BUILDING A BRIDGE BETWEEN FOOD PRODUCTION AND CONSERVATION: EXPERIENCES FROM LATIN AMERICA AND THE CARIBBEAN

A Dissertation

Presented in Partial Fulfillment of the Requirements for the

Degree of Doctorate of Philosophy

with a

Major in Natural Resources

in the

College of Graduate Studies

University of Idaho

by

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May 2014

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AUTHORIZATION TO SUBMIT DISSERTATION

This dissertation of Natalia Estrada-Carmona, submitted for the degree of Doctorate of Philosophy with a Major in Natural Resources and titled "Building a Bridge between Food Production and Conservation: Experiences from Latin America and the Caribbean," 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.

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ABSTRACT

Latin America and the Caribbean (LAC) region is a place where innovation to manage natural resources is taking place. The region is and will keep contributing to the global food market. However, this poses a threat to the biodiversity hotspots and the key ecosystem service they provide at local, national and global scale. The Integrated landscape management (ILM) and the Ecosystem Services (ES) approach are being widely used in the region to mediate between food production and conservation. Still, we lack information in terms of how common is the ILM implemented as a participatory and integrative strategy that engages local and regional stakeholders to promote sustainable agricultural production, biodiversity conservation and improvement of community's livelihoods. In addition, we lack a quantified understanding of which practices guarantee ES provisioning at the site level and how site level implementations across a watershed improve larger scale services in agroecosystems.

To assess if ILM is a promising approach to mediate between food production and conservation we surveyed 107 and interviewed 23 initiatives applying ILM in the region. We found that ILM is improving natural resources management, engaging farmers, empowering local leaders and increasing the ability of communities to self-organize while increasing their capacity to understand and implement landscape management. The progress and success of these initiatives is highly dependent on sufficient and sustainable sources of funding and support, on decreasing policies and laws that hinder integrated landscape management and, on developing strategies to actively involve key stakeholders, government and private sector entities.

We also assessed site level efforts (such as implementing soil conservation practices) on watershed scale ES provisioning (such as reducing sediment yields in reservoirs for hydropower prodiction). We used a coupled economic and soil loss model to evaluate multiple strategies for reducing soil loss and compared these estimates to the costs of dredging three reservoirs in the upper and middle part of the

Reventazon River, Costa Rica. Our results indicate that the cost of implementing ideal cropping systems (combination of at least two or three soil conservation practices) is potentially similar or cheaper than dredging, given our modeling assumptions. Our empirical-based and conservative methodology can be adapted and modeled iteratively to improve PES spatial planning in agroecosystems.

ACKNOWLEDGEMENTS

I am deeply grateful to my two major advisors, Dr. Alex Fremier and Dr. Fabrice DeClerck, who constantly motivated and supported me during my academic formation. I really appreciate all the support and guidance provided by my committee members, Dr. Lee Vierling, Dr. Jan Ball, and Dr. Juan Robalino. I am also grateful to all my co-authors Dr. Celia Harvey, M.Sc. Abby Hart, Dr. Jeff Milder and Dr. Elizabeth Harper for their support and enthusiasm. Both institutions, CATIE and UIDAHO made this experience possible; I would like to express my gratitude particularly to Sanford Eigenbrode, Lissette Waits, Nilsa A. Bosque-Perez and every person who make the join program possible. Finally, this journey would not have been possible without the constant support from all my friends and family.

Chapter 1: We thank all of the survey respondents for taking time to share their experiences with integrated landscape management. Diana Vega and Camila Medeiros provided excellent research assistance. We also thank Alexandra Judd of the Iberoamerican Model Forest Network for helping to contact with ILI practitioners from Model Forests within LAC. We gratefully acknowledge financial support from the Gordon and Betty Moore Foundation and the CGIAR Research Program on Water, Land and Ecosystems.

Chapter 2: We thank the 75 integrated landscape management leaders and practitioners interviewed for this study for taking the time to share their experiences and perspectives. Diana Vega and Camila Medeiros provided excellent research assistance. We gratefully acknowledge financial support from the Gordon and Betty Moore Foundation and the CGIAR Research Program on Water, Land and Ecosystems. This study is a contribution of the Landscapes for People, Food and Nature Initiative (http://landscapes.ecoagriculture.org).

Chapter 3: We are very grateful to Dr. Mark Nearing and Dr. Mark Risse who provided us with the original RUSLE dataset; and to Dr. Jan Boll for his valuable comments for improving the manuscript. We thank the hydrology division of ICE (Instituto Costarricense de Electricidad) in Costa Rica for providing measured sediment loads in eight basins of the Pacuare and Reventazón River. Funding for our research is provided by multiple sources, including the College of Natural Resources at the University of Idaho, Multifunctional Landscapes project at CATIE, the CGIAR Research Program on *Water Land and Ecosystems* and the Student Grant Program of University of Idaho. This is contribution XXXX of the University of Idaho Forest, Wildlife and Range Experiment Station and the Idaho Agricultural Experiment Station.

Chapter 4: We are very grateful to Jórge León and Juan Sebastián Lozano (affiliated to The Nature Conservancy-Water Funds) for their support implementing RIOS. We also acknowledge Dr. Kelly Wendland inputs at the initial stage of our research. Dr. Jan Boll and Juan Robalino provided us valuable comments for improving the manuscript. Funding for our research is provided by the CGIAR Research Program on *Water Land and Ecosystems*. This is contribution XXX of the University of Idaho Forest, Wildlife and Range Experiment Station and the Idaho Agricultural Experiment Station.

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CHAPTER 1: INTEGRATED LANDSCAPE MANAGEMENT FOR AGRICULTURE, RURAL LIVELIHOODS, AND ECOSYSTEM CONSERVATION: AN ASSESSMENT OF EXPERIENCE FROM LATIN AMERICA AND THE CARIBBEAN

Estrada-Carmona, N., Hart, A. K., DeClerck, F. a. J., Harvey, C. a., & Milder, J. C. (2014). Integrated landscape management for agriculture, rural livelihoods, and ecosystem conservation: An assessment of experience from Latin America and the Caribbean. *Landscape and Urban Planning*, *129*, 1–11. doi:10.1016/j.landurbplan.2014.05.001 [Open access].

1. Abstract

Approaches to integrated landscape management are currently garnering new interest as scientists, policymakers, and local stakeholders recognize the need to increase the multi-functionality of agricultural landscapes for food production, livelihood improvement, and ecosystem conservation. Such approaches have been attempted in many parts of Latin America and the Caribbean (LAC) but to date there has been no systematic assessment of their characteristics, outcomes, and limitations. To fill this gap, we surveyed participants and managers in integrated landscape initiatives throughout the LAC region to characterize these initiatives' contexts, motivations and objectives, stakeholders and participants, activities and investments, outcomes, and major successes and shortcomings. Results from 104 initiatives in 21 countries indicate that integrated landscape management is being applied across the region to address a variety of challenges in diverse contexts, and that use of this approach is expanding. Initiatives reported investing across four key "domains" of landscape multi-functionality: agricultural production, ecosystem conservation, human livelihoods, and institutional planning and coordination. Initiatives reported positive outcomes across all four domains, but particularly with respect to institutional planning and coordination. Initiatives with larger numbers of objectives, investments, and participating stakeholder groups all reported significantly higher numbers of positive outcomes, suggesting significant value in the core precepts of the integrated landscape management approach. Key challenges identified by survey respondents—including the long time horizon required to achieve results at scale, unsupportive policy frameworks, and difficulty in engaging the private sector and other important stakeholders—offer insights for improving the future effectiveness of integrated landscape initiatives.

Key words: Latin America, landscape planning, multifunctional, agriculture, rural development, biodiversity

2. Introduction

Recent years have witnessed a proliferation of research on the impacts, tradeoffs, and ramifications of rural land-use management relative to the set of social and ecological goods and services that society demands from landscapes, including food and fiber production, biodiversity conservation, ecosystem service delivery, poverty alleviation, and economic development (Barrett, Travis, & Dasgupta, 2011; Brussaard et al., 2010; Tscharntke et al., 2012). Much of this work has highlighted the scale and severity of agricultural impacts on ecological systems, as well as the formidable challenge of designing management approaches to meet escalating global demands for food production and ecosystem services in the context of limited land and water resources, climate change, and widespread ecosystem degradation (Ellis, Goldewijk, Siebert, Lightman, & Ramankutty, 2010; Foley et al., 2005). A parallel stream of work has elaborated a variety of landscape analysis, planning and management approaches to address some of these challenges (De Groot, Alkemade, Braat, Hein, & Willemen, 2010; Nelson et al., 2009; O’Farrell & Anderson, 2010; Selman, 2009).

The increasingly contested nexus between agricultural production, biodiversity and ecosystem service conservation, and economic development in rural landscapes is clearly evident in Latin America and the Caribbean (LAC). This region contains eight of the world’s 34 biodiversity hotspots and provides key ecosystem services at local, regional, and global scales (Myers, Mittermeier, Mittermeier, da

Fonseca, & Kent, 2000; Turner et al., 2012), but still contains high levels of rural poverty and inequality in many areas (Berdegué et al., 2012). During the last 30 years, the LAC region has accounted for the 35% of the growth in global food production (FAO, 2011). Looking ahead, as other regions of the world became increasingly land and water constrained, or continued to experience low productivity, the region's role as a food exporter is likely to grow, with agricultural land projected to increase 43% by 2050 (FAO, 2011). Historically, agricultural expansion in the LAC region has been associated with the loss of high-biodiversity tropical ecosystems (Clark, Aide, & Riner, 2012), often in a poorly regulated context where economic benefits associated with tropical deforestation accrued inequitably and did little to alleviate poverty (Schatan, 2002).

These dynamics highlight the need for strategies that support the delivery of multiple benefits from rural landscapes by increasing synergies and minimizing or mitigating tradeoffs among food production, biodiversity conservation, ecosystem service provision, and poverty alleviation. Approaches to "integrated landscape management" seek to do so by analyzing, implementing, and evaluating land management decisions relative to multiple land scape objectives and stakeholder needs (Sayer et al., 2013). This is achieved through landscape planning and design processes, improved coordination among sectoral activities and investments, enhancement of human and institutional capacities for decision support and negotiation, and supportive policies and incentives. Integrated landscape management processes may support the alignment of agricultural production and ecosystem conservation at a variety of scales, including both "land sharing" and "land sparing" approaches, as dictated by local context (Cunningham et al., 2013). Integrated landscape management has been practiced and studied under many names, including "whole landscape" management (DeFries & Rosenzweig, 2010), "multifunctional agriculture" (Jordan & Warner, 2010), "ecoagriculture" (Scherr & McNeely, 2008), "bioregional planning" (Brunckhorst, 2000), and "multifunctional landscapes" (Fry, 2001; Naveh, 2001), to name a few. Such approaches have recently garnered new interest as scientists, policymakers, and local stakeholders increasingly recognize both the need and the possibility for more synergistic management of mosaic rural landscapes (LPFN, 2012).

The LAC region has a history of integrated landscape management efforts dating back at least three decades. The region's first formal landscape management paradigm was likely the UNESCO's Man and the Biosphere program (established in 1977), which sought to balance human needs and ecological conservation through multi-objective management of critical landscapes. Beginning in the mid-1990s, the "new rurality" (la nueva ruralidad) was proposed as a framework for participatory, place-based economic development that linked agricultural production with rural poverty alleviation (Echeverry-Perico & Ribero, 2002). More recently, the concept of rural territorial development (desarrollo territorial rural) has been adopted in several LAC countries as a framework to support rural economic development, improve the multifunctionality of rural regions, and foster constructive interdependence between urban and rural populations (Bebbington, Abramovay, & Chiriboga, 2008; Schejtman & Berdegué, 2008). This approach has been catalyzed, in different places, by government-led efforts as well as by initiatives of rural communities and indigenous peoples.

Simultaneously, the biological corridor concept has been promoted—particularly in Mesoamerica—as a way to increase conservation value and habitat connectivity while improving livelihoods in fragmented landscapes that connect core nature reserves (Harvey et al., 2008; SINAC, 2008). More broadly, conservation- friendly management of agricultural mosaics is now regarded as critical for conserving the region's biodiversity while furnishing key ecosystem services (DeClerck et al., 2010; Perfecto, Vandermeer, & Wright, 2009). Various networks have emerged to support grassroots-led integrated landscape management efforts, such as the Ibero-American Model Forest Network, which was established in 2002 and now includes 27 "Model Forests" in 12 LAC countries, managed for multifunctional outcomes through participatory processes (IMFN, 2013). Beyond these specific paradigms for landscape and territorial management, other approaches such as community-based natural resource management (Armitage, 2005) and the establishment of indigenous and community conserved areas (Kothari, Corrigan, Jonas, Neumann, & Shrumm, 2012) have also been applied widely throughout the LAC region and often share some if not all of the characteristics of integrated landscape management.

But despite the growing practice of and interest in integrated landscape approaches in the LAC region, to date there has been little formal effort to characterize these approaches and their role in helping to address conservation, food production, and rural development challenges. Such work is urgently needed to take stock of the diverse forms, experiences, and results of integrated landscape approaches and to use this information to guide the design and implementation of new and ongoing efforts to reconcile agricultural production, economic development and biodiversity conservation. The purpose of this study is to begin to fill this critical need by conducting a systematic characterization of integrated landscape approaches in the LAC region. Specifically, the study seeks to document the location and context, motivations and impetus, participants and stakeholders, investments and governance structures, outcomes, and most and least successful aspects of integrated landscape approaches in the region, as identified by individuals involved in landscape approaches. Results of the study can help inform recommendations about where and when integrated landscape management may be an appropriate strategy and how landscape management efforts can be designed or conducted to address common challenges and barriers.

As integrated landscape management can take many forms—both explicit and nebulous—in the interest of clearly bounding the purview of this study, we focus our assessment on discernible "integrated landscape initiatives" (ILIs), which we define as projects, programs, platforms, initiatives, or sets of activities that: (1) explicitly seek to simultaneously improve food production, biodiversity or ecosystem conservation, and rural livelihoods; (2) work at a landscape scale and include deliberate planning, policy, management, or support activities at this scale; (3) involve inter-sectoral coordination or alignment of activities, policies, or investments at the level of ministries, local government entities, farmer and community organizations, NGOs, donors, and/or the private sector; and (4) are highly participatory, supporting adaptive, collaborative management within a social learning framework (Milder, Hart, Dobie, Minai, & Zaleski, 2014). Within these broad parameters, ILIs can take a diversity of forms, including efforts initiated and carried out by grassroots actors and local organizations as well as those catalyzed or substantially supported by external donors, governmental bodies, regional initiatives, private companies, or civil society organizations.

We address seven key questions with respect to ILIs in the LAC region: (1) where and in what contexts are initiatives taking place? (2) What are the motivations behind these initiatives, and what challenges and problems do they seek to address? (3) Who is designing and implementing these initiatives, and how are stakeholders involved? (4) What investments, activities, and governance structures are included in the initiatives? (5) What positive outcomes have practitioners and stakeholders reported? (6) What were key successes and failures associated with these initiatives? (7) Which aspects of initiatives' design, structure, and stakeholder participation most strongly predict levels and types of reported outcomes?

3. Methodology

3.1. Contacted initiatives

We developed and administered a structured survey tool for ILI practitioners and local leaders to characterize a sample of initiatives throughout Latin America (including Mexico, Central America, and South America) as well as the major Spanish-speaking Caribbean jurisdictions of Puerto Rico, Cuba, and the Dominican Republic. We began by searching broadly for potential initiatives by performing online keyword searches, including in project databases and websites of conservation and rural development organizations operating in the LAC region (for a list of search terms, see Appendix A). We identified additional initiatives through the networks of experts and organizations participating in the Landscapes for People, Food and Nature Initiative (LFPN, http://landscapes.ecoagriculture.org). Finally, we asked all persons contacted to identify any other initiatives of which they were aware. We screened the initiatives identified to select only those that were currently ongoing and had been active for at least two years at the time of the survey (or, if less than two years old, were continuations of prior efforts in the same landscape).

This process yielded a total of 382 initiatives that appeared to meet the above-stated ILI definition and criteria for duration and active status. These candidate initiatives included grassroots- led efforts as well as projects or programs initiated by groups external to the landscape, such as state or national government, civil society, or research organizations. For each initiative, we contacted and sent the survey to one practitioner or leader (e.g., a community leader, local or international NGO representative, or government official) who we expected to be deeply familiar with the initiative and its components. Of the survey respondents, 84% identified themselves as the coordinator, manager, or executive leader (e.g., director) of their respective ILI. The remaining 16% identified themselves as technical specialists involved in the initiative. The plurality of respondents (44%) was affiliated with local organizations (i.e., within the subject landscape), while others were affiliated with national (30%) or international (26%) government, non-profit, or research institutions.

3.2. The Survey

The survey questionnaire included a combination of closed-and open-ended questions oriented around our seven research questions to solicit information on the initiatives' location and context, motivations and impetus, participants and stakeholders, investments and governance structures, outcomes, and most and least successful aspects. The questions related to investments and outcomes were designed to gather information on four key activity domains: agriculture, conservation, livelihoods, and institutional planning and coordination (hereafter referred to as the four "domains"). To report investments and outcomes, respondents selected from a pre-defined set of options that were chosen to include common types of investments and outcomes in each of the four domains; respondents could also write in additional responses beyond these pre-defined choices. We asked respondents to differentiate between investments and outcomes included in or attributable to the initiative itself (“core” investments and outcomes) and those that were initiated or realized as a result of other activities or organizations present in the landscape (“associated” investments and outcomes). Prior to distributing the survey widely, we conducted a pilot test with practitioners from 15 initiatives and revised the survey as needed. The final survey included 45 questions and took about 40 min. to complete (for a copy of the survey, see Appendix B).

We used the online service, Survey Monkey, to administer the survey, which we made available in Spanish, Portuguese and English. We first contacted the selected representative of each initiative by email or telephone to request his or her participation. Representatives who did not respond to the survey after the first contact received a follow up email or telephone call. The survey had a response rate of 45% (173 out of 382). We screened the survey responses for completeness and for concurrence with our definition of ILIs. A total of 104 initiatives met these criteria and were included in subsequent analyses (for more information on the 104 initiatives, see https://mapsengine.google.com/map/edit?mid=zNfW1TNgZ8uI.kThRrJOI88sY)

3.3. Data analysis

We treated responses to the closed-ended questions as ordinal or binary variables, depending on the question. For instance, respondents reported on motivations according to their perceived level of importance (ordinal variable with four possible levels), while participation of each stakeholder group in the design and/or implementation of an initiative was reported as either present or absent (binary). We developed a set of indices to quantify the relative number of investments and outcomes in each domain, as well as the relative balance across all four domains. The “investment index” was calculated as the ratio of reported investments in each domain to the total number of possible investments (i.e., the total number of pre-defined choices offered on the questionnaire) in that domain. We normalized the ratio for each domain to a 25-point scale and summed these scores to derive an overall investment index, with possible scores ranging from 0 to 100. We calculated an "outcome index" in the same way. Although these indices do not necessarily reflect all core or associated investments and outcomes in a landscape, nor the magnitude of such investments and outcomes, they are useful for understanding the relative focus and breadth of each initiative across the four domains, as well as level of the "inter-sectorality" of the initiatives.

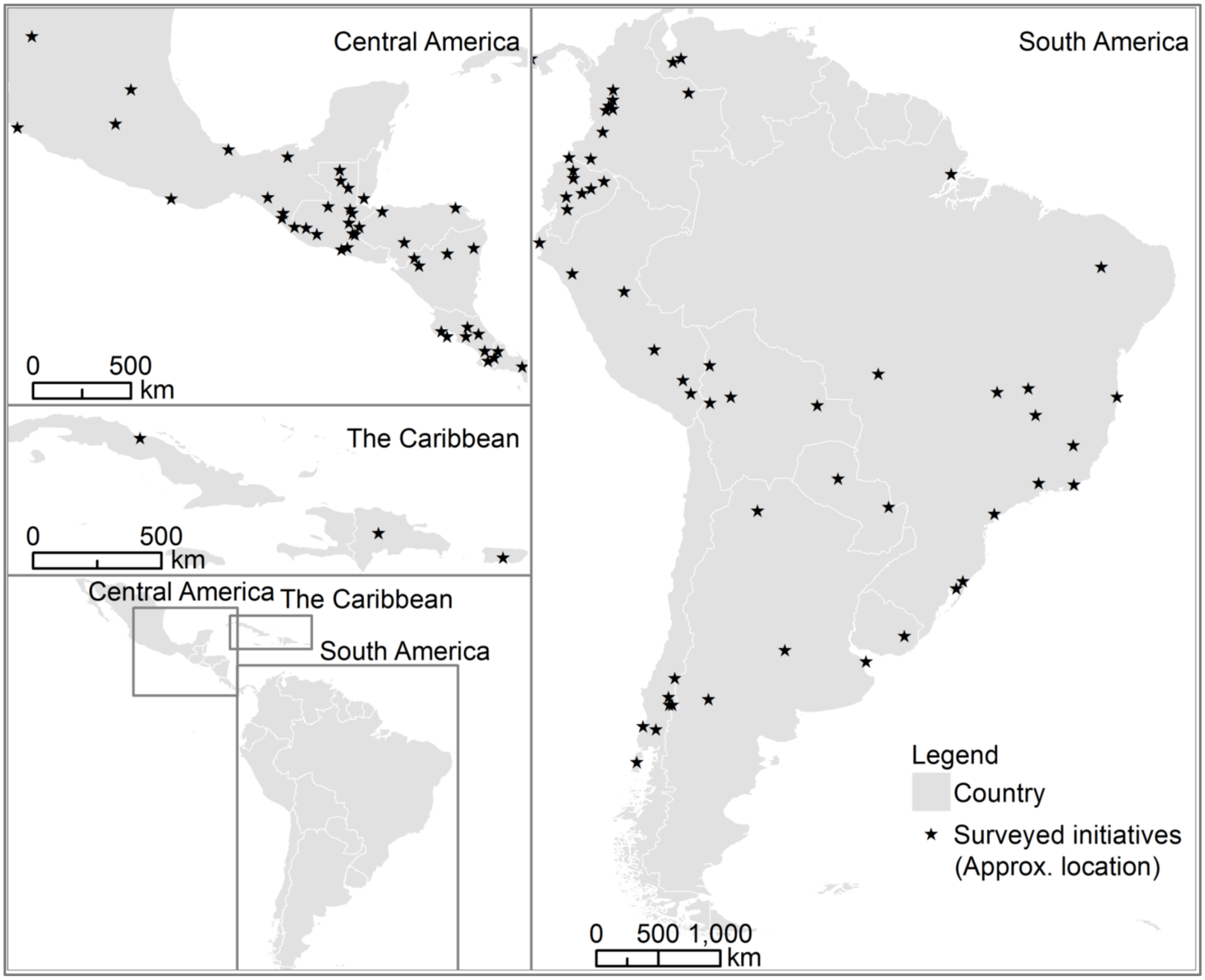
We analyzed the raw survey data and the derived indices to assess the distribution of each variable as well as the associations among the variables and trends among the initiatives. We used analysis of variance and Pearson's product-moment correlation analysis performed on the indices and other continuous variables to understand the relationship between investments and outcomes in general, and to compare investments and outcomes across the four domains. We used contingency table analyses to compare categorical variables with the index scores, which we transformed into high, medium, and low categories. For the open-ended questions on most and least successful aspects of the initiatives, we manually compiled responses to identify recurring themes, highlight illustrative examples, and clarify the significance of responses from the closed-ended questions.

4. Results

4.1. ILI locations and contexts

The 104 initiatives represented 21 countries, with the greatest numbers of initiatives in Brazil (13%), Guatemala (12%), Mexico (10%), Ecuador (9%), and Costa Rica (9%) (Figure 1). Survey response rates were not significantly different from country to country (X^2 test, $p = 0.29$) and follow-up interviews with non-respondents did not suggest other forms of self-selection bias that might have skewed the sample population ways unrepresentative of the full set of candidate initiatives. The main reasons that non-respondents elected not to participate were: (1) lack of interest, (2) the project or initiative had finished, (3) the contacted person no longer worked with the initiative and had lost contact with it, or (4) the respondent indicated that the initiative or project was not actually an ILI. Twenty-nine percent of the initiatives were started prior to 2000, 62% began between 2000 and 2009, and 9% began in 2010 or later (Figure 2). Several of the initiatives were associated with specific landscape management approaches such as biosphere reserves (17%), Model Forests (9%), and biological corridors (6%). Forty three percent had evolved from shorter-term projects into long- term or permanent initiatives. A majority of the initiatives (72%) reported that they used adaptive management. Eighty-eight percent included a monitoring and evaluation component, but only 60% had conducted a baseline assessment as part of monitoring and evaluation.

Figure 1. Locations of the 104 surveyed integrated landscape initiatives across Latin America and the Caribbean.



Central America
0
500
km
The Caribbean
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500
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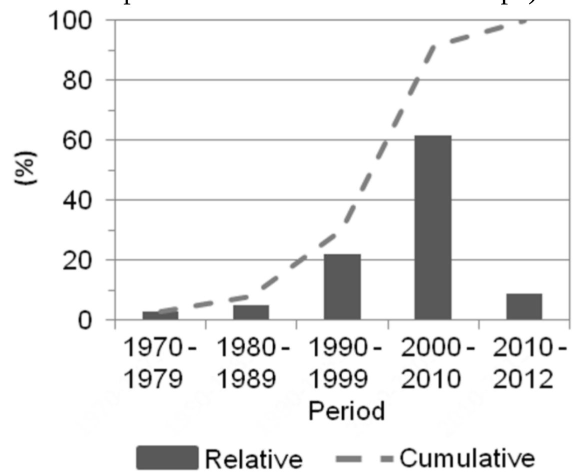
Central America
The Caribbean
South America
South America
Legend
Country
Surveyed initiatives
(Approx. location)
0
500 1,000
km

Figure 2. Percent relative and cumulative frequency of surveyed initiatives (n = 104) based on the decade in which they began. Note that the surveyed sample included only initiatives that were currently ongoing and had been active for at least two years at the time of the survey (or, if less than two years old, were continuations of prior efforts in the same landscape).

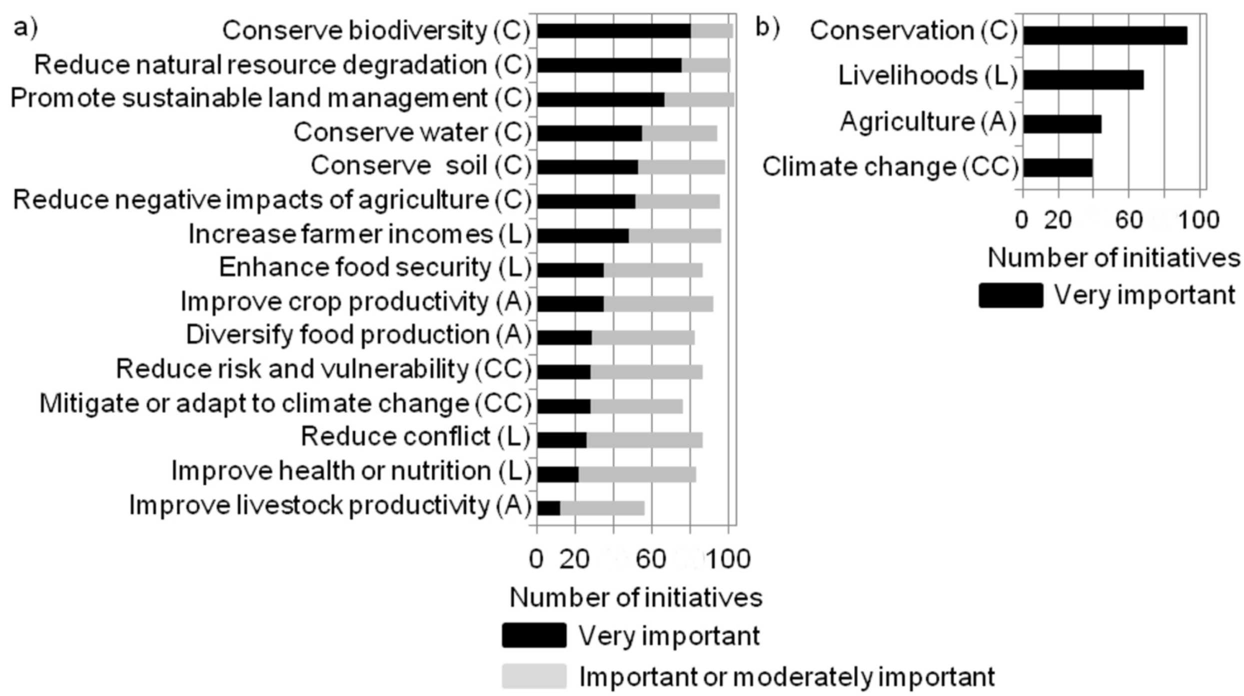


As expected, the initiatives generally took place in mosaic landscapes with multiple land uses. On average, these landscapes had a mean of five major land uses (SE = 0.2) that each occupied ⩾5% of the landscape area and six (SE = 0.2) minor land uses that each occupied <5% of the landscape area. The most frequently cited major land uses were managed pastures with livestock (59%), tropical wet forest (50%), annual grain crops (45%) and montane forest (39%). Villages, towns or cities were present in 93% of the landscapes and considered a major land use in 32%. Industrial or mining areas were present in 43% of the landscapes and considered a major land use in 34%. The most common minor land uses across the surveyed landscapes were annual horticultural crops (65%), forest plantations (59%), and annual grain crops (45%).

4.2. Motivations

Stakeholders were motivated to establish and participate in ILIs both to address current and pending threats and to collaborate around identified opportunities. Respondents identified a mean of six (SE = 0.3) “very important” objectives, four (SE = 0.3) “important” objectives, and two (SE = 0.2) “moderately important” objectives per initiative. Conservation-related motivations were, on average, twice as likely to be considered very important as those related to agricultural production, livelihood improvement, or climate change concerns (Figure 3). Ninety-three initiatives reported at least one conservation-related objective as very important. Conserving biodiversity and reducing natural resource degradation were the most frequently identified as very important, by 78% and 73% of initiatives, respectively. In addition to the 15 choices of potential motivations listed in the questionnaire, respondents wrote in additional motivations including the strengthening social networks, preserving local culture and traditions, creating new incentives for conservation, and reaching new markets (local, national or international) for organic and sustainably produced agricultural products.

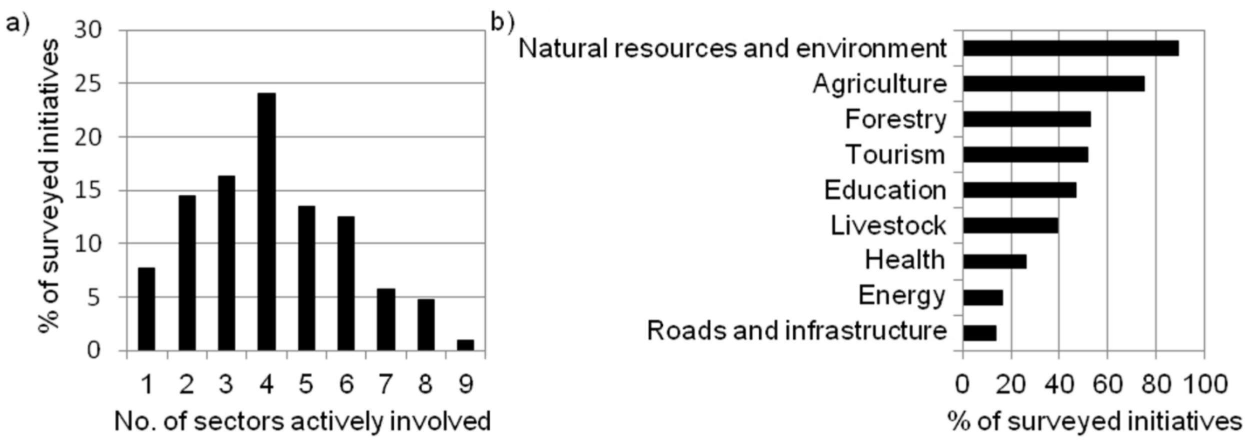
Figure 3. Motivations for the creation of the surveyed ILIs (n = 104), as reported by initiative leaders or participants. Panel a) indicates the number of initiatives that identified each given motivation as “very important” or as “important” or “moderately important.” Abbreviations in parentheses categorize these motivations into four thematic groups: agriculture (A), conservation (C), livelihoods (L), and climate change (CC). Panel b) indicates the number of initiatives for which the respondent selected at least one “very important” motivation in each group.



4.3. Participants and stakeholders

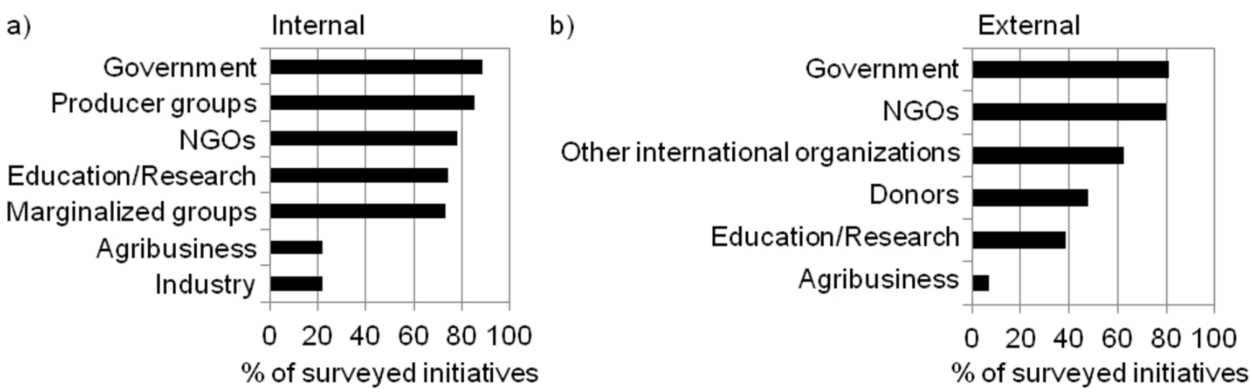
Most of the initiatives engaged multiple sectors in landscape management, with respondents reporting a mean of four (SE = 0.2) sectors involved in each initiative (Figure 4). However, 8% reported the involvement of only one sector. The most commonly involved sector (in 89% of initiatives) was "natural resources, conservation and environment" (characterized in the survey as a single sector). This was closely followed by the agriculture sector (75% of initiatives). The forestry, tourism, and education sectors were also each involved in more than 40% of surveyed initiatives (Figure 4).

Figure 4 Number (a) and identity (b) of the sectors involved in the surveyed landscape initiatives.



Respondents reported a mean of 11 (SE = 0.4) different stakeholder groups, out of 21 pre-defined questionnaire choices, participating in the design and/or implementation of each initiative. The most frequently involved groups were farmer or producer organizations (in 86% of initiatives), local government leaders (82%), and local non-governmental organizations (NGOs) (78%). At least one international organization (e.g., international conservation or agricultural NGOs, foreign universities or research organizations, and foreign donors) was involved in 87% of initiatives. Stakeholder groups less commonly reported included private sector interests including local agribusiness (22%), logging and forest industries (20%), landless people (18%), foreign agribusiness (7%), and mining and extraction industries (7%). On average, the number of participating stakeholder groups internal to the landscape was reported to be greater than the number of participating external stakeholder groups (paired t-test, $p < 0.001$), and in each category government stakeholders were the most commonly represented (Figure 5). An average of only three stakeholders groups per initiative participated in both the design and the implementation of the initiative, suggesting that different stakeholders played different roles in the initiative, and that there may have been limited continuity from design to implementation.

Figure 5. Proportion of initiatives that included at least one stakeholder group from each of the stated categories, which are denoted as either internal to the landscape (i.e., local individuals, organizations, or institutions) or external to the landscape (i.e., regional, national, or international government entities, companies, or civil society groups).



4.4. Investments, activities, and governance structures

The majority of initiatives (75%) reported core investments in all four domains. The investment index for institutional planning and coordination was significantly higher than that for the other three domains (ANOVA, $F3 = 3.978$, $p = 0.008$). This domain also included the two most frequently reported investments: strengthening capacity for conducting integrated management (71% of initiatives) and providing technical assistance for integrated landscape management (68% of initiatives). All but one of the activities in this domain was reported by more than half of respondents. Investments least commonly reported were those associated with conventional crop intensification

(6%) and irrigation (15%), and those associated with poverty alleviation efforts focused on hunger, malnutrition, and human health (each reported in about 30% of initiatives) (Figure 6).

On average, respondents reported a significantly higher number of core investments (those considered part of the initiative; mean core investment index = 50, SE = 2.1) than associated investments (those undertaken by others in the landscape; mean associated investment index = 22, SE = 1.6) (paired t-test, $p < 0.001$). However, we were unable to confirm the degree to which this result may reflect perception bias (i.e., seeing the landscape through the lens of the initiative), or respondents' incomplete knowledge of other landscape investments. The two domains with the lowest proportion of core investments—agriculture and livelihoods—were reported to have the highest proportion of associated investments (Figure 7).

4.5. ILI outcomes

Overall, initiatives were generally reported to have the largest relative number of core outcomes in the domains where they made the largest relative number of investments. The outcome index for the institutional planning and coordination domain was significantly higher than that of any other domain (ANOVA, F3 = 15.23, $p < 0.001$) (Figure 7). For instance, 80% of initiatives reported achieving improved coordination among stakeholders, 72% reported that local communities gained capacity to manage their natural resources, 65% reported that local communities became more empowered to participate in decision-making, and 64% reported that traditional knowledge about agriculture and natural resources had been preserved or used. Planning and coordination was the only domain in which all possible outcomes given as choices on the questionnaire were reported by more than half of the surveyed initiatives (Figure 6).

Figure 6. Proportion of the surveyed initiatives that were reported to include each of 33 investments and activities (left panels) and to achieve each of 22 outcomes (right panels). "Core" refers to investments that were part of the landscape initiative itself and to outcomes attributable to the initiative. "Associated" signifies investments undertaken by other organizations in the landscape and other outcomes occurring in the landscape but not attributable to the initiative. Abbreviations used in the figure: ag. = agriculture; cons. = conservation; eco. = ecosystem; ILM = integrated landscape management.

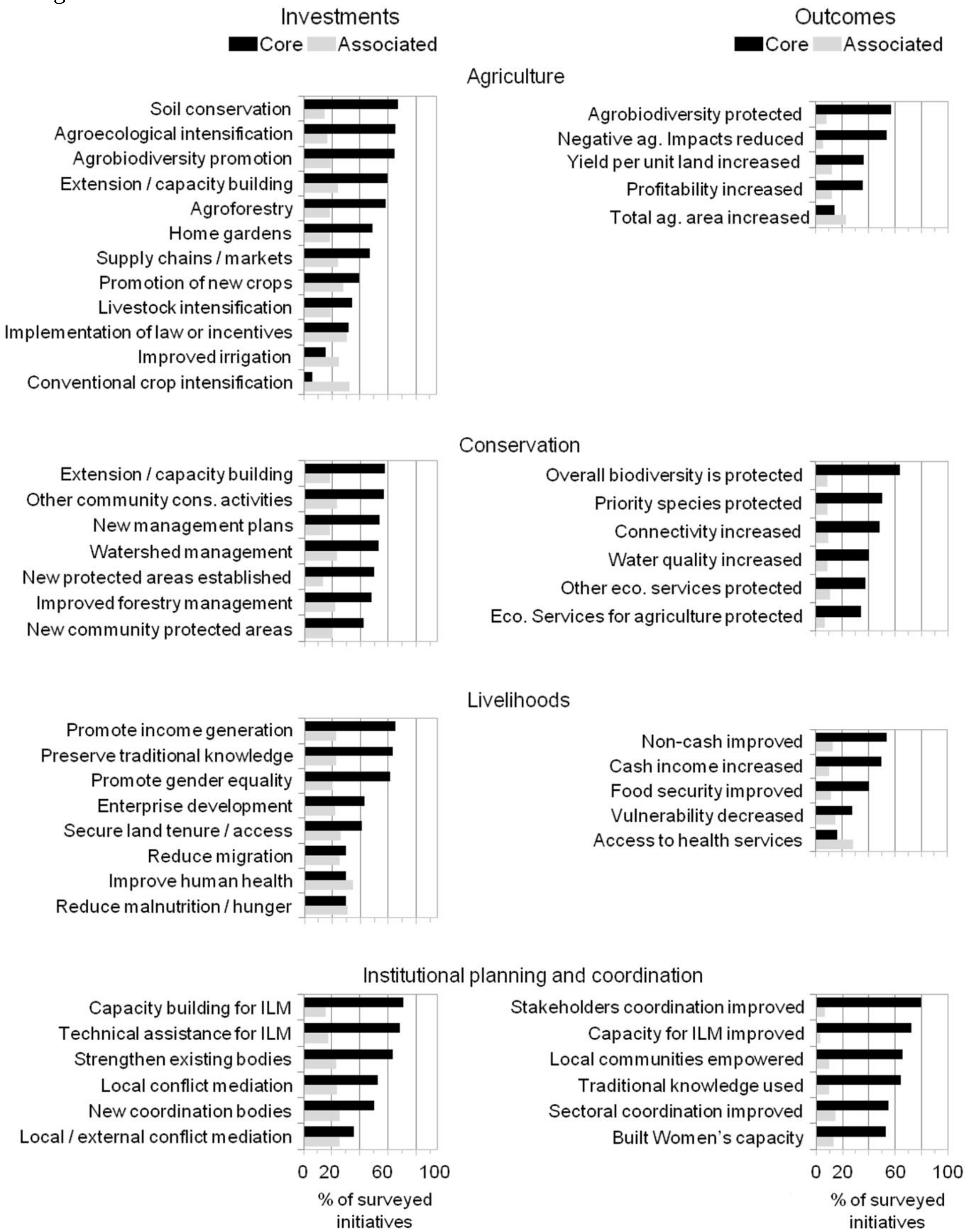
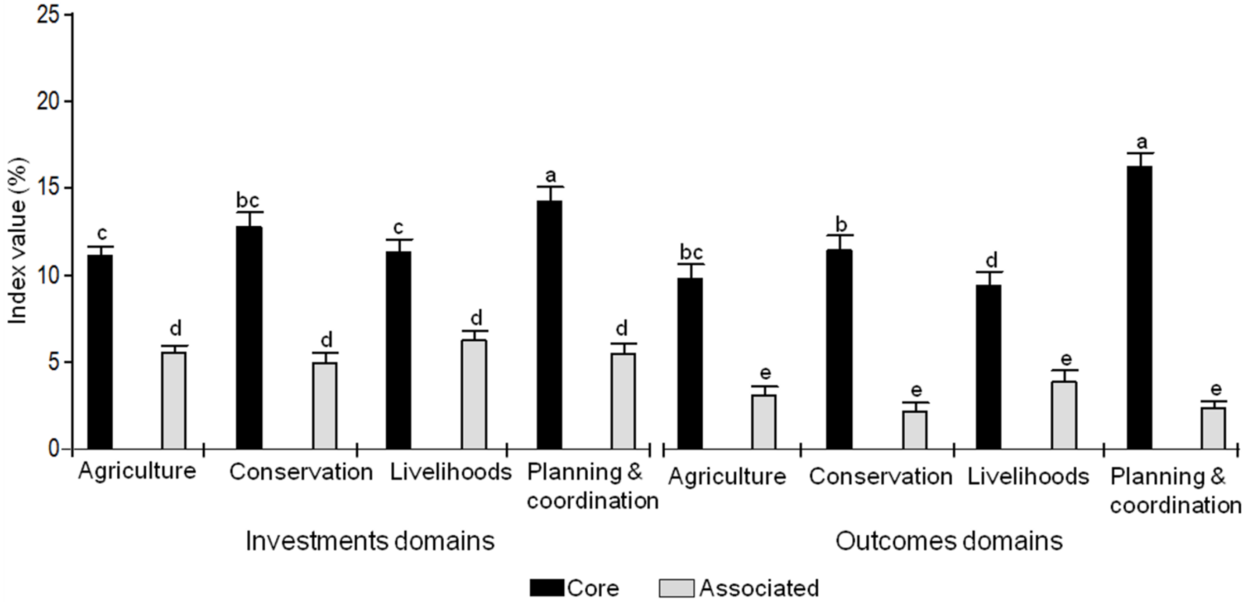


Figure 7. Mean and standard error of the core and associated investment and outcome index values across the four domains of landscape activity (agriculture, conservation, livelihoods, and institutional planning and coordination). See the narrative for further explanation of the investment and outcome indices. Different letters above the bars indicate significant differences among the mean index values for each domain for investments and outcomes (LSD Fisher test, α = 0.05).



In the agriculture domain, outcomes related to improving the sustainability of agriculture (e.g., protecting agrobiodiversity [57%] and reducing environmental impacts [54%]) were more commonly reported than those related to increased productivity (37%), increased profitability (36%), or increased land area under agriculture (14%). In the conservation domain, 63% of initiatives reported overall improvements in biodiversity protection; 50% reported improved protection of rare, threatened, or endangered species; and 48% reported increased habitat connectivity. Improvements in water quality, conservation of ecosystem services benefitting agriculture, and conservation of other ecosystem services were each reported in about 40% of initiatives. In the livelihoods domain, 50% of initiatives reported increased cash income for low-income residents while 54% reported increases in non-cash measures of human wellbeing. Forty percent reported improved food security while 28% reported a reduction in human vulnerability. Beyond the 22 pre-defined outcome choices included in the close-ended portion of the survey, respondents identified additional core outcomes related to improved perception and valuation of natural resources, improved infrastructure, and empowerment of local stakeholders.

Overall, respondents reported relatively few associated outcomes (i.e., outcomes resulting from activities outside the scope of the landscape initiative). To the extent that such outcomes were reported, they tended to be concentrated in areas that were less commonly foci of the initiatives themselves, such as agricultural expansion and increased access to health services (Figure. 6). When interpreting results on ILI outcomes, it is important to recall that this information is based on respondent self-reporting. The evidential basis for such self-reports undoubtedly varies in quality and rigor, and in some cases may be based primarily on perception.

4.6. Most and least successful aspects

We asked respondents to indicate what they saw to be the most and least successful aspects of their landscape initiative. Responses tended to emphasize the human and institutional aspects of landscape management. Among the most successful aspects, 31% of respondents reported increased capacity for understanding and implementing integrated landscape management. Thirty percent reported improvements in natural resource management through the formation of new protected areas, improved agroforestry and forestry management, and the protection of threatened species. Improved agricultural and agroforestry practices were mentioned by 26% of respondents, many of whom noted that these improvements resulted from strong farmer engagement, farmer-to-farmer communication, strengthening of farmer organizations, and engagement of farmers in participatory research at pilot sites where the benefits of environmentally friendly practices could be directly observed. Other important successes included the empowerment of local leaders (mentioned by 19% of respondents) and the ability of communities to self-organize for change (18% of respondents).

Thirty eight respondents recognized integrated landscape management to be a long-term endeavor requiring constant support (e.g., human, monetary, technological, and infrastructural), which they noted was difficult to maintain. The least successful aspects of the ILIs (often stated by respondents in the form of key challenges) were commonly associated with limitations in stakeholder participation (34% of respondents) and funding (20% of respondents). Fourteen percent of respondents reported poor integration, inconsistency or counterproductive laws or policies as a major challenge to meeting their initiative's objectives. Although local, sub-national and national government agencies were frequently involved in the initiatives as stakeholders, several respondents indicated that support from government entities was shallow and insufficient (14% of respondents). Finally, respondents reported difficulties establishing value chains for sustainable agriculture or non-timber forest products (10% of respondents) and getting the private sector involved (8% of respondents).

4.7. Relationships among ILI characteristics

Overall, initiatives that respondents characterized as more "multi-objective" (i.e., those reporting more motivations as "very important") had both higher investment index ($r = 0.4$, $p < 0.001$) and higher outcome index ($r = 0.4$, $p < 0.001$) scores. In other words, initiatives with a greater number and diversity of objectives also reported higher numbers of investments and outcomes across all domains than those with lower numbers of objectives. Investment index scores and outcome index scores were also positively and significantly correlated ($r = 0.59$, $p < 0.001$).

Duration of the initiatives was positively correlated with total outcome index scores ($r = 0.3$, $p < 0.003$) and more strongly correlated with outcome index scores in the conservation domain ($r = 0.4$, $p < 0.001$), suggesting that more outcomes might be progressively achieved over time, especially in the conservation domain. Initiative duration was also positively correlated with the number of sectors involved ($r = 0.3$, $p = 0.005$).

The number of stakeholder groups involved in the initiatives was positively correlated with both investment index ($r = 0.5$, $p < 0.001$) and outcome index ($r = 0.2$, $p = 0.024$). The number of sectors involved in the ILIs was also positively correlated with investment index and outcome index scores ($r = 0.4$, $p < 0.001$ and $r = 0.3$, $p = 0.005$, respectively). Higher outcome index scores were associated with the participation of women's groups ($X^2 = 0.023$) and local farmer's organizations ($X^2 = 0.028$) but not with other specific segments of local communities such as indigenous people or landless people. The participation of the private sector—the least frequently involved set of stakeholder groups—was not significantly associated with higher outcome index scores. Other investments in institutional planning and coordination that we expected might support positive outcomes—including the strengthening of existing landscape coordination bodies, creation of new landscape coordination bodies, and efforts to mediate conflict among stakeholders—were not associated with higher outcome index scores.

5. Discussion and Conclusions

This study provides the first broad characterization of integrated landscape management in the LAC region and, as such, is informative for understanding the current state of this field, the challenges and potential benefits of applying such an approach, and the needs for additional research. The size and diversity of the survey sample suggests that integrated landscape management is being applied across the region to address a variety of challenges in a wide range of contexts. Furthermore, data on the starting date of the surveyed initiatives (Figure 2) suggests that uptake of integrated landscape approaches within the LAC region has accelerated in the past decade. This trend is consistent with recent shifts in parts of the region from early territorial development paradigms focused on economic and social priorities (Bebbington et al., 2008; Schejtman & Berdegué, 2008) to current approaches that integrate conservation strategies with economic and human development plans (ERAS, 2008; SECAC, 2012). The proliferation of ILIs may also reflect the evolving interests and priorities of international donors and NGOs, who were present as stakeholders in 87% of the surveyed initiatives.

Because it was designed as a foundational region-wide characterization of ILIs, this study prioritized breadth and data comparability over in-depth analysis of individual ILIs. This design presents a few caveats for interpretation of the results. First, reliance on the Internet and practitioner networks to identify initiatives may bias the sample toward those that have published information or are associated with external organizations, and may underrepresent grassroots-led initiatives that lack these features. Second, all data are based on self-reporting by initiative participants. Thus, the accuracy of any factual information reported may be limited by the respondent's knowledge, while results related to more subjective themes (e.g., ILI motivations and stakeholder participation) may reflect respondents' deliberate or unintentional bias. Third, results are based on the perspectives of only one representative of each ILI, who may not be aware of all aspects of the initiative, or who may be inclined to portray the initiative in a positive (or negative) light. Fourth, results related to investments and outcomes identify only whether or not a particular activity or outcome occurred, not the level of effort or resources allocated to each investment or the magnitude and reach of each outcome. Finally, reported outcomes may not have been evaluated relative to a baseline or counterfactual scenario; thus, reporting of an outcome signifies that change occurred in the landscape, but not necessarily that this change was mainly attributable to the initiative. Despite these caveats, the results provide a rich portrait of the practice of integrated landscape management in the LAC region.

5.1. ILIs as a vehicle for advancing landscape multifunctionality

At the most general level, the results suggest that ILIs are not only pursuing landscape multifunctionality (as indicated by diverse objectives and investments spanning several sectors) and but also achieving it to some degree (as indicated by outcomes in at least three of the four domains for most initiatives). Furthermore, the data support the hypothesis that landscape initiatives that pursue a wider range of objectives and invest across several domains yield a broader range of reported outcomes than those that focus on fewer objectives. This finding suggests that deliberate efforts to pursue landscape multifunctionality in the LAC region are bearing fruit, at least in the eyes of initiative participants. What the data do not reveal is whether these initiatives are achieving landscape multifunctionality in a way that is simply additive (i.e., by amalgamating multiple investments under a single umbrella), or whether the initiative is serving to coordinate and integrate investments in a way that generates new synergies that multiply benefits on the ground.

To gain additional insight into the ability of ILIs to catalyze new synergies for landscape multifunctionality, it is instructive to compare the motivations and roles of the agriculture sector in the surveyed ILIs to those of the conservation sector. Conservation motivations were the most commonly cited “very important” drivers of ILIs, while motivations related to increased food production and crop and livestock productivity lagging behind in overall frequency and reported importance. The implication is that, in at least a subset of the initiatives, stakeholders that have conservation objectives foremost in mind are choosing to invest more broadly across multiple domains. This pattern may reflect the recent shift of major conservation organizations toward prioritizing conservation strategies that also support economic development and human wellbeing (Doak, Bakker, Goldstein, & Hale, 2013). In the wake of disappointing experience with integrated conservation and development projects in the 1990s, conservationists have now adopted new ways of integrating conservation and human development, including payments for ecosystem services and ILIs (Balvanera et al., 2012; Milder, Buck, DeClerck, & Scherr, 2012). Concurrently, research has elucidated the conservation value of—and conservation friendly management options for—Neotropical production landscapes to protect native species, habitat corridors, and ecosystem services in fragmented regions (e.g., DeClerck et al., 2010; Harvey et al., 2008; Porter-Bolland et al., 2012). These factors appear to create a comfortable fit for conservation stakeholders to participate in multi-objective projects that include potentially conservation-friendly economic activities such as diversified agriculture, agroforestry, and ecotourism.

Similarly, ILI participation from the agriculture sector generally emphasized agroecological approaches (Altieri, 1995) that conserve and use agricultural biodiversity, and foster local ecosystem functions (e.g., soil fertility, water conservation, and pest control), to support productivity. On the other hand, investments in conventional crop intensification and irrigation—core components of Green Revolution agriculture—were rarely reported to be part of the ILIs. Relatedly, small-scale farmers and producer groups, who are most likely to apply agroecological practices (Altieri & Toledo, 2011), were much more commonly involved as ILI stakeholders than agribusiness. These results suggest that many ILIs are focusing on the alignment among ecologically-based agriculture, resource- based livelihoods, and ecosystem conservation. While far from easy, such alignment in some sense represents the "low-hanging fruit" of integrated landscape management. More challenging—and apparently less common—is to pursue alignment among large-scale agriculture, other commercial interests, ecosystem conservation, and local livelihoods. Whereas conservation stakeholders apparently already have strong incentives to work across sectors to protect the environment and manage common-pool resources, this is less true of the full range of stakeholders principally interested in maximizing agricultural yields and economic returns, for whom it will be critical to identify the right incentives and entry points for constructive participation in ILIs.

5.2. The role of institutional development and multi-stakeholder processes

At its core, integrated landscape management is composed of human and institutional processes and systems for governing rural landscapes. Consistent with this observation, institutional planning and coordination emerged as the most important of the four domains for both ILI investments and outcomes—suggesting that many initiatives consider such functions to be a critical foundation for multi-stakeholder landscape governance. As highlighted by the open-ended responses on the most and least successful aspects of ILIs, many respondents considered improved stakeholder coordination and human and institutional capacity for multi-objective planning and decision-making to be successes in their own right.

However, these human and institutional outcomes can take years to achieve and there is no guarantee that they will ultimately translate into greater multifunctionality on the ground. Indeed, compared to landscape planning and coordination outcomes, tangible outcomes in the agriculture, conservation, and livelihood domains were each reported in a smaller percentage of initiatives (although most initiatives registered at least a few outcomes in each domain). These results imply that the road from institutional investments to on-the-ground results at a landscape scale may be a long one. Accordingly, the governments, donors, and community stakeholders who invest or participate in such efforts should understand the need for ongoing support (in the form of funding, technical backstopping, and/or other human resources) that allows for flexible and non-linear adaptive management approaches. Similarly, monitoring programs and indicators for ILIs should track both “slow” and “fast” variables related to each of the four domains to assess not only biophysical and socioeconomic results at each stage of an initiative, but also the human and institutional capacities that may support long-term sustainable management and enable appropriate responses to future challenges (Walker, Carpenter, Rockstrom, Crépin, & Peterson, 2012).

The results also suggest that ILIs can provide a constructive platform to convene stakeholders in a way that brings a broad set of perspectives and interests to address landscape management challenges. The surveyed initiatives were reported to involve a large number and diversity of stakeholders in design and implementation, including both internal stakeholders from the landscape itself and external stakeholders from the public, private, and civil society sectors. This finding suggests that most ILIs cannot be considered as strictly bottom-up or top-down efforts, but, rather, commonly involve an interplay between both sets of stakeholders in which stakeholders roles may shift over time. Prior research has indicated that multi-objective land and resource governance may promote the engagement of diverse stakeholders at multiple scales by raising questions or framing challenges that cannot be addressed through the expertise or perspective of any one group (Berkes, 2009; Southern, Lovett, O'Riordan, & Watkinson, 2011) and facilitating relationships that foster engagement (Höppner, Frick, & Buchecker, 2007). This dynamic appeared to be at play in many of the surveyed ILIs, where the set of participating stakeholders extended far beyond the convening body. Nonetheless, the frequent absence of commercial interests, as well as the superficial nature of government participation in some cases, raises concern that powerful stakeholders are not being fully incorporated into ILIs. Efforts of political and economic elites to circumvent participatory and democratic governance processes are common and well-documented (e.g., Cornwall, 2008; Platteau & Abraham, 2002), and should be recognized as a particular challenge for ILIs given the emphasis that they place on fostering multi-stakeholder processes that are both technically sound and politically legitimate.

5.3. Future research directions

As noted above, this study provides a foundational characterization of the practice of integrated landscape management in the LAC region, but was not designed to independently evaluate or attribute the impacts of ILIs in quantitative terms. Further research is therefore warranted to deepen the understanding of landscape approaches and their relative effectiveness. We suggest that such work be conducted at two levels: 1) in-depth case studies of individual ILIs, and 2) comparative studies and meta-analyses of larger sets of initiatives.

At the level of individual ILIs, rigorous evidence of effectiveness will require systematically collecting quantitative data on ecological, social, economic, and agricultural outcomes of ILIs and evaluating the relationships among these outcomes to document the degree to which the desired synergies and complementarities are being achieved. Such research must be designed to disentangle the multiple interacting consequences of a landscape management initiative from exogenous factors and change trajectories not attributable to the initiative. Landscape management interventions are not necessarily amenable to experimental approaches, but counterfactual scenarios can nevertheless be established or modeled to infer the net effects of landscape initiatives. In addition to quantitative outcome monitoring, qualitative methods will be important for understanding the perspectives and roles of different stakeholders in each landscape and for delving more deeply into the institutional and policy factors that support or undermine effective integrated landscape management.

While case studies can be informative and provide rigorous evidence about ILIs in specific contexts, policy recommendations and investment decisions related to integrated landscape management may be better informed if they are based on evidence from a range of contexts. For this reason, comparative studies and meta-analyses should also be considered as a critical part of the research agenda on ILIs. At present, such analyses are probably not possible, as there has been little or no comparability in monitoring approaches or research methods that have sought to document and quantify ILIs outcomes. However, as the practice of integrated landscape management expands over time, meta-analyses may become more feasible if a major portion of ILIs conduct credible monitoring, and particularly if such monitoring adheres to some basic common parameters to facilitate data comparability. Several frameworks for multi-scalar, multifunctional, long term monitoring of agricultural landscapes have recently been proposed (e.g., Sachs et al., 2010; Vital Signs, 2013), and could serve as useful starting points to improve the comparability of data on ILIs to support future meta-analyses.

Taken together, research on integrated landscape management at these two levels will assist ILI practitioners, investors, and policymakers in conducting and supporting more effective landscape approaches by: 1) clarifying the causal relationships between ILI investments and outcomes under different institutional and landscape configurations; 2) highlighting mechanisms, tools, methodologies, approaches or strategies that tend to support better outcomes across multiple domains of multifunctionality; 3) suggesting how policy frameworks can more effectively support ILIs and landscape multifunctionality; and 4) identifying feasible and efficient strategies for supporting landscape initiatives such that they can sustain themselves indefinitely.

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CHAPTER 2: INTEGRATED LANDSCAPE MANAGEMENT IN ACTION: INSIGHTS FROM TWENTY-THREE CASES IN LATIN AMERICA AND THE CARIBBEAN

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1. Abstract

Integrated landscape approaches are being widely used across Latin America and the Caribbean (LAC) to manage multi-functional landscapes for their potential to mediate between food production and conservation, while improving livelihoods and governance at a landscape scale. An initial survey of 104 initiatives across LAC has described the contexts, motivations, activities, participants and outcomes, however there is still poor understanding of the particular historical, social and economic forces that drive integrated landscape initiative (ILI) formation, the roles of pre-existing and newly established organizations in ILIs, the impact specific policies and financial mechanisms in sustaining them, and their perceived effectiveness in relation to stated objectives. To fill this gap, we interviewed 75 leaders and key stakeholders in a subset of 23 of the 104 surveyed initiatives, systematically selected for geographic diversity, range of management systems and range of investments and outcomes. We use an analytical framework developed from the survey and interview data to describe pathways for ILI development, as well as some potential pitfalls. Although we found a logical progression from establishing a landscape identity to perceiving outcomes at the landscape scale, in reality the levels of engagement are not always pursued or achieved sequentially. Results indicate that the creation or strengthening of the landscape identity occurs due to the conjunction of several factors such as land use change or response to crisis. We found that although local organizations play an important role in leading initiatives and providing continuity of management with a landscape, international or national organizations also offer key support through funding, technology and research. Activities are most often oriented toward building human capital and creating participatory management plans, however they also include activities related to conservation and sustainable agriculture in targeted areas. ILIs report their greatest effectiveness as building human capital and establishing more effective mechanisms for governance. Policy mechanisms were found to be supportive in some cases and prohibitive in others. In some cases, policies granting legal status to initiatives were instrumental in ILI formation, in others, policies created perverse incentives, limiting ILI effectiveness. Financial support for ILIs was often fragmented and intermittent throughout levels of development. While long term funding was helpful in supporting ILI activities and establishing coordinating organizations, many ILIs established organizations and achieved outcomes through widespread volunteerism. Other limitations that ILIs face are a lack of law enforcement, low levels of governmental support, and intermittent participation or absence of key stakeholders. These 23 in depth cases enrich our understanding of ILI characteristics, and present a framework for looking at the patterns of their development, the roles of policy and finance mechanisms in the development process, and potential pathways that lead to landscape scale outcomes.

Keywords: landscape, conservation, agriculture, rural development, governance, Latin America

2. Introduction

In recent years, there has been a surge of interest in integrated landscape management approaches to address complex challenges in rural landscapes where multiple stakeholders are pursuing potentially competing interests related to food production, social and economic development, and ecosystem conservation (Milder et al., 2012; Sayer et al., 2013; Scherr et al., 2012; Scherr and McNeely, 2008). Landscape approaches are now being applied to address a wide range of linked challenges including biodiversity conservation in human-modified landscapes (Perfecto et al. 2009), conservation and management of ecosystem services (Tscharntke et al. 2005), terrestrial climate change mitigation and REDD+ (reduce emissions from deforestation and forest degradation) (Harvey et al. 2013), food security, disaster risk reduction, and eco-certification (Ghazoul et al. 2009), among others. Integrated landscape approaches have also attracted considerable interest among the international donor and policy communities, exemplified recently by the convening of a two day “Global Landscapes Forum” at the UN Framework on Climate Change Convention’s 2013 Conference of Parties to address all issues related to land use and climate change in an integrated manner.

But although there is now considerable interest in landscape approaches, very little detailed information exists on how these initiatives function in practice and what factors influence their outcomes and effectiveness. Recent literature on integrated landscape approaches has tended to focus on its potential benefits and limitations (Sayer, 2009; Scherr and McNeely, 2008) or to offer guiding principles for implementing such approaches (Frost et al., 2006; Sayer et al., 2013). To date, however, empirical studies of landscape initiatives have tended to be anecdotal or case-specific in nature and therefore unable to elucidate common themes, mechanisms, or challenges. Additionally, case studies and characterizations of landscape initiatives have not necessarily been detailed or thematically comprehensive enough to clarify the political, social and economic contexts in which these initiatives take place, or the effectiveness of management strategies intended to deliver and measure outcomes across multiple objectives.

Given these existing limitations in the knowledge base, more robust evidence is urgently needed to provide empirically-rooted guidance for the growing set of rural communities, governments, civil society organizations, policy makers, and donors that seek to apply integrated landscape approaches. In this study, we conduct an empirical assessment of the practice of integrated landscape management in Latin America and the Caribbean (LAC) to help address these critical gaps. The resulting evidence can inform the design of future investments in landscape approaches (e.g., donor-funded programs) and identify important lessons that may assist the communities and multi-stakeholders group that are attempting to navigate the complex terrain of integrated, multi-functional landscape management.

The terms “landscape approach” and “integrated landscape management” have been used to refer to many different types of activities that vary widely in their scale and focus (Scherr & Shames 2012). To bound this investigation, therefore, we focus on discrete “integrated landscape initiatives” (hereafter referred as “landscape initiatives” or simply “initiatives”), which we define as projects, programs, platforms, or sets of activities that: 1) explicitly seek to improve food production, biodiversity or ecosystem conservation, and rural livelihoods; 2) work at a landscape scale and include deliberate planning, policy, management, or support activities at this scale; 3) involve inter-sectoral coordination or alignment of activities, policies, or investments at the level of ministries, local government, farmer and community organizations, civil society groups, donors, and/or the private sector; and 4) are highly participatory, supporting adaptive, collaborative management within a social learning framework (Milder et al., 2014).

In a companion study (Estrada-Carmona et al., in review), we provided an initial characterization of 104 landscape initiatives in the Latin America and the Caribbean (LAC) region, including the context, objectives, participants, component activities and investments, outcomes, and key successes and failures of such initiatives. This study revealed that such initiatives are relatively common across the LAC region. Although many of the individual landscape initiatives were initiated or supported by externally-supported projects or programs, the region has developed its own capacities and paradigms for conducting integrated landscape management, and most of the initiatives involved significant participation and support from local and national governmental bodies. Consistent with the definition of landscape initiatives presented above, the LAC initiatives were clearly multi-stakeholder efforts, involving an average of more than 11 stakeholder groups per case. In addition, the initiatives took a strongly “multi-functional” approach to landscape management, each pursuing an average of more than nine specific objectives, spanning at least three of four main areas (hereafter referred to as “domains”) of landscape multi-functionality: food production, ecosystem conservation, rural livelihoods, and institutional planning and management (Estrada-Carmona et al., in review). However, the initiatives were reported to have the highest levels of investment in, and positive outcomes related to, institutional planning and coordination. This finding suggests that institutional strengthening is often considered as a critical foundation for multi-functional landscape management, but that it is often too early to say whether such foundations will translate into the delivery of sustainable benefits for food production, ecosystem conservation, and livelihoods improvement.

To deepen empirical understanding of landscape initiatives, the present study investigates in greater detail a representative subset of 23 of the 104 initiatives included in the companion analysis. To do so, the study moves beyond existing conceptual and anecdotal perspectives on landscape management to provide a more systematic and nuanced characterization of why landscape approaches are being used, what types of institutions and governing mechanisms are being put into place to implement them, how effectively these structures function to implement landscape activities, and to what degree landscape-level benefits are being delivered. This information is critical for understanding how stakeholder groups can more effectively navigate the complex terrain of landscape management and what governments, civil society organizations, and donors might do to support landscape approaches more effectively in the future.

We address three research questions. First, to what extent do initiatives contribute to or engage in each of four elements of integrated landscape management—namely, landscape identity, landscape institutions, landscape action, and landscape results—as defined by an analytical framework we elaborate below. Second, which internal and external factors have been most important in supporting or undermining initiatives' effectiveness relative to their stated objectives? And, third, in light of experience of these 23 initiatives, what appear to be promising levers by which governments, donors, and civil society might improve the enabling environment to support effective landscape initiatives where stakeholders choose to pursue them?

3. Methodology

This study and the earlier companion study described above (Estrada-Carmona et al., in review) were designed as complementary research activities to review and analyze experience with landscape initiatives in the LAC region. The pair of studies follows a mixed methods sequential explanatory design to conduct systematic analysis of quantitative and qualitative data (Ivankova et al., 2006). The earlier study used an online survey of leaders and managers of landscape initiatives to characterize and quantify initiative objectives, participating stakeholders and sectors, investments, and outcomes of a relatively large sample of initiatives (Estrada-Carmona et al., in review). Data from the survey responses informed the design of a semi-structured interview template to guide the present study, which was based on in-depth interviews with representatives of multiple stakeholder groups per initiative. This method enabled us to collect information and document insights from multiple perspectives on each landscape initiative, and to triangulate among potentially divergent views. Data from both phases of research (i.e., the online survey and the semi-structured interviews) were used to address the four research questions relative to the analytical framework elaborated below.

Of the 104 initiatives analyzed in the Estrada-Carmona et al. study, we selected a subset of 42 as candidates for more in-depth study according to three criteria: 1) overall geographic representation relative to the full set of 104 initiatives; 2) representation of a range of different development or land management paradigms present in the LAC region (e.g., Model Forests, biological corridors, and Biosphere Reserves); and 3) focus on initiatives that registered high levels of "multi-functionality" as indicated by investments and/or outcomes spanning the four domains of agriculture, ecosystem conservation, livelihood development, and institutional strengthening. For each of the 42 candidate initiatives, we first contacted the representative who completed the online survey and invited him or her to participate in a one-hour interview. During this initial interview, we requested contact information for at least three additional stakeholders who possessed deep knowledge of the initiative and the landscape, and who could, collectively, accurately represent the agricultural, rural development, and ecosystem conservation efforts in the landscape. We then contacted each of these stakeholders to request the opportunity to conduct a semi-structured interview. Of the 42 candidate initiatives, there were 23 for which we were able to interview the survey respondent and at least one other landscape stakeholder. We analyzed only this subset of 23 initiatives for which we were able to collect sufficient data.

Interviews followed a semi-structured template that included a core set of 15 mostly open-ended questions posed to all interviewees, and additional questions posed to those with the greatest expertise and familiarity with particular aspects of each initiative or landscape. To address the research questions, we posed interview questions related to seven different themes: 1) characterization of the landscape's economic, ecological, political and historical context; 2) motivations, objectives, and core activities of the initiative; 3) modes of participation by key stakeholder groups internal and external to the landscape; 4) the role, establishment and evolution of the local institutions supporting integrated landscape management; 5) policy context, barriers, and any efforts at policy reform included within the initiative; 6) initiative results and effectiveness; and 7) additional reflections and lessons learned. (For a copy of the interview template, please see the Supplemental Information.) We pilot-tested the interview template on two initiatives and subsequently refined it based on these tests, prior to full-scale implementation. For the 23 initiatives included in the study, we conducted a total 75 interviews, in Spanish and Portuguese, from June to August 2012.

We analyzed the interviews at two levels. First, we compared interview responses within each initiative to corroborate survey results and assess the level of agreement in interviewees' perceptions regarding the initiative's context, main characteristics, and effectiveness. This analysis was particularly important for assessing whether there was a common landscape identity, shared objectives across sectors and scales, and consistent perceptions of the distribution of benefits and costs among stakeholder groups. In cases of contradictory answers among respondents, we made note of the areas of contradiction, while also identifying, for the purpose of longitudinal analysis, the most common answer (or, in the case of a tie, the answer provided by the respondent who also participated in the online survey). We then analyzed responses for each initiative as a collective whole to understand, as completely as possible, the initiative's context, characteristics, outcomes, successes, and limitations.

Second, we analyzed the full set of 23 initiatives to discern patterns, commonalities, differences, and recurring trends or lessons learned. Results pertaining to factual characteristics of the full set of initiatives are reported as basic descriptive statistics. Based on the analytical framework, we also evaluated the degree to which the initiatives displayed clear and common understandings of landscape identity, developed effective landscape institutions, implemented activities in support of landscape management objectives, and achieved equitably distributed landscape-level results. Finally, we used tallies to summarize additional interviewee observations and themes related to successes, failures, lessons learned, and key aspects of the enabling environment reported to affect each initiative.

3.1. Analytical framework

To structure the data analysis, we developed an analytical framework defining the major elements and stages of a landscape initiative (Figure 8). The framework incorporates evidence on key dimensions of landscape approaches from the companion study (Estrada-Carmona et al., in review) and is informed by relevant literature on natural resource management and polycentric governance. Specifically, the frameworks construes mosaic landscapes as complex social-ecological systems in which human behavior and decision-making shape, and are shaped by, land use patterns and functions—all within the context of dynamically changing ecosystems, climate, markets, and external policies.

Landscape initiatives may be seen as including four critical elements: 1) formation of a shared landscape identity accepted by a range of stakeholders, 2) establishment or strengthening of institutions to plan or coordinate activities at landscape scale, 3) implementation of activities and investments to improve landscape performance, and 4) delivery of outcomes at a landscape scale. As indicated in Figure 8, these elements may be conceptualized as a series of four stages that succeed one another in logical progression. In reality, though, the stages are not always pursued or achieved sequentially. Activities in the early stages of identity formation and institutional establishment are neither a prerequisite for nor a guarantee of landscape scale activity or outcomes: an initiative may derail at any stage for a variety of reasons, or, conversely, top-down processes may contribute to landscape activities or outcomes even when not predicated on a shared landscape identity or landscape institutions (Figure 8). Additionally, the process of landscape management is often iterative and adaptive, as local institutions and even the identity of the landscape itself evolve alongside management efforts.

The first element involves formulating a landscape identity that is generally shared among a range of stakeholders. By this, we mean not only the cultural-spatial landscape identity that people attribute to a place based on its spatial layout, human geography, ecology, and history (Stobbelarr & Pedroli 2011) but also a “functional” landscape identity by which the landscape is construed as a cohesive management unit for addressing specific conflicts, challenges, or opportunities. In the latter instance, the landscape provides an appropriate scale and context in which to understand and address specific management needs. Landscape identity may emerge more or less spontaneously through stakeholders' common experience and understanding, or it may be forged or solidified through interactive, multi-stakeholder processes such as participatory mapping or rural appraisal exercises.

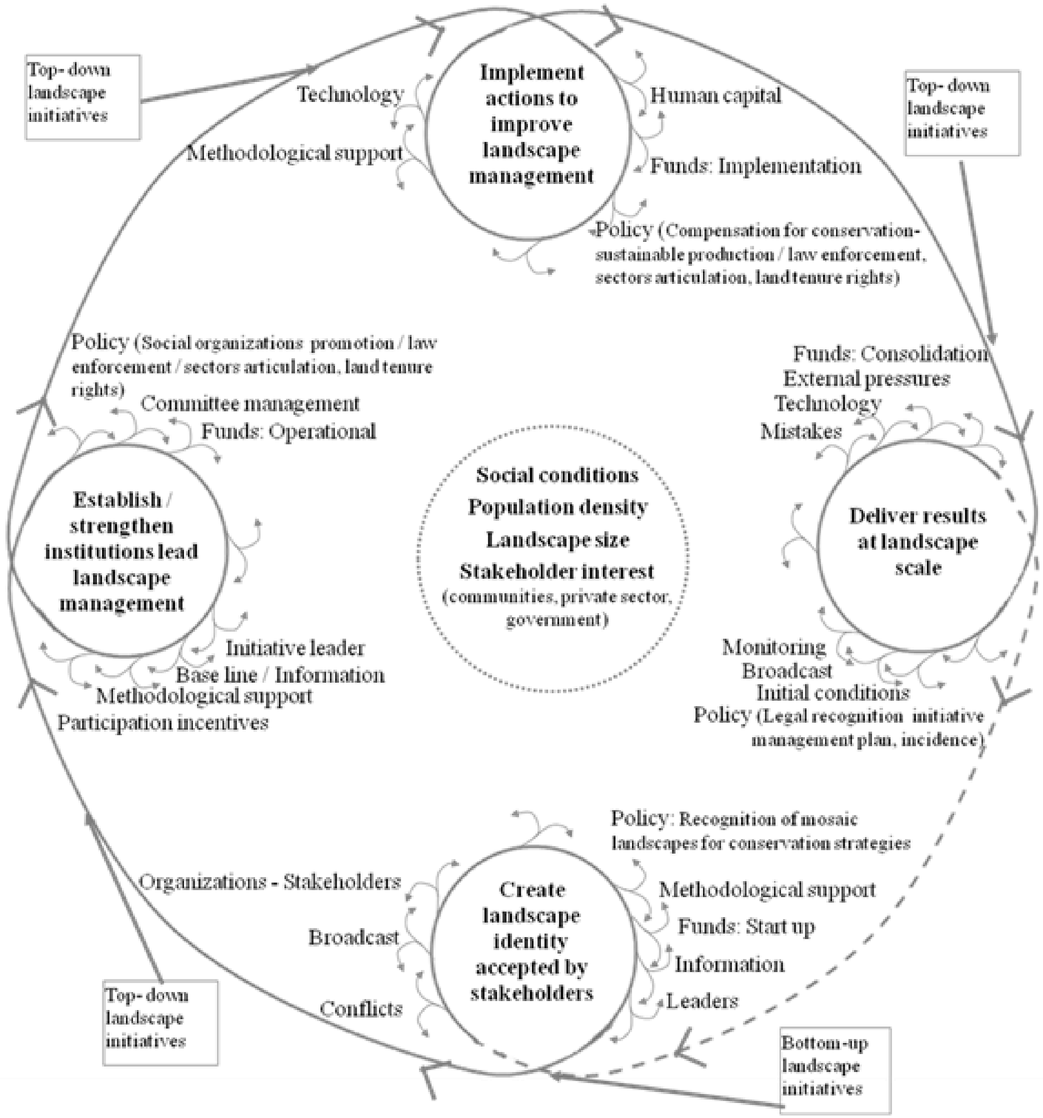
The second stage entails establishing or strengthening institutions and formal or informal governing bodies to lead or facilitate integrated landscape management. As highlighted elsewhere, the process of alignment or adapting these existing systems to address cross-sector landscape-scale challenges is one that has been characterized—using terms such as "muddling through" and "bricolage"—as complex, messy, and often ad-hoc (Sayer 2009, Cleaver 2002). Functions of landscape institutions: to coordinate actions across scales (local to national) and sectors, manage complex negotiation processes among stakeholders with divergent interests.   repurposing or re Institutions for landscape management would be expected often to have much in common with—if not be identical to—institutions for multi-scale governance of natural resources. As such, they should be equipped to guide the management of socio-ecological systems, particularly where these systems have fuzzy boundaries or cross jurisdictional boundaries, where they contain common pool resources that are susceptible to the "tragedy of the commons", or where they are expected to provide flows of benefit to numerous stakeholders with differing and potentially conflicting needs. However, institutions for integrated landscape management may sometimes place a stronger emphasis on economic development and social welfare than those oriented more narrowly toward natural resource management. Specific functions of "landscape institutions" may include fostering dialogue, negotiation, and planning processes to define a shared vision for the landscape; coordinating activities and investments of different actors in the landscape; governing rights and regulations related to land and natural resources; monitoring landscape condition and initiative outcomes; and advocating for supportive policies, market incentives, and investments from external actors.

The third stage involves the implementation of activities to improve landscape management, particularly through efforts that enhance synergies or negotiate tradeoffs among food production, ecosystem conservation, and rural livelihoods. Such activities and investments would typically include: 1) management actions explicitly occurring at the landscape scale, such as landscape-level zoning regulations, watershed management efforts, or regional infrastructure or value chain investments; 2) management actions occurring at smaller scales, but with a deliberate aim of contributing to landscape-level outcomes, such as conservation-friendly farming practices; and 3) implementation of, or advocacy for, policies and incentives (e.g., local, provincial, or national) that support the aims of landscape stakeholders. As indicated in Figure 8, within the logical sequencing of landscape initiatives, landscape action often flows from multi-stakeholder mandates and planning processes embedded in earlier steps. But landscape action can also flow from top-down processes that bypass these steps.

The fourth and final stage—landscape-scale results—refers to the achievement of specific outcomes, impacts, or benefits related to characteristics or functions that are mediated at a landscape level. For instance, the conservation of wide-ranging species, improvements in downstream water quality in a major catchment, or the establishment of robust post-harvest value chains beyond a local market may all be examples of "landscape results" predicated on coordinated activities and management practices in several different parts of the landscape. Where a landscape initiative has been effective, such outcomes will be closely related to stakeholders' original objectives for landscape multi-functionality, and benefits should be equitably distributed among stakeholders.

Overall, the framework defines an idealized notion of landscape initiatives as comprising four logically sequential stages (the main circle in (Figure 8), while also representing a range of variations from this model (arrows into and out of the main circle) that are likely to occur sometimes in practice. Taken together, the model provides a framing hypothesis about how landscape initiatives progress and deliver results. We use the lens of this hypothesis to evaluate the 23 landscape initiative included in this study.

Figure 8. Visual depiction of the analytical framework described in the narrative. Landscape initiatives may be seen as comprising four stages, with a logical though not inevitable progression beginning with landscape identity (bottom loop) and advancing clockwise to landscape institutions, landscape actions, and landscape results. This progression is indicated by the prevailing clockwise direction of arrows, while lighter-colored grey arrows indicate feedbacks and iterations that can occur within landscape initiatives. At each of the four stages, numerous factors may either support (small clockwise arrows) or undermine (small counterclockwise arrows) an initiative, potentially accelerating or impeding its progression from one stage to the next, or even derailing an initiative entirely. Factor in the center are present in all stages.



4. Results

We present the results in three sub-sections. First, we briefly characterize the 23 landscape initiatives and their context. Next, we present results related to the first two of our three research questions: 1) analysis of landscape identity, landscape institutions, landscape action, and landscape results according to the analytical framework; and 2) assessment of key factors that supported or undermined the effectiveness of the initiatives. Insights related to the third research question (policy implications) are provided in the Discussion section.

4.1. Characterization of the landscape initiatives and their context

The 23 initiatives represent 13 countries: five in Central America, six in South America, plus Cuba and the Dominican Republic in the Caribbean (Figure 9). Initiatives tend to take place in mosaic landscapes with diversified economies including food production for subsistence and local use as well as export. Agriculture was identified as an important economic activity in almost all of the landscapes, while forestry and/or tourism were also prevalent in the majority of cases. Extractive industries were an important part of the economy in about half of the cases. Almost three-fourths of the landscapes produced a major export crop, such as coffee, soy, pineapple, avocado, or tobacco. In addition, nearly all of the landscapes produced a variety of crops for subsistence and local sale, including basic grains, vegetables, potato, and others. The landscapes tended to include a mixture of land ownership and land tenure arrangements, with all 23 containing land owned and managed by individual private owners and the large majority also containing public or state lands (21 initiatives) and communal lands (15 initiatives). Seven of the landscapes included private land owned by large companies. Landscapes size ranged from approximately 10 to 550,000 square kilometers, with populations ranging from approximately 400 to 535,000 inhabitants. For additional descriptive information about the 23 landscapes and corresponding initiatives, please see Table 1and APPENDIX C.

Figure 9. Location of the 23 integrated landscape initiatives included in this study.

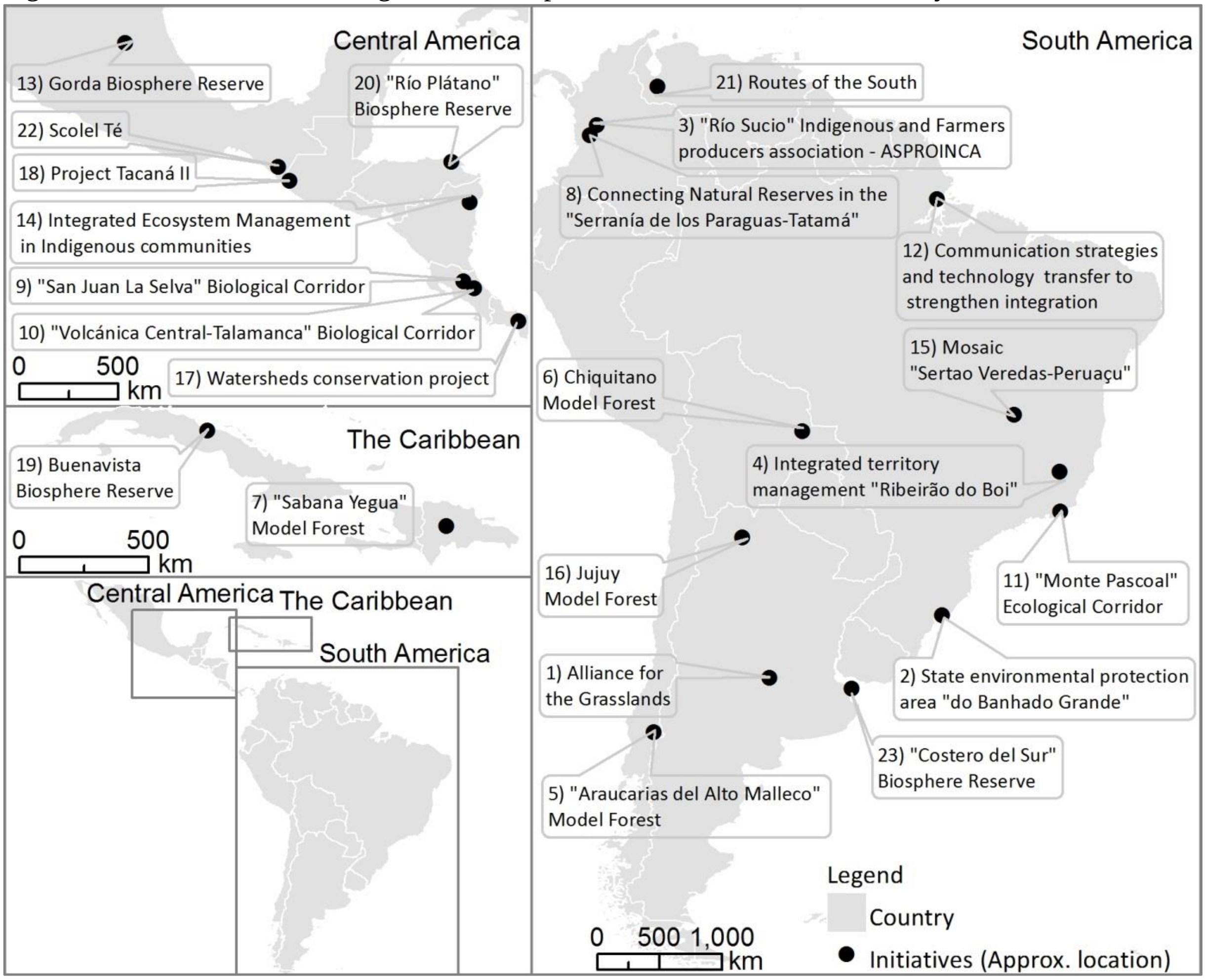


Table 1. Summary descriptions of the 23 integrated landscape initiatives included in this study. The first column indicates numbers by which the initiatives are referred in the narrative.

#	Initiative name	Country	Description
1	Grasslands Alliance	Argentina	Focuses on creating alliances between farmers and other stakeholders to manage grasslands and remaining forests for agricultural production (predominantly soy and livestock) as well as biodiversity across more than 500,000 km^2 of northwestern Argentina
2	State environmental protection area of the Banhado Grande	Brazil	Aims to mitigate wetland drainage due to agriculture and infrastructure changes through participatory management and socioeconomic development in 137 km^2 of the Rio Gravatai basin in Southeastern Brazil
3	Río Sucio Indigenous and Farmers producers association - ASPROINCA	Colombia	Promotes agroecology-based farming to improve local livelihoods, natural resource conservation and food security with smallholder farmers, especially by slowing the conversion of farms to full sun coffee across 430 km^2 of Colombia’s western mountain range
4	Integrated territorial management of the Ribeirão do Boi	Brazil	Links stakeholders engaged in agriculture and mining to improve integrated territorial management of approximately 40 km^2 of the Ribeirão do Boi watershed to reduce natural resource degradation and poverty through production diversification and value chain development
5	Araucarias del Alto Malleco Model Forest	Chile	Uses the Model Forest framework to co-manage 600 km^2 in south-central Chile for livestock, fodder, and pine forests, and to protect the native Araucaria species and preserve the local culture
6	Chiquitano Model Forest	Bolivia	Aims to bring together livestock and grain farmers with forest managers and conservationists under the Model Forest framework to protect the largest remaining patch of tropical dry forest, covering 200,000 km^2 of eastern Bolivia
7	Sabana Yegua Model Forest	Dominican Republic	Engages farmers and other stakeholders in watershed management in the Dominican Republic’s Sebana Yegua region to reduce natural resource degradation, poverty and erosion, and to safeguard downstream water supplies
8	Serranía de los Paraguas-Parque Natural Nacional Tatamá Micro-Corridor	Colombia	Works with a network of rural producers and artisans to reduce resource degradation, address social conflict, and implement agroecological farming practices that maintain key ecosystem services in the Serranía de los Paraguas – Parque Nacional Tatamá
9	San Juan La Selva Biological Corridor	Costa Rica	Preserves remnant forests and promotes landscape connectivity over nearly 2,500 km^2 of eastern Costa Rica to safeguard habitat for key species alongside sustainable economic development to support livelihoods of local communities
10	Volcánica Central Talamanca Biological Corridor	Costa Rica	Promotes sustainable agricultural practices in coffee, sugarcane, livestock and horticulture for economic development and engages local communities in tourism and conservation incentives for re-establishing connectivity among protected areas over 1,140 km^2 in the highly fragmented Talamanca region
11	State environmental protection area “Santo Antônio”	Brazil	Supports local participation in sustainable and diversified economic development, particularly related to coffee, fruit and timber production systems, to reduce watershed degradation, biodiversity loss and deforestation over nearly 6,000 km^2 of Brazil’s Atlantic coast.
12	Communication strategies and technology transfer for market development	Brazil	Connects stakeholders interested in agroecological production practices for oil palm, grain and vegetable production, particularly through the development of a regional value chain and market for organic products, as well as technology transfer through a nationally supported program on more than 25,000 km^2

#	Initiative name	Country	Description
13	Sierra Gorda Biosphere Reserve	Mexico	Promotes integration of resource conservation and sustainable agricultural practices to reverse soil degradation, protect traditional seeds, improve communities' livelihoods and food security, and reduce migration in approximately 384 km^2 in the eastern branch of the Sierra Madre mountains
14	Integrated ecosystem management in indigenous communities	Nicaragua	Strengthens indigenous and farmer communities to use an integrated approach to managing indigenous territorial lands, while decreasing poverty levels and increasing employment opportunities in fragile ecosystems in 8,500 km2 of Nicaragua's northern and southern autonomous regions
15	Sertao Veredas-Peruaçu mosaic	Brazil	Integrates protected area management with the promotion of sustainable agricultural practices, community-based tourism and non-timber forest product extraction to protect biodiversity, preserve local culture and halt agricultural expansion over 18,000 km^2 of the Brazilian cerrado
16	Jujuy Model Forest	Argentina	Aligns stakeholders under an integrated watershed management framework to protect remaining cloud forests; promote sustainable production of tobacco, sugarcane, fruit and basic grains; encourage resource conservation activities; and provide community education over 1,500 km^2 of Jujuy province in northwestern Argentina
17	Watersheds Conservation Project	Panama	Strengthens watershed governance to address water use conflicts and stop deforestation by fostering environmental education programs, supporting local economic development and promoting sustainable agricultural practices for cocoa, plantain, root crops and basic grains on nearly 15,000 km^2 across Panama
18	Tacaná Project II	Guatemala	Strengthens watershed governance by improving coordination and capacity of local stakeholders to implement integrated watershed management, decrease land degradation, and reduce poverty over 2,600 km^2 of watersheds around the Tacaná volcano in western Guatemala
19	Buenavista Biosphere Reserve	Cuba	Promotes diversified and sustainable production practices that decrease soil degradation and overexploitation of forests to protect key terrestrial and marine ecosystem goods and services that contribute to communities' well-being and livelihood opportunities over 700 km^2 of Cuba's northern coast
20	Río Plátano Biosphere Reserve	Honduras	Engages indigenous communities in management of the larger Rio Plátano landscape in Honduras to protect the area's natural resources by reducing deforestation, promoting sustainable agricultural practices to improve food security and slow agricultural expansion, and conducting supportive research activities
21	Routes of the South	Venezuela	Improves and diversifies local economic opportunities primarily through developing a network of eco-tourism businesses and promoting sustainable agricultural practices for coffee, vegetable, grain and livestock production in 5,600 km^2 of the tropical Andes in southern Venezuela
22	Scolel Té	Mexico	Promotes sustainable agriculture and forest conservation on small farms and communal lands to reduce poverty and improve community livelihoods, primarily through participation in carbon payments for climate change mitigation related to forest restoration in a small (10 km^2) landscape in Chiapas, Mexico
23	Costero del Sur Biosphere Reserve	Argentina	Fosters community involvement in protecting the unique biodiversity of the Rio de la Plata estuary as well as the area's traditional cultural and agricultural practices through economic development activities, research and education on 250 km^2 of Argentina's Atlantic coast

4.2. Evaluating four stages of the initiatives' development

To move beyond the basic descriptors presented above, here we evaluate the development of the 23 initiatives and their corresponding landscapes at the four stages defined in the analytical framework: 1) landscape identity, 2) landscape institutions, 3) landscape actions and 4) landscape results (Figure 8).

4.2.1. Landscape identity

As noted above, in the context of landscape initiatives we construe landscape identity to refer not only to stakeholders' understanding of a landscape's geographic boundaries and characteristics but also its history, context, and key challenges to be addressed. Overall, respondents from twenty of the 23 landscapes appeared to share a common landscape identity based on at least one of these factors, but only in nine landscapes were there largely concurring views on all such factors. In discussing the landscape's geography and context (interview questions 2.4, 2.5, and 3.1), respondents frequently referred to landscape scale dynamics and interdependencies (e.g., among stakeholder groups or portions of an ecosystem or watershed) as driving key local needs and challenges. But in no more than half the cases did stakeholders appear to share a common understanding of the landscape's physical boundaries. Where there was a commonly held geographic landscape identity, this was frequently linked to watershed or ecosystem boundaries around which the initiative had been developed in the first place.

In contrast to geographical notions of the landscape, historical context and a common understanding of key local challenges and needs tended to be stronger sources of shared landscape identity. In many cases, respondents shared a conception of the landscape as being fundamentally defined by combinations of events over the past few decades. These typically included some combination of major land use changes (e.g., deforestation, agricultural expansion, major changes in cropping patterns), land degradation (e.g., severe erosion, drought), natural disasters (e.g., floods, hurricanes), infrastructure development, major demographic shifts (such as colonization), and major military or political events (e.g., violent conflict, regime change, land redistribution). For the most part, these defining changes were presented in a negative light, although some positive changes were identified, including better transport infrastructure, land tenure regularization, and other policy reforms.

Similarly, shared landscape identity was evidenced by concordant understandings of landscape challenges and priorities. Not surprisingly, many of these related to recent shaping events, and included strong foci on improved natural resource management, watershed protection, forest conservation and restoration, and more ecologically compatible farming systems (e.g., agroecology). Poverty alleviation and economic diversification emerged as important landscape needs in about one-third of the cases. Needs for more participatory management approaches, improved alignment among sectors and stakeholders, or landscape or territorial level planning were mentioned in more than half the cases. Overall, we found considerable evidence of shared landscape identity but this identity was generally more strongly related to understandings of the landscape as a functional entity or management unit than as a geographic entity.

4.2.2. Landscape institutions

Institutional structures for convening and supporting landscape initiatives were quite diverse, spanning continua from more participatory to less so, and from well-orchestrated multistakeholder platforms to looser agglomerations of activities and decision-making authorities. Below we describe the role and structure of landscape institutions relative to the initiatives' genesis, decision-making systems, and coordination and support for implementation.

4.2.3. Genesis

Initiatives arrive at integrated landscape management through a variety of pathways. Ten of the initiatives were created out of an existing project or through the leadership of external actors with priorities for the landscape. In some cases, they were national or regional actors tapping into available funding to work with communities in landscapes of interest to them (e.g., the multiple Biosphere Reserves, initiatives 13, 19, 20, 23). In other cases, the development of the initiative was prompted by an international actor with interest in engaging in a particular landscape (e.g., initiatives 14 & 22). Only three of the initiatives developed from purely local, grassroots efforts (initiatives 3, 7 and 8). However, five of the ten initiatives that developed out of a network of actors were led by a consortium of local stakeholder groups (e.g., initiative 10), while the other five developed out of networked actors were led by a variety of local and external actors, often with distinct roles in the initiatives. In some cases the networks were characterized by loose, informal collaboration (e.g., initiative 9) while in others, collaboration was highly structured (e.g., initiative 18). In seventeen cases, one actor facilitated the formation and development of the initiative. These actors were most commonly a local or national level NGO, but also occasionally a government actor or a new group formed specifically to facilitate the initiative.

4.2.4. Leadership/decision-making structures

The management committee is comprised by different stakeholders and its main roles are to define priorities, design and implement the management plan, define strategies to fundraise resources for activities implementation, monitor initiative progress, find allies inside/outside the landscape, strengthen and support local and community based organizations, conflict resolution or mediation and define stakeholders and organizations roles for the landscape functioning. Seventeen initiatives supported the establishment of a management committee explicitly to coordinate or facilitate integrated landscape management (i.e. communitarian base organization, management committee, or directory). The management committee tends to work at smaller and more manageable territorial units such as basin like in Tacaná II (initiative 18), subcorridor like in Costa Rican biological corridors; or municipalities (initiative 6). The smaller units are articulated across the landscape to reach initiative goals, however, it facilitates the planning of each unit according to its own social-environmental context.

4.2.5. Capacity and implementation structures

Initiative leaders are in charge of guaranteeing initiatives functioning by articulating the diverse stakeholders and coordinating the management committee, fundraising, planning, communicating and coordinating logistics. Local organizations with an active and longtime presence in the area play a key role leading the initiative (i.e. Mopawi or Grupo Ecológico Sierra Gorda), often in alliance with governmental sectors such as protected areas (Grupo Ecológico Sierra Gorda). Local and national governmental sectors and offices can also highly support and lead the initiatives as is in Buenavista Biosphere Reserve (initiative 19). Scientific and environmental organizations (CCT, CATIE) have been also leading and supporting biological corridors formation and establishment in Costa Rica. And, other types of initiative leaders are communitarian-based organizations (Serraniagua, ASPROINCA, CORNASAM), private non-profit foundation (Ándes Tropicales, Funatura, BioAtlantica) and international organizations supporting bottom-up governance process (UICN). Initiatives with the same management scheme, for example model forest, also present different institutions structures where the initiative leader is a local organizations (FCBC, Surfuturo) or the management committee (directory) itself legally conformed as a civil association (Initiatives 5 and 16). We found that rather than the type of the initiative leader (i.e. research center, local organizations), the strength and leadership of the initiative leader is what determines initiative progress. Initiatives with a weak leader or heavily based on voluntarism work face strong limitations (i.e. Volcánica Central – Talamanca Biological Corridor; initiative 10).

Sometimes the initiative leader and the management committee are two separate organizations, for example, the Scientific Tropical Center is currently leading the San Juan la Selva Biological Corridor (initiative 9), but the corridor has its multi-stakeholder and participatory management committee.

Also, in some cases the organizational leader and the management committee is the same and fulfill both institutions' functions, as in Model Forest Araucarias del Alto Malleco (initiative 5). The management committee may be founded via voluntarism (initiative 10), governmental support (initiative 19), combined international and local funding or by a mixture of all.

ILIs often require new local actors to develop new capacities and functions to support multi-stakeholder, multi-objective management. In many of the cases, a combination of international organizations, national and state governmental agencies, or national NGOs help develop the capacities of an existing actor to coordinate and facilitate the ILI's activities. In the majority of cases, NGOs are most frequently supported to play these new roles (e.g., initiatives 2, 3, and 4, to name a few), although in a few cases local governments (e.g., initiative 23 and initiative 12) were also supported for taking on new responsibilities and functions associated with ILI activities. International conservation, development and research organizations, as well as universities or governmental aid agencies were the most common supporters investing in building the capacity of local actors. Even in the case of initiatives with strong local leadership, international networks such as the Biosphere Reserve Network or International Model Forest Network provided sources of funding, legal recognition, technical resources for design and implementation of ILI activities, and networks for knowledge exchange.

In 12 of the 23 cases, management committees or advisory boards were formed to guide the initiatives' activities. These committees brought together new sets of stakeholders for collaborative management. In a subset of those 12 cases, a new organization was formed to facilitate the ILI. The most common purpose these ILIs mentioned for forming a new organization to manage the ILI was the need for a neutral body for seeking and managing funding for the initiative, rather than designating an existing institution with an established agenda and mission those particular functions. In the cases studied, the new organizations always took the form of a non-governmental, non-profit institution or cooperative institution. In addition to management committees, facilitating or leading organizations played important roles organizing stakeholders, leading funding proposals, hiring staff to support ILI management activities, or more generally maintaining the momentum of collaboration and activities. Of the 12 ILIs with management committees, 10 of these also had facilitating organizations, some of which were the newly formed organizations mentioned above. Seven of the cases without management committees also had facilitating organizations to guide activities, four of which were NGOs, one led by a government program, and the remaining two which were led by hybrid organizations.

4.2.6. Roles of other organizations and stakeholders

In addition to the capacity development, management and facilitating roles already mentioned, participating stakeholder groups played a variety of other roles in the initiatives. Local communities – particularly associations of producers, indigenous groups, women and youth – were reported as the most influential stakeholders in elucidating the needs, concerns, goals, commitments and expectations during the different stages of the initiatives. They were also key actors during the implementation stage through participation in and management of pilot programs or farmer to farmer education (e.g., Initiatives 3, 12, 13 and 22). Although private companies had the lowest participation, they played key roles in funding, training, value chain development, sustainable production and technical support (e.g., initiative 4).

Although government agencies were very frequently involved in the 23 cases, particularly at the local level, seven initiatives mentioned that the participation of government was weak or absent during the design of the initiative. At times, government bodies were present in the management committees or decision making bodies but didn’t engage to the extent desired by other stakeholder groups. However, government participation was linked with establishing the legitimacy of the ILIS and supporting them through law enforcement, legal recognition and technical assistance, in addition to their aforementioned roles in capacity development and facilitation.

International organizations provided a range of functions and, in contrast to government groups, were often involved in the design of initiatives. They play key roles in channeling funds, providing technical support, support knowledge exchange, and developing methodological approaches. Initiatives link to international networks (e.g., Biosphere Reserves or Model Forests) or regional management schemes (e.g., biological corridors), indicated that they had better support in establishing guidelines and standards, learning from similar examples, creating seed fund programs and gaining legal support from the government.

Successful collaboration between stakeholder groups was most often described as ongoing participation and engagement in the initiatives activities – which they considered a sign that the initiatives' activities were perceived as legitimate and added significant value to stakeholders existing activities in the landscape. Initiatives also defined success in terms of the diversity of participating stakeholders, the initiatives' ability to resolve conflicts internally, and the emergence of new collaborations as a result of the initiative. Although these were the measures of success mentioned by the initiatives, not all felt that they had achieved high levels of success. Only half reported high or very high levels of success. At least five of those reported ongoing improvement of stakeholder collaboration. Another ten initiatives reported moderate or mixed success, achieving some aspects of stakeholder collaboration (e.g., ongoing participation), but falling short of other aspects (e.g., collective decision-making or engaging key stakeholder groups). Of the remaining initiatives, only one reported low levels of success and another reported to still be in the initial stages of establishing collaborative activities.

4.2.7. Landscape action

Respondents across initiatives were consistent in terms of the higher investments on activities related to strengthening governance by creating institutional planning (all) and elaborating a participatory management plan (16 initiatives), and empowering local communities by strengthening human capital (all). Investments on activities related to sustainable agriculture practices (23initiatives), natural resources conservation (22initiatives), and sustainable economic development either via value chain development (14 initiatives) or sustainable tourism (9 initiatives) were also consider as part of the top four or five key activities among initiatives.

High poverty levels, high dependence to natural resources, high vulnerability to extreme events, and high stakeholders de-articulation were shared characteristics of local inhabitants across landscapes according to respondents. The threat to an ecosystem and its services was also a commonalty across initiatives; but the importance and the need of protecting those ecosystems was often highlighted due to a research or scientific project that provided key information.

Degree to which Initiatives activities on communities' governance and empowerment tend to be targeted to cover the whole landscape, however, other activities tend to be targeted or localized in strategic areas to overcome landscape limitations. Initiatives leaders and/or management committee worked at landscape scale strengthening initiative governance by reaching and getting all landscape stakeholders actively involved while reinforcing landscape identity; as respondents mentioned this is a continuous process at both temporal and spatial scales. Investments on human capital were directed to both, local communities and landscape initiative stakeholders. This investment included diverse activities such as formal (incorporated at the local schools and universities level) and informal efforts (training, seminars, workshops, field practice), and covered different subjects, from natural resources management, organic production, sustainable agriculture practices, agro and eco-tourism, cooperatives and association, project design and management, post harvesting production and monetary resources management.

Specific activities: Investments on promoting sustainable practices were often planned at smaller spatial units such as demonstrative units/villages or pilot farms (i.e. Initiatives 3, 12, 13 and 22), and often depended on the availability of funding. These spatial units also helped to work at manageable scales, while facilitating training, learning process, adopting sustainable agriculture practices and often used as an example of the initiative goals. From these spatial units, initiatives extend their action area based on community request or funding. Conservation actions were at both, farm and landscape scale. At farm scale, initiates worked with farmers to help and promoted the protection and establishment of private protected areas (i.e. Initiative 8 and 22). At landscape scale, key species (i.e. Initiative 9), remnant forest patches or ecosystems were identified and legally protected (i.e. Initiative 8 and 19). Also management plans for existent protected areas (i.e initiative 22) and connectivity between protected areas (i.e initiative 10 and 11) were created and planned at landscape scale. Scenic beauty and touristic potential was also planned at landscape scale as a strategy for sustainable development and conservation (i.e. Initiative 21). Activities that supported a sustainable economic development (value chain and tourism) were targeted to work with local farmers associations and cooperatives to facilitate funds/inputs to farmers (i.e. micro loans, seeds) (initiatives 4 and 21), improve practices (initiative 12), research to produce high quality products (agriculture and NTFPs) (initiative 5), access to local markets (initiatives 3 and 8), and even work with the consumers (Initiative 1).

4.2.8. Landscape-scale results

To assess landscape scale results, respondents evaluated the effectiveness of the initiative accomplishing each one of the four or five main objectives of the initiative, altogether with the used criteria to evaluate them. We asked respondents to evaluate the effectiveness by giving a score as follows, one - two (no effective), three (poorly effective), four (moderately effective), five (effective) and six-seven (very effective). The used criteria's by respondents to assess effectiveness (assign the score values) were often related to monitoring strategies (i.e. land use change, species monitoring, water quality, soil quality), respondent perception, social changes (i.e. farmers- promoters, cooperatives formed, active civil participation, greater concern for natural resources conservation), and specific initiative products (i.e. web page, elaborated plans, protected areas, products in the market).

The most often mentioned objectives were related to sustainable economic development (21 initiatives), conservation (19 initiatives), governance (18 initiatives), local communities' empowerment (15 initiatives) and sustainable agriculture (12 initiatives). Interestingly, although not all the initiatives considered local empowerment and sustainable agriculture as a main objective, all initiatives invested on training (building human capital) and promoting agrobiodiversity-sustainable practices. Initiatives are effective (in average) achieving sustainable economic development, conservation and local communities' empowerment objectives. While initiatives are moderately effective achieving governance and sustainable agriculture production objectives. Respondents also highlighted across initiatives that despite the achieved outcomes, there is still much work to do due to the landscapes and population size, landscape conflicts, initiative ambitions, and the complexity of participatory and adaptive management approaches.

Outcomes in communities' economic development were related to new markets for farmer products (8 and 14), more empowered and engaged families (initiative 3), more profitable agriculture (initiative 13), better infrastructure (initiative 7) and new productive cooperatives or associations that are successfully functioning (initiatives 3, 11, 14 and 21). However, communities economic development outcomes were limited due to population size (large), social conditions, and time (outcomes are perceive in the middle-long term). Outcomes in conservation were related to positive changes on ecosystems functions and health (initiative 2), improvements on biodiversity connectivity (initiative 19), and restoration and protection of natural resources (initiative 9); however, conservation outcomes were limited due to landscape size, persistent deforestation (external/internal pressures), land degradation, and the fact that conservation is a slow process with low outcomes in short term (i.e. reforestation, ecosystems restoration). Outcomes in governance and more specifically in institutional planning were mostly associated to the creation of the inter-sectoral management committee, the management plan elaboration, stronger and empower local organizations; however, institutional planning outcomes were limited due to poor incidence in policy, intermittent participation of several stakeholders and conflicts of interest between stakeholders.

Local communities empowerment particularly through training and human capital formation was an outcome that respondents identify have a positive effect on initiative effectiveness. Despite initiatives highly invested in this aspect, there was also a common agreement on the need of investing more on human capital formation and thinking about this objective as a constant process. The main limitations for human capital formation were related to landscape and population size, stakeholders lack of interest, implementation cost (limited funds) and social conditions in terms of institutions, education and poverty levels (Figure 8). And finally, outcomes on sustainable agriculture practices were related to an implementation of sustainable practices by local farmers (initiative 3, 13, 22), implementation of new sustainable activities (initiative 19), better infrastructure (i.e. biogas waste management) (initiative 10). Limitations were related to climate conditions, land tenure (i.e micro farms <0.5 ha; or lack of property rights),   social conditions, landscape size and population density.

4.3. Key factors supporting or undermining effectiveness

Across initiatives, there exist well defined factors that can undermine or support the initiatives maturation. Initiatives maturation process includes passing through each one of the initiatives stages several times until reaching a self-sustainable phase with a high incidence in the whole landscape area and with a high inclusion and involvement of all the landscape population and stakeholders. The undermining or supporting factors of the maturation process are present in each one of the stages either decreasing or increasing the time it will take to an initiative to make "loop" in each stage. These factors have also a cumulative effect through stages making initiatives fail or be successful (Figure 8).

4.3.1. Laws and policies

Initiatives leaders used and were beneficiated from existent national legislation to create the initiative per se (creating landscape identity stage), to foment social organizations (establishing institutions stage), to guarantee law enforcement in the landscapes and to get access to incentives or benefits for conservation or sustainable production (implementing stage). The existence of legislation that recognize and regulate alternative landscape management and conservation units in mosaic landscapes such as biological corridors, environmental protected areas or mosaics, were mentioned as useful for initiative creation and for a stronger legal-governmental support (mentioned by one or more initiative from Costa Rica and Brazil). During the establishment and strengthening of the institutions that lead the initiative, one of the most challenging aspects is low coordination across sectors and the intermittent participation from governmental offices. One of the most often mentioned cases (but not limited to) of low coordination among sectors was between agriculture and environmental sectors. For example, at national level the agriculture sector promotes and invest on expanding and establishing conventional agriculture and monocultures without considering the social (migration and emigration) and environmental impacts (deforestation, loss of biodiversity, soil degradation) (Mentioned by some of the initiatives in Honduras, Colombia, Venezuela, Mexico and Bolivia). Respondents highlighted that this implies a disadvantage to initiatives who are trying to convince farmers to establish more sustainable practices and to protect natural resources, particularly because there exist financial - technical support and subsidies from the government to establish conventional agriculture. According to respondents experiences, the policies for conventional agriculture modernization and expansion, and mining usually generate inconsistencies with forest, soil, water and environmental legislation.

Initiatives can find in pre-existent legislation opportunities to regulate land use, establish protected areas, and channelize funds to farmers through mechanism such as payments for ecosystem services (Costa Rica and Guatemala), important legislation for implementing actions to improve landscape management. However, low or lack of legislation enforcement and generalized legislation (not differentiated by farmer's typology) were also mentioned by respondents as policies or factors that undermined or limited initiatives effectiveness during the implementation and other stages. In most of the cases, the existence of a legislation or regulation was something positive; however, the low level of enforcement forced initiatives to heavily invest on enforcing the law. Low or null land tenure rights or titling was also mentioned as a constrain for farmers inclusion and investments at farm scale, mainly because the uncertainty for farmers to invest in those lands is high and because some incentives (payment for ecosystem services) or programs require land tenure rights or title (mentioned by one or more initiative from Mexico, Guatemala).

After 11 years in average of initiatives work (deliver results stage), initiatives still have null or low power to influence legislation (local/national). Initiatives are investing on creating a long term management plan at landscape scale (16 initiatives); however, plans are fairly being incorporated or recognized by local/regional/national government offices. This poor recognition generates a friction between government and initiatives. Initiatives identified that empowered communities and leaders are using legislation as a tool for change.

4.3.2. Funding

The sources of funding for initiatives are diverse and vary through time. Across initiatives, the most common sources of funding were from external sources (18 initiatives), government (16 initiatives), voluntary work (13 initiatives) and local association or organization (10 initiatives). Respondents indicated that the initiatives efforts are oriented to reach a self-sustainable stage through voluntarism but also through local associations or organizations contributions. Nonetheless, initiatives are still highly dependent from external sources which are time-limited and products oriented, constraining initiatives need for funding: start-up, operational, implementation and consolidation funds. Initiatives tend to get start-up and operational funds through external sources and voluntarism. Some initiatives leaders fundraise funds from different sources; however, it was often mentioned the need to develop and improve fundraise skills. Voluntarism work importantly contributes to the landscape logistics; however, initiatives heavily based on voluntarism make progress at slower pace. Funds from local stakeholders, associations or organization are used to support the institutions functioning and the implementation of activities.

4.3.3. Stakeholders interest / participation

All bottom-up initiatives reported to be inclusiveness and open to the different landscape stakeholders to guarantee participatory processes at the different stages. Top-down initiatives, may limit the participatory process during the design of the initiative to avoid false expectation, however, after some actions and results are implemented and delivered respectively, initiatives start creating identity and establishing institutions that lead the initiative in a inclusive and open process (Figure 8 & Figure 9; initiatives 18, 21). In average, twenty initiatives included marginalized groups and small producers during the design and the implementation stage, but large landowners actively participated in only seven landscapes. Despite the wide and open invitation to participate, seventeen initiatives agreed on the need to actively involved national government, municipal or local governments, agro-industry, mining and local community. Although local and national governments were stakeholders often involved, respondents highlighted the critical need of a permanent and active participation and coordinated development of efforts between the government and the initiatives through time. Agro-industry and mining are important stakeholders and initiatives allies, since usually have economical resources, and occupy large areas. These stakeholders affects initiative objectives either positively (funding, enforcing the law, research, technical support) (i.e initiative 2), or negatively (apathy, environmental impacts, conflicts), however, their active involvement and participation in the initiatives is still low. Finally, although it was recognized the active participation of local communities it is still needed a more and active participation. This is one of the challenging aspects of working at large areas and with large populations. Developing strategies or incentives that promotes a higher and active participation of different stakeholders is strategic and a challenge.

4.3.4. Social conditions

High levels of poverty, illiteracy, culture diversity, communities' apathy, social conflicts among others, are factors that add to the initiative extra-challenges. To overcome these challenges, initiatives highly invest on human capital during the different stages (all initiatives), work at smaller scales to plan according to each unit context (microwatershed, subcorridor, municipality) and use pilot or demonstrative units to increase communities sensitivity and sympathy.

4.3.5. Landscape size and population density

Respondents identified that the landscape as a cohesive management unit, offers a natural delimitation and identification of threats (and its sources), challenges, potentialities and constrains, including stakeholders roles and responsibilities. However, working at landscape scale poses challenges. Seventy one percent of the responses to the question about the limitations of working at landscape scale were related to both logistics and stakeholders actively involvement and articulation. Logistics represent challenges in terms of cost (e.g. transportation, material, and infrastructure), technical support (e.g. training, human capital, equipment) and communication (e.g., cell phone / internet coverage, poor roads, dissemination strategies). Stakeholders involvement is even more complex when initiatives are trans-boundaries (country, state, county), since policy, stakeholders interest and social conditions varies across regions or conservation units (mentioned by some of the initiatives in Guatemala, Argentina, Bolivia, Brazil, Chile, Colombia , Honduras, Mexico and Venezuela). Landscape scale challenges are exacerbated due to the difficulty of guaranteeing permanent and constants starting and operational funds (15% responses) and due to the lack of permanent support from governmental organizations or entities, all across the landscape and through time (13% responses). The larger the landscape the larger the challenges at the different stages. Smaller landscapes may have still important challenges during landscape identity and establishment of institution stages due to social conditions and stakeholder interest, however, it may facilitate implementing and delivering outcomes stages.

5. Discussion and Conclusions

This article presents results from among the first longitudinal studies—based on a common methodology, analytical framework, and representative region-wide sample—to evaluate how landscape initiatives are functioning and the types of successes, challenges, and limitations they are experiencing. Given the inherent challenges of aligning action in rural landscapes across scales, sectors, and stakeholders, it is logical to expect that landscape approaches would rarely be pursued when simpler options were likely to suffice. In fact, we did find that the initiatives generally had strong motivations related to addressing challenges that stakeholders felt could not be resolved in other ways. In the majority of the cases, these challenges centered around a natural resource management issue (e.g., watershed management, wildlife habitat connectivity, or disaster risk reduction) combined with alleviating rural poverty, building agricultural value chains, reconciling past conflicts, and building more effective governance structures. Our results related to initiative motivations, contexts, and stakeholder participation suggest integrated landscape management to be, fundamentally, a problem-solving approach driven by context-specific demand—not merely a new conceptual paradigm or development model that is being applied in a top-down way.

However, the strong sense of purpose driving many of the ILIs was not always matched by a similarly comprehensive or far-reaching set actions or results. Specifically, most of the ILIs had registered significant progress and alignment of stakeholders relative to the first two levels of landscape engagement (landscape identity and landscape institutions), but not always relative to the third and fourth levels (landscape action and landscape results). Initiatives progress is not linear but cyclic, since each one of the stages is constantly "visited" facing new or the same challenges/factors; factors such as policy context, funding, social conditions, stakeholders interest, landscape size and population may either undermine or support initiatives at each stage. This result does afford a degree of optimism in the sense that ILIs appear to be putting into place the social and governance structures that are typically needed to undergird participatory, evidence-based approaches to addressing complex land-and resource-based challenges. The lack of far-reaching sets of actions and outcomes across most of the cases may also reflect the long duration needed for such engagement to come to fruition—at least at scales readily recognizable as “landscape.” In short, our research finds integrated landscape management approaches to be necessary (relative to the scope of problems faced by rural landscape stakeholders) and promising (in terms of activity at the first two levels of landscape engagement), yet not fully mature in many instances.

This characterization depicts ILIs to be most suitable as an approach for long-term investment in rural prosperity and sustainability—that is, not only solving difficult current problems but also heading off emerging problems such as climate change, natural disaster risk, and livelihood vulnerability due to reduced economic diversification. To capitalize on this promise of long-term sustainability, of course, requires long-term commitment to an initiative. The life cycle of initiatives offer an opportunity to better understand the different challenges that initiatives face through time and the need for long term support and commitment. For example, now it is clear that initiatives require specific funding at each stage (starting, operational, implementation, consolidation). Also, the review indicate that financial resources not always come from external donors, local stakeholders and organizations are also more actively funding initiatives as an strategy to reach a self-sustainable stage. We found little evidence of private investment in support of initiatives or their component objectives, and suggest this to be a critical gap and opportunity for future efforts to leverage such investment. This initiatives requires long-term commitment. In the interviews, we found that an important nexus of such commitment was frequently local volunteers and professionals, acting in their capacity as community members, farmer or women’s group leaders, local NGO members, or others. In the interviews, we found that an important nexus of such commitment was frequently local volunteers and professionals, acting in their capacity as community members, farmer or women’s group leaders, local NGO members, or others. Not surprisingly, financial resources also identified as a critical need, but these need not always come from external donors: some of the more successful ILIs were engaged in allocating and programming the use of public-sector funds flowing from governmental line ministries to support ILI objectives at a local level. We found little evidence of private investment in support of ILIs or their component objectives, and suggest this to be a critical gap and opportunity for future efforts to leverage such investment.

The practice of conservation and rural development in past decades is replete with projects and programs established to solve imminent, pressing problems within a short time frame. These “band aid” approaches—whether designed to prevent human starvation, aid in disaster recovery, or save a species at the brink of extinction—are typically carried out at high cost and frequently fail, or do not even attempt, to address underlying causes. The need for, and importance of, such work will never cease. Yet a complementary set of strategies, addressing problems at a larger scale, across longer time spans, and hopefully in a more durable way, is needed to manage for the escalating societal demands, challenges, conflicts, and resource constraints that increasingly characterize rural landscapes. ILIs present one such approach to holistic, forward-looking management of rural regions. While the model is still nascent in many ways, promising indications identified in this study suggest that with greater policy support, capacity building, and sharing of lessons and best practices, ILIs could merit adoption, and provide important benefits, at a much wider scale.

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CHAPTER 3: GLOBAL SENSITIVITY ANALYSIS OF RUSLE ILLUSTRATES IMPORTANCE OF COVER MANAGEMENT ACROSS ENVIRONMENTS IN PREDICTING SOIL EROSION RATES

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Geomorphology

1. Abstract

Soil loss remains a critical issue for sustained agricultural production and reduction of downstream environmental impacts. Modeling soil loss at watershed scales helps researchers and decision makers quantify the impact of policy and land use decisions. The Revised Universal Soil Loss Equation (RUSLE) is a common empirical model used for quantifying soil loss. This model is widely applied across spatial extents and environmental conditions despite a lack of site-specific data for many regions. To better understand the consequences of the broad applications of RUSLE and to provide recommendations for prioritization of site specific data collection, we performed a global sensitivity analysis (GSA) on three dissimilar factor estimate datasets, covering varying scales (plot and watershed) and environmental conditions (temperate and tropical). The GSA technique allowed us to rank factor importance in estimating erosion rates and identify important factor interactions controlling soil loss across environmental conditions. We also compared the robustness of both global and local sensitivity analyses in assessing factor contributions to model uncertainty. Using a non-parametric approach (Random Forest and Classification and Regression Trees), we found that the greatest soil loss comes from small proportions of the watersheds and is largely determined by the interaction of cover management with slope steepness in steep areas, and with soil erodibility in level areas. Results highlight the importance of cover management in soil loss predictions regardless of environmental condition and model parameterization. Our findings reinforce that conservation practices should be targeted at specific locations of high erosion by adjusting cover management, specifically root density

and surface cover. In addition, we argue that a global sensitivity approach is more robust than the local sensitivity analysis because higher order interactions among factors are quantitatively considered.

2. Introduction

Soil loss poses threats to biodiversity with significant on- and off-site impacts, including impacts to water quality, reservoir capacity, and food production (Pimentel et al., 1995; Bilotta et al., 2012). Decision makers and land managers require efficient scientifically defensible findings to prioritize implementation of soil conservation programs. Empirical and physical-based models are commonly used to quantify the mechanisms and patterns of soil loss across scales, environmental context, and land use. Model parameterization is a key step in representing inherent environmental variability (Box-Fayos et al., 2006), in particular, it is necessary to identify the factors and parameter estimates that produce the most uncertainty in model predictions for different environmental conditions and scales of data resolution.

Empirically and physically based models are commonly used to predict watershed scale soil loss from a range of systems (WEPP -Flanagan and Nearing 1995; RUSLE - Renard et al., 1997; EUROSEM - Morgan et al., 1998). One of the most commonly applied models is the Universal Soil Loss Equation (USLE) and its revised version RUSLE (Wischmeier & Smith, 1978; Renard, et al., 1997,Table 2). These empirical models are used to predict soil loss over large scales, particularly in data poor locations (Mueller et al., 2005; Bewket & Tefari 2009). Although physical-based models more precisely represent the forces control soil loss, empirical models remain widely used due to the lack of available data to parameterize more physical-based models (Gaffer et al., 2008; Bewket & Teferi, 2009).

The Universal Soil Loss Equation (USLE) was formulated from more than 10,000 plot years of basic runoff and soil loss data measurements on agricultural lands during 50 years in the United States

(Wischmeier & Smith, 1978). In the 1990s, the USLE equation was revised and improved to be applicable across a wider range of environmental conditions and crops (Renard et al., 1997). Both equations estimate long-term average annual soil loss (*A*) per unit of area ($A = R \cdot S \cdot L \cdot C \cdot K \cdot P$). Factor estimation for both models is relatively straightforward at different scales, and includes topography (*L* and *S* factor), soil erodibility (*K* factor), cover management (*C* factor), support practices (*P* factor), and rainfall- runoff erosivity (*R* factor) (Renard et al., 1997; Bryan, 2000, Table 2). Two main limitations of empirical models are: 1) soil loss is a stochastic process with greater variability for soil losses of lower magnitudes (Nearing et al., 1999; Nearing, 2000), and 2) processes that drive soil loss vary with spatial scale (plot and watershed) and location (Lal, 2001).

Table 2. RUSLE factor description, units and reference. Each factor parameters used to construct the theoretical dataset.

Factor (description)	**Independent parameters**	**Source**
Long term average soil loss - *A* ($t \cdot ha^{-1} \cdot yr^{-1}$) $A = C \cdot K \cdot L \cdot S \cdot R \cdot P$		Renard et al., 1997
***C*:** cover-management: Crop type and management practices such as the impacts of previous cropping and management, the protection offered to the soil surface by vegetative canopy, erosion reduction due to surface cover, and surface roughness (Dimensionless, but less erosive crops or land cover have smaller values)	*Sp*: Percentage of land area covered by surface cover; *Bur*: Mass density of live and dead roots found in the upper inch of soil ($lb \cdot acre^{-1} \cdot in^{-1}$); *b*: effectiveness of surface cover; *Bus*: mass density of incorporated surface residue in the upper inch of soil ($lb \cdot acre^{-1} \cdot in^{-1}$); *Cf*: surface soil consolidation factor; *Ru*: surface roughness; *H*: Canopy height (ft); *Ru*: Surface roughness; *Fc*: Fraction of land surface covered by canopy (%); *Cur*: Impacts of the subsurface residues ($acre \cdot in \cdot lb^{-1}$)	Yoder et al., 1997
***K*:** Soil erodibility: Soil profile reaction to hydrologic processes (e.g. raindrop impact, surface flow, roughness (topographic or induced), and rain water infiltration). K is affected by physical, chemical and mineralogical soil properties and their interactions and is calculated as an average annual value ($ton \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}$)	*s*: Soil Structure; *p*: Soil Permeability; *OM*: Organic matter (%); *M*: (%Silt +%Very fine sand)(100-%Clay)	Romkens et al., 1997
***LS*:** Topography: Slope length (L) which is the horizontal distance from the starting point of the overland flow until deposition or channel formation and slope steepness (S), the slope gradient effect on soil erosion	Θ: slope angle (degrees); λ: Slope length (ft)	McCool et al., 1997

Factor (description)	Independent parameters	Source
(Dimensionless)		
R**:** rainfall- runoff erosivity: The effect of raindrop impact and rate of runoff associated with rain of moderately sized storms with occasional large storms. ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot y^{-1}$).	*j*: No events per year; *I*: Erosive rain Intensity ($in \cdot hr^{-1}$)	Renard et al., 1997
P**:** Support practice The runoff reduction rate by implementing practices such as contouring, strip-cropping, terracing and sub-surface drainage (Dimensionless)		Foster et al., 1997

RUSLE has been applied at different scales, both, in the US where the data were originally collected (Renard & Ferreira, 1993; Gardiner & Meyer, 2001; Gaffer et al., 2008) and elsewhere, including regions with differing environmental conditions (Biesemans et al., 2000; Lu et al., 2004; Bewket & Teferi, 2009; Falk et al., 2009). Likewise, the purposes of applying RUSLE have been diverse. For example, to assess past, present and projected soil loss at a global scale (Yang et al., 2003), soil loss risk (Lu et al., 2004; Schuler & Sattler, 2010), policy effect on soil loss (Schuler & Sattler, 2010), soil management (Wang et al., 2007), conservation priority or policy design (Burke & Sugg, 2006), and more recently, ecosystem service provisioning (Nelson et al., 2009).

Reviews of USLE and RUSLE have demonstrated its capacity to accurately predict on-site soil loss at the plot and the watershed scale. At the plot scale, both equations predicted measured soil loss accurately (coefficient of correlation $R^2>0.75$, Nash Sutcliffe model efficiencies > 0.72), but both models tend to over predict and have lower accuracy for lower measures of soil loss (<10 ton ha^{-1} y^{-1}) (Nearing et al, 1999; Tiwari et al., 2000). At watershed scales, assessments of transported eroded sediment and measured sediment loads at the basin outlets demonstrated that RUSLE can be used to estimate soil loss in South East Asia ($R^2>0.72$) (Ranzi et al., 2012) and in Kenya ($R^2= 0.80$) (Mutua et el., 2006).

Assessments of the individual importance of each factor in model uncertainty at the plot scale found that the cover-management factor (*C* factor) was the most important in determining soil loss under different agriculture systems, with the second most important factor being topography (Risse et al., 1993; Benkobi et al., 1994; Ferreira et al., 1995). At the watershed scale, discrepancies exist regarding which factor produces the most model uncertainty, with some studies highlighting the topographic factor (Biesemans et al., 2000), the slope steepness (Falk et al., 2009), and rainfall-runoff erosivity (Zhang et al., 2013). In all cases, local sensitivity analyses (LSA) were applied to understand model uncertainty.

LSA is a common statistical method to assess uncertainty or importance of individual factor impact on model predictions (e.g. Renard and Ferreira 1993; Risse et al., 1993; Ferreira et al., 1995). However, LSA is limited in that it does not assess factor interactions as it estimates the contribution of each factor to model predictions by varying each one of the factors at a time while holding other factors constant (Saltelli et al., 1999). LSA is a constructive analysis, but it does not capture the potential interactions among factors (Wagner 1995; Harper et al., 2011). Global sensitivity analysis (GSA) is a more robust approach because it considers higher order interactions among factors or parameters to assess model uncertainty and to estimate factors of importance (Harper et al., 2011). GSA varies all factors simultaneously to sum all factor uncertainty and evaluate the combined impact of each factor on the model prediction (Wagner, 1995). For the RUSLE, despite the wide application and accuracy assessments, a GSA has not been completed. Results from a GSA (described in section 3.1) will further help focus model parameterization when the model is applied to new environmental contexts.

The overall goal of this study was to understand factor contributions to uncertainty in RUSLE predictions over a range of factor and parameter estimate conditions. To do this, we selected two datasets with factor estimations covering different scale of source data and environmental conditions. We also created a randomized synthetic dataset with the widest possible range of factor and parameter estimates from the original values used to created RUSLE to test overall model sensitivity. Since the goal of our analysis was not to predict soil loss nor compare soil loss predictions across datasets, we did not select comparable datasets (e.g. same location, different source data, or vice versa) nor validate model predictions against observed data. We reviewed model accuracy assessments and parameterization methods from the literature, but do not perform an accuracy assessment with our dataset as model accuracy does not directly impact our goal of confirming whether factor or parameter estimation influences model sensitivity. The results of this study provide a description of model sensitivity within and amongst factor estimates across different environmental conditions and can be used to focus parameterization efforts for future applications of RUSLE. The results are particularly important in data-poor areas where parameterization of physically-based models is limited.

3. Data preparation and description

In order to understand RUSLE sensitivity to parameterization, we conducted a GSA on two datasets parameterized at different scales (plot versus watershed), using different methods (ground collected data versus geographic systems proxies -GIS) and covering different environmental conditions (agriculture in level versus mountainous regions). We also created a synthetic dataset with the widest range of factor and parameter estimates. We performed a GSA of RUSLE on three datasets with different factor estimates to: 1) rank factor importance in predicting soil loss, 2) identify specific factor interactions predicting greater and lower soil losses, and 3) compare differences between LSA and GSA in assessing factor importance. These datasets represent the original data used to calibrate the model and environmental conditions where RUSLE is actively being applied.

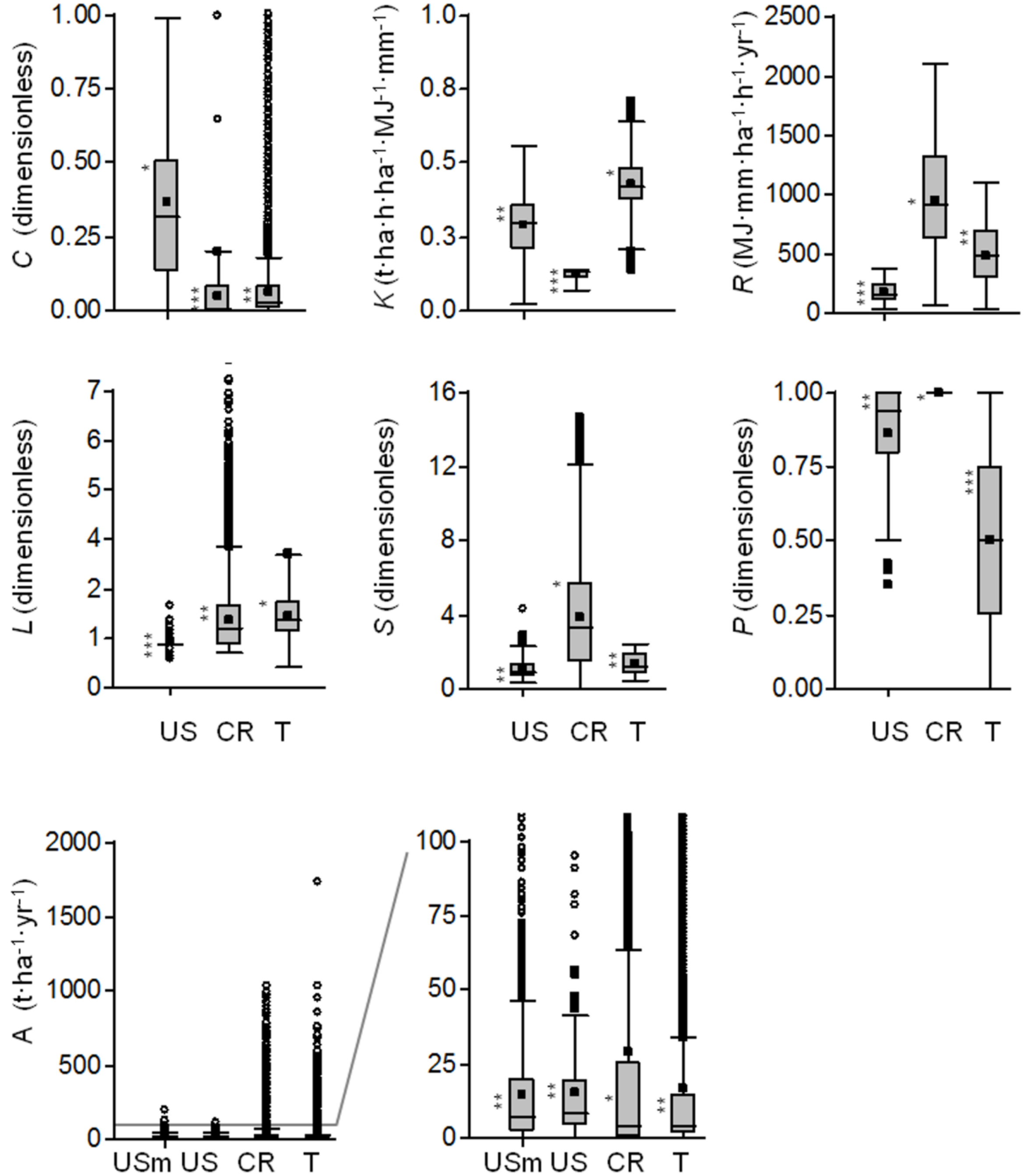
3.1. US dataset.

The purpose of the US dataset is to understand how RUSLE behaves when applied at the plot level where the model was originally calibrated. The US dataset comprises 1,704 plot years of data from natural runoff in 198 plots at 21 sites, with annual measurements of soil loss and estimates of each

RUSLE factor (*C*, *R*, *LS*, *P*, *K*) also used and analyzed by Rapp (1994) and Tiwari et al., (2000). Because this dataset provides estimates for the *L* and *S* factors combined (*LS*), we used equations from McCool et al. (1997) to estimate the *L* and *S* factors separately. The US dataset was primarily collected and measured prior to 1960 and therefore it does not represent modern agricultural practices or instrumentation to measure each factor (Risse et al., 1993). Tiwari et al. (2000) estimated a Nash and Sutcliffe model efficiency of R^2=0.72 (i.e. accuracy in predicting measured soil loss).

The range of the estimates for the *L* and *S* factors in the US dataset was relatively narrow because data were obtained from agricultural erosion plots where 80% of the data had a slope length (*L* factor) lower than 25 m and 70% of the plots had a slope steepness (*S* factor) lower than 10° (Figure 10). The cover management factor (*C* factor) included values for 21 crops, mostly annual crops with large average *C* values (erosive crops). This dataset covers a wide range for the rainfall, runoff erosivity factor (*R* factor) and soil erodibility (*K* factor) (Figure 10).

Figure 10. Factor distribution and estimates for the US, CR and T (theoretical) datasets (Box-plot). Mean values are represented by the black squares. Different numbers of asterisk (*) mean significant differences between mean values (Fisher LSD test, p-value<0.05). The estimated (US, CR, and T) and Measured (USm) soil loss (A) across datasets at the bottom.



The annual measurements of both soil loss and RUSLE factor estimates were averaged per plot to perform the GSA. We used averaged values since the RUSLE is better at predicting long-term average values than annual values or isolated events (Wischmeier & Smith, 1978; Renard et al., 1997). We tested differences in the annual and averaged values to assess the effect that sampling variability (among plots, sites and within plots) of both soil loss and RUSLE factors have on the sensitivity analysis results from the GSA and LSA.

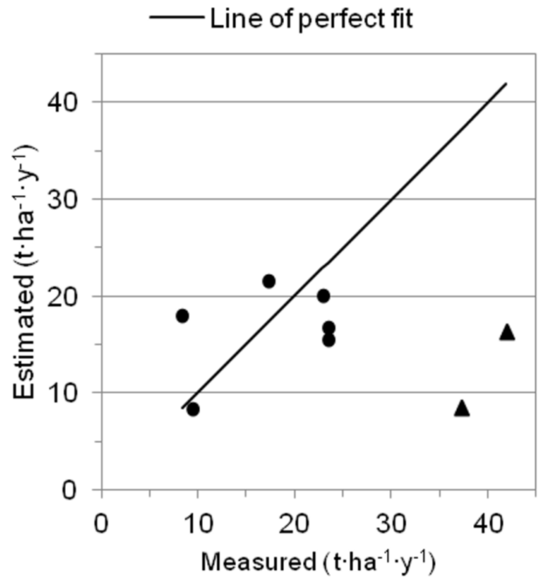
3.2. Costa Rica dataset.

The purpose of this dataset is to understand how RUSLE behaves when applied to conditions outside the data range of the original dataset. We estimated RUSLE factors for a set of watersheds in Costa Rica (CR) using a widely applied methodology for estimating potential soil loss at a watershed scale (Yang, et al., 2003; Hoyos, 2005). We performed our analysis in the uppermost portions of the Pacuare (area 64,919 ha) and the Reventazon (area 175,915 ha) watersheds located on the Caribbean side of CR's central mountain range. The *L* and *S* factors were estimated from a digital elevation model with 10 meter resolution and with the ArcInfo™ Arc Macro Language program developed by Van Remortel et al. (2004). The *C* values for local crops were collected from previous studies in the region (Gómez-Delgado, 2002; Marchamalo-Sacristian, 2004), whereas the land uses were defined by a 1996 LandSat image classification (Pedroni, 2003). The *K* values were obtained from FAO surveys at a national level and soil type classification at a scale of 1:200,000 (FAO, 1989). The *R* factor was estimated using the total storm energy (E) and a maximum 30 minute intensity (I30) for each erosive storm (i.e. storms with total accumulated rainfall greater than 13 mm and separated by at least 6 hours) for 148 station years of measurements in 54 meteorological stations of the Costa Rican Institute of Electricity– (ICE; Gómez-Delgado, 2002). The *P* factor was assumed to be 1.0 because no detailed information about the support practices in the watersheds exists.

The CR dataset comprised an area of 240,834 ha with 2,675,934 pixels so it was necessary to sub-sample to generate factor estimates. We randomly sampled the CR dataset with 30,000 pixels to overcome computer and program limitations. The sampled dataset was not statistically different from the complete CR dataset (we tested each factors using T test, p-value>0.05). In contrast to the US study site, the CR site includes a topographically complex terrain with long, steep slopes and elevation ranges from 70 to 3,470 meters above sea level. This region is characterized by intense rainfall events and high mean annual precipitation (3,251 mm yr^{-1}) (Waylen et al., 1995). The *C* factor range and estimates in the CR dataset are smaller than the US dataset (Figure 10). The *C* factor range in the CR dataset is low because 52% of the area is covered by forest (low erosive land cover), while the other 34% is covered by perennial crops such as coffee (18%), pastures with trees (13%) and bi-annual sugarcane (3%) (low/medium erosive land cover), and annual or ornamental crops (high erosive land cover).

To estimate errors in model prediction we performed a correlation analysis between measured and estimated sediment loads in eight stations in the Pacuare and Reventazon watersheds. We used the tool N-SPECT to estimate sediment loads at each stations (Eslinger et al., 2005). We used the average sediment loads measured by ICE during 1996 for the eight available stations in the studied watersheds. Before the correlation analysis, we excluded two basins with high gravel mining and frequent landslides, erosion factors not accounted in RUSLE which leaded to underestimation of sediment loads (Figure 11). The correlation coefficient between measured and estimated sediment loads for the remaining six basins was R^2=0.4. Importantly, however, given that our analysis focused on model sensitivity and not accuracy, we consider this level of correlation between predicted and observed sufficient to continue the analysis.

Figure 11. Comparison of the average sediment load estimated and measured at the outlet in eight basins of the Pacuare and Reventazón watersheds in Costa Rica. Underestimated sediment loads in basins represented with a triangle are due to other erosive processes not captured by RUSLE (i.e. gravel mining landslides).



3.3. Theoretical dataset.

The purpose of the theoretical dataset is to evaluate model uncertainty given the large possible range of factor and parameter estimates. We used the reported maximum and minimum values for each parameter and estimated each RUSLE factor according to the equations from the Agriculture Handbooks 537 and 703 (Wischmeier & Smith 1978; Renard et al., 1997 respectively; APPENDIX D). The ranges of the parameters in this dataset are based on maximum and minimum values corresponding to a physical process or plot measurements (Supplementary material I). This is the only dataset that provided us with information at the parameter level (Table 2, APPENDIX D). Here, parameters were used to estimate each one of the six factors of the RUSLE and can be a fixed number or a range of values that are independent of one another (APPENDIX D).

We created a script in Matlab to create 30,000 Monte Carlo simulations of randomly chosen parameter estimates (Sobol' 2001). Each parameter set was created by randomly drawing from a uniform distribution within the documented parameter ranges, and each factor value was estimated using the reported equations (Renard et al. 1997, Supplementary material I). Random interactions between parameters were constrained (when required) to represent real interactions; for example, to estimate the *K* factor the percentage of clay, silt and sand must sum to one hundred. We used the 30,000 Monte Carlo simulations at factor (six factors) and at parameter level (18 independent parameters, Table 2 and APPENDIX B) in the GSA. This randomization process breaks potential correlations between parameters and factors, but does not impact the GSA results (Harper et al. 2011).

3.4. Unstructured datasets.

The aim of the unstructured datasets was to validate the theoretical dataset and assess how correlations among factors affect GSA outcomes. In both the US and CR datasets, factors were cross-correlated (e.g. greater rainfall- runoff erosivity at greater altitude and slope steepness in CR), but factors in the theoretical dataset were uncorrelated since we know the maximum and the minimum values but not how the factors cross-correlate. To assess the effect of factor correlations on GSA results, and assess the validity of the results from the theoretical dataset, we disaggregated cross-correlations in the US and CR datasets by randomly selecting (with replacement) new estimates from the original datasets. Unstructured datasets had the same sample size as their corresponding structured datasets but the factor estimate combinations were different. We compared GSA outcomes from the structured and unstructured datasets.

4. Methods

We conducted three statistical analyses. First, we tested if there were significant differences in factor distribution and factor mean values across datasets. Second, we performed a GSA on the US, CR and theoretical dataset to assess factor importance and factor interactions determining soil loss. We also performed the GSA on the unstructured US and CR datasets to assess the effect of potential cross-correlation among factors and validate the results from the Theoretical dataset. And finally, we performed a LSA on the US dataset to compare the LSA and GSA statistical methods.

4.1. Statistical Analyses

Analysis of variance and mean value comparisons among datasets: We tested differences between factor estimates and estimated soil loss across the three datasets. We tested factor estimate distributions using an ANOVA using a significance value of $p < 0.001$.We tested factor mean value differences using Fisher's Least Significant Difference – LSD. All analyses were performed in the R statistics software (R core team, 2012).

Global sensitivity analyses: We used the GSA approach designed by Harper et al. (2011). This GSA approach uses Random Forest (RF) to rank factor and parameter importance and Classification and Regression Tree (CART) to analyze and visualize the complex relationships among model factors. Random Forest is an improved version of CART, since it is a forest (a collection of trees) where each tree is created by bootstrap sampling and where the factor and parameter at each node of the tree is randomly selected (Cutler et al., 2007). For each tree, 30% of the data (called the out of bag - OOB data) are randomly sampled and used to estimate model efficiency by cross validating results with the other 70% of the data (Cutler et al., 2007). Model efficiency is estimated as one minus the ratio between the mean squared error (MSE) and the variance of the response variable (Pang et al., 2006) (Table 3). We used the *R* package randomForest 4.6-2 to estimate model efficiency (Breiman & Cutler, 2011).

The contribution of each factor to model predictability can be assessed by two metrics from RF. The first metric, the lost efficiency metric, estimates factor importance by calculating the changes of the mean squared error when each factor is randomly permutated. The second metric, the node impurity metric, measures changes in the residual sum of squared errors by splitting the factor at each node of the tree (Breiman & Cutler 2012). Node impurity values for each factor were normalized by the sum of the total node impurity and estimated the relative importance of each factor (Table 3). *R* package randomForest 4.6-2 was used to estimate both factor importance metrics (Breiman & Cutler, 2012). To visualize the higher order interactions between factors, we applied a CART analysis on each dataset. With CART we were able to identify the specific factor combinations that generated lower and greater estimates of soil loss (*R* package rpart 3.1-50; Therneau & Atkinson, 2010).

Table 3. Description of model efficiency measures and factor/parameter importance metrics for both global and local sensitivities analysis.

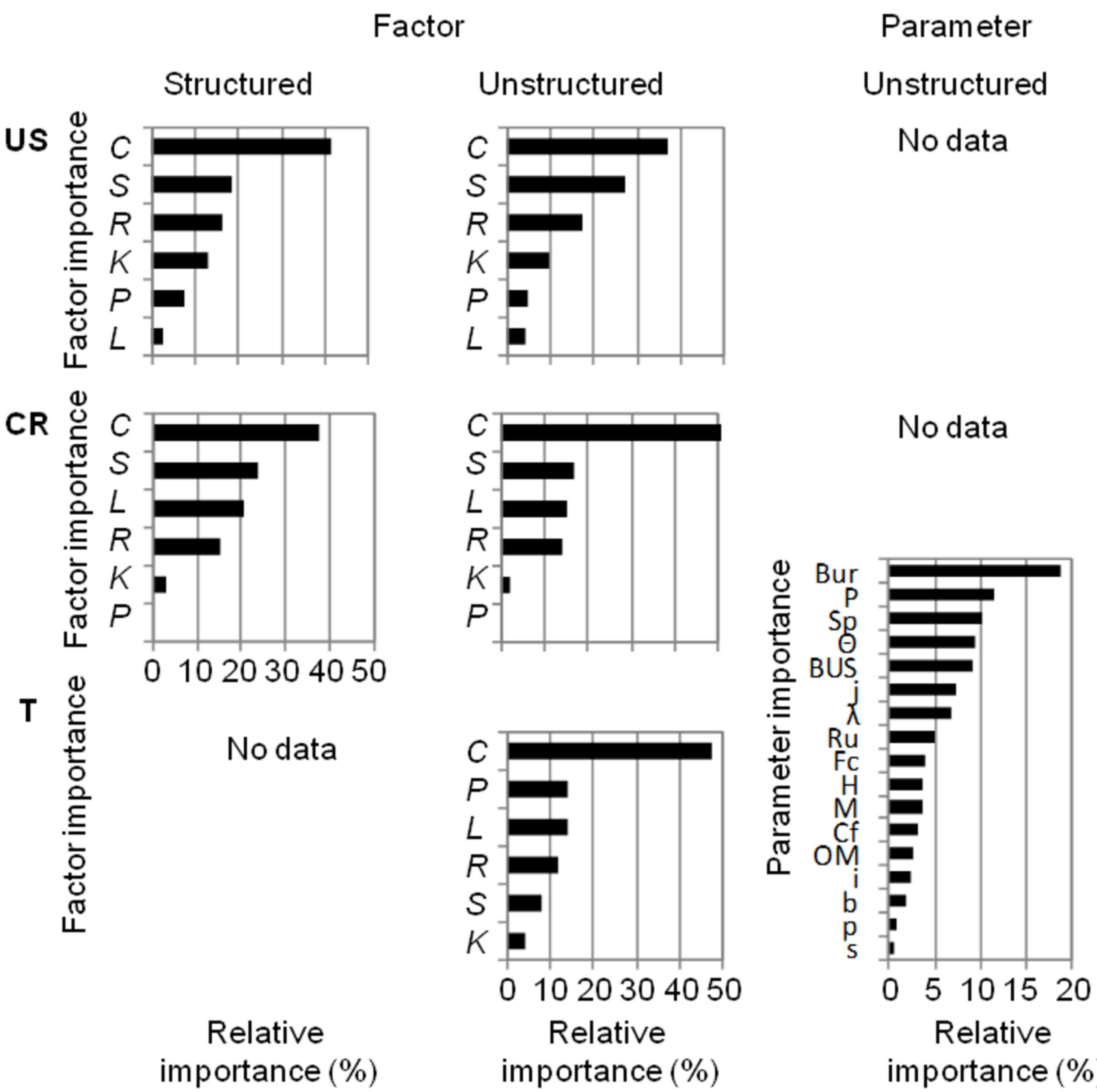
Metric	LSA	GSA
Model efficiency (i: 1...*n* factors/parameters; M_i: measured value of the i^{th} observation; E_i: estimated value for the i^{th} observation, M_{avg}: measured average value)	$R^2 = 1 - \frac{\sum_{i=1}^{n}(M_i - E_i)^2}{\sum_{i=1}^{n}(M_i - M_{avg})^2} \times 100$ R^2= 1: perfect model; R^2= 0: model results are not better than the mean; R^2= -1: model predictions worse than using the mean (Risse et al., 1993)	$R^2 = 1 - \frac{MSE}{Var(M)} = 1 - \frac{\frac{1}{n}\sum_{i=1}^{n}(E_i - M_i)^2}{\frac{1}{n}\sum_{i=1}^{n}(M_i - M_{avg})^2} \times 10$ Pang et al. (2006)
Lost efficiency metric	Estimates the difference between the original model efficiency (R^2) and a new model efficiency estimated after replacing a factor values by its mean value	Estimates each tree mean squared error (MSE) between the OOB data and 70% of data the left after randomly permutating each factor value at a time. MSEs are averaged over all trees and normalized by the standard deviation of the differences (Breiman & Cuttler., 2012)
Node impurity metric	NA	Is the decrease on the residual sum of squared errors (RSS) after splitting on a factor. RSS values are averaged over all tress. Each factor's relative importance was standardized by dividing it by the total RSS.

Comparison of LSA and GSA: For the LSA, we used the methodology proposed by Risse et al. (1993). LSA consists of estimating the Nash and Sutcliffe (1970) statistic. We compared both model efficiencies (pseudo R^2) estimated from the RF and LSA (Table 3). The LSA assesses the approximate contribution of each factor to the model predictability by estimating the loss of model efficiency. The loss of model efficiency value is estimated as the difference between the Nash - Sutcliffe statistic using all original factor values and the estimated Nash - Sutcliffe statistic after one factor's values are replaced by the factor's mean value; this process is repeated for each factor (Risse et al., 1993). We compared the loss of model efficiency values from LSA and RF. The US dataset is the only dataset with predicted and measured soil loss; and therefore, is the only dataset that provided information about model efficiency and the loss of efficiency metric.

5. Results

Global sensitivity analyses across all the datasets showed that the RUSLE predictions are most sensitive to the cover management factor (*C* factor) regardless of factor and parameter estimation (Figure 10and Figure 12). In most datasets, the relative importance of the *C* factor was twice as high as the second most important factor in each dataset (Figure 12). This result was consistent despite significant differences among factor estimates across datasets (Fisher LSD test, p-value <0.05) for all factors with the exception of slope length (*S* factor) in the US and theoretical datasets (Figure 10). We also found that estimated soil loss with the CR dataset was significantly greater than with other datasets (Fisher LSD test, p-value <0.05); yet, the US and theoretical estimated soil losses were not significantly different from each other (Figure 10). These consistent results across datasets indicate that the sensitivity of RUSLE model predictions is produced from the formulation (equations) of soil loss processes, with less uncertainty coming from variability in the parameter estimates. At the parameter level, root mass density (Bur) and percent surface cover (Sp) were found to be the most important parameters from the *C* factor driving uncertainty in model predictions (Table 2, Figure 12).

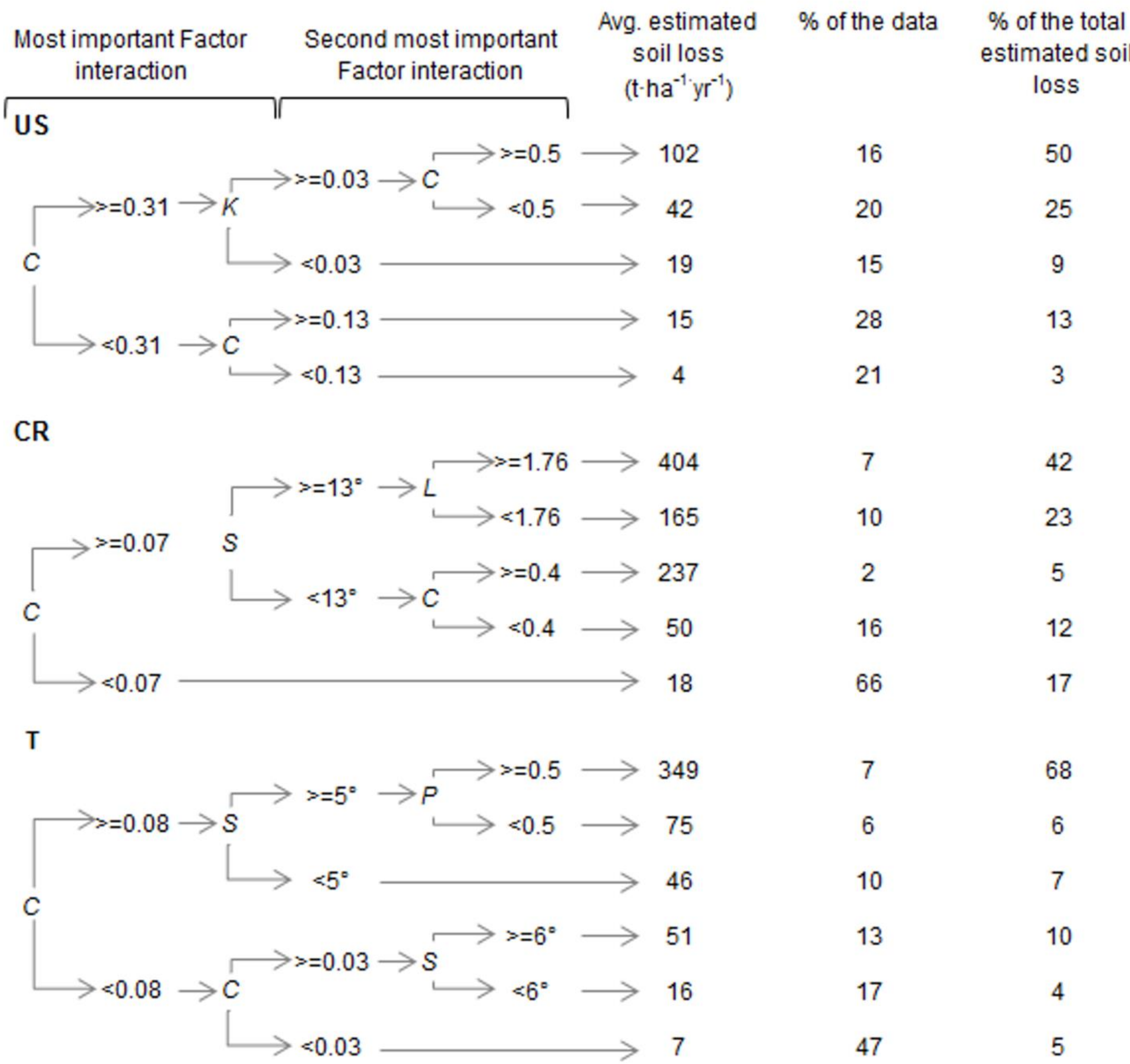
Figure 12. Factor importance order for US, CR and T (theoretical) datasets for structured and unstructured datasets at factor and parameter level (see Table 2 for factor and parameter descriptions). Relative importance is the normalized factor node impurity metric obtained from the Random Forest statistical procedure and indicates the relative importance of each factor/parameter in influencing model predictions.



Factor estimation procedures (ground collected data versus GIS proxies) or factor range estimates in each dataset (mountainous, high rainfall versus plains, less rainfall) may cause differences in the less important factors (Figure 10 and Figure 11). After the *C* factor, no clear pattern of factor importance emerged other than soil erodibility (*K* factor) being ranked in the three last positions across all analyses (Figure 12). *L* and *S* factors are the second and third most sensitive factors (respectively) in the CR dataset (Figure 12) despite the greater rainfall-runoff erosivity (*R* factor) estimates (Figure 10). Results between structured and unstructured data were consistent (Figure 12), implying that correlations among factors have a weak or null effect on model factor importance.

Higher order factor interactions, illustrated by the CART analysis, indicated that the interaction between the *C* and *K* factors was the most important in determining greater magnitudes of soil loss, despite the low *K* factor order for the US dataset (Figure 12 and Figure 13, US). Here, crops with mean *C* values above 0.31 (rye, potatoes, fallow or cotton) lost soil at a mean rate between 19 and 102 $t \cdot ha^{-1} \cdot yr^{-1}$, depending on soil type (Figure 13, US). This is contrasted with the CR dataset where the greater *C* and slope steepness (*S* factor) estimates indicate greater erosive loss (Figure 13, CR). Annual crops or bare soil with a mean *C* value above 0.4, produced erosion rates between 50-237 $t \cdot ha^{-1} \cdot yr^{-1}$ when located on slopes below 13°, however, perennial crops (i.e. coffee) with C value above 0.07 can be also highly erosive when located on slopes above 13° (Figure 13, CR). The theoretical dataset behaves similar to the CR dataset, where the interaction between *C* and *S* determined greater soil loss. The *C* factor threshold that defined low and medium soil loss was similar *C*~0.08 - 0.07 for the theoretical (within original equation factor estimates) and CR datasets (outside original equation factor estimates) (Figure 13, CR and T).

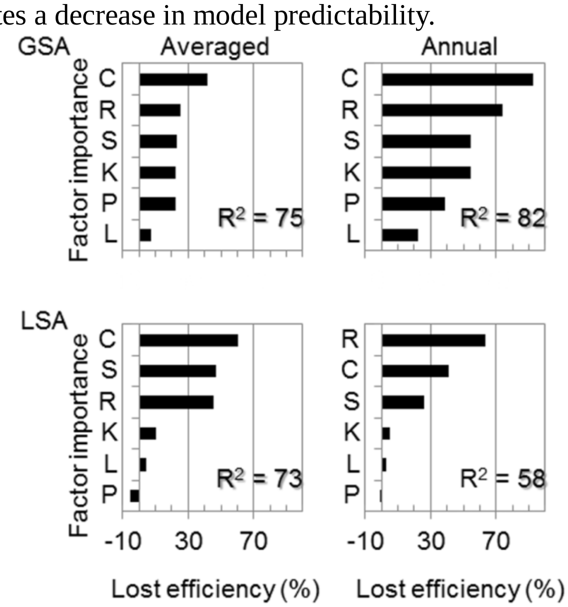
Figure 13. Factor interactions for US, CR and T (theoretical) datasets obtained from the CART analysis. Each dataset is represented as a tree, the left side of the tree represents factors combinations and the right side represent the end of the tree with the averaged soil loss, the percentage of data that follow each specific factor combination (or tree branch) and the percentage of the total estimated soil loss. Factor interactions importance is from left to right, and the value next to each factor is the factor threshold value at which the data are split and combined with the next factor.



Magnitudes of soil loss across datasets follow a similar pattern despite the different factor and parameter estimates. The CART analysis shows that greater magnitudes of soil loss come from a limited proportion of the area and from a limited combination of factors (Figure 10 and Figure 12). For example, soil loss estimated above 20 $t \cdot ha^{-1} \cdot yr^{-1}$ comes from 36% of the US parcels, 34% of the CR pixels and 36% of the theoretical runs, but account for 75%, 83% and 91% of the total estimated soil loss respectively (Figure 13).

The GSA and LSA similarly explained average plot-level soil loss in the US study site (LSA 73% and GSA 75%, Figure 14). However, the GSA explained more of the measured annual plot-level soil loss (82%) than the LSA (58%) (Figure 14). Both LSA and GSA indicated that the *C* factor is the most important factor determining soil loss when averaged plot-level data are used. The LSA results were highly affected by the difference in data variability between the averaged versus annual plot data, since the order of the three most important factors was different (Figure 14). The LSA and GSA on averaged plot-level data distinctly disagreed on the role of the support practice (*P* factor). The GSA ranked this factor as more important than slope length (*L* factor), a factor with narrower range of estimates (Figure 10and Figure 13).

Figure 14. RUSLE efficiency and factor importance order for global and local sensitivity analyses of the average and annual US datasets. Model efficiency corresponds to a pseudo R^2 from estimated and measured soil loss. Loss of efficiency value indicates the contribution of each factor to model error. The negative value indicates a decrease in model predictability.



6. Discussion

Our results indicate that cover management is the most important factor driving soil loss in RUSLE, across both the scale of data resolution and environmental context. In other words, the *C* factor produces the greatest degree of variation in model predictions. This illustrates the need to focus on *C* factor estimation over other factors to improve the accuracy of model predictions. In addition, this result suggests that the *C* factor in RUSLE could be further improved to reduce uncertainty in model predictions. This is not surprising considering the complex processes in which vegetation influences soil loss (Schwilch, Hessel, & Verzandvoort,2012). The results also underline the importance of understanding the complex interactions among vegetation, topography and soil type in determining soil loss and the high spatial variability in soil loss rates.

6.1. Model uncertainty under different environmental conditions

Our modeling efforts illustrate the importance of C factor estimation because across datasets the *C* factor is the main contributor to model uncertainty regardless of factor parameterization. For example, the CR dataset had four factor estimate ranges outside the theoretical estimates (*K*, *R*, *L*, *S* factors), yet still the *C* factor was the most important factor controlling soil loss. For this reason, we suggest that applications pay close attention to *C* factor parameterization regardless of the method used or the scale of the data source. Other factor contributions to model uncertainty were dataset or context dependent. Level landscapes require more accurate parameterization of the *C* and *K* factors, whereas estimation of the *C* and the *S* factors require greater focus on steeper landscapes. This particular result differs compared to other studies at the watershed scale. Zhang et al. (2013) highlighted the importance of the *R* factor in mountainous areas, while Falk et al. (2010) highlighted the *S* factor in flatter areas in contributing to model uncertainty. These differences are potentially explained by the higher order interactions considered when a GSA approach is used.

Our discussion here is not intended to support or refute the application of RUSLE outside the original factor and parameter estimates. We understand that RUSLE's wide use and acceptance for management (Eslinger et al., 2012) is due to its relatively easy calibration and lack of data requirements compared to more mechanistic models (Mueller et al., 2005; Bewket & Tefari, 2009). We do suggest, however, that parameter estimation of the *C* factor should be a main focus during model calibration and continued improvement of the RUSLE. We also recommend the implementation of the GSA approach in improving model parameterization by assessing factor importance, including interactions.

6.2. GSA versus LSA.

We show that a GSA approach provides a more detailed analysis of model uncertainty than LSA. GSA is not highly affected by data variability, and factor interactions are explicitly considered and visible. Assessing data that are naturally highly variable in space and time such as soil loss (Nearing et al., 1999), with statistical methods sensitive to data variability may lead to inaccurate results. Finally, consistent results obtained in the GSA were due to the method's capacity to capture a broader range of model sensitivities and interactions among model factors and parameters (Wagner, 1995). Both of these are key characteristics to understand better and parameterize empirical models (Harper et al. 2011).

6.3. Management implications.

Our GSA results further underline two key points in soil loss management across environments. The cover management factor is the most important factor in RUSLE and much of the soil loss occurs in a limited area of the watershed. These findings are important because cover management is the only factor that can be easily manipulated to reduce soil loss from agricultural lands (Shi et al., 2012) and reduce sediment accumulation in downstream reservoirs (Estrada-Carmona and DeClerck, 2011). The consistency across databases on most of the soil loss coming from a small portion of the landscape, reinforces the need to implement targeted soil conservation interventions where the location and the rate of soil control can be assessed to improve ecosystem service-based interventions (Fremier et al., 2013).

Finally, the creation of a theoretical dataset might help to provide information about the most important factor interactions, and even information at the parameter level, particularly in those areas with poor or no site specific data. This will help to provide insights on the most important parameters to guide management changes. For example, our results from the theoretical dataset indicate that the mass density of live and dead roots found in the upper centimeters of soil and the percentage of land area with surface cover as the most important parameters in determining soil loss. Multiple studies report similar findings where an increase of the root density and surface cover were demonstrated to be particularly efficient in controlling soil loss (Linse et al., 2001; Gyssels et al., 2005; De Baets et al., 2006).

7. Conclusion

We assessed RUSLE behavior and factor contributions to model uncertainty under different environmental conditions and compared global and local sensitivity analyses. The GSA approach is an informative procedure for identifying sources of model uncertainty, mainly because it captures interactions amongst factors and it is little affected by data variability. The application of a GSA before final model parameterization will help constrain model uncertainty and focus resources and efforts on parameterizing the most important factors. Our datasets from different environmental conditions indicate that the cover management factor is the most important factor in RUSLE and much of the soil loss occurs on a limited area of the watershed. However, the importance of other RUSLE factors varies across environmental contexts.

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CHAPTER 4: PREVENTION IS BETTER THAN CURE: IMPLEMENTING SOIL CONSERVATION PRACTICES MAY BE CHEAPER THAN DREDGING

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1. Abstract

Assessing changes in the provisioning of ecosystem services (ES) due to changes in agroecosystem management will better inform Costa Rican PES escheme. This scheme is recognizing the role of agroecosystem as ES providers, still an assessment of the provisioning of ES by implementing ideal cropping systems (combination of at least two or three soil conservation practices) rather than only spread trees is missing. One of the most critical ES provided in agroecosystems is soil retention, this ES have on-site benefits for the farmer and off-site benefits for downstream consumers such as hydropower companies. We estimated changes on soil retention ES by implementing ideal cropping systems in three of the most important basins for hydropower and agricultural production in the Upper-Middle Reventazon watershed in Costa Rica. We tested three targeting strategies, four budgets allocations and compared the avoided cost of dredging the retained soil with current dredging cost. We quantified the provision of the soil retention ES using the Integrated Valuation of Environmental Services (InVEST). We used the Tradeoffs and the Resources Investment Optimization System (RIOS) to test our three targeting strategies: (1) RIOS default optimization, (2) RIOS constrained to current land uses in conflict with soil legislation and (3) RIOS constrained to erosive crops and crops on steep slopes. The tested budget included the lowest budget allocated in the watershed for soil conservation programs in the past up to the maximum amount it will be requiered to implement ideal cropping systems across all the agricultural land. Our results indicate that targeting efforts on erosive crops or crops on steep slopes will likely provide the highest cost-effectiveness investment scenario, or in other words, the highest soil retention per dollar spent. Under this particular targeting strategy, investments in ideal cropping systems may be more cost effective than dredging sediment from the downstream

reservoirs, given our modeling assumptions. Our modeling strategy, offers a conservative and simple but robust first approximation to a methodology that can be adapted and modeled iteratively to assess ES provisioning due to changes in agroecosystems management.

2. Introduction

Agroecosystems production and sustainability along with forest conservation should be top priorities for Costa Rica (Hall et al., 2000). Approximately 35% of Costa Rica land for food production has poor management practices (Vignola et al., 2010; CADETI, 2004). Poor management practices impacts the national economy with an estimated reduction of 7.7% of the agriculture gross domestic product due to soil erosion and nutrient depletion (MINAE 2002). Costa Rica consumes 4-8 times more fertilizers, particularly nitrogen and potash, than the average Latin America country (FAO, 2013). High amounts of fertilizers are required to compensate for the high erosion rates that probably are exceeding soil formation rates in most of the agricultural land (Rubin & Hyman, 2000). In addition to the loss of crop productivity from soil loss, the transport and accumulation of sediment has further economic implication for downstream reservoirs for hydropower (Vignola et al., 2008). Hydropower is the main source of energy in Costa Rica, constantly challenged by the high sediment loads and pollution into upstream reservoirs (Haun et al., 2013; Brandt & Swenning, 1999). Besides, high sediment loads reduce the life span of dams by rapid infilling (Haun et al., 2013). Pollution (source and non-source) from agriculture production affects water quality, riparian habitats and aquatic communities (Echeverría-Sáenz et al., 2012).

Efforts to protect soil (and the services it provides) are weaker than the efforts to protect forest cover (and the services it provides) in Costa Rica. Forest cover area in Costa Rica is slightly increasing (FAO, 2013) while soil is being depleted (MINAE 2002). The increase of forest cover is due to a combination of factors such as the creation and enforcement of the Forestry Law 7575 in 1997 which forbids deforestation while promotes incentive-based conservation via payment for environmental services (PES) schemes; besides other external factors such as the increase of ecotourism and the reduction of cattle ranch profitability (Robalino & Pfaff, 2013). The Soil Law 7779 created in 1998 has a poor enforcement that has led to poor conditions, law inconsistencies and constrained budgets that weakened agricultural extension offices, key organizations transmitting information, technology and sustainable soil conservation practices (Vignola et al., 2013; Vignola et al., 2010). Hydropower companies, an industry highly dependent and affected by water quality, has been also promoting environmental education (Blackman & Woodward, 2010), supporting soil conservation management (Vignola et al., 2012) and supporting watershed management plans (PREVEDA, 2008) to increase soil retention at the source. Also, major voluntary or non-voluntary (tax payments) investments to fund the PES scheme comes from hydropower companies to improve the provision of hydrological services and extend the life span of the dams: but most importantly to improve their relationship with local stakeholders (Blackman & Woodward, 2010).

Payment for ecosystem services (PES) scheme goals is to increase national forest cover to generate multiple ecosystem services (ES), such as hydrological services (particularly water quality), scenic beauty, carbon sequestration, and biodiversity (Pagiola, 2008). The PES scheme provides funds for forest protection, forest management, reforestation, and, recently, agroforestry. The recognition of agroforestry (only trees within agricultural land) in the Costa Rican PES scheme was an important step towards recognizing the role agroecosystems as ES providers. The total land area covered with PES for agroforestry has increased from 2% in 2003 to 12% in 2011 (FONAFIFO, 2014). Despite this increase, we still lack a quantified understanding of which practices guarantee ES provisioning at the site level and how site level implementations across a watershed improve larger scale services in agroecosystems, such as soil retention. Design efficacy and site prioritization of agroforestry practices becomes key component in designing PES programs that get what they pay for.

To curb soil loss from agroecosystems, many conservation practices (not only spread trees as current PES scheme) have proven to increase farm productivity while improving soil retention and water quality (Dogliotti et al., 2013; Lenka et al., 2012; WOCAT, 2012; Cocchi & Bravo-Ureta, 2007; Alegre, & Rat, 1996). In Honduras, ground-cover technologies such as crop-mulch/residue management, green manure and conservation tillage led to an increase of farm income up to 20% (Cocchi & Bravo-Ureta, 2007). While in Chile, multi-year planning and farm redesign halved soil erosion rates (Dogliotti et al., 2013). Past experiences studying a PES scheme on degraded pastures in Costa Rica, Nicaragua and Colombia, indicated that implementing both, high density of trees and shrubs, improved rangeland productivity, biodiversity, carbon sequestration and water quality (Pagiola et al., 2005; Garbach et al., 2012). However, potential negative effects such as competition for nutrients and light, increase of diseases and seedlings suppression should also considered in full cost-benefit analyses (Alegre, & Rat, 1996). Vegetative conservation practices offer diverse ES and are as effective as physical or structural practices (particularly retaining soil) but are more cost-effective and more flexible (Bravo-Ureta et al., 2006; Maetens et al., 2012).

Farmer's voluntary implementation of conservation practices is limited by short-term needs, lack of information and lack of resources (Vignola et al., 2010). In addition, masking factors such as external inputs, soil deposition, deep soils and everyday contact also limits voluntary implementation (Lal, 2001, Vignola et al., 2012). However, a recent research in one of the most erosive and hydrological important watershed in Costa Rica indicated that farmers (ES providers) and hydropower companies (ES consumers) agreed on the need to change existent conditions in terms of land use and management towards a more sustainable (Vignola et al., 2008). Local stakeholders highlighted that efforts to promote the desired change should be targeted to high priority areas (Vignola et al., 2012).
To define which targeting strategy will be the most cost-effective, we used a coupled economic and soil loss model to evaluate multiple strategies for reducing soil loss and compared these estimates to the costs of dredging three reservoirs in the upper and middle part of the Reventazon River, Costa Rica. We estimated the effect of implementing soil conservation practices as a strategy to provide the ES soil retention under three targeting strategies and three budget levels. We were particularly

interested on two key questions. First, which targeting strategies, investment distribution and budget is the most effective to provide the ES soil retention? Second, at which point investments to provide the ES soil retention are cheaper than the cost dredging? To answer both questions, we conducted a literature review to select the most suitable practices according to the agroecological and productive conditions of the study area. We also conducted a meta-analysis to estimate the efficacy of each practice retaining soil. The Integrated Valuation of Environmental Services and Tradeoffs (InVEST) help us to estimate soil retention under current and the different targeting strategies at the watershed scale. And, we used the Resources Investment Optimization System (RIOS) tool to test three targeting strategies. Though excluded from our analysis all the transaction costs associated with implementation, we focused on establishment and maintenance cost of the soil conservation practices.

3. Methodology

3.1. Study area

The upper and middle part of the Reventazon watershed has an area of 139,644 ha and generates approximately 38% of the national energy, 25% of the consumed water in San José and 11% of the agricultural products for exportation (ProDUS, 2011). Our analysis covers the drainage area of three of the most important dams within the Reventazon: Cachi, Angostura and Birris (Table 4; Figure 15). In 2000, the government created legislation (Law Nº 8023, 2000) to regulate and promote the sustainable management of the watershed due to its importance to the national economy. The upper and middle part of the watershed developed a management plan to improve local capacity, risk management, environmental education and soil conservation particularly on highly erosive basins (PREVEDA, 2008). These efforts to reduce soil loss have had only marginal impacts and the watershed still has high level of erosion and pollution (PREVEDA, 2008).

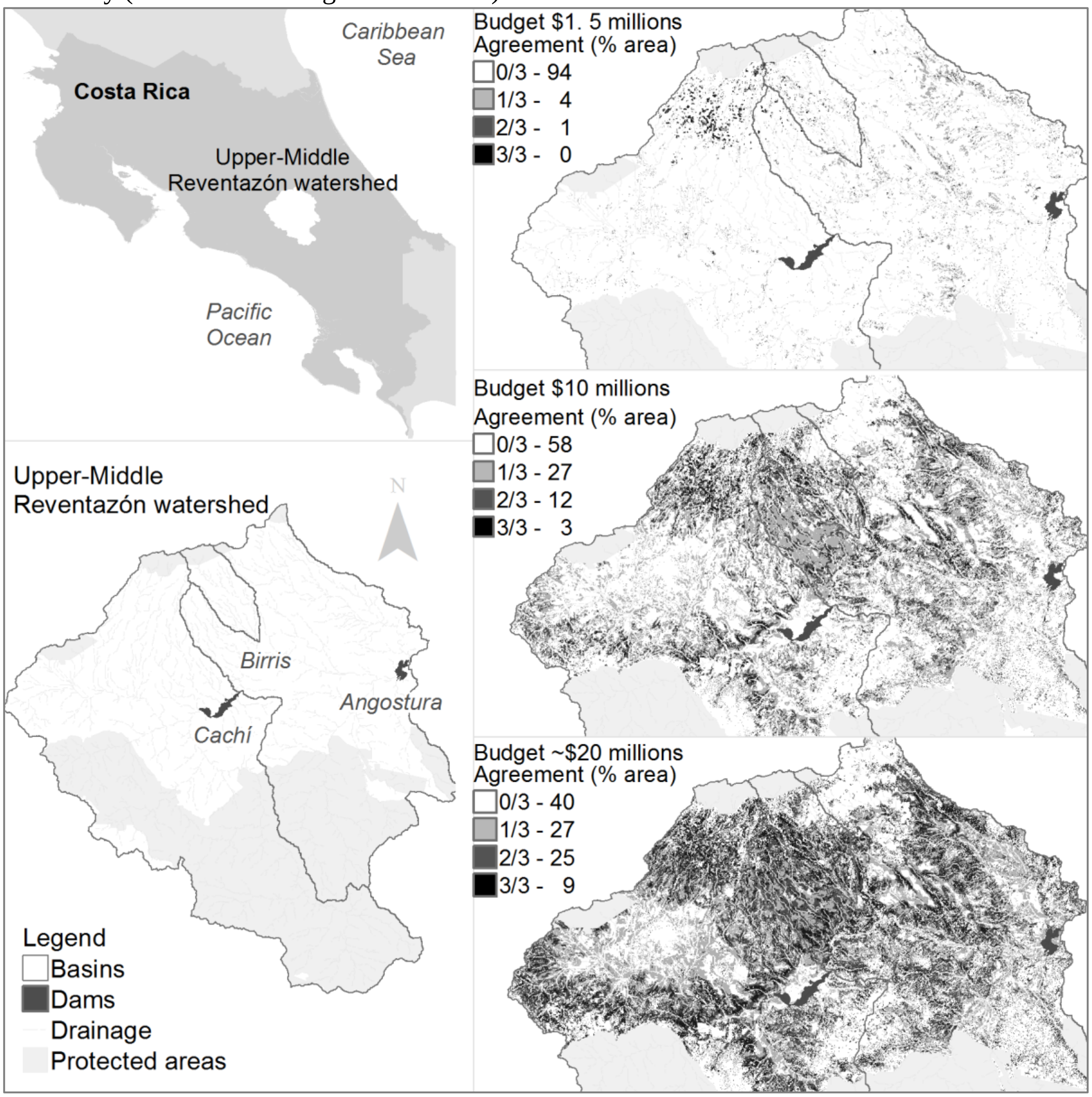
Table 4. Characteristics of the assessed dams in the Reventazon watershed. Assessment accuracy based on the comparison between the reported sediment yield to each reservoirs and the estimated exported sediment with InVEST.

	Starting	Current production (projected)	Capacity	Removal cost	Sediment yield	InVEST Exported Sediment	Accuracy Assessment		
							Sediment delivery ratio	Reported Soil loss	Estimated Soil loss
Dam/ Reservoir	year	MW	millions·m^3	\$millions·y^{-1}	\$millions·y^{-1}	\$millions·y^{-1}		t·ha^{-1}	t·ha^{-1}
Cachi/ ICE	1966	100 (160)	48*		1,1	3.5	0.32	26***	14
Birris/ JACEC	1990	4.3(13.6)			0.2	0.6	0.28	42***	42
Angostura/ ICE	2000	177	10.7**		1,5**	5.5	0.27	26****	26
Total				>2-4	2.8				

JASEC: Junta Administrativa del Servicio Eléctrico Municipal de Cartago
ICE: Instituto Costarricense de Electricidad
*The original volume is 54Mm^3, however, the latest estimation in 1993 indicated a volume loss of 11% of the original volume (Jiménez-Ramírez and Rodríguez-Mesa, 1992)
**The original volume is 11Mm^3, however, after two years of functioning the dam lost 2.5% of the original volume (Jiménez-Ramírez and Rodríguez-Mesa, 1992)
***Marchamalo (2004); Abreu (1994)
**** Vignola et al., (2010)

The Reventazon watershed is located on the Caribbean side of the Costa Rica mountain range (Figure 15), with annual precipitations ranging from 1,551 to 6,303 mm·y-1 with an average of 2,955 mm·y-1. The watershed is characterized by steep slopes in the upper and middle part of the watershed of altitudes ranging from 449 to 3,475 m.a.s.l and with an average slope of 21° (slope 37.5%). The watershed is largely covered with forest (51% of the total area), perennial crops (25%), pasture (16%) and semi-perennial and annual crops (5%). Coffee and sugarcane are the dominant perennial and semi-perennial crops. Forest cover has been constant through time the Reventazon watershed, but pastures, urban and sugarcane areas are increasing by replacing coffee and shrubland areas (Brenes, 2009).

Figure 15. The left panel shows the location of the Upper – Middle Reventazon watershed and the drainage area of the dams. The right panel shows the distribution of the targeted areas and the level of agreement across the three targeting strategies: 1) RIOS, 2) RIOS&Legislation and 3) RIOS&C-S. The level of agreement indicates which areas were targeted (or not) by the strategies. For example, with a budget of $1.5 millions, ninenty four percent of the area was excluded from all three targetting strategies to implement ideal croping systems and, all the three strategies allocated the budget differently (3/3 – 0% of the agricultural land).

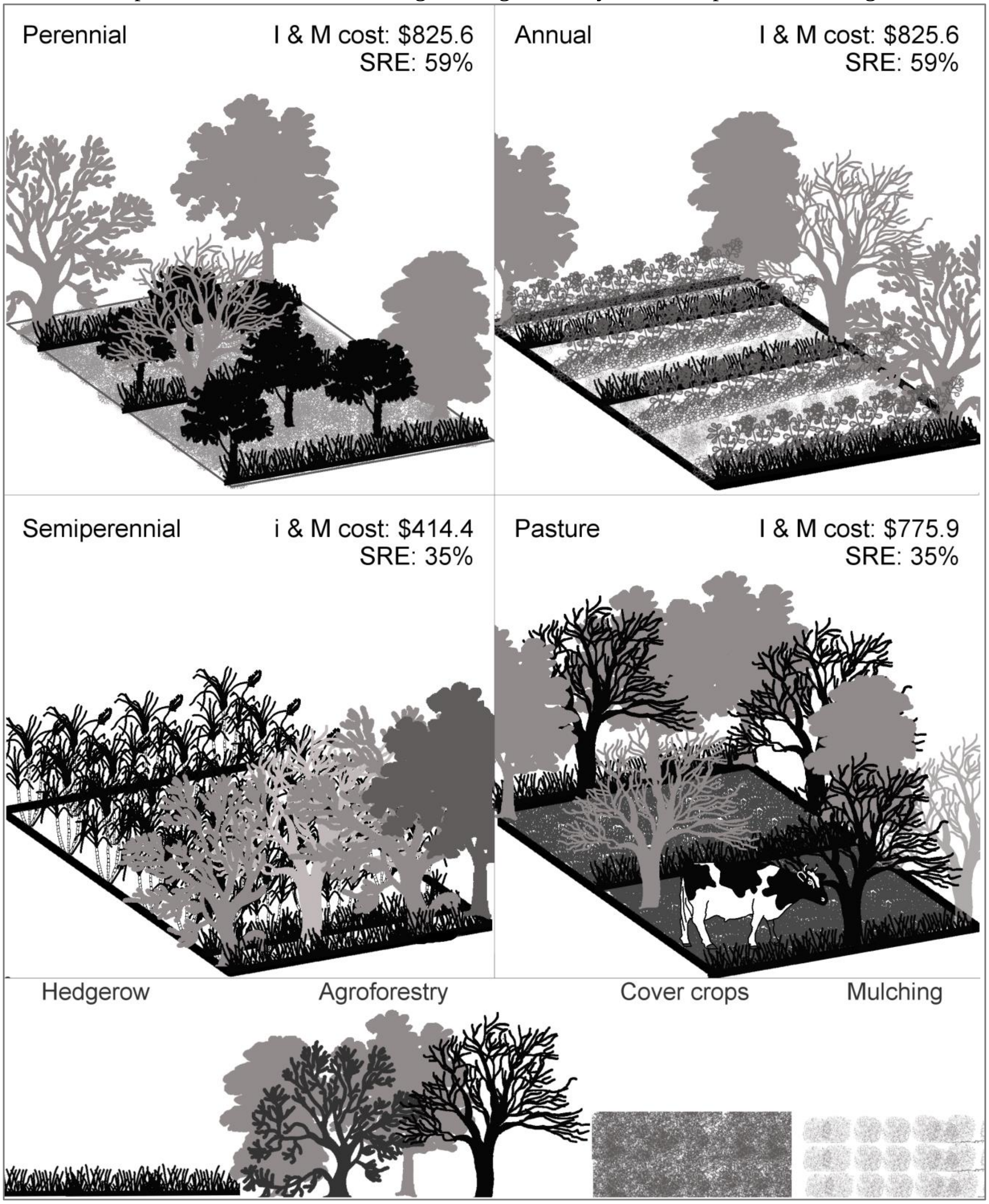


3.2. Activities: Ideal cropping systems – coupled soil conservation practices

Agroforestry is supported by the PES scheme to increase the number of trees within agricultural land (FONAFIFO, 2014). Spread trees can particularly provide ES such as scenic beauty, carbon sequestration and biodiversity (Harvey et al., 2006; Perfecto et al., 2008). However, to particularly provide hydrological services, other soil conservation practices should be considered. In this modeling effort, we incorporated other vegetative soil conservation practices that minimize soil loss and maintain agricultural production, with lower implementation cost than engineered structures (Bravo-Ureta et al., 2006; Maetens et al., 2012). For each selected soil conservation practice we completed a literature review to list the pros and cons (Supplemental Material I) and to estimate the cost of implementation and the soil retention efficiency (Figure 16).

The Program for Sustainable Agriculture in Steep-lands in Central America (PASOLAC) systematized, revised and validated promising soil conservation practices using Honduras, Nicaragua and El Salvador farmers, technicians and organizations' knowledge and experience (PASOLAC, 2000). We used this dataset and selected the most suitable soil conservation practices for the agroecological and production conditions of the Reventazon. Four main soil conservation practices were selected: mulch, herbaceous hedgerows, agroforestry systems (low and high density) and cover crops or intercropping (Figure 16). In the Reventazon watershed farmers are already familiar with these selected practices (Vignola et al., 2010) which are actively being promoted by the watershed management plan (COMCURE, 2009). In our analysis we also assessed the combined effect of coupling multiple of the soil conservation practices (termed ideal cropping systems). Coupled practices were based on previous research (WOCAT, 2012; Vignola et al., 2010; Raudes & Sagastume 2009; COMCURE, 2009; FAO 2000 and 2001,) (Figure 16).

Figure 16. Ideal cropping systems or activities implementation and maintenance cost per hectare (I & M) estimated as the sum of each soil conservation practices implementation and maintenance cost (**¡Error! No se encuentra el origen de la referencia.**). Soil retention efficacy (SRE) estimated as the um of the minimum reported efficacy for each soil conservation practice. Legend of the soil conservation practices at the bottom: Hedgerow, agroforestry, cover crops and mulching.



Each soil conservation practice has important pros and cons, and factors that limit their efficacy trapping soil and the adoption by individual farmers (**¡Error! No se encuentra el origen de la eferencia.**). For example, soil conservation practices might limit the ability of machinery to enter the field or a practice could increase crop management complexity or increase shade area thereby increase pest risk (Raudes & Sagastume 2009). In addition, the specific crop, be it annual, perennial or semi-perennial, impacts the possible combinations of soil conservation practices. For example, burning is practiced in the region to harvest sugar cane (semi-perennial); therefore, hedgerows with trees in lineal arrangement are advocated over intermixed plantings. We considered these factors to design our ideal cropping systems and to model the effect of implementing those as a strategy to minimize soil loss. For example, cover crops or mulch will protect the soil from detachment, but if detached, hedgerows downslope will potentially retain it and agroforestry systems will promote deeper roots and grater infiltration rates (Supplemental Material I). We implemented ideal cropping systems on current perennial, annual, semi-perennial and pasture land cover types. But, we implemented reforestation with endangered tree species on bare soil cover type rather ideal cropping systems.

Implementation and maintenance cost for each one of the soil conservation practices were adopted from PASOLAC (2000) and updated to Costa Rican wages and prices (**¡Error! No se encuentra el rigen de la referencia.**). Seed costs were obtained from a tropical research center in Costa Rica (CATIE) seed bank prices and the cost of the tree seed species correspond to the tree endangered species promoted according to Costa Rican legislation. The cost of implementing hedgerow increases with the slope steepness, so we estimated the total cost for each ideal cropping as the sum of each soil conservation practice cost on level (<15%), moderate (15-30%) and steep (>30%) slopes and used the averaged total cost across slope steepness (**¡Error! No se encuentra el origen de la referencia.**). The ost of reforestation with endangered tree species equals the payment that FONAFIFO is currently (2014) assigning to this activity ($1,470). Our cost of implementing and maintaining ideal cropping systems do not include cost associated with running and maintaining a PES program. This includes transaction, training and opportunity costs. Targeting efforts to a small portion of the landscape will decrease transaction and monitoring costs, yet without a quantification of these costs, this analysis should not be considered a complete program analysis (Garrick et al., 2013).

The soil retention efficacy by each conservation practice and coupled practices were estimated from a meta-analysis. We searched in ScienceDirect using keywords such as "mulch" & "soil loss", “cover crops" & "soil loss", "hedgerow" & "soil loss" and "agroforestry" & "soil loss". We found 30 articles and 105 observations that reported the soil retention efficacy of specific soil conservation practices (the difference in measured soil loss with and without the soil conservation practice; 0% no retention and 100% maximum retention) (**¡Error! No se encuentra el origen de la referencia.**). We performed n analysis of variance (ANOVA) to test differences in soil retention efficacy between practices across slope ranges. The ANOVA indicated that agroforestry and agroforestry combined with hedgerow have significantly lower soil retention efficacy (36% and 43%, respectively) (p-value = 0.042). There were no significant differences between the other practices and at the different slopes categories.

We use a conservative method to estimate the soil retention efficacy of each soil conservation practices and ideal cropping systems due to the high variability among experiments and the lack of clear trends. We used the minimum reported value across the 105 observations for each practice (**¡Error! No se ncuentra el origen de la referencia.**). We assumed that the interaction and retention efficacy among soil conservation practices in the ideal cropping system was additive; and therefore, we estimated the total soil retention efficacy of each ideal system as the sum of the minimum reported soil retention for each soil conservation practice (Figure 16, **¡Error! No se encuentra el origen de la referencia.**). In his study we only assessed soil retention as an ES; however, vegetative practices can also improve water regulation, nutrient cycling and biological control among other ES at the plot scale (Comerford et al., 2013). At larger scales, increase forest cover can improve habitat connectivity (Martínez-Salinas

& DeClerck, 2010), food security and human nutrition (DeClerck et al., 2011) and reduce vulnerability to extreme events (Altieri, 2002; Holt-Giménez, 2002).

3.3. Tools: Integrated Valuation of Environmental Services and Tradeoffs (InVEST) and Resources Investment Optimization System (RIOS)

Our metric for ecosystem service provision was soil retention, or in other words, the reduction of the exported soil off site by implementing the ideal cropping systems, estimated with InVEST and RIOS. InVEST and RIOS were developed by the Natural Capital Project and are complementary tools to assess ecosystem services. InVEST determines the quantity or presence of an ecosystem service; while RIOS identifies priority areas where changes on land use management to protect or restore an ecosystem service are potentially more cost-effective (Sharp et al., 2013; Vogl, et al., 2013). Soil retention was estimated as the difference between the estimated exported soil with InVEST under current conditions and the three targeting strategies we explored using also three budget levels with RIOS, over the current conditions' exported soil. Our analysis only included agricultural lands available to ideal cropping systems (53% of the watershed [73,441 ha] area). For instance we excluded protected areas, forest, urban, or water bodies, as well as areas classified as clouds or shadows.

RIOS identifies the areas that are more cost-effective retaining soil by combining information about the user desired activities (i.e. soil conservation practices), the cost of implementing each activity, the user´s available budget and the critical factors determining potential effectiveness retaining soil such as the contributing area, crop management (Factor C), riparian continuity restoration among others (Table 5) (Vogl et al., 2013). The critical factors determining soil loss come from a detailed review of literature and hydrological experiments and models; however, the user can modify the goal and weight of each critical factor according to local conditions (maximize or minimize), exclude factors from the analysis or use the defaults values as we did (Table 5) (Vogl et al., 2013). RIOS scores each pixel potential effectiveness for retaining soil as the weighted sum of each one of the critical factors values per activity (i.e. Figure 16), then, the cost of an activity is assigned to each pixel for all the included activities. This is done to allocate the budget yielding the biggest return on investment; therefore, the priority areas for an activity will potentially yield the greatest benefit at the lowest cost (Vogl et al., 2013).

Table 5. Critical factors consider by RIOS to score each pixel's potential effectiveness retaining soil.

Category	Factors determine effectiveness	Goal	Weight	Description	Calculated from (by who):
Upslope Source Index	Upslope retention index	Maximize	1	Estimates the contributing area to a pixel and the magnitude of the contribution	Flow accumulation, pixels sediment export coefficients, retention factors, slope (RIOS)
Downslope Retention Index	Downslope index	Minimize	1	Estimates potential retention downslope of a pixel	Flow length, slope, retention factors (RIOS)
On-pixel source:	Sediment export coefficient	Maximize except for transition keep native veg (Minimize)	0.25	Factor C in USLE. Indicates the impacts of previous cropping systems, the protection offered to the soil surface by vegetative canopy, erosion reduction due to surface cover, and surface roughness	Obtained from literature review or by measuring surface cover, mass density of superficial roots, effectiveness of surface cover; mass density of incorporate surface residue, surface soil consolidation factor, surface roughness; canopy height, surface roughness, fraction of land surface covered by canopy impacts of the subsurface residues (USER)
On-pixel source:	Erosivity factor	Maximize	0.25	Factor R in USLE. Indicates the effect of raindrop impact and rate of runoff associated with rain of moderately sized storms with occasional large storms	No events per year, erosive rain Intensity (USER)
On-pixel source:	Erodibility factor	Maximize	0.25	Factor K in USLE. Reflects soil profile reaction to hydrologic processes (e.g. raindrop impact, surface flow, roughness (topographic or induced), and rain water infiltration).	Soil structure; soil permeability, organic matter, %Silt , %Very fine sand, %Clay (USER)
On-pixel source:	Soil depth	Maximize	0.25		(USER)
On-pixel retention	Sediment retention	Minimize except for transition keep native vegetation (Maximize)	0.5	Reflects the efficacy of a pixel trapping sediment and holding it	From literature review. Factor affected by land cover type and management, geomorphology, climate. (USER)
On-pixel retention	Riparian continuity	Maximize	0.5	Indicated the continuity riparian areas	DEM and land use map (RIOS)
	Beneficiaries	Maximize	1	Indicate priority areas based on the number of beneficiaries of the ES (no people) or by the amount of the service (energy produced)	(USER)

InVEST models soil retention using the Universal Soil Loss Equation - USLE (Wischmeier & Smith 1978). The USLE is an empirical but robust model that combines the effect of the characteristics of the soil (K factor), the intensity of the precipitation (R factor), conservation practices (P factor), slope steepness (S factor), slope length (L factor) and cover management (C factor) (Wischmeier & Smith 1978). The empirical equation has important limitations (Sharp et al., 2013; Estrada-Carmona et al., in review); however, it has shown to be applicable across a wide range of conditions to indicate areas of greater risk to soil erosion by water (Gaffer et al., 2008).

We parameterized the USLE using available data for the area. The K values were obtained from FAO surveys at a national level and soil type classification at a scale of 1:200,000 (FAO, 1989). The R factor was estimated using the total storm energy (E) and a maximum 30 minute intensity (I30) for each erosive storm (i.e. storms with total accumulated rainfall greater than 13 mm and separated by at least six hours) for 148 station years of measurements in 54 meteorological stations of the Costa Rican Institute of Electricity– (ICE; Gómez-Delgado, 2002). InVEST estimates the L and S factors using Desmet and Govers (1996) methodology for the watershed's digital elevation model with a 28.5 m resolution (Imbach, 2006). Land uses were defined by a 1996 LandSat image classification (Pedroni, 2003), the most accurate land use classification with the best spatial and thematic resolutions for our analysis to our knowledge. The C factor and the crop soil retention values for each the current land use were obtained from RIOS's extensive literature review (Vogl et al., 2013). The P factor was assumed to be 1.0 for current conditions since no detailed information about the support practices in the watersheds exists. But, we incorporated the effectiveness of the ideal cropping systems retaining soil by modifying the practices factor (P factor). The P factor was estimated as one minus the soil retention efficacy for each cropping system.

The USLE is better at estimating long term average erosion and it only estimates erosion by water (sheet and rill) (Wischmeier & Smith 1978). Therefore, other erosive processes such as bank erosion, landslides or even other types of erosion such as wind erosion are not considered (Wischmeier & Smith 1978). This is particularly true in the Cachi drainage area where there is a greater frequency of landslides within the basin (Ramírez et al., 2008). Yet, this source of sediment is not directly related to land use decisions (afforestation is unlikely to stop land sliding) and should be considered background variability. A potential larger unquantified land use impact is the construction of unpaved roads (Gómez-Delgado et al., 2011).

We calculated the sediment delivery ratio, the proportion of the gross sediment exported per each pixel that actually reaches the reservoirs, to assess the accuracy of the USLE estimations. The delivery ratio was estimated as the ratio between the measured sediment yield in each reservoir (Table 4) and the gross sediment for each dam's drainage area (Bhattarai & Dutta, 2006). Our estimated average sediment per hectare was calculated as the total gross sediment exported per pixels divided by the drainage area multiplied by the sediment delivery ratio.

3.4. Targeting strategies

Defining priority areas to target efforts can be based using different criteria. For this reason, we tested the effectiveness of implementing cropping systems using three targeting strategies: RIOS default optimization (named RIOS), RIOS constrained to areas in conflict with current legislation (named RIOS&Legislation) and RIOS constrained to areas with erosive crops or crops on steep lands (named RIOS&C-S). RIOS optimization uses the pre-determined critical factors (Table 5) to find the most cost-effective areas to implement ideal cropping systems as we discussed in section 2.3. However, we also tested if enforcing current land use capability legislation is the most effective strategy or if using verifiable criteria's in field and key drivers of soil erosion is the most effective.

We determined the targeting strategy RIOS&Legislation by overlapping the land use capability developed for the Reventazon management plan (PREVDA, 2008) with the land use from 1996 (Pedroni, 2003). Costa Rica established in 1994 the land use capability for the national territory according to local conditions such as soil nutrients, soil depth, relieve, rockiness, floodable (Act N°

23214-MAG-MIRENEM, 1994). The land use capability classifies the land into eight categories, from null restrictions for productive activities (i.e. class I) to high restrictions (i.e. class VIII). We defined conflict areas as those areas that corresponds to 1) any productive activity occurring in areas that should be dedicated to forest protection (i.e. classes VII, VIII), 2) other agricultural activities than perennial crops in areas with severe limitations (i.e. class VI) and 3) other agricultural activities than semi-perennial and perennial crops occurring in areas with strong limitations (i.e. classes IV). We constrained RIOS to run and prioritize using only the areas in conflict (33,693 ha, ~41% of the upper Reventazon watershed area).

We determined the targeting strategy RIOS&C-S by overlapping the land use map and the slope. Estrada-Carmona et al., (in review), identified for the same watershed using a global sensitivity analysis, that the interaction between cover management and slope steepness is what mainly drives soil erosion in the region. Therefore, we used Estrada-Carmona et al. (in review) results and identify those areas located on 1) steep areas (steepness >23%) with productive uses (C factor > 0.07) and 2) erosive crops (C factor >0.4) on level landscapes (steepness <23%). We constrained RIOS to run and prioritize using only the areas where C and S factors interacts generating greater soil loss in the upper Reventazon watershed area (36,009 ha, ~44%).

3.5. Budget allocation

We assessed the changes on the provision of the ecosystem service soil retention across different budget levels. Low budget allocations correspond to the amount ($0.3 million USD) the Reventazon watershed plan assigned to invest on soil loss control and to implement agroforestry systems during 2008-2010 (PREVDA, 2008). The medium budget allocations correspond to the lowest and larger reported yearly dredging cost for both, Angostura and Cachi reservoirs. The national hydropower company, ICE, spent between $2-4 million dredging the dams (Vignola et al., 2012, Vignola et al., 2010). These costs exclude the financial support the ICE contributed to the Reventazon management plan (PREVDA, 2008). Finally, the largest budget corresponds to the maximum amount ($7million) that would be needed to allocate to cover the maximum extent of agricultural land available for ideal cropping systems. We assumed an adoption rate of 100% during the first five years of implementing and maintaining ideal cropping systems.

We assumed that at least a five year of continuous budget allocation would be needed for two reasons. First, this period is approximately what it will take to fully establish ideal cropping systems (maximum soil retention) and to potentially increase yield production (Alegre, & Rat, 1996). Second, FONAFIFO distributes the payments for agroforestry in a five-year period (FONAFIFO, 2014).

We estimated the avoided cost as the cost of dredging the retained soil by each targeting strategy at the different budget allocations for the life span of the dams. Then we compared both, the cost of implementing ideal cropping systems (budget allocation) and the avoided cots. The cost of dredging one ton of sediment in the area is $1.3t-1 according to Vignola et al. (2010), who reported that ICE dredges every year 1.5millions·tonnes of sediment from the reservoirs (Angostura and Cachi) with a cost of at least $2 million USD. Approximately 70% of the sediment yield in the reservoirs is removed during the dredging. For instance, the life span of the dams was estimated as the sum of the accumulated sediment (30% of the sediment yield) through time until the reservoir capacity was full. The total retained soil is the cumulative throughout the life span of the dams. The avoided cost is estimated then as the dredging cost multiplied by the extended life span of the dam and the total retained soil up-stream due to the implementation of the ideal cropping systems. We excluded the first five years after of implementation to account for the time it will take to the practices to fully establish. The avoided cost is estimated only for Cachi and Angostura’s dams. Birris was incorporated into the Angostura drainage area in this analysis since we lacked information about the volume of the reservoir (Table 4.). We assumed constant conditions (i.e. sediment yield in the reservoirs, land cover) through time to estimate the avoided cost and the extension of the life span of the dams since we lack of historical data for all the dams. Measurements in Angostura indicates a high yearly variability with reported extremely high sediment yields in the reservoirs up to five times greater than the average yields (Jiménez-Ramírez et al., 2004).

4. Results

Modeling results indicated a wide range of ES provisioning rates across targeting and budget allocation. InVEST (particularly the USLE) accuracy assessment indicated that model predictions are consistent with reported values for the study area. Our comparisons across targeting strategies and budget allocations indicated that the most cost-effective (highest soil retention per dollar) strategy is to target lands with erosive crops and crops on steep lands (RIOS&C-S) using medium budgets ($10-16.4million). Low budget allocations ($1.5million) yielded similar results across targeting strategies. And, the benefits of investing on ideal cropping systems exceeded the dredging cost using RIOS&C-S targeting strategy across budgets, given our modeling assumptions.

4.1. Universal Soil Loss Equation accuracy assessment

The soil retention ES provision rate was estimated as the relative change between current condition and each targeting strategy across the three budgets (Figure 17 and 18). We used this rate to estimate the reduction in sediment yield reaching the reservoirs and its effect extending the life span of the dams (Table 6), rather than the gross estimates of cumulative sediment. As a simple accuracy assessment of the gross estimates we compared our estimated average sediment per hectare with reported values. The estimated average sediment per hectare for the Birris and Angostura dams correspond to the values reported in other studies. The USLE underestimated measured values for the Cachi drainage area in which the frequency of landslides is higher (Table 4).

Figure 17. Covered area and retained soil by the implemented ideal cropping systems in each drainage area (Angostura, Cachi and Birris) under three targeting strategies (RIOS, RIOS constrained to areas in conflict with legislation and RIOS constrained to areas with erosive crops on steep slopes) and at different budget levels. The percentage of the cover area corresponds to the total area of each one of the drainage area of each dam.

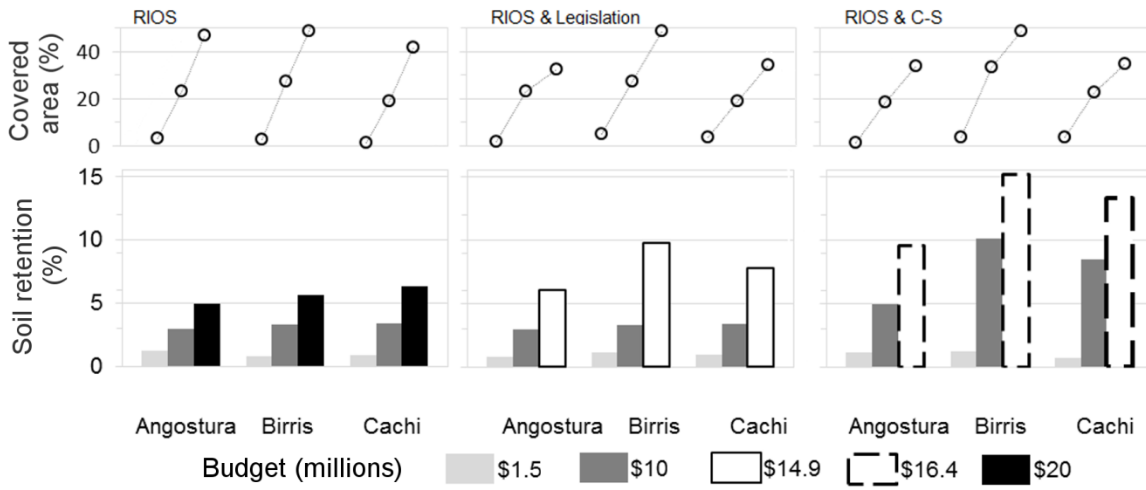


Figure 18. Covered area and retained soil in the upper and middle part of the Reventazon watershed by using three strategies to target ideal cropping systems (RIOS, RIOS constrained to areas in conflict with legislation and RIOS constrained to areas with erosive crops on steep slopes) at different budget levels. One-hundred percent of the area refers to the 73,441ha in the watershed where ideal cropping systems can be implemented.

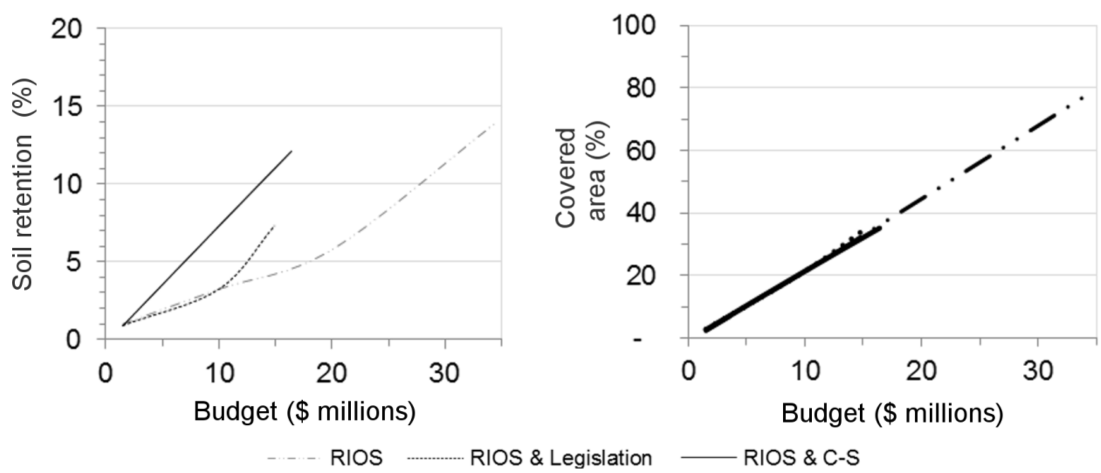


Table 6. Dams lifespan extension and avoided cost if ideal cropping systems (ICS) are implemented using different targeting strategies at different budgets levels.

	Implementation cost ($millions)		Life span (y)		Sediment yield (millions·t·y^{-1})		Up-stream retention (millions·t·y^{-1})	Total retained (millions·t)	Avoided cost ($millions)
Targeting strategies	Budget	Dam	No ICS	ICS	No ICS	ICS	ICS	ICS	ICS
RIOS&Legislation	1.5	Angostura	24	24	1.5	1.49	0.01	0.3	0.4
	1.5	Cachi	145	147	1.1	1.09	0.01	1.2	1.6
Total									1.9
RIOS&C-S	1.5	Angostura	24	24	1.5	1.49	0.01	0.2	0.3
	1.5	Cachi	145	147	1.1	1.09	0.01	1.8	2.3
Total									2.6
RIOS	1.5	Angostura	24	24	1.5	1.49	0.01	0.3	0.3
	1.5	Cachi	145	147	1.1	1.09	0.01	1.9	2.6
Total									2.9
RIOS&Legislation	10	Angostura	24	25	1.5	1.45	0.05	1.0	1.3
	10	Cachi	145	150	1.1	1.07	0.03	4.7	6.3
Total									7.6
RIOS&C-S	10	Angostura	24	26	1.5	1.37	0.13	2.7	3.6
	10	Cachi	145	153	1.1	1.05	0.05	8.1	10.8
Total									14.4
RIOS	10	Angostura	24	25	1.5	1.45	0.05	1.0	1.3
	10	Cachi	145	150	1.1	1.07	0.03	4.7	6.3
Total									7.6
RIOS&Legislation	14.9	Angostura	24	25	1.5	1.41	0.09	1.8	2.4
	14.9	Cachi	145	155	1.1	1.03	0.07	9.9	13.2
Total									15.7
RIOS&C-S	16.4	Angostura	24	26	1.5	1.36	0.14	3.0	4.1
	16.4	Cachi	145	161	1.1	1.00	0.10	16.3	21.8
Total									25.9
RIOS	20	Angostura	24	25	1.5	1.43	0.07	1.5	2.0
	20	Cachi	145	153	1.1	1.05	0.05	8.0	10.7
Total									12.7
RIOS	34.5	Angostura	24	27	1.5	1.34	0.16	3.5	4.7
	34.5	Cachi	145	163	1.1	0.98	0.12	18.8	25.0
Total									29.7

4.2. Targeting strategies and budget allocation comparison

The Birris dam has smallest drainage area yet has the highest erosion rates (Figure 15). This basin occupies only 3% of the upper and middle Reventazon, still both targeting strategies RIOS&C-S and RIOS&Legislation covered more area in this basin with ideal cropping systems yielding slightly higher soil retention rates, particularly at the higher budget levels (Figure 17). Cachi and Angostura's dams have the largest drainage area, occupying 55% and percent 42% of the Reventazon watershed, respectively. In these two dams, both targeting strategies RIOS and RIOS&Legislation tended to cover the same proportion of area at the medium budgets yielding similar soil retention rates. Modeling results show similar soil retention rates across targeting strategies with the lowest budget allocation

(Figure 17). Finally, RIOS&C-S yielded the highest soil retention rates across dams when medium and larger budgets were available (Figure 17 and 18).

The targeting strategy with RIOS and the maximum budget ($34.5million) yielded the maximum soil retention rate (14%). However, the targeting strategy RIOS&C-S yielded similar results (12%) using half of the budget ($16.4millions) and covering half of the area (Figure 18). The RIOS & Legislation targeting strategy is only more effective than RIOS when larger budgets were available (Figure 18). With low budgets ($1.5millions), all the different targeting strategies had low effectiveness since they only reduced ~1% of the total exported sediment and changed less than 3% of the area. The targeting strategies of RIOS & C-S and RIOS & Legislation used partially the $20millions budgeted ($16.4millions and $14.9millions, respectively), indicating that the most effective areas retaining soil can be covered with lower budgets (Figure 18).

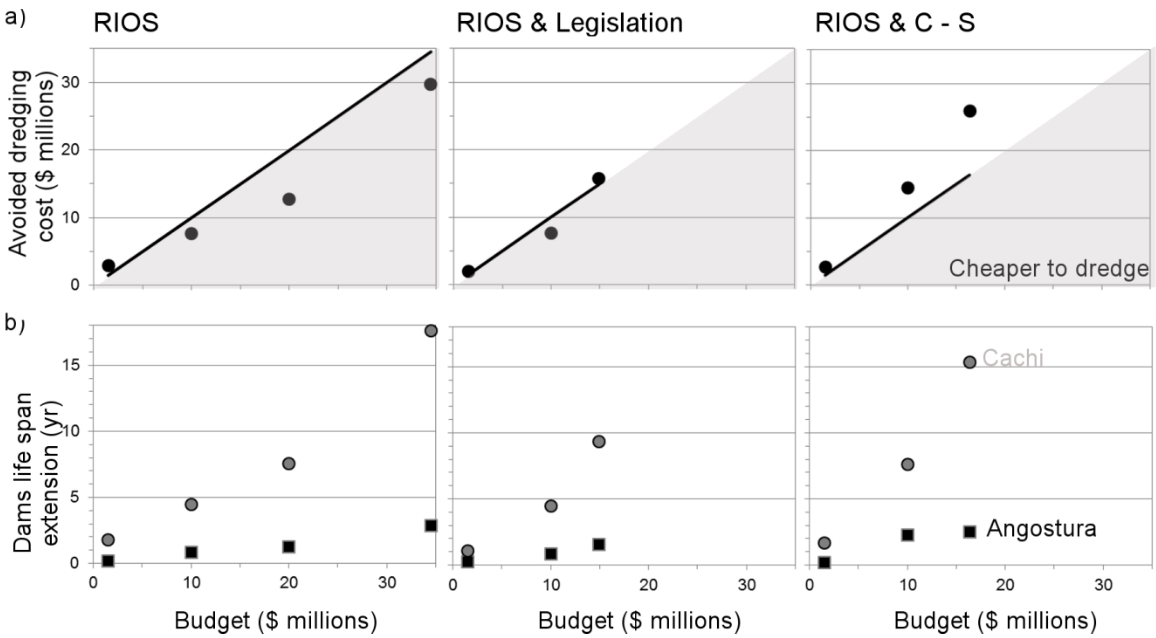
The slope of both the covered area and the soil retention at different budgets indicates a marginal benefit (Figure 18). Modeling results indicates that on average, every million invested may cover with ideal cropping systems 2.3% (1,689 ha) of the agricultural land; however, every extra million invested will only reduce exported soil in a magnitude of 0.4, 0.5 and 0.8 percent using RIOS, RIOS & Legislation and RIOS & C-S targeting strategies, respectively. The marginal benefit across budgets was constant for RIOS & C-S, but it increased for RIOS (from 0.3 to 0.6) and RIOS & Legislation (from 0.3 to 0.8) when budget was increased from $10 to $20 million (Figure 18).

Budget allocation across cropping systems (i.e. annual, perennial, semi-perennial, pasture or reforestation) was consistent with the current land use distribution. The largest proportion of the budget (approximately 75%) across targeting strategies and budgets was designated to support perennial and pasture ideal cropping systems. Bare soil, although occupying low proportion in the watershed (1.2% of the area), was the third most invested activity across targeting strategies and budgets, despite the highest implementation and maintenance cost (Supplemental Material II). This means that investing on bare soil is effective in comparison to other activities.

4.3. Benefit of implementing soil conservation practices (avoided cost)

Avoided cost is the cost the hydropower companies would have to spend dredging if the retained soil by the cropping systems entered the reservoir. Here, we assumed a constant sediment yield through the life span of each dam. We also assumed a constant soil retention rate through time after five years of cropping system establishment (Table 6). The estimated rates indicated that the targeting strategy RIOS & C-S is the only strategy that consistently retained enough soil up-stream across budgets allocations to make the investment on cropping systems cheaper than to remove the sediment from the reservoirs (Figure 19a). The targeting strategy RIOS & C-S also extended the dams' life span close to the maximum that could extended with RIOS and the highest budget ($34.5), which covers 78% of the watershed area where ideal cropping systems can be implemented (Figure 18). RIOS targeting strategy with a budget of $34.5millions extended the life span of the Angostura and Cachi dams, 2.9 years and 17.6 years, respectively. RIOS&C-S targeting strategy and with half of the budget ($16.5millions) extended both dams life span, 2.5 years and 15.3 years, respectively (Figure 19b).

Figure 19. Panel a) shows the avoided cost by the hydropower companies estimated as the cost of removing the sediment retained up-stream by the cropping systems (black dots) at the different budget levels and targeting strategies. The black line represents the implementation cost of the cropping systems, below this line (gray area), the implementation and maintenance cost of the ideal cropping systems is more expensive than the dredging cost of the retained soil by the ideal cropping systems. Panel b) shows the extension of the dams' life span across targeting strategies and budgets.



Other targeting strategies avoided costs was similar or lower than the implementation cost of the ideal cropping systems, potentially due to a low soil retention rate (Table 7). Still, almost all targeting strategies extended the life span of the dams between 0.8y and 1.5y for Angostura's dam and between 4.5y and 9.3y for Cachi's dam with budgets greater than $1.5millions (Figure 19b and Table 7). Comparing the total retained soil accumulated up-stream by the ideal cropping systems with the reported sediment yield in each reservoir offered a non-monetary assessment of the benefits. We found that targeting strategies RIOS&C-S (budgets $10 and $16.4 million) and RIOS (budget $34.5 million) retained up-stream during the whole dam's life span, the equivalent to two years of the current sediment yield in Angostura's dam (1.5millions·t·y·r-1, Table 4 and 7). The same targeting strategies retained up-stream what is the equivalent amount to 7, 15 and 17 years, respectively, of the annual sediment yield (1.1millions·t·y·r-1, Table 4) in Cachi's dam.

5. Discussion

Our application of InVEST and RIOS tools to assess the provisioning of the soil retention ES is an initial attempt to better assess the role of agroecosystems as ES providers in Costa Rica. Our results indicate that targeting efforts to implement ideal cropping systems (combination of at least two or three soil conservation practices) on erosive crops or crops on steep slopes will likely provide the highest cost-effectiveness investment scenario, or in other words, the highest soil retention per dollar spent. Under this particular targeting strategy, investments in ideal cropping systems may be more cost effective than dredging sediment from the downstream reservoirs, given our modeling assumptions.

5.1. Role of agroecosystems as ES providers

The Costa Rican PES scheme is becoming more supported by local ES consumers such as hydropower companies, industry, tourisms among others (Pagiola et al., 2008; Blackman & Woodward, 2010). These consumers may demand a higher provision of ES at this local scale such as water quality. Improving water quality will require the provision of ES not only from the forested areas or spread trees but also from a proper agroecosystem management and planning.

ICE previous efforts in the upper-middle Reventazon watershed such as raising awareness, trainings, nurseries to foment agroforestry and technological transfer (i.e. vermicomposting or biodigestors) improved in agricultural lands the management of natural resources (Sims & Sinclair, 2008). Still, the benefits of those efforts in terms of the reduction of sediment loads and pollution in the reservoirs are marginal (PREVEDA, 2008). Marginal benefits on reducing sediment yield may be due to a poor monitoring strategy of the on-site and off-site effects of the efforts, to a spatiotemporal lag (e.g. Fremier et al., 2013) or to a low budget allocation. Low budget allocation ($1.5 million) in our analysis indicates low rate of ES provisioning (less than 2% increase on soil reduction) regardless the targeting strategy. Yet, these investments might be profitable by the hydropower company as they not only reduce soil transport into the reservoir, but also for public relations. When considering higher investments, the amount of soil retained by investments in ideal cropping systems using the RIOS&C-S method might be enough to make investments more cost effective than remediating the effects of dredging (e.g. implementation and maintenance cost $16.4millions versus estimated dredging cots $23.3millions; Figure 4). Investments in soil conservation practices might also extend dam life span, which is one of the most critical concerns of hydropower companies with high sedimentation rates (Haun et al., 2013).

5.2. Targeting strategies

The majority of ES are spatially explicit as well as the pressure or threats (e.g. deforestation, soil erosion) to ecosystems and the services they provide. Targeting efforts, incentive or policy based, rather than "first-come first-served" guarantees the additionality and efficiency of the efforts (Robalino & Pfaff, 2013; Pfaff & Robalino, 2012; Wünscher et al., 2008). The Costa Rican PES scheme prioritizes PES for agroforestry systems based on land use capability (FONAFIFO, 2014), similarly to our RIOS&Legislation targeting strategy yet less aggressive at targeting erosive lands. However, our results indicate that targeting efforts to increase the provision of the ES soil retention on erosive crops and crops on steep slopes (> 23%) (RIOS&C-S) potentially will yield the highest benefits per dollar invested. Particularly, with the medium and larger budgets we tested for this targeting strategy ($10 or $16.4 million). Another advantage of the RIOS&C-S targeting strategy is that both, the slope steepness and cover management factors, are verifiable on the field. Using verifiable factors on the field to determine participation criteria in the PES scheme may add a sense of fairness to the program (Vignola et al., 2010) and decrease negative behavioral spillovers (Alpízar et al., 2013) such as reducing current voluntary implementation of conservation practices or reducing aversion to participate.

We tested three targeting strategies using an empirically based approach, USLE, to quantify the provisioning of the soil retention ES. Our modeling strategy, offers a simple but robust and conservative first approximation to a methodology that can be adapted and modeled iteratively to assess the potential contribution that changes in agroecosystems management has on providing ES. This first approximation also contributes to move beyond the assumption that spread trees will provide the demanded hydrological services by local consumers and contributes to improve spatial planning, one of the weaknesses of the Costa Rican PES scheme (Robalino & Pfaff, 2013). Also, this modeling exercise offers an opportunity to quantify the approximate benefits of investing on provisioning ES and, particularly private sector, may get more engage with more clear and direct benefits (Ruckelshaus et al., 2012). Higher engagement of the private sector in conservation is currently an important challenge in agricultural landscape planning across Latin America and the Caribbean (Estrada-Carmona et al., 2014). Future efforts with more complete available data may include more comprehensive hydrological and calibrated models to assess hydrological services (e.g. Gómez-Delgado et al., 2011).

6. Conclusion

Our results indicate that the cost of implementing ideal cropping systems (combination of at least two or three soil conservation practices) is potentially similar or cheaper than dredging. Particularly, we estimated that the highest soil retention per dollar spent is obtained by targeting efforts on erosive crops (C factor >0.4) or crops (C factor > 0.07) on steep lands (>23%) using medium budget allocations such as ~$10-20 millions. Low budget allocations yielded marginal benefits providing an increase of soil retention ES lower than 3%. However, all targeting strategies extended the life span of the dams by reducing sediment yields in the reservoirs, given our modeling assumptions. Our estimation of the provisioning of the soil retention ES due to changes in agroecosystem management is an empirical-based and conservative methodology that can be adapted and modeled iteratively to improve PES spatial planning in agroecosystems. Our methodology may also improve private or industry sector long-term and strong engagement with more clear and direct benefits of their investments. Future research should incorporate transaction cost and explore other strategies to boost the voluntary implementation of ideal cropping systems through training, experimental farms or farmer scientist.

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APPENDIX A

Internet Search Terms (in English, Spanish and Portuguese)

Terms (English)
1. Agrobiodiversity
2. Agroecology
3. Agroforestry
4. Biological corridor
5. Buffer zone
6. Community-based forest management
7. Community-based natural resource management
8. Conservation agriculture
9. Food security and conservation
10. Initiative
11. Integrated landscape management
12. Integrated management
13. Integrated watershed management
14. Landscape initiative
15. Landscape management
16. Landscapes and livelihoods
17. Livelihoods
18. Multi-stakeholder
19. Natural resource management
20. Participatory
21. Program
22. Project
23. Socio-ecological
24. Territorial development
25. Territorial management
26. Territory

Plus names of each of the countries in Latin America and the Caribbean (23 Countries).

APPENDIX B

Survey to assess Integrated Landscape Management for agriculture, rural Livelihoods, and ecosystem conservation in Latin America and The Caribbean.

Continental Review Survey (LPFN)- English

1. Welcome!

Dear colleague,

Thank you for responding to this survey. By sharing your experiences, you will be contributing to a global effort to document and share lessons learned from landscape-scale initiatives to support food production, ecosystem conservation, and human wellbeing in rural landscapes ("ecoagriculture" initiatives). These results, in turn, will contribute to a strategic, international action and advocacy program to expand the use of sustainable landscape management approaches around the world. For more information on this program, please visit http://landscapes.ecoagriculture.org.

This questionnaire includes 7 pages, and should take about 20 minutes to complete. The survey asks questions about a landscape initiative in which you have been involved, and about the landscape where this initiative is located. A landscape initiative is defined as a multi-stakeholder project, program, or community-led effort to increase food production, ecosystem conservation, and rural livelihoods through integrated planning, decision-making, and management at a landscape scale. Landscape initiatives can include community-led efforts, government projects or programs, or initiatives supported by organizations from outside the landscape.

In appreciation of your contribution, you will receive an electronic copy of the final review study, highlighting key lessons learned, resources, and opportunities for supporting and expanding ecoagriculture initiatives. We will send this document to the e-mail address that you provide us in your survey response. Also, upon completion of the full questionnaire, you will be automatically entered to win one of three Apple iPad computers, which will be awarded to three randomly-selected respondents.

If you have any questions about the survey, please contact Abby Hart at ahart@ecoagriculture.org. Thank you very much for your valuable contribution to this research and to supporting the sharing of knowledge about sustainable landscape management!

Sincerely,
The Ecoagriculture Global Review Team

Continental Review Survey (LPFN)- English

2. Part 1: Respondent Information

Please provide the following basic information about yourself and your role in the landscape or landscape initiative.

Title:

First name:

Middle name:

Last name:

Email address:

What is the name of your organization?

Telephone number (please include any country or regional codes)

What is your position or title within the organization?

What is your role in the landscape or landscape initiative? (please describe)

Continental Review Survey (LPFN)- English

3. Part 2: Basic information on the landscape

Please describe the landscape where you were involved in promoting integrated activities to benefit food production, ecosystem conservation, and rural livelihoods.

On which continent is the initiative located?

Where is the landscape located? (please fill in as many as relevant)

Country:

State, province or region:

Locality (please list the districts, municipalities or towns within the landscape):

If the landscape has a name, please provide it here:

Approximately how large is the landscape (area)? (please answer in hectares or in square kilometers)

Hectares

Square kilometers

Do you know approximately how many people live in the landscape? (an estimate is OK)

☐ Yes: ☐ No:

How many people?

Continental Review Survey (LPFN)- English

Please provide a general characterization of land use/land cover in the landscape by checking the boxes that apply:

	Major landscape component (occupy more than 5% of the area)	Minor landscape component (present, but occupy less than 5% of the area)	Does not exist in the landscape
Tropical moist forest	○	○	○
Tropical dry forest	○	○	○
Temperate, upland, or montane forest	○	○	○
Grassland or savanna (without livestock)	○	○	○
Pasture (grassland for livestock)	○	○	○
Lakes and other water bodies	○	○	○
Annual grain crops	○	○	○
Other annual crops (horticulture, etc.)	○	○	○
Perennial crops in agroforestry systems (e.g., shade-grown cocoa or coffee)	○	○	○
Other sun-grown perennial crops (e.g., fruit orchards, coffee)	○	○	○
Wetland	○	○	○
Forestry plantations	○	○	○
Villages / towns / urban	○	○	○
Industry, mining, oil/gas development	○	○	○

Please list any other land use/land cover that is

a major landscape component (occupy more than 5% of the area) ________

a minor landscape component (occupy less than 5% of the area) ________

Continental Review Survey (LPFN)- English

4. Part 3: Basic information on the landscape initiative

Please tell us about the landscape initiative in which you have been involved.

In your responses, please describe the landscape initiative as it is currently organized and managed, even though it may have a longer history under previous organization and management.

Initiative name (or brief description):

Initiative dates:

Starting date (year only):

End date (year, if applicable):

State of the project (beginning, in process, ending, permanent):

Which organizations lead the initiative? (please provide the complete name of the organization if possible)

Please list key organization(s) within the landscape (e.g., farmers' associations, community or indigenous groups, local government, local NGOs):

Please list key organization(s) outside the landscape (e.g., donors, international organizations or NGOs):

Is this initiative a continuation of a previous project or effort?

☐ Yes ☐ No ☐ I do not know

If so, please provide the name of the previous effort:

Continental Review Survey (LPFN)- English

Which of the following issues were the main motivations for the landscape initiative? Indicate the level of importance of each issue that is trying to be improved with the landscape initiative.

	Very important	Important	Moderate important	No important	N/A
Enhance food security	○	○	○	○	○
Improve crop productivity	○	○	○	○	○
Diversify food production	○	○	○	○	○
Conserve biodiversity	○	○	○	○	○
Conserve soil or increase soil fertility	○	○	○	○	○
Stop or reverse natural resource degradation	○	○	○	○	○
Enhance sustainable land management	○	○	○	○	○
Reduce conflict among different resource users in the landscape	○	○	○	○	○
Increase farmer incomes	○	○	○	○	○
Improve livestock productivity	○	○	○	○	○
Improve health or nutrition	○	○	○	○	○
Conserve or increase water quality or water flow	○	○	○	○	○
Reduce the environmental impacts of agriculture	○	○	○	○	○
Mitigate climate change or obtain carbon credits	○	○	○	○	○
Reduce vulnerability to extreme weather events	○	○	○	○	○

There were other issues that motivated the establishment of the initiative? (Indicate the level of importance)

What percentage of the landscape has been directly affected by the initiative's activities, programs or policies?

☐ Yes: ☐ No:

What percentage (0-100%)?

Continental Review Survey (LPFN)- English

How many people has the initiative sought to benefit? (please provide either the number of people benefited or the percent of the landscape population benefited by the initiative)

☐ Number of beneficiaries: ☐ Percent of total landscape population: ☐ I do not know:

How many?

At the beginning of the initiative, was a baseline study, pre-project assessment, project document, or similar material prepared?

○ Yes: ○ No: ○ I don't know:

Does the initiative have cartographic information, aerial photographs or imagery of the landscape?

○ Yes ○ No ○ I don't know

If so, has this cartographic information been used for analysis and planning at landscape scale?

○ Yes: ○ No: ○ I am not sure:

Continental Review Survey (LPFN)- English

5. Part 4: Initiative activities and investments

Please tell us about the major activities, investments, or other changes that were included as part of the initiative.

Which of the following investments in agriculture were actively promoted by the landscape initiative?

	Was actively promoted	Was not actively promoted, but it occurred simultaneously in the landscape	Was not actively promoted and did not occurred in the landscape	N/A or Don't know
Promotion or introduction of new crops or crop varieties	○	○	○	○
Crop intensification with increased mechanization or application of fertilizers, pesticides, or herbicides	○	○	○	○
Crop intensification with agroecological methods (e.g., organic production, conservation agriculture, no-till, integrated pest management, improved fallows, etc.)	○	○	○	○
Livestock intensification with agroecological methods (e.g. improved grass and browse supply, management of water availability, etc.)	○	○	○	○
Establishment or improvement of irrigation systems	○	○	○	○
Adoption or expansion of agroforestry	○	○	○	○
Programs to adopt or improve home gardens	○	○	○	○
Implementation of laws or incentives to reduce the environmental impacts of agriculture	○	○	○	○
Implementation of soil conservation practices	○	○	○	○
Extension or capacity building programs to support agriculture	○	○	○	○
Establishment of new supply chain or marketing channels (including value addition and certification) for agricultural products	○	○	○	○
Promotion of native food species and agrobiodiversity	○	○	○	○

Other investment in agriculture (please specify)

Continental Review Survey (LPFN)- English

Which of the following investments in forestry, conservation, and natural resource management were actively promoted by the landscape initiative?

	Was actively promoted	Was not actively promoted, but it occurred simultaneously in the landscape	Was not actively promoted and did not occurred in the landscape	N/A or Don't know
New protected areas established	○	○	○	○
New management plans for existing protected areas	○	○	○	○
Other new reserves or community-based conservation areas (including areas that allow sustainable harvest and use of natural resources)	○	○	○	○
Other community-based natural resource management activities	○	○	○	○
Improved forestry management	○	○	○	○
Extension or capacity building programs to support forestry or natural resource management	○	○	○	○
Watershed management program or activities (e.g., restoration of riparian areas)	○	○	○	○

Other investment in forestry, conservation, or natural resource management (please specify)

Continental Review Survey (LPFN)- English

Which of the following investments in livelihoods and human wellbeing were actively promoted by the landscape initiative?

	Was actively promoted	Was not actively promoted, but it occurred simultaneously in the landscape	Was not actively promoted and did not occurred in the landscape	N/A or Don't know
Programs to reduce malnutrition and hunger	○	○	○	○
Programs for improving human health (e.g., improved access to health services)	○	○	○	○
Programs for improving gender equity	○	○	○	○
Programs to help secure land tenure and resource access rights	○	○	○	○
Preservation of traditional knowledge, values, or cultural resources	○	○	○	○
Programs to support enterprise development, savings and investment, or financial education	○	○	○	○
Activities to promote income generation and diversification outside of agriculture or forestry (e.g., handicrafts, ecotourism)	○	○	○	○
Efforts to reduce migration out of the landscape	○	○	○	○

Other investment in livelihoods and human wellbeing (please specify)

Continental Review Survey (LPFN)- English

Which of the following investments in multi-sectoral coordination and planning were actively promoted by the landscape initiative?

	Was actively promoted	Was not actively promoted, but it occurred simultaneously in the landscape	Was not actively promoted and did not occurred in the landscape	N/A or Don't know
Activities to strengthen existing coordination bodies (e.g., inter-jurisdictional councils, public-private partnerships)	○	○	○	○
Creation of new landscape coordinating bodies	○	○	○	○
Dialogue and mediation of conflicts among local communities or resource users	○	○	○	○
Dialogue and mediation of conflicts between local, national and international communities or resource users	○	○	○	○
Capacity building activities to help communities and stakeholders conduct integrated, landscape-scale management	○	○	○	○
Technical assistance to support integrated, landscape-scale management	○	○	○	○

Other investment in livelihoods and human wellbeing (please specify)

Please list any other activities or investments that were

actively promoted

not actively promoted, but it occurred simultaneously in the landscape

Continental Review Survey (LPFN)- English

6. Part 5: Stakeholders' roles in the initiative

Please tell us about the roles of different local and external groups in the initiative.

Which of the following types of groups have participated in designing or implementing the initiative? Please list only those groups that played a role in creating or carrying out the initiative or its component activities. Do not include groups that were merely informed or consulted about the initiative as affected stakeholders. Please check all that apply:

	Active participation designing the landscape initiative	Active participation implementing the landscape initiative	N/A
Local farmers' or producers' association	☐	☐	☐
Womens' association	☐	☐	☐
Indigenous group	☐	☐	☐
Group representing rural landless people	☐	☐	☐
Local government leaders (village leaders, mayors, chiefs, etc.)	☐	☐	☐
Government extension officers	☐	☐	☐
Other local or district government offices or staff	☐	☐	☐
State or provincial government offices or staff	☐	☐	☐
National ministries or national-level government staff	☐	☐	☐
Local non-governmental organization (NGO)	☐	☐	☐
Sub-national or national NGO	☐	☐	☐
International NGO	☐	☐	☐
Local or national university or research center	☐	☐	☐
Foreign or international university or research center	☐	☐	☐
In-country agribusiness (e.g., large plantation or ranch owners, agricultural land investors, etc.)	☐	☐	☐
Foreign agribusiness (e.g., large plantation or ranch owners, agricultural land investors, etc.)	☐	☐	☐
Logging/forest products industry	☐	☐	☐
Mining, oil, gas, or other industry	☐	☐	☐
Bi-lateral or multi-lateral donor(s)	☐	☐	☐
International organization focused on agriculture	☐	☐	☐

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International organization focused on conservation	☐	☐	☐

Other (please specify the name and if the organization is local, national or international)

Which sectors have been directly involved in the initiative? Direct involvement could include, for example, providing funding or staff resources, carrying out activities on the ground, or providing extension or capacity building services. Please check all that apply, but do not check sectors that were not directly involved in the initiative, even if they were conducting other activities in the landscape.

- ☐ Agriculture
- ☐ Livestock
- ☐ Forestry
- ☐ Natural resources, conservation, or environment
- ☐ Tourism
- ☐ Health
- ☐ Education
- ☐ Energy
- ☐ Roads, transportation, or infrastructure

Others (please specify)

Was any new institution or mechanism established to support the initiative?

○ Yes: ○ No: ○ I do not know:

If so, what type of institutions or mechanisms were established to support integrated landscape management?

- ☐ New cross-jurisdictional planning or governance entity (e.g., council of governments or territorial development group)
- ☐ Other organization that plays the role of supporting landscape-wide planning and coordination
- ☐ Mechanism or process to coordinate plans and investments proposed by different sectors (e.g., agriculture, forestry, infrastructure, irrigation)
- ☐ Mechanism or platform to allow different groups of land and resource users to resolve conflict

Other institutions or mechanisms? (specify)

Continental Review Survey (LPFN)- English

7. Part 6: Initiative outcomes/results

Please tell us about the initiative's outcomes and results.

Does this initiative include a monitoring and evaluation component?

- Yes
- No

Does the initiative use an adaptive management approach? (Note: adaptive management an iterative process that involves monitoring the results and effectiveness of project activities, reflecting on lessons learned from this experience, and then adjusting strategies to respond to this new information or to changing conditions.)

- Yes
- No
- I am not sure

Which of the following outcomes or changes took place within the ten years following the start of the initiative? (If the initiative started less than ten years ago, please indicate changes since the start of the initiative.) For each change, please indicate if the change took place as a result of the initiative or not as a result of the initiative. Please check the most appropriate box for each line:

Effects on agriculture:

	This change took place as a result of the initiative	This change took place, but not as a result of the initiative	This change did not take place	I am not sure if this change took place, or it is too early to tell
Agricultural yield per unit of land area (e.g., tons per hectare) increased	○	○	○	○
Agriculture became more profitable	○	○	○	○
Total area under agriculture and pasture increased	○	○	○	○
Environmental impacts of agriculture were reduced	○	○	○	○
Agricultural biodiversity (agrobiodiversity) was protected or enhanced	○	○	○	○

Other benefit (please specify)

Continental Review Survey (LPFN)- English

Effects on conservation and ecosystem services

	This change took place as a result of the initiative	This change took place, but not as a result of the initiative	This change did not take place	I am not sure if this change took place, or it is too early to tell
Rare, threatened, or endangered species were better protected	○	○	○	○
Overall biodiversity of the region was better protected	○	○	○	○
The amount or connectivity of natural habitats was increased	○	○	○	○
Water quality, quantity, or regularity improved	○	○	○	○
Ecosystem services that support agriculture (e.g., irrigation water supply, pollination, soil fertility) were restored or protected	○	○	○	○
Other ecosystems services (e.g., urban water supplies, flood control, carbon storage) were restored or protected	○	○	○	○

Other benefit (please specify)

Effects on livelihoods and the poor:

	This change took place as a result of the initiative	This change took place, but not as a result of the initiative	This change did not take place	I am not sure if this change took place, or it is too early to tell
Food security or nutrition for landscape inhabitants were improved	○	○	○	○
Household cash income for low-income residents was increased	○	○	○	○
Non-cash measures of livelihoods (e.g., greater material assets, cleaner or more reliable water, better educational resources) were improved	○	○	○	○
Communities became less vulnerable to shocks and disasters (e.g., landslides, floods, droughts, epidemics)	○	○	○	○
Access to health services improved	○	○	○	○

Other benefit (please specify)

Continental Review Survey (LPFN)- English

Effects on governance, institutions, and social capital:

	This change took place as a result of the initiative	This change took place, but not as a result of the initiative	This change did not take place	I am not sure if this change took place, or it is too early to tell
Local communities gained capacity to sustainably manage agriculture and natural resources	○	○	○	○
Local communities became more empowered to negotiate and participate in political decisions	○	○	○	○
Coordination and cooperation among stakeholders (e.g., local communities, district government, private sector, NGOs) improved	○	○	○	○
Coordination and cooperation among sectors (e.g., agriculture, environment, health) improved	○	○	○	○
Women gained power or capacity to improve their wellbeing	○	○	○	○
Traditional and local knowledge on agriculture and natural resources has been preserved and used	○	○	○	○

Other benefit (please specify)

What has been the most successful aspect of the initiative?

What has been the least successful aspect of the initiative?

Would you be willing to participate in a more in depth interview regarding your experiences with this landscape initiative?

○ Yes ○ No

Continental Review Survey (LPFN)- English

Do you know of any other ecoagriculture initiatives in Latin American that might be willing to share about their experiences?

Name of the initiative(s):

Country:

Region:

Contact person:

Telephone:

Email:

Help us improve our survey. Please leave your comments about the survey - Did you have any difficulty understanding the questions? Was the survey too long or difficult? Did you have any technical difficulties completing the survey? Thank you for your thoughtful comments!

Continental Review Survey (LPFN)- English

8. Thank you!

Thank you very much for completing this questionnaire! In appreciation of your contribution, we will send you an electronic copy of the final review study to the e-mail address that you provided. You have also been entered to win one of three Apple iPad computers, which will be awarded to three randomly-selected respondents.

For more information about the Landscapes for People, Food and Nature Initiative that is supporting this study, please visit http://landscapes.ecoagriculture.org.

APPENDIX C

Interview to assess Integrated Landscape Management for agriculture, rural Livelihoods, and ecosystem conservation in Latin America and The Caribbean

NOTAS SOBRE LA ENTREVISTA DEL TIER 2

LOGISTICA

Verifique que la conexión entre el skype y el callnote está activa. Este segura de comenzar la grabación antes de llamar.

Leer las respuestas del TIER 1 para estar un poco contextualizada con la iniciativa

Antes de llamar verifique cuáles pregunta le hará al entrevistado

ESTRUCTURA ENCUESTA

Las preguntas están divididas con base en los HECHOS o las INTERPRETACIONES, y con base en quién/cuántos entrevistados deben responder las preguntas. Estas clasificaciones tienen los siguientes significados:

HECHOS –básicamente preguntan sobre una información objetiva (basada en hechos) que debe ser verificable independientemente. Cualquier entrevistado(a) bien informado(a) debe proveer básicamente la misma respuesta para cuestiones basadas en HECHOS. Así, no es necesario preguntar cuestiones de HECHOS para todos(as) los(as) entrevistados(as).

INTERPRETATIVA – la pregunta incluye un elemento de subjetividad, interpretación y percepción personal. Inclusive donde existe una realidad objetiva (e.g., que tan efectiva ha sido una iniciativa con relación a indicadores variados), diferentes personas pueden tener percepciones distintas de esa realidad. Cuando estamos interesados en entender esas diferentes percepciones, es cuando hacemos las preguntas INTERPRETATIVAS.

SOLO 1 – la entrevistadora debe preguntar la pregunta a solamente un(a) entrevistado(a), él(la) cual se considera ser él(la) mayor conocedor(a) del asunto en cuestión. Las preguntas SOLO1 son basadas en HECHOS, y una vez que obtenemos la información necesaria, no hay necesidad de hacer la pregunta a otras personas.

TRIANGULAR – la entrevistadora debe hacer la pregunta a cuantos(as) entrevistados(as) crea necesario para establecer una respuesta confiable. Preguntas TRIANGULARES generalmente son preguntas basadas en HECHOS, en relación a las cuales es posible que algunos(as) entrevistados(as) no tengan la información completa o precisa y entonces nos podrían proveer una respuesta engañosa. La entrevistadora debe empezar haciendo la pregunta al primer entrevistado(a) que se considere conocedor del asunto. Si hay duda respecto a la confiabilidad de la respuesta, la entrevistadora debe continuar haciendo la pregunta a entrevistados(as) adicionales hasta que ella esté satisfecha y con información consistente y precisa.

PREGUNTE A TODOS(AS) – esas son generalmente preguntas INTERPRETATIVAS cuyo objetivo es comprender cómo distintos actores perciben la iniciativa y sus resultados. Tales cuestiones deben ser hechas a todos(as) los(as) entrevistados(as).

Objetivo: cerca de 15 preguntas; no más que 20

Tamaño de la muestra (# de paisajes): seleccionar 12-14 paisajes de alta prioridad que estamos seguros de incluir, además de 6-8 adicionales que intentaremos incluir si tenemos tiempo.

Intensidad de la muestra (# de entrevistados por paisaje): mínimo de 4, máximo de 6.

Entrevistados(as) deben representar distintos sectores, niveles y perspectivas. Debe haber al menos alguna representación del sector de conservación y del sector de agricultura. Entrevistados(as) deben incluir al menos una organización local, una representación rural o de comunidades, y, cuando aplique, un actor externo (donante, organización nacional o internacional, etc.) para cada iniciativa.

La mayoría, si no la totalidad, de los entrevistados(as) deben tener una perspectiva de todo el paisaje. No queremos respuestas que sean informadas solamente por el conocimiento del entrevistado(a) respecto a su finca o pueblo. Una posible excepción es cuando algunos actores ubicados en comunidades estén familiarizados principalmente con un área local, pero no con todo el paisaje. Esto está OK en la medida que sus perspectivas parezcan temáticamente anchas (i.e., consciente de las cuestiones de agricultura, medios de vida y conservación, además de las instituciones, políticas y estrategias relacionadas a ellas).

<u>Presentación nuevo contacto en el TIER 2</u>
Introducción: Actualmente Amigos de la Ecoagricultura en asocio con el CATIE estamos llevando a cabo una sistematización o búsqueda de experiencias de ecoagricultura en América Latina. La finalidad de este estudio es conocer y aprender sobre el contexto o bajo qué condiciones de dan este tipo de manejo de integral de paisajes. Nosotros definimos una iniciativa de ecoagricultura como aquella iniciativa que busca al mismo tiempo mejorar la producción agropecuaria, la conservación de los recursos naturales, la calidad y medio de vida de las comunidades y la gobernanza o empoderamiento de las comunidades sobre sus RN a una escala de paisaje.

Descripción proyecto: La primera etapa del proyecto consistió en contactar a las personas líderes o personas contacto de un conjunto de iniciativas, proyectos o programas que buscamos a través del internet. En el caso del [INICIATIVA] contactamos al Sr. / Sra. [NOMBRE CONTACTO], al cual le solicitamos su colaboración con el llenado de una encuesta. Después de analizar las encuetas que fueron diligenciadas, seleccionamos unas iniciativas las cuales estamos interesados en conocer más detalladamente. Para lograr esto queremos entrevistar a varios actores o líderes claves en el paisaje que han venido trabajando con la iniciativa [INICIATIVA] y tienen un buen conocimiento del paisaje. Lo estamos contactando porque [NOMBRE CONTACTO] nos indicó que usted nos podría colaborar.

La entrevista: La entrevista que le vamos a hacer, dura aproximadamente una hora. En esta entrevista le haremos preguntas sobre el paisaje donde se encuentra ubicada la iniciativa [INICIATIVA], sobre la iniciativa misma, la participación de diferentes actores o grupos en la iniciativa, las instituciones y la gestión de la iniciativa, políticas y gobernanza, y finalmente sobre las inversiones y los logros de la misma. No dude en interrumpirme o preguntarme si alguna pregunta o concepto no es claro. Algunas veces usamos terminología que es muy específica y que puede ser confusa, así que por favor no dude en preguntarme. De igual manera si no tiene conocimiento o información para responder alguna pregunta no hay ningún problema y solo pasamos a la siguiente pregunta.

Antes de comenzar me gustaría agradecerle de antemano por su tiempo y colaboración, y también me gustaría saber si tiene alguna duda o comentario.

<u>Presentación contacto del TIER 1</u>
De antemano le agradezco por su colaboración y participación, en días anteriores estuvimos revisando y analizando las diferentes encuestas que fueron llenadas por las diferentes iniciativas en América Latina, y seleccionamos la iniciativa [XXXX] para conocerla más detalladamente.

En esta segunda etapa de nuestra búsqueda de iniciativas ecoagrícolas, nos gustaría poder entrevistar a varios actores o líderes del paisaje que tiene buen conocimiento sobre la iniciativa y que ha estado involucrado con la iniciativa durante un buen tiempo. Lo ideal sería si me puede brindar los nombres y teléfonos de otras 5 o 6 personas que usted considera pueden participar en la entrevista y que han estado trabajando en los diferentes componentes como el agropecuario, conservación, calidad de vida de las comunidades, gobernanza, educación, etc. y/o que hace parte de organizaciones locales, gobiernos, ONG, universidades, etc. [ANOTAR CONTACTOS].

La entrevista:
La entrevista durará aproximadamente una hora y cubriremos temas similares a la encuesta que ya diligenció pero en más detalle. No dude en interrumpirme o preguntarme si alguna pregunta o concepto no es claro. Algunas veces usamos terminología que es muy específica y que puede ser confusa, así que por favor no dude en preguntarme. De igual manera si no tiene conocimiento o información para responder alguna pregunta no hay ningún problema y solo pasamos a la siguiente pregunta.

Antes de comenzar me gustaría agradecerle de antemano por su tiempo y colaboración, y también me gustaría saber si tiene alguna duda o comentario.

SECCION 1: INFORMACIÓN SOBRE LA PERSONA ENTREVISTADA

Por favor, provea la siguiente información básica sobre usted mismo y su papel en el paisaje y/o en la iniciativa de paisaje.

*Primer nombre: ______________________

Segundo nombre: ______________________

*Apellidos: ______________________

*Dirección correo electrónico: ______________________

*Nombre de su organización: ______________________

Teléfono (Por favor incluir el código del país - región): ______________________

*Su posición o cargo dentro de la organización:

____

¿Cuál es su papel en el paisaje o en la iniciativa de paisaje? (por favor describa):

____

____

SECCION 2: INFORMACIÓN SOBRE EL PAISAJE

POR FAVOR USE EL CUADRO PARA INGRESAR LA INFORMACIÓN ¿? 2.1, 2.11.
ESTE SEGURA QUE **INDICA LA IMPORTANCIA**. 1: más importante, 4: menos

En orden de importancia, cuáles son las cuatro sectores económicos (p.e. *agropecuario, forestal, pesquero, turismo, extracción, industria y otros*) más importantes en el paisaje?
(HECHOS/TRIANGULAR)

Si la agricultura es mencionada, por favor clasifique si es:

Sector		Pequeña escala			Mediana escala		Gran escala	
		Subsistencia	Comercial		Comercial		Comercial	
			Mercados locales / nacionales	Mercados internacionales / Exportación	Mercados locales / nacionales	Mercados internacionales / Exportación	Mercados locales / nacionales	Mercados internacionales / Exportación
Agropecuario								
Forestal								
Pesca								
Turismo								
Extracción								
Industria								
Otro:								
Otro:								

Es posible que varias de esas categorías agrícolas sean prioritarias

POR FAVOR USE EL CUADRO PARA INGRESAR LA INFORMACIÓN ¿? 2.2, 2.2.1.
ESTE SEGURA QUE **INDICA LA IMPORTANCIA**. 1: más importante, 4: menos importante

En orden de importancia, cuáles son los cultivos u otros productos agropecuarios / forestales más importantes en el paisaje?
(HECHOS / ¿? SOLO A 1)
Nota entrevistador: *Esto puede incluir cultivos, ganadería, fibras, cultivos para biocombustible, otros productos maderables y no maderables, etc.*
Se debe especificar el cultivo o el producto, *por ejemplo, maíz, banano, café, leche, puercos, teca o piscícolas.*
"Más importantes" *en términos de su contribución económica (para el caso de cultivos orientados a mercados) o contribución para suplir los mercados locales (para el caso de los cultivos de subsistencia)*

Cuál es el mercado principal o usos para cada uno de esos cinco cultivos o productos:
(HECHOS / ¿? SOLO A 1)

p.e cultivos (cuáles?), ganadería, fibras, cultivos para biocombustible, otros productos maderables y no maderables, etc.	Subsistencia	Mercados locales / nacionales	Mercados internacionales / Exportación
Prod1:			

Prod2:			
Prod3:			
Prod4:			
Prod5:			

Cuál es el tipo de tenencia de la tierra más común en el paisaje?
(HECHOS / ¿? SOLO A 3)
Nota entrevistador: *La meta es entender los principales tipos de propiedad y tenencia de la tierra en el paisaje.*

Ejemplos de las categorías de tenencia	**Solo las más importantes:** abarcan más del 10-20% del paisaje
a) tierras públicas o del estado	
b) tierras comunales	
c) propiedad privada manejada por los propietarios	
d) propiedad privada manejada por compañías	
e) propiedad privada aprovechada o manejada por arrendatarios	
Otro:	
Otro:	

Cómo considera usted que el paisaje donde se encuentra la iniciativa es definido o delimitado geográficamente?
(INTERPRETATIVA / ¿? TODOS) aclarar
Nota entrevistador: *De pronto es necesario hacer la misma pregunta de diferentes maneras para garantizar que el entrevistado la entienda. Básicamente queremos saber cómo el entrevistado ve la extensión geográfica del paisaje, y cómo ésta es delimitada. La pregunta* ***NO*** *pretende preguntar sobre el proceso de delineación del paisaje.*

Queremos saber si el entrevistado piensa que los límites corresponden a:	Si	No
Jurisdicciones (p.e. villas, municipalidades, cantones)		
Límite legal (p.e. áreas protegidas y sus zonas de amortiguamiento)		
Cuencas		
Río, lago, divisoria de aguas, u otro elemento geográfico mayor		
Ecosistema (p.e. un humedal grande)		
Rango de una o más especies de interés para la conservación		
Límite cultural o grupo étnico		
Un problema que debía ser resuelto		
Usaron otro criterio? Cuál?		
Otro:		
Otro:		

Los límites originales del paisaje han cambiado? Cómo y por qué?
(INTERPRETATIVA/ ¿? TODOS)

Hubo eventos (naturales, políticos, sociales, económicos, conflictos) que afectaron el paisaje y generaron cambios importantes en los últimos 25 años. Por favor, mencionar los más importantes.

(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Esta debe ser una pregunta abierta. Queremos saber si hay un entendimiento común del paisaje y sus dinámicas. La pregunta también debe revelar algunos de los retos que la iniciativa pretende resolver. Si el entrevistado necesita o quiere ayuda para entender la pregunta, se pueden dar algunos ejemplos de cambios importantes, como los cambios mayores en el uso de la tierra o las actividades económicas (p.e. deforestación, nuevas plantaciones), conflictos/guerras, e importantes designaciones de tierras como áreas protegidas.*

SECCION 3: INFORMACIÓN SOBRE LA INICIATIVA
Cuáles fueron los retos principales o problemas que motivaron la creación de la iniciativa de paisaje?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Hacer como pregunta abierta. Esperamos que en algunos casos habrá un reto o un problema principal, mientras que en otros casos habrán más. Queremos que el entrevistado identifique los retos/problemas **más importantes** - no una lista inservible. Si se ve que el entrevistado se esta desviando, hacerlo que mencione **máximo tres o cuatro** de los retos claves.*

1)
2)
3)
4)

Cuáles cree usted son los objetivos más importantes de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *De nuevo, puede haber solo un objetivo o varios. Si el entrevistado piensa que hubo varios objetivos, déjelo listarlos y anótelos. Pero asegúrese al final que tiene claro **los tres o cuatro objetivos más importantes**, ya que se preguntará más adelante sobre la efectividad de la iniciativa en relación a esos objetivos.*

1)
2)
3)
4)

Cuáles fueron las 3 o 4 actividades o inversiones principales de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Queremos obtener dos cosas de esta pregunta.*
La primera, *es entender qué hizo la iniciativa y si esto incluyó un conjunto de actividades "balanceadas" para alcanzar los múltiples objetivos de la iniciativa. Por lo tanto, l**a pregunta debe ser abierta** para dejar que la persona mencione las 3 o 4 principales actividades, inversiones, o intervenciones, a pesar del sector u objetivo en la que esta caiga.*
Lo Segundo, *es entender si la iniciativa realmente incluyó actividades relacionadas a la agricultura (cultivos/ganado), conservación, medios de vidas rurales, y fortalecimiento institucional - inclusive si el entrevistado no identifica estas en las tres o cuatro actividades. Por lo tanto, si las tres o cuatro actividades no incluyen las actividades o inversiones relacionadas a las categorías, hacer la siguiente pregunta.*

1)
2)
3)
4)

La iniciativa incluyó alguna actividad relacionada con X?
(INTERPRETATIVA/ ¿? SI ES NECESARIO)
Nota entrevistador: *X puede ser agricultura (cultivos/ganado), conservación, medios de vidas rurales, y fortalecimiento institucional, si no fue mencionada en las tres o cuatro más importantes.*

Cuáles fueron las principales fuentes de financiamiento para las actividades o componentes?
(HECHOS / TRIANGULAR)
Nota entrevistador: *Esta pregunta debe ser hecha varias veces,* ***una para cada una de las tres o cuatro actividades*** *o inversiones que fueron mencionadas en la pregunta 3.3.*

Actividades mencionadas 3.3 y 3.3.1	*apoyo local en especie / directo (p.e. plantación árboles, terrazas hechas por los finqueros o grupos comunitarios, esfuerzos de los trabajadores de los gobiernos)*	*apoyo externo (p.e. donante o fondos del gobierno)*

<u>SECCION 4</u>: PARTICIPACIÓN EN LA INICIATIVA
Cuáles fueron los principales grupos involucrados en el **diseño** de la iniciativa? Cuál fue el papel de cada uno de estos grupos?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Esta es una pregunta abierta.* ***Estamos interesados en ver si los entrevistados identifican los grupos locales y externos, y cuáles sectores son considerados <u>los más influyentes</u>.*** *Los grupos pueden ser. Los entrevistados puede que mencionen varios grupos de actores del paisaje, como grupos que no son actores del paisaje pero que están involucrados en el financiamiento/desarrollo/facilitación de la iniciativa.*

Grupos (p.e *organizaciones locales/comunitarias, gobiernos locales, gobiernos regionales/nacionales, sociedad civil, sector privado, donantes, organizaciones internacionales, academia u otros)*	Papel	Externo o local

Grupos (p.e *organizaciones locales/comunitarias, gobiernos locales, gobiernos regionales/nacionales, sociedad civil, sector privado, donantes, organizaciones internacionales, academia u otros)*	Papel	Externo o local

Se involucraron los grupos marginados del paisaje en el **diseño** de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS SI NO SALIÖ EN LA PREGUNTA 4.1, sino obviar)
Nota entrevistador: *"Grupos marginalizados" puede incluir minorías étnicas, campesinos sin tierra y mujeres. De todas maneras, sin definir el término, le permitimos al entrevistado interpretar la pregunta basado en los grupos que él piensa son marginalizados dentro del paisaje.*

Se involucraron a los pequeños productores o las asociaciones de productores [nota entrevistador: incluir si aplica a los gestores forestales de pequeña escala] del paisaje en el **diseño** de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS SINO SALIO EN LA PREGUNTA 4.1)

Se involucraron a los grandes productores o agronegocios [nota entrevistador: incluir si aplica a los gestores forestales de gran escala] del paisaje en el **diseño** de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS SINO SALIO EN LA PREGUNTA 4.1)

Considera que se debió incluir algún grupo de actores en el **diseño** de la iniciativa y que no fue incluido? Cuáles grupos?
(INTERPRETATIVA/ ¿? TODOS)

Cuáles fueron los principales grupos involucrados en la **implementación** de la iniciativa? Cuál fue el papel de cada uno de estos grupos?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Esta es una pregunta abierta.* ***Estamos interesados en ver si los entrevistados identifican los grupos locales y externos, y cuáles sectores son considerados los más influyentes.*** *Los entrevistados puede que mencionen varios grupos de actores del paisaje, como grupos que no son actores del paisaje pero que están involucrados en el financiamiento/desarrollo/facilitación de la iniciativa.*

Grupos (p.e *organizaciones locales/comunitarias, gobiernos locales, gobiernos*	Papel	Externo o local

regionales/nacionales, sociedad civil, sector privado, donantes, organizaciones internacionales, academia u otros)		

Se involucraron los grupos marginados del paisaje en la **implementación** de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS SINO SALIO EN LA PREGUNTA 4.2)
Nota entrevistador: *s. Preguntar sin definir el término "marginado", le permitimos al entrevistado interpretar la pregunta basado en los grupos que él piensa son marginado dentro del paisaje. Si el entrevistado no entiende el concepto o se desvía, dar ejemplos: "Grupos marginados" puede incluir minorías étnicas, campesinos sin tierra y mujeres*

Se involucraron a los pequeños productores o las asociaciones de productores [nota entrevistador: incluir si aplica a los gestores forestales de pequeña escala] del paisaje en la **implementación** de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS SINO SALIO EN LA PREGUNTA 4.2)

Se involucraron a los grandes productores o agronegocios [nota entrevistador: incluir si aplica a los gestores forestales de gran escala] del paisaje en la **implementación** de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS SINO SALIO EN LA PREGUNTA 4.2)

Considera que se debió incluir algún grupo de actores en la **implementación** de la iniciativa y que no fue incluido? Cuáles grupos?
(INTERPRETATIVA/ ¿? TODOS)

<u>SECCION 5</u>: INSTITUCIONES Y GESTION DE LA INICIATIVA
Al comienzo de la iniciativa existían grupos en el paisaje que estaban liderando o facilitando actividades para apoyar el manejo integrado del paisaje (p.e. evaluaciones de paisaje, planeación, procesos multi-actores, etc)? Si fue así, cuáles fueron esos grupos y qué estaban haciendo?
(HECHOS/ TRIANGULACIÓN)

Grupos que existían	*<u>aspectos técnicos(</u> p.e. que tipo de información, datos, o análisis fueron usados para hacer la evaluación del paisaje)*	*<u>aspectos sobre el proceso</u> (p.e. cómo los grupos fueron ayudados para guiar o construir las decisiones sobre el manejo del paisaje, quién estuvo involucrado en el procesos de toma de decisiones, y si el proceso fue más tecnocrático o participativo)*

En el transcurso de la iniciativa se crearon nuevos grupos para liderar o facilitar las actividades del manejo integrado del paisaje?, o fueron grupos existentes que antes no cumplían estas funciones pero que después de la iniciativa tomaron este papel?. Si fue así, cuáles fueron esos grupos y qué hacen?
(HECHOS/ TRIANGULACIÓN)

Grupos creados	*<u>aspectos técnicos(</u> p.e. que tipo de información, datos, o análisis fueron usados para hacer la evaluación del paisaje)*	*<u>aspectos sobre el proceso</u> (p.e. cómo los grupos fueron ayudados para guiar o construir las decisiones sobre el manejo del paisaje, quién estuvo involucrado en el procesos de toma de decisiones, y si el proceso fue mas tecnocrático o participativo)*

Como son financiados los nuevos o existentes grupos? El financiamiento tiene un tiempo limitado o es contínuo?
(HECHOS/ TRIANGULACIÓN)

<u>SECCION 6</u>: POLÍTICAS Y GOBERNANZA

***<u>Nota entrevistador</u>*:** Provea una breve transición "Ahora, me gustaría preguntarle sobre el papel de las políticas apoyando o limitando el desarrollo de la iniciativa".

Hubo algunas políticas públicas, leyes, o procedimientos que fueron especialmente útiles para apoyar e incentivar desarrollo de la iniciativa?

(INTERPRETATIVA/ TRIANGULACIÓN)

Nota entrevistador: *Acá estamos preguntando específicamente sobre las políticas que apoyaron el proceso integrado o participativo del manejo del paisaje. Por lo tanto, eso puede incluir políticas de descentralización, políticas que reconocen a las entidades locales como administradores de los recursos, procesos a nivel regional para la planeación de los usos de la tierra o desarrollo territorial, etc.* ***NO*** *estamos preguntado a los entrevistadores que identifiquen las políticas que tienen el propósito de incrementar la compatibilidad entre la agricultura y el ambiente, o apoyar paisajes multifuncionales como los pagos por servicios ambientales, leyes para la protección ambiental, etc.*

Hubo alguna política pública, ley o procedimiento que especialmente obstaculizó el desarrollo de la iniciativa?

(INTERPRETATIVA/ TRIANGULACIÓN)

Nota entrevistador: *Similar a la pregunta anterior, acá estamos preguntando específicamente sobre las políticas que inhibieron el proceso integrado o participativo del manejo del paisaje. Por lo tanto, esta puede incluir estructuras de gobierno que fallaron en devolver el poder a las autoridades locales o entidades administradoras de los recursos naturales. De nuevo,* ***NO e****stamos preguntando al entrevistado identificar las políticas relacionadas a la agricultura y el ambiente, p.e subsidios perversos a la agricultura.*

La iniciativa resultó en algún cambio importante en la política o gobernanza en relación a uso tierra, el manejo de los recursos naturales, o la regulación de actividades económicas? Si fue así, por favor describa según su percepción los cambios más importantes y explique como la iniciativa lo logró.

(HECHOS/ TRIANGULACIÓN)

Nota entrevistador: *Similar a las preguntas 6.1 y 6.2, cuál es el contexto político para el proceso del manejo integrado del paisaje, acá se pregunta sobre el nivel en que la iniciativa incluyó el cambio de políticas como una estrategia para alcanzar los paisajes integrales y multifuncionales.* ***Por lo tanto, si la iniciativa resultó en nuevas leyes de protección ambiental, subsidios o incentivos para la agricultura sostenible, etc., esos pueden ser mencionados.*** *Igualmente estamos interesados en aprender sobre* ***nuevos sistemas de gobernanza o políticas,*** *por lo tanto cambios en la tierra o tenencia de la tierra, procesos de toma de decisiones, nuevas entidades de gobernanzas como mancomunidades, etc.*

Hay algunos cambios adicionales en las políticas o gobernanza que usted considera se deberían de crear o implementar para apoyar los objetivos de la iniciativa?

(INTERPRETATIVA/ TRIANGULACIÓN)

<u>SECCION 7</u>: RESULTADOS Y EFECTIVIDAD DE LA INICIATIVA

Al comienzo de la conversación, usted identificó tres [O la cantidad que mencionó en la pregunta 3.2] objetivos de la iniciativa de paisaje. Ahora nos gustaría conocer su opinión sobre la efectividad de la iniciativa en alcanzar cada objetivo. Me gustaría preguntarle en una escala del 1 al 7 cual fue el nivel de efectividad de cada objetivo, siendo. Luego me gustaría conocer por que les dio esa calificación (indicadores y/o resultado de la iniciaitva. Vamos a comenzar con el primer objetivo [mencionarlos].

(INTERPRETATIVA/ ¿? TODOS)

Objetivo (ver ¿? 3.2)	Nivel efectividad (**7** cuando se logró totalmente el objetivo, **4**	Por qué / cómo les asignó ese valor? Usó indicadores o percepción?. (trate de comprobar si los resultados son claramente atribuibles

	cuando se logró parcialmente y **1** cuando no hubo ningún progreso)	propiamente a la iniciativa)
4)		

Que tan efectiva ha sido la iniciativa reuniendo a los diferentes actores para incrementar la cooperación y resolver los conflictos para alcanzar los múltiples objetivos en el paisaje?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Esta es una pregunta abierta. Buscamos entender de igual manera la parte exitosa y no exitosa del proceso del manejo del paisaje con múltiples actores. Queremos conocer si la iniciativa ayudó a incrementar la coordinación y colaboración entre sectores (p.e. agricultura, forestal, agua, salud) y a diferentes escalas (p.e. finca, villas, distritos, cuenca, región)*

Me gustaría preguntarle sobre los beneficios e inconvenientes de trabajar a escala de paisaje. De qué manera el enfoque de paisaje de la iniciativa ayudó a los actores a entender y a abordar mejor diferentes temáticas, problemas y retos en el paisaje? [Pausa para la persona responder, continuar con:] De qué manera el enfoque de paisaje dificultó el logro de objetivos claves?
(INTERPRETATIVA/ ¿? TODOS)
Nota entrevistador: *Estamos tratando de entender si el enfoque de manejo integral de paisajes (p.e. reuniendo personas de diferentes sectores y en diferentes escalas) ayuda a los actores a encontrar un sentido común entre los diferentes intereses, o áreas de negociación de discordia o conflicto?. Igualmente queremos entender si el enfoque de paisaje pudo haber distraído la atención de puntos claves locales, si este enfoque es considerado irrelevante por algunos actores que están más preocupados por asuntos sectoriales o locales, o si el enfoque de paisaje creó problemas muy grandes o complejos de resolver.*

Finalmente, me gustaría preguntarle sobre el impacto de la iniciativa en algunos grupos comunitarios en el paisaje. Me podría decir si la iniciativa benefició, no tuvo ningún efecto, o perjudicó a cada uno de los siguientes grupos? [Omitir los que no aplican para paisaje]
(INTERPRETATIVA/ ¿? TODOS)

Grupos	Benefició	No tuvo ningún efecto	Perjudicó
Pequeños productores y/o ganaderos			
Medianos productores y/o ganaderos			
Grandes productores y/o ganaderos beneficio			
Personas sin tierra (p.e como los trabajadores de las fincas, arrendatarios, “parceros”, “tala y quema”)			
Comerciantes e industriales agropecuarios.			
Responsables / administradores del bosque			
Comunidades nativas dependientes del bosque			

Grupos	Benefició	No tuvo ningún efecto	Perjudicó
Mujeres.			
Comunidades viviendo en los pueblos y/o ciudades (no involucradas con la agricultura / forestería).			
Más ricos:			
Más pobres:			
Otros:			

<u>SECCION 8</u>: LECCIONES APRENDIDAS Y REFLEXÓN GENERAL

Finalmente, nos gustaría solicitarle reflexionar críticamente sobre la iniciativa y compartir algunas de las lecciones que usted aprendió, y pensamientos sobre cómo las iniciativas de paisaje, como la actual, pueden ser más efectivas en el futuro.

Cuál fue el aspecto más exitoso de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS, menos al que llenó la encuesta del TIER 1)

Cuál fue el aspecto menos exitoso de la iniciativa?
(INTERPRETATIVA/ ¿? TODOS, menos al que llenó la encuesta del TIER 1)

Si tuviera más plata para diseñar e implementar esta iniciativa qué haría diferente?
(INTERPRETATIVA/ ¿? TODOS, menos al que llenó la encuesta del TIER 1)
Realizaría un monitoreo y control más eficientes

De acuerdo a su experiencia, qué consejo le daría a sus colegas que están comenzando una iniciativa de paisaje?
(INTERPRETATIVA/ ¿? TODOS)
<u>Nota entrevistador:</u> *Esta pregunta está hecha para combinar las dos preguntas anteriores en términos de las lecciones aprendidas y los aspectos de la iniciativa que son replicables en cualquier lugar. Si el entrevistado no parece responder la pregunta de esta manera, siéntase libre de redirigirlo.*

[Termine agradeciendo a la persona por su participación y déjele saber que recibirá una copia del estudio cuando éste termine]

APPENDIX D

Description of each factor and its parameters, including the maximum values, minimum values and equations used to create the theoretical dataset. HB: handbook·

Factors / Parameters	Max	Min	Equations / Max and min values sources
	RUSLE (S=C•R•K•L•S) ($tonf \cdot acre^{-1} \cdot year^{-1}$)*		
Cover - Management factor C (dimensionless)			
C factor	1	0	C= PLU•CC•SC•S
PLU (Prior Land Use)	1	0	PLU=Cf•Cb•EXP[(-Cur•Bur)+(Cus•Bus/Cf^Cuf)]
Cf: surface soil consolidation factor (decay exponentially when soil is left undisturbed)	1	0.05	"The value of Cf for freshly tilled conditions is 1. If the soil is left undisturbed, this value decays exponentially to 0.45 over 7 yr, or over some other length of time specified by the user". HB 703
Bur: Mass density of live and dead roots found in the upper inch of soil ($lbacre^{-1}in^{-1}$)	1,750	345	Based on the RUSLE2 CROP dataset and HB 703 tables
Bus: mass density of incorporate surface residue in the upper inch of soil ($lbacre^{-1}in^{-1}$)	1,700	0	Based on the RUSLE2 CROP dataset and HB 703 tables
Cuf: impact of soil consolidation on the relative effectiveness of incorporated residue		0.5	Describe the relative effectiveness of subsurface biomass in reducing erosion. The values were calibrated using information from Van Liew and Saxton (1983), values from table 5 and 5d in
Cb: relative effectiveness of subsurface residue in consolidation		0.951	Agricultural Handbook 537 (Wischmeier and Smith, 1978), and an extensive data set collected from a broad series of no-till experiments. hb 703
Cur: calibration coefficient indicating the impacts of the subsurface residues (acre in lb^{-1})	0.00398	0.00199	
Cus: calibration coefficient indicating the impacts of the subsurface residues (acre in lb^{-1})	0.000832	0.00042	
CC (Canopy cover)	1	0	CC= 1-Fc•exp(-0.1•H)
Fc: Fraction of land surface covered by canopy	1	0.05	HB 703
H: distance that rain drops fall after striking the canopy (ft)	33	0.5	Data based on the listed crops on the HB 703
SC (Surface cover)			SC=exp[-b•Sp•(0.24/Ru)^0.08]
b: empirical coefficient. indicate the effectiveness of surface cover in reducing soil loss	0.07	0.024	Extreme values from the different b values reported by several authors: Laflen et al., (1980) and Laflen and Colvin (1981) b=0.030 to 0.070 for row crops; Dickey et al., (1983) b=0.024-0.032 for small grains; b>0.05 small grains in northwestern wheat and range region; Simanton et al., (1984) b= 0.039 for rangeland. HB 703
Sp: Percentage of land area covered by surface cover (crop residue, rocks, cryotogams and other no erodible material that is in direct contact with the soil surface	100	0.1	HB 703

Ru: surface roughness in in	1.9	0.25	From table 5-5 in HB 703, In Figure 4-3 it is indicated that a Ru =4 indicate more roughness than from most primarily tillage operations. It is kept the value of 2 because Wischmeier and Smith (1978) affirms that the USLE equation estimate accurately soil loss for consistent cropping and management systems that have been represented in the erosion plot studies
SR (Surface roughness)	1	0.9	SR=exp[-0.66(Ru-0.24)]
Rainfall-runoff erosive factor R (100 foot•tonf•inch•acre^{-1} •hour^{-1}•year^{-1})**			
R factor			R = ∑(j=1 to j=n)E•I30
I30 (in/hr): Erosive rain Intensity	3.00	0.50	The limit of 3in/h is because median drop size does not continue to increase when intensities exceed this threshold (Carter et al., 1974). The limit for rain showers less than 0.5in and separated from other rain periods by more than 6 h are omitted, because these light rains are usually too small for practical significance and that, collectively, they have little effect on the distribution of the annual EI or erosion. Also reduce time consuming processing EI. HB 703
E (100ft tonf acre^{-1} in^{-1}): Kinematic Energy	10.81	6.80	E = (1099•(1-0.72•EXP($^{-1}$.27•I)))/100
j (no storm / yr): No events per year	50.00	5.00	HB 703
Soil - erodibility factor K (tonf•acre•hour•100^{-1}acre^{-1} foot^{-1} tonf^{-1} inch^{-1})***			
K factor			K= [2.1•〖10〗^(-4) (12-OM) M^1.14+3.25• (s-2)+2.5• (p-3)]/100
OM%: Organic matter	4.00	-	Based on the nomograph HB 537
Clay% (<0.002 mm)	40.00	10.00	
Silt% (0.002 - 0.1 mm)	70.00	10.00	Based on the nomograph HB 537
Sand% (0.1 - 2 mm)	70.00	10.00	Based on the nomograph HB 537
p: Permeability	5	2	Wischmeier and Smith (1978) affirms that the
s: Structure class	4	1	USLE equation estimate accurately soil loss "for medium – textured soil"
M			M=(%Silt +%Very fine sand)(100-%Clay);
Topographic factor (dimensionless)			
Slope length			L= (λ/72.6)^m
Slope steepness	10	2	S= IF(θ<5, (10.8•sinθ+0.03), (16.8•sinθ-0.5)) θ: slope angle in degrees
λ: Slope length (ft). Horizontal projection	400	10	Soil runoff will usually concentrate in less than 400ft, which is a practical slope length limit in many situations, although longer slope lengths of up to 1,000 ft are occasionally found. The equation for S can't be applied to slopes shorter than 15 ft
m: a variable slope length exponent	0.44	0.17	m=β/(1+β)
β: ratio of rill erosion to inter-rill erosion	0.80	0.21	β=(sinθ/0.0896)/[3•(sinθ)^0.8+0.56]

*Conversion to SI system: 2.242 metric ton•ha^{-1}•yr^{-1}
**Conversion to SI system: 17.02 megajoule•millimeter•ha^{-1}•hour^{-1}•year^{-1}
*** Conversion to SI system: 0.1317 metric ton•ha•hour•ha^{-1}•megajoule^{-1}•millimeter^{-1}

APPENDIX E

Description of the selected soil conservation practices in terms on the mechanism to retain soil, pros and cons, and factors that limit the efficacy of the practices.

	Mulch	Cover crops	Hedgerow	Agroforestry
Mechanism	Mitigates the impact of the rain drops, reduction soil detachment and increase water infiltration (Donjadee & Chinnarasri, 2012).	The root system offers resistance to the overland flow (Edwards & Burney, 2005) Also, offers same protection as Mulch	Reduce Runoff, promotes deposition and water infiltration	Mitigates the impact of the rain drops, protect soil and return nutrients via litter or mulch material Deep roots favors water infiltration and reduce runoff (Niemeyer et al., 2013)
Pros	Reduce soil loss and runoff (Adekalu, Okunade, & Osunbitan, 2006) Mulch may form dams and build up hollows which delays the afterflow (Döring et al., 2005) Finer mulch texture cover higher land with not to moderate effects on soil moisture nor crop yield (Döring et al., 2005) Improves soil moisture, moderate soil thermal regime, improves soil aeration, promotes biological activity, improves soil structure, add organic matter and nutrients, reduction N loss (Acharya, Hati, & Bandyopadhyay, 2005)	Incorporate organic matter and nutrients to the soil (Edwards & Burney, 2005) Prevent nutrient loss (Ruiz-Colmenero, Bienes, & Marques, 2011) May form positive associations with crops providing key nutrients and improving main crop yield (i,e, total N content) (Armecin et al, 2005) Protect soils from extreme climatic fluctuations, improves soil aggregates (Armecin et al., 2005) In the long-run it facilitates water infiltration, increases soil organic carbon and aggregate stability, (Ruiz-Colmenero et al., 2013) Result in higher macrofauna density and biomass, higher density of facultative phytophagous, bacterial-feeding and predatory nematodes, and lower density of obligatory (Blanchart et al., 2006) Helps to solve weed management (Erenstein, 2003)	Facilitates terraces formation through time (Lin et al., 2009) Provides fodder for ruminants, mulch or grains (Angima et al., 2002; Dinh et al., 2014) Increase crop yields due to the control of soil loss and the improvement of soil bulk density, gravimetric moisture content and infiltration parameters (Oshunsanya, 2013) Increase soil organic matter, total nitrogen and total phosphorus contents (Bu et al., 2009)	More profitable than conventional agriculture (Neupane & Thapa, 2001) Deep-rooted trees reduce the environmental risk by NO3-N pollution and increased water retention capacity of subsurface soil (Wang, Zhang, Lin, & Zepp, 2011)
Cons	Low levels of mulch may have no effect on weeds, weed cover and above ground biomass of weeds (Döring et al., 2005) If poor planned it can affect sowing or tillage, increase diseases or pest, and limit seedling emergence (Acharya, Hati, Bandyopadhyay, 2004)	Competition with the main crop for water and nutrients may reduction main crop yields (Ruiz-Colmenero, Bienes, & Marques, 2011)	After long periods the portions below of the plant hedgerows can also suffer severe erosion (Chaowen et al., 2007) Can compete with main crop for nutrients and light (Dinh et al., 2014; Oshunsanya, 2013), Cutting cost to avoid crop competition increase farm labor (Kinama et al., 2007)	Lower trunk biomass and slower tree growth due to competition with crops during establishment (Ong et al., 2000) Superficial roots and high demand for water affect crop yields (Ong et al., 2000)
Efficacy reduced by	Slope gradient, soil type, mulch type and dominant soil process (Smets, Poesen, & Knapen, 2008) Dislodged by wind or frequent runoff (Edwards & Burney, 2005)	Quantity and quality of biomass (Edwards & Burney, 2005) Cover type (Ruiz-Colmenero, Bienes, & Marques, 2011) Insecure land tenure, need of short-term outcomes (Erenstein, 2003)	Low tillering ability and low root densities (Rodriguez, 1997; Xiao et al., 2011; Xiao et al., 2012) Steeper slopes and higher rainfall intensities (Xiao, et al., 2011) Tillage technologies (Thapa, Cassel, & Garrity, 1999)	Insecure land tenure, land fragmentation, poor extension service, limited technical know-how, and unavailability of planting materials (Neupane & Thapa, 2001) Mulch with poor nutrients quality and complex decomposition patterns (Heineman et al., 1997)

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APPENDIX F

Establishment and maintenance cost for the selected soil conservation practices. Some cost varies depending the slope steepness (gentle <15%, moderate 15-30%, steep >15%). Cost are established at pixel level (900m2).WD: Working days

	Hedgerow								
	<15%, 60 lineal m			15-30%, 90lineal m			>15%, 180lineal m		
Establishment	Qty	$	Total ($/ha)	Qty	$	Total ($/ha)	Qty	$	Total ($/ha)
WD*	4.4	18.0	79.1	8.0	18.0	143.8	14.0	18.0	251.6
Seeds (kg)	10.0	5.0	50.0	18.2	5.0	90.9	31.8	5.0	159.1
Maintenance (y)									
WD	1.1	18.0	19.8	2.0	18.0	35.9	3.5	18.0	62.9
Total			**148.8**			**270.6**			**473.6**
	Agroforestry high density			Agroforestry low density					
	277 trees**			62 trees***					
Establishment	Qty	$	Total ($/ha)	Qty	$	Total ($/ha)			
WD	13.1	18.0	235.7	3.2	18.0	57.7			
Seeds (kg)****	0.06	96.0	6.7	0.01	87.0	1.4			
Maintenance (y)									
WD	13.1	18.0	235.7	3.2	18.0	57.7			
Total			**462.2**			**116.7**			
	Mulch			Cover crops					
	<15%			>15%					
Establishment	Qty	$	Total ($/ha)	Qty	$	Total ($/ha)			
WD	8.5	18.0	153.1	4.3	18.0	76.5			
Seeds (kg)				51.6	5.0	258.1			
Animal (day)	1.4	20.0	28.4						
Maintenance (y)									
WD	7.1	18.0	127.6	7.1	18.0	127.6			
Total			**309.1**			**462.2**			

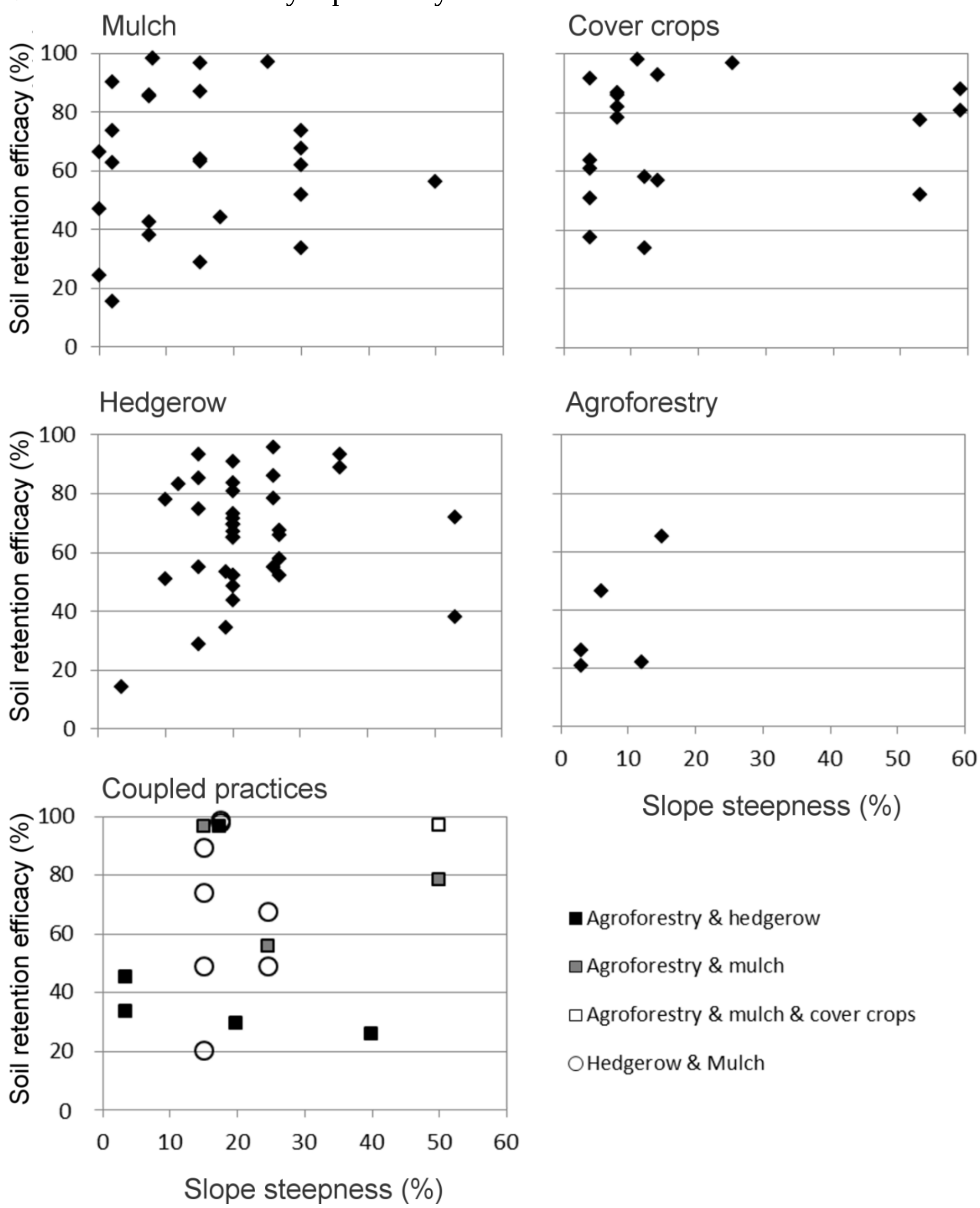
* Minimum wage in Costa Rica for 2014 is ₡8944.51 according to the Ministry of labor and Social Security (http://www.mtss.go.cr/images/stories/Lista_salarios-2014-1semestre.pdf). We used the average value reported in Oanda to convert it from Costa Rica currency to US dollar (₡497.677=$1).
**Highest tree density usually associated to pastures. Density reported in the agroforestry guideline of the Costa Rican national office (http://onfcr.org/media/uploads/documents/guia_saf_onf_para_web.pdf).
*** Rainforest Alliance certified coffee farms number of trees in average (http://www.rainforest-alliance.org/about/documents/tensie-25anniversary-presentation.pdf)
****One kilogram of mixed seeds of endangered trees species contain in average 19,950 viable seeds per kilogram.

APPENDIX G

Results from the literature review to estimate the soil retention efficacy of each soil conservation practice we modeled.

We conducted a literature review to estimate the soil retention efficacy (SRE) of each soil conservation practice. A larger numbers of the assessed experiments were conducted at gentle slopes (Figure 1).

Figure 1. Soil retention efficacy reported by 30 studies and 107 observations



We estimated SRE since the reported combinations of soil conservations practices in the reviewed experiments did not match the combinations of our ideal cropping systems. Also, we consider the high variability of the reported SRE and decided to choose a conservative method. The estimated SRE is the sum of the minimum reported SRE for each soil conservation practice in each ideal cropping system. Ideal cropping systems at slopes higher than 30% should not incorporate mulching practices but cover crops. We used the average estimated SRE for ideal cropping systems using mulching or cover crops (i.e. perennial avg =59%) (Table 1). Reported SRE corresponds to seventeen experiments also with highly variable results. Table 1 also shows the minimum value reported for the combinations reported in the reviewed research.

Table 1. Minimum reported and estimated soil retention efficacy (SRE) for coupled soil conservation practices. Reported soil retention efficacy corresponds to the minimum reported value in seventeen experiments. Estimated SRE is the sum of the minimum SRE reported for each soil conservation practice.

Coupled soil conservation practices	**Mulch**	**Cover crops**	**Hedgerow**	**Agroforestry**	**SRE**
Reported SRE			X	X	26
	X			X	56
	X	X		X	97
	X		X		20
Estimated SRE per ideal cropping system					
Perennial		X	X	X	69
	X		X	X	50
Annual		X	X	X	69
	X		X	X	50
Semi-perennial			X	X	35
Pasture			X	X	35

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