as an indicator species for changes happening in the environment. If climate shifts are impacting beekeepers and their livelihoods, there is a need to understand these patterns and their impacts on floral phenology and related processes, particularly in under-studied regions of the tropics.

Finally, future studies should combine methods such as those we present here with ES valuation from different disciplinary perspectives. For example, combining ecological data from monoculture tree plantations versus silvopastoral systems with LEK and valuation of various services of these land uses to different stakeholders will improve our understanding of potential trade-offs, as illustrated by this study. Economic valuation could quantify the extent to which land use and cover change have impacted groups such as beekeepers relative to the landowners who are receiving PES and who also depend on these land uses for their livelihoods. By combining social valuation methods with established ecological and economic methods, researchers can produce more integrated analyses to inform policymakers and improve conservation strategies for diverse stakeholder groups.

Acknowledgements

This project was funded by NSF-IGERT grant # 0903479 the USAID Borlaug Fellowship in Food Security # 12724. Research was conducted with approval from the University of Idaho Internal Review Board for work with human subjects (project 13-282).

References

Aizen, M.A., & Harder, L.D. (2009). The global stock of domesticated honey bees is growing slower than agricultural demand for pollination. Curr. Biol., 19, 915–918.

Albertin, A., & Nair, P.K.R. (2004). Farmers' perspectives on the role of shade trees in coffee production systems: An assessment from the Nicoya Peninsula, Costa Rica. Hum. Ecol., 32, 443–463.

Anglaaere, L.C.N., Cobbina, J., Sinclair, F.L., & McDonald, M.A. (2011). The effect of land use systems on tree diversity: Farmer preference and species composition of cocoa-based agroecosystems in Ghana. Agrofor. Syst., 81, 249–265.

Baasch, D.M., Tyre, A.J., Millspaugh, J.J., Hygnstrom, S.E., & Vercauteren, K.C. (2010). An evaluation of three statistical methods used to model resource selection. Ecol. Mod., 221, 565–574.

Barber, M., & Jackson, S. (2015). "Knowledge Making": Issues in modelling local and indigenous ecological knowledge. Hum. Ecol., 43, 119-130.

Beekman M., & Ratnieks F.L.W. (2000). Long-range foraging by the honey-bee, Apismellifera L., Funct. Ecol., 14, 490–496.

Bradbear, N. (2009). Bees and their role in forest livelihoods: A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. Food and Agriculture Organization of the United Nations, Rome.

Brauman, K.A., Daily, G.C., Duarte, T.K., & Mooney, H.A. (2007). The nature and value of ecosystem services: An overview highlighting hydrologic services. Annu. Rev. Environ. Resour., 32, 67–98.

Brown, J.C. (2001). Responding to deforestation: Productive conservation, the World Bank, and beekeeping in Rondonia, Brazil. Prof. Geogr., 53, 106–118.

Brown, M.J.F., & Paxton, R.J. (2009). The conservation of bees: a global perspective. Apidol., 40, 410–416.

Calvo-Alvarado, J., McLennan, B., Sánchez-Azofeifa, a., & Garvin, T. (2009). Deforestation and forest restoration in Guanacaste, Costa Rica: Putting conservation policies in context. For. Ecol. Manage., 258, 931–940.

Cáceres, D.M., Tapella, E., Quetier, F., & Diaz, S. (2015). The social value of biodiversity and ecosystem services from the perspectives. Ecol. Soc., 20, 1-19.

Cárdenas, J.M., Sepúlveda, C.J., Ibrahim, M., Tobar, D., Villanueva, G., & Rodríguez, E. (2014). Artículo I: Caracterización de fincas ganaderas con y sin pago por servicios ambientales bajo el marco de los capitales de la comunidad en la península de Nicoya, Costa Rica. M.S. Thesis: CATIE, Turrialba, Costa Rica.

Cerdán, C.R., Rebolledo, M.C., Soto, G., Rapidel, B., & Sinclair, F.L. (2012). Local knowledge of impacts of tree cover on ecosystem services in smallholder coffee production systems. Agric. Syst., 110, 119–130.

Dahlquist, R.M., Whelan, M.P., Winowiecki, L., Polidoro, B., Candela, S., Harvey, C. a., Wulfhorst, J.D., McDaniel, P.A., & Bosque-Pérez, N.A. (2007). Incorporating livelihoods in biodiversity conservation: a case study of cacao agroforestry systems in Talamanca, Costa Rica. Biodivers. Conserv., 16, 2311–2333.

Daw, T., Brown, K., Rosendo, S., & Pomeroy, R. (2011). Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. Environ. Conserv., 38, 370–379.

Delgado, D.L., Pérez, M.E., Galindo-Cardona, A., Giray, T., & Restrepo, C. (2012). Forecasting the influence of climate change on agroecosystem services: Potential impacts on honey yields in a small-island developing state. Psyche A J. Entomol., 2012, 1–10.

Drew, J.A. (2005). Use of traditional ecological knowledge in marine conservation. Conserv. Biol., 19, 1286–1293.

Esquivel Mimenza, H. (2007). Tree resources in traditional silvopastoral systems and their impact on productivity and nutritive value of pastures in the dry tropics of Costa Rica. Dissertation: CATIE, Turrialba, Costa Rica.

Fagerholm, N., Käyhkö, N., Ndumbaro, F., & Khamis, M. (2012). Community stakeholders’ knowledge in landscape assessments - Mapping indicators for landscape services. Ecol. Indic., 18, 421–433.

Fisher, B., Turner, R.K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecol. Econ., 68, 643–653.

Fontaine, C.M., Dendoncker, N., De Vreese, R., Jacquemin, I., Marek, A., Van Herzele, A., Devillet, G., Mortelmans, D., & François, L. (2013). Towards participatory integrated valuation and modelling of ecosystem services under land-use change. J. Land Use Sci., 9, 278–303.

Fremier, A.K., DeClerck, F.A.J., Bosque-Pérez, N.A., Estrada Carmona, N., Hill, R., Joyal, T., Keesecker, L., Klos, P.Z., Martínez-salinas, A., Niemeyer, R., Sanfiorenzo, A., Welsh, K., & Wulfhorst, J.D. (2013). Understanding spatiotemporal lags in ecosystem services to improve incentives. Biosci., 63, 472–482.

Gadgil, M., Olsson, P., Berkes, F., & Folke, C. (2003). Exploring the role of local ecological knowledge in ecosystem management: three case studies, in: Berkes, F., Johan, C., Folke, C. (Eds.), Navigating social-ecological systems: Building resilience for complexity and change. Cambridge University Press, Cambridge, UK, pp. 189–209.

Gómez-Baggethun, E., Corbera, E., & Reyes-García, V. (2013). Traditional ecological knowledge and global environmental change: Research findings and policy implications. Ecol. Soc., 18, 72.

Gómez-Baggethun, E., Martín- López, B., Barton, D., Braat,L., Saarikoski, H., Kelemen, M., García-Llorente, E., van den Bergh, J., Arias, P., Berry, L., Potschin, M., Keene, H., Dunford, R., Schröter-Schlaack, C., & Harrison, P. (2014). State-of-the-art report on integrated valuation of ecosystem services. European Commission FP7 OpenNESS Project Deliverable 4.1., EU FP7.

Hallett, J.T., Diaz-Calvo, J., Villa-Castillo, J., & Wagner, M.R. (2011). Teak plantations: Economic bonanza or environmental disaster? J. For., 109, 288–292.

Harvey, C.A., Villanueva, C., Villacís, J., Chacón, M., Muñoz, D., López, M., Ibrahim, M., Gómez, R., Taylor, R., Martinez, J., Navas, A., Saenz, J., Sánchez, D., Medina, A., Vilchez, S., Hernández, B., Perez, A., Ruiz, F., López, F., Lang, I., & Sinclair, F.L. (2005). Contribution of live fences to the ecological integrity of agricultural landscapes. Agric. Ecosyst. Environ., 111, 200–230.

Hauck, J., Gorg, C., Varjopuro, R., Ratamaki, O., Maes, J., Wittmer, H., & Jax, K. (2012). "'Maps have an air of authority'": Potential benefits and challenges of ecosystem service maps at different levels of decision making. Ecosyst. Serv., 4, 25-32.

Hausman J. (2012). Contingent valuation: from dubious to hopeless. Journal of Econ. Perspec., 26, 43-56.

Huntington, H.P., (2000). Using traditional ecological knowledge in science: Methods and applications. Ecol. Appl., 10, 1270–1274.

Ingram, V., & Njikeu, J. (2011). Sweet, sticky, and sustainable social business. Ecol. Soc., 16, 1-18.

Jackson, R.B., Jobbágy, E.G., Avissar, R., Roy, S.B., Barrett, D.J., Cook, C.W., Farley, K. a, le Maitre, D.C., McCarl, B.A., & Murray, B.C. (2005). Trading water for carbon with biological carbon sequestration. Science, 310, 1944–1947.

Keating, K.A., & Cherry, S. (2004). Use and interpretation of logistic regression in habitat-selection studies. J. Wildl. Manage., 68, 774–789.

Kleinman, D.L., & Suryanarayanan, S. (2012). Dying bees and the social production of ignorance. Sci. Technol. Hum. Val., 38, 492–517.

Kling, C.L., Phaneuf, D.J., & Zhao, J. (2012). From Exxon to BP: Has some number become better than no number? J. Econ. Perspect., 26, 3–26.

Krippendorff, K. (2004). Reliability in content analysis. Hum. Comm. Res., 30, 411-433.

Millenium Ecosystem Assessment (MEA). (2005). Ecosystems and human well-being: an assessment series (four volumes and summary). Island Press, Washington DC.

Martín-López, B., Gómez-Baggethun, E., García-Llorente, M., & Montes, C. (2014). Trade-offs across value-domains in ecosystem services assessment. Ecol. Indic., 37, 220–228.

McLennan, B., & Garvin, T. (2012). Intra-regional variation in land use and livelihood change during a forest transition in Costa Rica's dry North West. Land Use Pol., 29, 119–130.

Milder, J.C., Scherr, S.J., & Bracer, C. (2010). Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. Ecol. Soc., 15, 2, 1-19.

Moller, H., Berkes, F., Lyver, P.O.B., & Kislalioglu, M. (2004). Combining science and traditional ecological knowledge: Monitoring populations for co-management. Ecol. Soc., 9, 3, 1-15.

Muradian, R., Arsel, M., Pellegrini, L., Adaman, F., Aguilar, B., Agarwal, B., Corbera, E., Ezzine de Blas, D., Farley, J., Froger, G., Garcia-Frapolli, E., Gómez-Baggethun, E., Gowdy, J., Kosoy, N., Le Coq, J.F., Leroy, P., May, P., Méral, P., Mibielli, P., Norgaard, R., Ozkaynak, B., Pascual, U., Pengue, W., Perez, M., Pesche, D., Pirard, R., Ramos-Martin, J., Rival, L., Saenz, F., Van Hecken, G., Vatn, A., Vira, B., & Urama, K. (2013). Payments for ecosystem services and the fatal attraction of win-win solutions. Conserv. Lett., 6, 274–279.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, Dr., Chan, K.M., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H., & Shaw, Mr. (2009). Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Front. Ecol. Environ., 7, 4–11.

Ortiz, E. (2013). Mapa de tipos de bosque de Costa Rica. Inventario Nacional Forestal, Costa Rica.

Pagiola, S., Arcenas, A., & Platais, G. (2005). Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America. World Dev., 33, 237–253.

Polidoro, B.A., Dahlquist, R.M., Castillo, L.E., Morra, M.J., Somarriba, E., & Bosque-Pérez, N.A (2008). Pesticide applications, pest knowledge, and cost-benefits of plantain production in the Bri-Bri-Cabécar Indigenous Territories, Costa Rica. Environ. Res., 108, 98-106.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W.E. (2010). Global pollinator declines: trends, impacts and drivers. Trends Ecol. Evol., 25, 345–53.

Raymond, C.M., Fazey, I., Reed, M.S., Stringer, L.C., Robinson, G.M., & Evely, A.C. (2010). Integrating local and scientific knowledge for environmental management. J. Environ. Manage., 91, 1766–77.

Schneider, S.S., & Hall, H.G. (1997). Diet selection and foraging distances of African and European-African honey bee colonies in Costa Rica. Insectes Sociaux, 44, 171–187.

Serrano Dávila, M.E. (2005). Evaluación y planificación del manejo forestal sostenible en escala de paisaje en Hojancha, Costa Rica. M.S. Thesis, CATIE, Costa Rica.

Thapa, B., Sinclair, F.L., & Walker, D.H. (1995). Incorporation of indigenous knowledge and perspectives in agroforestry development. Part 2: Case-study. Agrofor. Syst., 30, 249-261.

Turnhout, E., Bloomfield, B., Hulme, M., Vogel, J., & Wynne, B. (2012). Conservation policy: Listen to the voices of experience. Nature, 488, 454-455.

Vallejo, A., Gutierrez, I., Chacon, M.L., Roojj, W. van, Davila, M.S., Arce, J.J.C., & Villalobos, R. (2006). Biodiversity- Human well-being linkages for teak farms in Hojancha, Nicoya Peninsula, Costa Rica. Case study commissioned by Netherlands Environmental Assessment Agency.

Vanbergen, A.J. (2013). Threats to an ecosystem service: pressures on pollinators. Front. Ecol. Environ., 11, 251–259.

Vandame, R., & Palacio, M.A. (2010). Preserved honeybee health in Latin America: a fragile equilibrium due to low-intensity agriculture and beekeeping. Apidologie, 41, 243-255.

Weston, C., Gandell, T., Beauchamp, J., McAlpine, L., Wiseman, C., & Beauchamp, C. (2001). Analyzing interview data: The development and evolution of a coding system. Qualit. Socio., 24, 381-400.

Zbinden, S., & Lee, D.R. (2005). Paying for environmental services: an analysis of participation in Costa Rica's PSA program: institutional arrangements for rural poverty reduction and resource conservation. World Develop., 33, 255–272.

Table 4.1: Output of logistic regression procedure. Significance at P<0.01 denoted with (**)

Coefficient	Estimate	SE	Z value	Pr(>|z|)	Odds ratio	95% confidence interval
Intercept	-0.6957	0.477	-1.460	-0.144	0.499	0.188, 1.243
Forest	-0.001	0.006	-0.157	0.875	0.999	0.099, 1.010
Pasture	0.017	0.006	3.046	0.002**	1.017	1.006, 1.028
Tree plantation	-0.004	0.009	-0.413	0.680	0.996	0.978, 1.014

Table 4.2: Plants reported as most valuable for beekeeping. Plants are listed in order from most to least mentioned. Data include the proportion of participants who listed the plant as one of the top five most important for beekeeping (Proportion of participants) and proportion that the given plant comprises of the total list of plants mentioned, including those not displayed in the table (Proportion of mentions). Plant categories are: native tree (NT; any tree considered native by the local population), vine, or herbaceous plant (herb). We include all responses that were mentioned by at least 5 beekeepers (10% of participants).

Common name	Scientific name	Number of mentions	Proportion of participants	Proportion of mentions	Plant category
Carao	*Cassia grandis*	22	0.46	0.1	NT
Madroño/Salamo	*Calycophyllumcandidissimum*	21	0.44	0.09	NT
Saino	*Caesalpiniaeriostachys*	21	0.44	0.09	NT
Gallinazo	*Schizolobiumparahyba*	18	0.38	0.08	NT
Laurel	*Cordia alliodora*	15	0.31	0.06	NT
Pochote	*Pachiraquinata*	15	0.31	0.06	NT
Bejuco	NA: vines	10	0.21	0.04	Vine
Espavel	*Anacardiumexcelsum*	9	0.19	0.04	NT
Florecilla	Asterácea: eg.,*Melampodium sp.*	9	0.19	0.04	Herb
Palo de agua	*Bravaisia integerrima*	9	0.19	0.04	NT
Guacimo	*Guazumaulmifolia*	5	0.1	0.02	NT

Figure 4.1: Map of the study region. The Nicoya Peninsula is located in the province of Guanacaste, and we included four counties within the peninsula: Nicoya, Hojancha, Nandayure and Puntarenas.

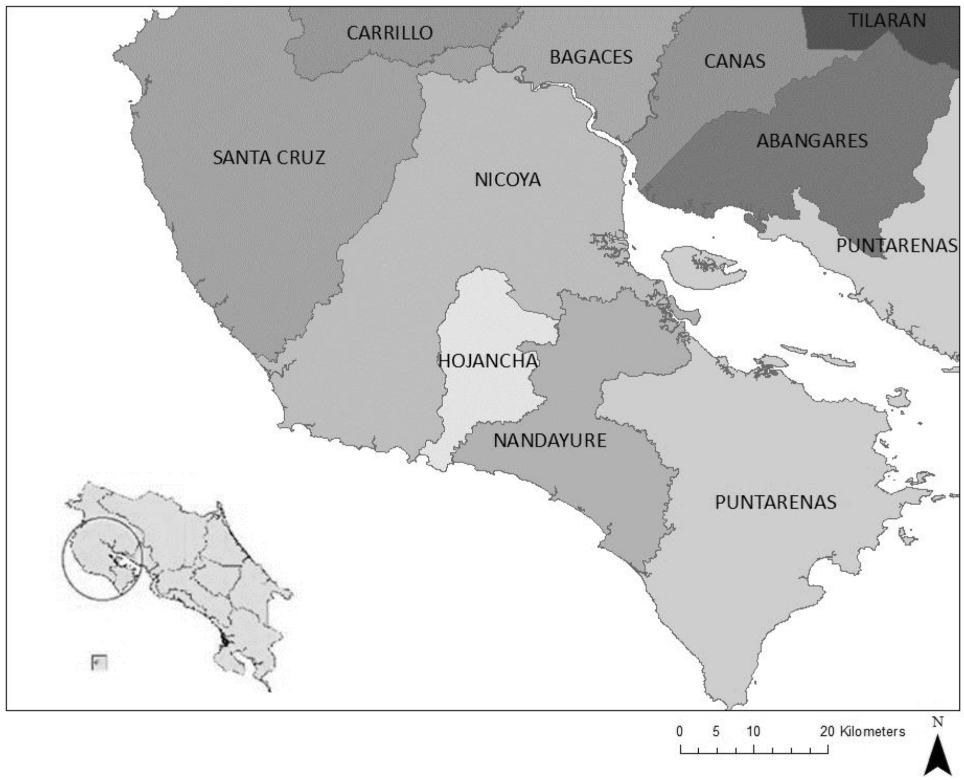


Figure 4.2: Proportion of land cover types surrounding apiary locations. Columns represent mean proportion of land uses for the 215 hives, sampled at 500-meter and 2 kilometer radii. Bars represent standard error.

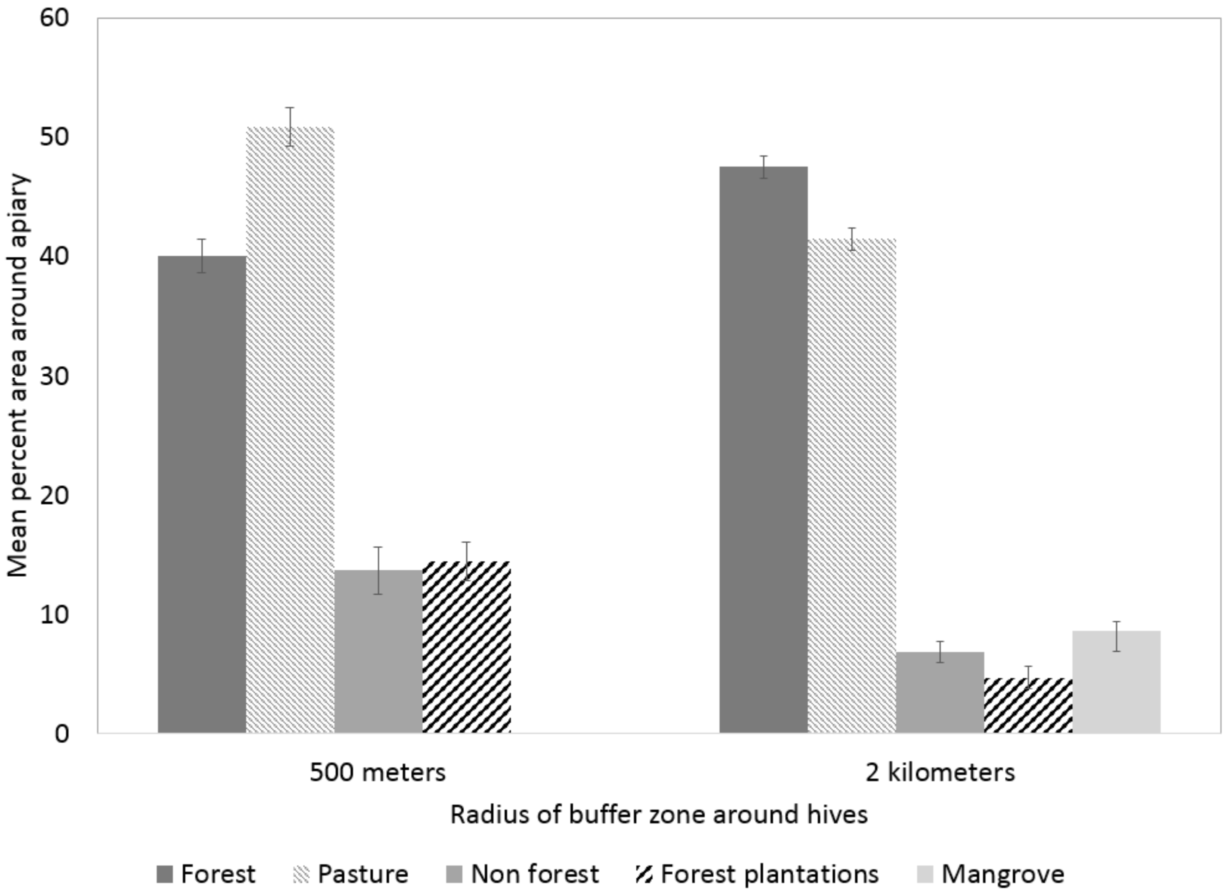


Figure 4.3: Importance of factors for selecting apiary locations. Columns represent mean responses based on 5-point Likert scale from 0 (not important) to 4 (extremely important). Error bars represent standard error.

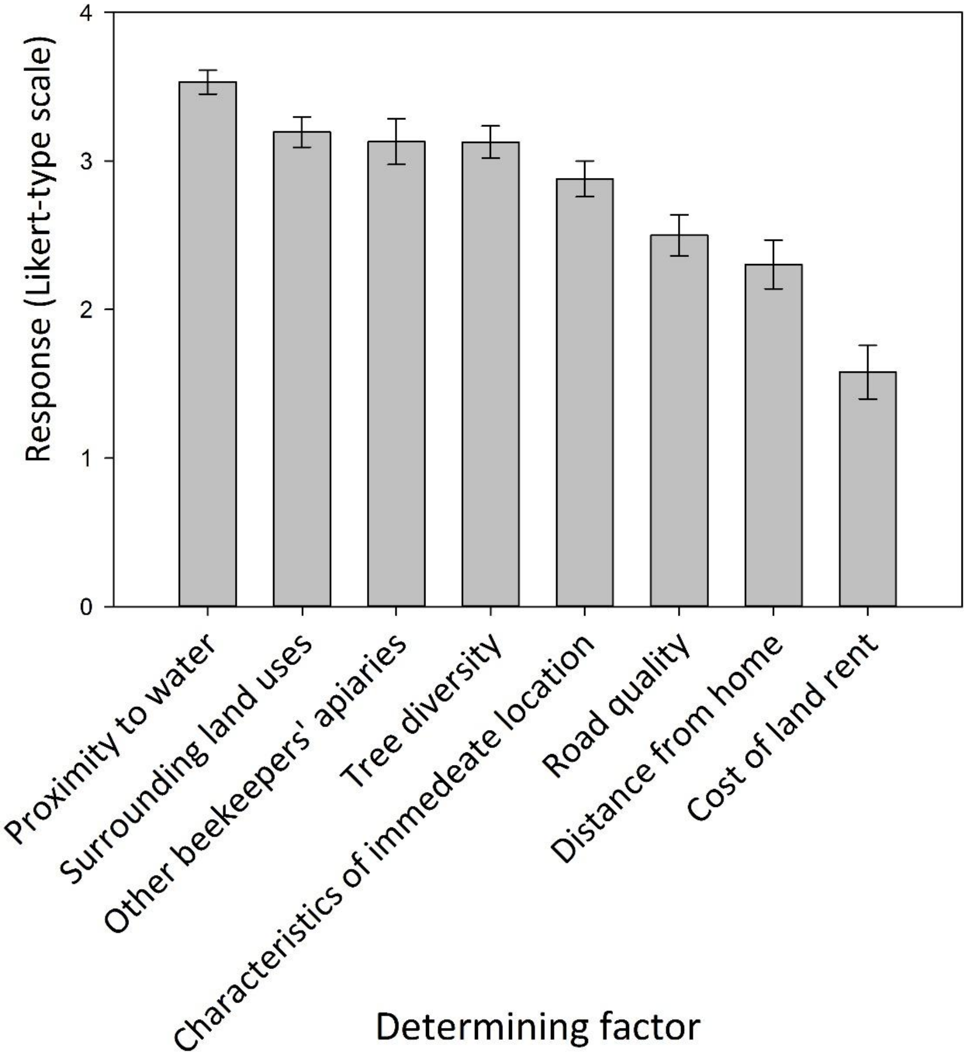
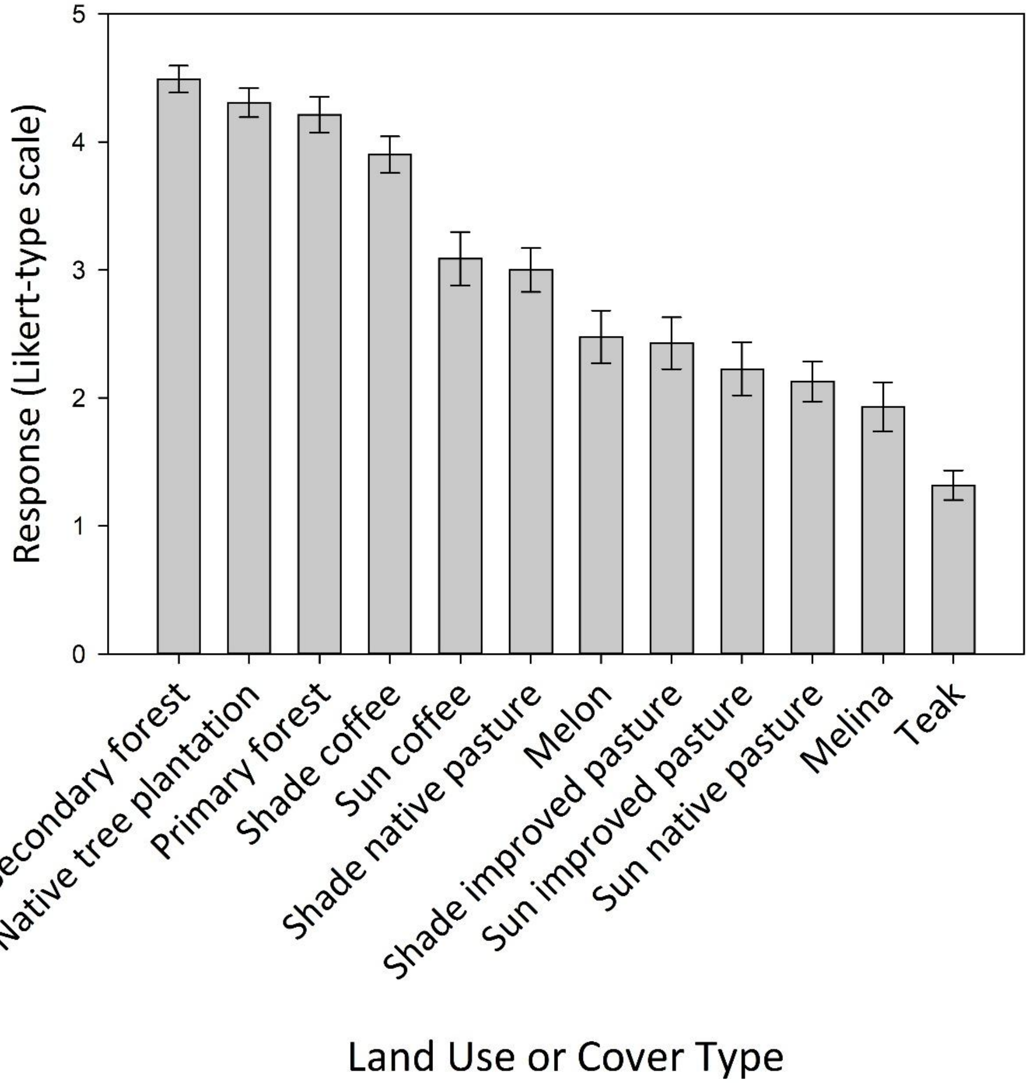
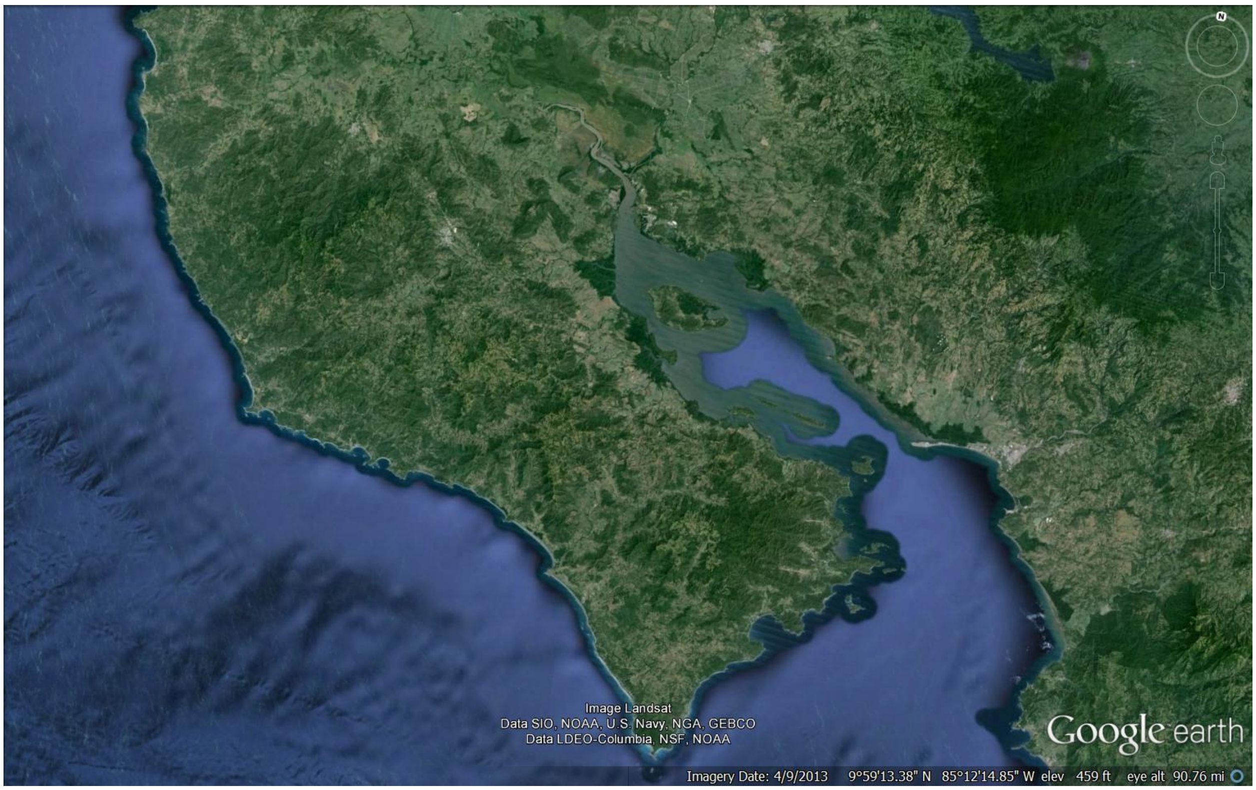


Figure 4.4: Land use and cover preferences for beekeeping activities. Columns represent mean response from 1 (bad for beekeeping) to 5 (excellent for beekeeping). Error bars represent the mean with standard error bars.



Appendix A: Survey instrument

Alleviating water scarcity in seasonally dry rural Costa Rica: The value of ecosystem service co-benefits from reforestation



Survey conducted by

CATIE and University of Idaho

Environmental Science program

Date: ________________ Starting time: ______________
ASADA #: _____ End time: ______________
Treatment: _____ Participant ID: ______________

Esteemed participant:

As you are probably aware, some of the ASADAS confront water scarcity problems from January to April every year. In fact, some regions that are not confronting water scarcity may be having this problem during the next years due to climate changes or population growth. Some studies have shown that reforestation may help to fix this problem by providing groundwater which improves the water flow in springs and/or wells during the dry season. Thus, water users may have water provisioning due to infiltration provided by reforestation. Policy designs which help solve these issues are needed. In order to provide recommendation for decision makers, this study aims to estimate the value of water for households in the Nicoya Peninsula and what are some of the factors that affect such value.

The document is divided in two sections. Section A is asking for your preferences in different scenarios provided in 9 different tables. Section B is asking for personal information, socio-demographic and economic questions as well as general questions.

Section A:

This section is composed of a set of tables that show different levels of characteristics that may be important for you. Here, you are asked to select the option (column) that you prefer given all the characteristics involved in each table. Notice that option C in every table means that if you have a chance you will not chose either option A or option B and will prefer to keep the situation in its current state as described in each table. These tables are part of a choice experiment, which is the instrument for knowing the value of water for household use. Remember that this study is real and the answer that you provide could be used for future policy designs. There is no wrong or correct answer.

Definitions of characteristics used in the tables

Forest cover in the watershed surrounding the ASADA- The amount of hectares that will be reforested to increase hours of water for household use.

Increase in water availability- The number of hours of water for household uses that can be increased.

Probability of failure- Probability of failure is defined as the probability of a project has in failing to achieve the expected increase in water availability. It is possible that increases in forest cover will increase water availability, but not achieve the expected level. We refer to this as a fail to achieve the expected change.

Cost- The amount of money that you will pay monthly for the time the service is provided if a project decides to conduct the respective option.

It has been estimated that the ASADA where you live has on average 240 hours (equivalent of 10 days) of water shortage during the whole year. If you disagree with this number, for purpose of this study, please assume that you have 240 hours of water shortage. Reforestation is one of the projects considered to increase water in household. This project will increase forest cover in the ASADA and/or its' surrounding areas (see the map at the end of the survey), but it is unknown exactly the lands that will be reforested. With the exception of residential areas, all lands are eligible for reforestation. Notice that in addition to water the forest provides other benefits, such as protection of biodiversity, reduction of climate change, contribution to scenic beauty, etc. However, after reforestation additional water may start to become available only after a few years and it may take up to 15 or more years to generate maximum water and other benefits provided by trees.

1. Please, in each of the different tables select the option you consider is the best.

a) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 140 and 180 hectares more than current situation	Between 300 and 340 hectares more than current situation	Same as today
Water availability	72 hours more than current situation (equivalent of 3 days)	144 hours more than current situation (equivalent of 6 days)	Same as current situation
Probability of failure	40%	0%	40%
Cost	₡2,000	₡3,000	₡0
	❑	❑	❑

b) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 300 and 340 hectares more than current situation	Between 140 and 180 hectares more than current situation	Same as today
Water availability	24 hours more than current situation (equivalent of 1 day)	168 hours more than current situation (equivalent of 7 days)	Same as current situation
Probability of failure	40%	0%	40%
Cost	₡2,000	₡1,000	₡0
	❑	❑	❑

c) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 300 and 340 hectares more than current situation	Between 140 and 180 hectares more than current situation	Same as today
Water availability	168 hours more than current situation (equivalent of 7 days)	24 hours more than current situation (equivalent of 1 day)	Same as current situation
Probability of failure	0%	40%	0%
Cost	₡3,000	₡500	₡0
	❑	❑	❑

d) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 300 and 340 hectares more than current situation	Between 140 and 180 hectares more than current situation	Same as today
Water availability	144 hours more than current situation (equivalent of 6 days)	168 hours more than current situation (equivalent of 7 days)	Same as current situation
Probability of failure	0%	40%	0%
Cost	₡1,000	₡3,000	₡0
	❑	❑	❑

e) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 300 and 340 hectares more than current situation	Between 140 and 180 hectares more than current situation	Same as today
Water availability	72 hours more than current situation (equivalent of 3 days)	24 hours more than current situation (equivalent of 1 day)	Same as current situation
Probability of failure	40%	0%	0%
Cost	₡2,000	₡500	₡0
	❑	❑	❑

f) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 140 and 180 hectares more than current situation	Between 300 and 340 hectares more than current situation	Same as today
Water availability	72 hours more than current situation (equivalent of 3 days)	24 hours more than current situation (equivalent of 1 day)	Same as current situation
Probability of failure	0%	40%	40%
Cost	₡1,000	₡3,000	₡0
	❑	❑	❑

g) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 300 and 340 hectares more than current situation	Between 140 and 180 hectares more than current situation	Same as today
Water availability	24 hours more than current situation (equivalent of 1 day)	168 hours more than current situation (equivalent of 7 days)	Same as current situation
Probability of failure	40%	0%	40%
Cost	₡1,000	₡2,000	₡0
	❑	❑	❑

h) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 140 and 180 hectares more than current situation	Between 300 and 340 hectares more than current situation	Same as today
Water availability	144 hours more than current situation (equivalent of 6 days)	72 hours more than current situation (equivalent of 3 days)	Same as current situation
Probability of failure	40%	0%	40%
Cost	₡500	₡3,000	₡0
	❑	❑	❑

i) If you currently experience 240 hours (equivalent of 10 days) of water shortage, which option would you choose?

	Option A	Option B	Option C
Forest cover in the watershed surrounding the ASADA	Between 300 and 340 hectares more than current situation	Between 300 and 340 hectares more than current situation	Same as today
Water availability	72 hours more than current situation (equivalent of 3 days)	168 hours more than current situation (equivalent of 7 days)	Same as current situation
Probability of failure	40%	0%	0%
Cost	₡2,000	₡500	₡0
	❑	❑	❑

2. If you selected option C **at least once during the first 8 tables**, why did you choose to not pay, or participate, for the projects? (Mark an "X" in allthenecessaries)

I really don't care about hours of water for household use. We have enough water even with the shortage.	
I don't have money to pay for it	
I prefer to spend my money in other ways (e.g. purchase of other goods)	
I don't know how my money will be administered	
Government should pay for the water	
I don't think that there is or will be a severe problem related to water scarcity	
I don't agree to pay if the payment vehicle is unknown	
The forest nor the water should be measured in monetary terms	
I think that the selected projects will fail to increase water	
I think that the selected projects will increase less than the stated amount of water to be increased	
I did not understand the options and choices to be made	
Other (explain):	

3. How complex were the choice tables above?
Very easy___ easy___ moderate___ complex___ very complex ___

4. As previously stated, the ASADA where you live has 240 hours (equivalent of 10 days) of water scarcity per year. At this moment I would like you to suppose that the government or the municipality of your county would be willing to construct a well to increase by 168 (equivalent of 7 days) the amount of water hours for household uses during the dry season. Wells generate water immediately but it has been found that some wells in the past have become dry after several years of being constructed. If this project (well construction) is developed, this will result in a fixed monthly payment. Given the high costs, the well will be implemented only if a high number of household are willing to pay the rate. All households will pay the same rate.

Let's suppose that the project implementation will cost you __________ colons monthly for the time the service is provided, would you be willing to pay for the well construction?
Yes _____ No _____

5. In your opinion, mark with a "X" in the appropriate cell

	YES	NO	Don't know
I obtain benefits for other services, other than water provision, provided by the forest			
The forest provides more water than well construction			
The forest provides a better water quality than well construction			
Due to climate changes, the forest may be a better option for increasing hours of water in the long run			
Well construction provides water with more certainty			
Well construction provides more water than the forest			
Well construction is more expensive than the forest			
I prefer well construction because the process of obtaining water is faster			
There is a high chance that a project based on reforestation fails to			

increase water availability			
There is a high chance that a project based on well construction fails to increase water availability			
I prefer reforestation over well construction because (explain) ____ ____			

Section B:

This section is designed to collect all relevant data needed to analyze the tables above.This section is divided in three sub-sections: Personal information, social-demographic and economic information, and general questions.

Personal information:

6. Are you for the most part responsible of financial decisions of the household?
   Yes _____ No_____

7. How old are you?
   ______ years old

8. What is your gender?
   Male_____ Female_____

9. What is your marital status?
Single___ Married ___ Divorced ___ Widower ___ Domestic partnership ___

10. Are you a member of an environmental organization?
    Yes _____ No _____

11. Do you work for any organization (including the government) focused in environmentalprotection?
    Yes _____ No _____

12. Are you part of the ASADAS committee in this community?
    Yes _____ No _____

Socio-demographic and economic information:

13. What is your level of education?
None___ Primary school ___ High school ___ College___ Graduate school ___

14. How many people depend on your income (Children or adults who depends on your income 50% or more to fulfill their necessities)? _____ people

Before answer the following question, remember that all the information in this study is confidential (your name and contact information is not required). So, please, feel free to provide the information requested. If you have any doubts or questions at any time, do not hesitate to ask the interviewer.

15. What is your individual total income? (*Please mark with a "X" the appropriate level of income, only one)*

(1) Less than or equal to ₡200,000 per month	
(2) ₡200,005 - ₡400,000 per month	
(3) ₡400,005 - ₡600,000 per month	
(4) ₡600,005 - ₡800,000 per month	
(5) More than or equal to ₡800,005 per month	

16. What is the total household income? (*Please mark with a "X" the appropriate level of income, only one)*

(1) Less than or equal to ₡200,000 per month	
(2) ₡200,005 - ₡400,000 per month	
(3) ₡400,005 - ₡600,000 per month	
(4) ₡600,005 - ₡800,000 per month	
(5) More than or equal to ₡800,005 per month	

General questions:

17. a. Do you have a garden in your household? Yes _____ No _____

b. What do you produce in your garden? (*Mark with a "X" all the products you have in your garden)*

Lime	
Cilantro	
Tomatoes	
Oregano	
Banana	
Orange	
Mango	
Peppers	
Others (list): 1. 2.	

18. Are there drought periods (months with water interruption due to water scarcity) in the region where you live? Yes _____ No _____ (go to question 21)

19. What are the dry months?
____

20. How often do you **not** receive water service in your tap during the dry season?
_____ hours per dryseason

21. Overall, how important are Environmental Services (benefits that humans obtain from the forest)?
very important_____ important_____ somewhat important_____ Not important _____

22. How is your satisfaction level with the performance of the ASADAS committee?
very satisfied _____ satisfied _____ somewhat satisfied _____ Not satisfied _____

23. How is your satisfaction level with the water quality in your ASADAS?
very satisfied _____ satisfied _____ somewhat satisfied _____ Not satisfied _____

24. How is your satisfaction level with the water yield in your ASADAS?
very satisfied _____ satisfied _____ somewhat satisfied _____ Not satisfied _____

25. Do you think that there will be water scarcity problems during the next years?
Yes ____ No ____

If yes, what are the factors that you perceive as drivers of water scarcity in the future?
(Mark with a "X" the appropriate level for each function)

Population growth	
Elevated temperatures	
Decrease in precipitation (Less rain)	
Bad management and distribution of water	
Decrease in water quality	
Increases in deforestation	
Land use changes	
Others (specify):	

26. How important are in your view the following functions of forests in your area? (Mark with a "X" the appropriate level for each function)

Functions	Not important	Somewhat important	regular	Important	Very important	I dont know
a.Recreational opportunities						
b. Clean water						
c. Reduction of soil erosion						
d. Protection of biodiversity						
e.Contribute scenic beauty						
g. Reduce climate change, carbon sequestration						
h. Increase groundwater yield						
i. Flood control						
j. Habitat for pollinators (e.g., bees)						
k. Wood production						
l. others (what?):						

Please, answer the following questions only if you are a landowner and your lands are located in the map at the end of the survey):

27. Are you a landowner? Yes _____ No _____
    If "yes", how is the land used?
    ______________________________ ______________________________
    ______________________________ ______________________________
    ______________________________ ______________________________

28. How many hectares do you have in each of the land uses?
    ______________________________ ______________________________
    ______________________________ ______________________________
    ______________________________ ______________________________

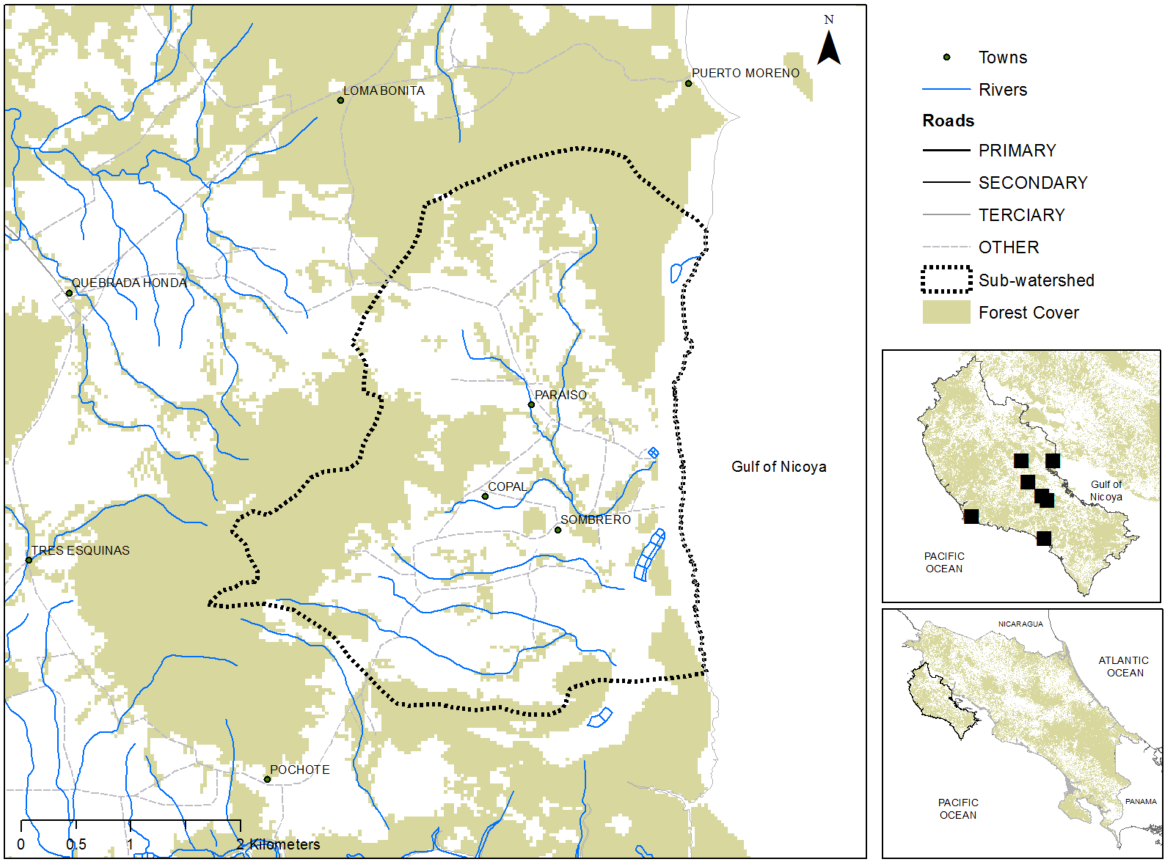
29. How much money per hectare should you be paid in order to change to forest each of the land uses?
    ______________________________ ______________________________
    ______________________________ ______________________________
    ______________________________ ______________________________

30. Do you have contracts with the PES program (FONAFIFO)? Yes _____ No _____
    If "Yes", how many hectares do you have in the PSA program?
    __________ hectares

    How many of those hectares are under the modality of "forest conservation"?
    _______ hectares

If you have any question or comment, please feel free to write it down in this space:

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____


N
PUERTO MORENO
LOMA BONITA
QUEBRADA HONDA
PARAISO
Gulf of Nicoya
COPAL
SOMBRERO
TRES ESQUINAS
POCHOTE
0
0.5
1
2 Kilometers
Towns
Rivers
Roads
PRIMARY
SECONDARY
TERCIARY
OTHER
Sub-watershed
Forest Cover
Gulf of Nicoya
PACIFIC OCEAN
NICARAGUA
ATLANTIC OCEAN
PACIFIC OCEAN
PANAMA

University of Idaho
Office of Research Assurances
Institutional Review Board
875 Perimeter Drive, MS 3010
Moscow ID 83844-3010
Phone: 208-885-6162
Fax: 208-885-5752
irb@uidaho.edu

To:	Levan Elbakidze
From:	Traci Craig, Ph.D., Chair, University of Idaho Institutional Review Board University Research Office Moscow, ID 83844-3010
Date:	6/11/2014 11:17:27 AM
Title:	Alleviating water scarcity in seasonally dry rural Costa Rica: the value of ecosystem service co-benefits from reforestation
Project:	14-279
Approved:	June 11, 2014
Renewal:	June 10, 2015

On behalf of the Institutional Review Board at the University of Idaho, I am pleased to inform you that the protocol for the above-named research project is approved as offering no significant risk to human subjects.

This study may be conducted according to the protocol described in the application without further review by the IRB. As specific instruments are developed, each should be forwarded to the ORA, in order to allow the IRB to maintain current records. Every effort should be made to ensure that the project is conducted in a manner consistent with the three fundamental principles identified in the Belmont Report: respect for persons; beneficence; and justice.

This IRB approval is not to be construed as authorization to recruit participants or conduct research in schools or other institutions, including on Native Reserved lands or within Native Institutions, which have their own policies that require approvals before Human Participants Research Projects can begin. This authorization must be obtained from the appropriate Tribal Government (or equivalent) and/or Institutional Administration. This may include independent review by a tribal or institutional IRB or equivalent. It is the investigator's responsibility to obtain all such necessary approvals and provide copies of these approvals to ORA, in order to allow the IRB to maintain current records.

As Principal Investigator, you are responsible for ensuring compliance with all applicable FERPA regulations, University of Idaho policies, state and federal regulations.

This approval is valid until June 10, 2015.

Should there be significant changes in the protocol for this project, it will be necessary for you to submit an amendment to this protocol for review by the Committee using the Portal. If you have any additional questions about this process, please contact me through the portal's messaging system by clicking the `Reply¿ button at the top of this message.

Traci Craig

Traci Craig, Ph.D.

University of Idaho

Office of Sponsored Programs
PO Box 443020
Moscow ID 83844-3020

Phone: 208-885-6651
Fax: 208-885-5752
osp@uidaho.edu

November 8, 2013

Borlaug Fellows
Purdue University
West Lafayette, IN 47907

The University of Idaho is transmitting a Fall 2013 US Borlaug Fellow in Global Food Security; Graduate Research Grant Application prepared by Hector S. Tavarez Vargas, mentored by Dr. Levan Elbakidze, and entitled *Alleviating Water Scarcity in Seasonally Dry Rural Costa Rica: The Value of Ecosystem Service Co-Benefits from Reforestation.* The appropriate University of Idaho program and administrative personnel have reviewed and approved this proposal. The budget totals $19,696.

Please contact Steve Kirkham if you require further information. He can be reached at (208) 885-6651, or by email at osp@uidaho.edu.

Sincerely,

Polly Knutson
Director of Research Administration

SK