Considering people in systematic conservation planning: insights from land system science

Takuya Iwamura[1]*, Yann le Polain de Waroux[2], and Michael B Mascia[3]

Species and ecosystems worldwide continue to decline and disappear in spite of decades of investment in conservation efforts. Systematic conservation planning (SCP) is a field of study designed to improve conservation programs by identifying land configurations that, if protected, would most efficiently sustain biodiversity. Despite contributing to species persistence in landscapes, SCP has been criticized for replacing site-based conservation plans that often consider social context. In contrast, land system science (LSS), an emerging field that explores the process of land-use and land-cover change, integrates social systems and processes into conservation analyses. We suggest that by incorporating insights from LSS on social processes (eg livelihood adaptation or agricultural intensification), SCP can enhance the legitimacy of conservation plans, thereby reducing the gap between conservation planning and implementation. This represents a necessary first step for SCP to reinvent itself as a decision-support tool that helps to reconcile the long-standing divide between landscape-level species conservation and social needs.

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Despite decades of investment in conservation efforts, species and ecosystems continue to decline around the globe (Butchart *et al*. 2010). Landscape conservation seeks to counter this trend by enabling the persistence of species through networks of national parks and other protected areas (Simberloff 1988; Hutton *et al*. 2005). Although landscape conservation is indeed integral to conserving biodiversity, the effectiveness of protected area networks has often been hindered by inappropriate siting, weak implementation, and external threats such as illegal logging and hunting pressure from surrounding areas (eg DeFries *et al*. 2010). Planners who seek to identify appropriate locations for protected areas face various difficulties, such as heterogeneous species distributions, continuously changing environments, and limited resources (Pressey *et al*. 2007). With increasing globalization leading to intensified demands for agricultural land and other human-dominated systems (Meyfroidt *et al*. 2013), the need for thoughtful approaches to conservation planning and efficient land use is greater than ever.

In a nutshell:

- Systematic conservation planning (SCP) is a field of study that focuses on protecting biodiversity by identifying land configurations that, if protected, would ensure the survival of species in a landscape at minimal cost
- Although SCP has helped in conservation efforts, it has also been criticized for its limited consideration of social processes, such as changes in people's livelihood choices
- Land system science (LSS) is an emerging field that explores processes of land-use/land-cover change and that integrates social systems and dynamics into its analyses
- By drawing on insights from LSS, SCP can more fully represent social processes in its analyses, potentially reducing the gap between conservation planning and implementation

[1]*School of Zoology, Faculty of Life Sciences, Tel Aviv University, Tel Aviv, Israel* *(takuya@tauex.tau.ac.il); [2]*Institute for the Study of International Development and Department of Geography, McGill University, Montreal, Canada;* [3]*Moore Center for Science, Conservation International, Arlington, VA*

Systematic conservation planning (SCP; Panel 1 and WebPanel 1) was developed to improve biodiversity conservation by identifying land that, if protected, would most effectively sustain biodiversity over the long term (Margules and Pressey 2000; Moilanen *et al*. 2010). Although SCP encompasses the entire cycle of conservation actions, from planning to implementation, evaluation, and adaptation (Pressey and Bottrill 2008), its central focus is to identify optimal land configurations with the highest potential for species conservation (Sarkar and Margules 2002). In recent years, sophisticated mathematical algorithms and associated computer software packages have facilitated the use of SCP approaches around the world, most notably for zoning in the Great Barrier Reef Marine Park in Australia (Fernandes *et al*. 2005).

Landscape (or seascape or riverscape) conservation, while implementing ecologically sound principles based on island biogeography and landscape ecology, has been criticized for replacing more site-based conservation plans that often emphasize support and participation of local communities, such as integrated conservation and development projects (ICDPs) (Hutton *et al*. 2005; Dressler *et al*. 2010). The widespread use of SCP in conservation has attracted similar negative assessment for its lack of incorporation of people and social processes (Ban *et al*. 2013; Stephanson and Mascia 2014). Biodiversity conservation has social implications (eg restrictions on agriculture, hunting, fishing, and logging) that often accompany conservation actions (Knight *et al.* 2006); SCP reduces social impacts by avoiding areas most needed for human activities (Polasky *et al.* 2001; Naidoo *et al.* 2006) based on factors such as agricultural opportunity cost (Naidoo and Iwamura 2007), an approach that reflects the "land sparing" paradigm (Phalan *et al.* 2011). However, incorporating social processes into SCP requires a much wider and deeper understanding of human behavior (Figure 1). Human activities are dynamic and nested within a social context, and are shaped by political, economic, and social institutions. In its current forms, SCP is not equipped to realistically incorporate these social factors, despite their importance for successful conservation.

By contrast, analyses based on land system science (LSS), an emerging field that explores the processes of land-use/land-cover change (hereafter "land change"), effectively integrate social context, dynamic social–ecological processes, and human agency (ie the ability of people to make autonomous decisions within a certain context) (WebTable 1; Berkes and Folke 1998; Ostrom 2007; Turner *et al.* 2007). LSS integrates data about land systems (eg satellite images, agricultural production, population, and other social data) with theories on socioecological dynamics (DeFries *et al.* 2004) to examine both the immediate and underlying causes of land change (Lambin *et al.* 2001; Meyfroidt *et al.* 2013). As such, LSS can be used to inform SCP by providing social datasets (Stephanson and Mascia 2014), and therefore has the potential to catalyze conceptual advances in SCP.

To clarify possible pathways for including people and social processes in SCP, we articulate key insights from LSS. To orient the reader, we first provide brief histories of SCP and LSS, then highlight the key challenges facing SCP, and discuss ways in which LSS can be used to address them.

The fields of SCP and LSS

Systematic conservation planning

Conservation biology, which first emerged as a "crisis discipline" in the 1980s in response to concerns over the loss of biodiversity, emphasizes the importance of incorporating a broad knowledge basis, including information derived from the social sciences (Soulé 1985; Meine *et al.* 2006). However, efforts to integrate people and social processes into conservation plans and interventions have been elusive (Adams *et al.* 2004). In 1982, the principle of including people and social needs in habitat-based conservation was recognized at the Third World Parks Congress in Bali. Various donor organizations established projects focusing on local capacity and participatory schemes, such as ICDPs or community-based natural resource management (Dressler *et al.* 2010). But by the late 1990s, substantial amounts of funding were being shifted instead toward landscape conservation (Hutton *et al.* 2010), which advocates for creating networks of multiple protected areas to achieve species persistence in landscapes, and is based on ecological principles drawn from island biogeography and landscape ecology (Wilcox and Murphy 1985; Simberloff 1988).

Panel 1. Typical SCP steps

SCP software users are usually required to provide model parameters in order to apply SCP to the region of interest, a process that can be summarized in nine steps: (1) determining the extent of the planning area, (2) determining the planning units, (3) determining the budget, (4) listing species within each planning unit, (5) representing the land use at each planning unit, (6) representing the cost of conservation actions, (7) determining the targets and benefits of each conservation action, (8) determining patterns of spatial configuration, and (9) obtaining and communicating outputs (WebTable 2; WebPanel 1). Among these, although land use itself is not required as a parameter, most SCP software requires input regarding whether an area is already protected or is unavailable for protection.

Against this background, SCP emerged as a means of developing methods and decision-support tools to identify the most cost-effective configurations of land for protecting other species from human threats (Margules and Pressey 2000). Like landscape conservation, SCP builds on insights from island biogeography and landscape ecology (eg "single large or several small", SLOSS; Simberloff 1988), and has provided computing tools for landscape conservation (Hutton *et al.* 2010). One key SCP principle is that of *complementarity*, or the degree to which locations contain different sets of species and thereby complement one another in a network of conservation areas (Margules and Pressey 2000; Sarkar and Margules 2002). SCP approaches consider every piece of land as a potential candidate for a new protected area within a network of sites; an area with fewer species than others may nevertheless add some or all of the missing species at a relatively low cost and therefore represents a wise conservation investment.

Finding cost-effective land configurations that consider complementarity among all sites is extremely computationally intensive because of the huge number of possible combinations of selected areas (2^n, where n = the number of candidate areas). Without using approaches derived from operational research and artificial intelligence, calculating the conservation value of every possible combination of land would be prohibitively time consuming (Sarkar and Margules 2002), given that the number of possible land configurations for protected areas increases exponentially with the number of areas that are candidates for protection. Beginning in the mid-1990s, computational algorithms were embedded within software packages, which automated the process of land configuration to select protected areas that maximize biodiversity protection while minimizing costs (Polasky *et al.* 2001). Today, SCP software continues to incorporate new insights, such as connectivity between protected areas (Moilanen *et al.* 2010) or multiple land uses, including recreational uses (Watts *et al.* 2009). Although its true impacts on conservation goals have yet to be measured (McIntosh *et al.* 2017), SCP has been applied in a variety of environments, from terrestrial (Cowling *et al.* 2003) to marine (Smith *et al.* 2009) to freshwater (Linke *et al.* 2011).

Figure 1. (a) Agricultural expansion, here around Río Negro National Park (Paraguay), makes it necessary to account for dynamic anthropogenic threats when designating protected areas. (b) The Rupununi savanna (shown here in Guyana) is developed on the Brazilian side of the Rupununi River, highlighting the importance of accounting for land governance. (c) The designation of protected areas in highly populated regions, such as Indonesia's Gunung Gede Pangrango National Park, can impact the livelihoods of multiple communities. (d) Indigenous hunting practices, such as controlled fires (shown here in Guyana), can be restricted by protected areas, incentivizing hunters to shift to other areas and thereby shifting impacts on biodiversity.

Despite its widespread contribution to conservation planning and practice, much criticism has been leveled against SCP, and conservation planning in general (Knight *et al.* 2006; Ban *et al.* 2013; Stephanson and Mascia 2014). First, SCP tends toward a static view of landscapes, which may not accurately reflect the dynamics of the real world, given that both ecological systems (eg species distribution; Pressey *et al.* 2007) and land cover (Geist and Lambin 2002) change over time. In addition, SCP applies a rather inflexible view toward anthropogenic threats (eg deforestation trends) even though it is well known that future human actions cannot be directly predicted from historical trends (Chowdhury and Moran 2012). Second, SCP analyses have been faulted for focusing on natural ecological processes (Ban *et al.* 2013; Stephanson and Mascia 2014) while ignoring the role of human activity in shaping the global atmosphere, ecology, and even geology (Waters *et al.* 2016). SCP software rarely incorporates social data (eg land titles, willingness to participate) or processes that might affect human behavior (eg distribution of conservation income and burden). Finally, conservation planning often fails to view humans as agents of change, despite clear evidence that individual human choices collectively affect social and ecological systems; for example, planners rarely take into account the fact that individuals shift their resource-use patterns following the establishment of protected areas (Ewers and Rodrigues 2008). These shortcomings limit the ability of SCP to inform conservation planning and practice because it leads to conservation plans that do not reflect dynamic social processes.

Land system science

LSS emerged in the 1990s in response to growing recognition of the role of land change as a major component of global change, motivating researchers from the natural, social, and geographic sciences to unite around its study (Gutman *et al.* 2004; Turner *et al.* 2007). LSS considers land as an integrated social–ecological system (Berkes and Folke 1998; Haberl *et al.* 2004; Ostrom 2007) and relies on both social and environmental data to improve our understanding of the processes of land change. LSS is primarily concerned with observing and monitoring land change; understanding its causes, location, timing, and magnitude; modeling it; and assessing its outcomes in terms of environmental and social sustainability (Turner *et al.* 2007).

Although advances in Earth observatory technologies (eg remote sensing) provide LSS with the ability to monitor land changes over wide spatial and temporal ranges, the integration of social-science theories enables the investigation of the role of social processes in causing such changes (Meyfroidt 2015). For example, following classical economic theory, land is used for the activity that generates the highest profit; this activity itself is a function of both the biophysical properties of the land, and the distance to markets (Walker 2004). The New Economic Geography literature suggests that positive feedbacks favor the formation of land-use clusters (eg for soybean production in Brazil; Garrett *et al*. 2013). Institutions (eg land tenure, access, and governance) are also major determinants of land use, as has been demonstrated in studies of the effects of property rights on deforestation (Nolte *et al*. 2013) or of market-driven governance institutions (Heilmayr and Lambin 2016). Finally, land use can be a function of population density and local households' livelihood strategies, as reflected in the induced intensification hypothesis (Turner and Ali 1996) and by livelihood studies (eg Zimmerer 2007), respectively.

Land-use models typically represent the process of land change as a state transition for a spatial unit (eg a grid pixel). The location, timing, and magnitude of change are predicted based on spatial attributes (often proxies of profits from alternative land uses, but also representations of other structural drivers such as land tenure) and the attributes of decision makers, captured at various levels (eg administrative units, communities, individuals, and households). Some dynamic land-use models, such as the Conversion of Land Use and its Effects (CLUE) model (Verburg and Overmars 2009), combine aggregate modeling of land demand with spatial allocation algorithms to predict changes in land use. Others, such as agent-based models, allow for a more complex representation of human agency and decision making by specifying decision rules at the level of individual agents (Parker *et al*. 2003).

LSS researchers are increasingly seeking to improve understanding of the determinants of land change by transcending a purely "place-based" perspective and incorporating concepts like global value chains (linkages between stages and actors of production occurring in multiple locations; Rueda and Lambin 2013), telecoupling (interactions over distances; Liu *et al*. 2013; Gasparri *et al*. 2016), indirect land-use change (Searchinger *et al*. 2008; Meyfroidt *et al*. 2013), and flow-centered land governance (Sikor *et al*. 2013). Similarly, the increasing role of private actors, such as global agricultural corporations, is shifting the research agenda toward the study of private governance mechanisms (Lambin *et al*. 2014) and of "commodity" or "neoliberal" frontiers, where expansion of large-scale commodity farms leads to the appropriation and conversion of natural habitats (Brannstrom 2009; le Polain de Waroux *et al*. 2017). Integrating different models to improve model dynamics is another challenge currently being addressed, in particular the integration of land-use models with more complex ecosystem and macro-economic models, such as computable global equilibrium models (Brown *et al*. 2013). Calls have also been made to transcend a neoclassical economic framing and to more fully integrate insights from economic geography into LSS (Munroe *et al*. 2014).

Emerging insights

Side-by-side comparison between SCP and LSS provides insights into the potential to incorporate social processes into SCP (WebTable 1). These insights can be categorized into three main themes: dynamic landscape, social context, and human agency.

Dynamic landscape

SCP operates on the assumption of a static human pressure on landscapes, assuming, for example, a constant human population in a given region, static demand for land-related products (eg crops), and fixed market prices. These assumptions are, in turn, reflected in static conservation costs (eg opportunity cost layer) and anthropogenic threats (eg constant deforestation rate). However, we know that costs and threats vary over time in response to human activity. LSS recognizes that social, economic, and demographic changes make landscapes fundamentally dynamic, and can therefore use information on these human drivers of land use (eg DeFries *et al*. 2004; Verburg and Overmars 2009) to provide estimates of future conditions, such as future land cover and conservation costs. Although dynamic ecological models for conservation have existed for a long time (eg Fahrig and Merriam 1994), they generally fail to consider human actions as part of the system; LSS represents a way of integrating the human factor into landscape dynamics.

One way by which to incorporate a dynamic approach through LSS was proposed by Faleiro *et al*. (2013), who used the probability of future land conversion in the Cerrado savanna ecoregion of Brazil to select priority areas for conservation and to protect ~154 species of non-flying mammals that inhabit the savanna. Future land cover in 2015 was calculated from a transition matrix for land-cover change based on a dataset from 2002–2008, using the Land Change Modeler module of ArcGIS (https://clarklabs.org/land-change-modeler-for-arcgis) to estimate the future rates of land-cover change based on various variables. The authors used parameters such as elevation and precipitation, as well as proximity to roads, recent deforestation sites, and cities, to predict the likelihood of land change. These were combined with future predictions of species distributions to explore alternatives for better conservation planning in the Cerrado.

The approach illustrated above does not incorporate feedback between conservation actions and land changes resulting from these actions, which is crucial for the implementation of adaptive management (Lee 2001). To achieve such feedback loops between conservation actions and land changes, one can assume iterative conservation investments over multiple (eg annual) cycles, where

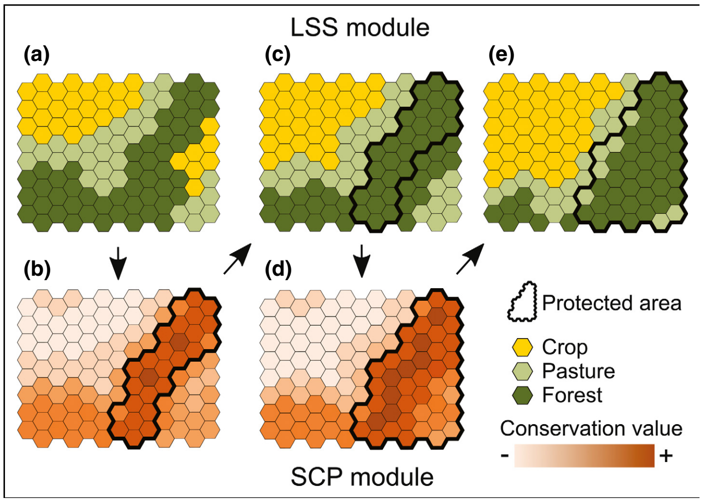

Figure 2. Integrating land-use feedbacks into SCP with gradual conservation investment. Based on (a) an original landscape, (b) a protected area is proposed through SCP. After its designation, the landscape continues to change, altering conservation values; (c) for example, abandonment of cropland and rangeland following protected area establishment may increase the conservation value for these lands. The protected area network is updated based on (d) changing conservation values, contributing to (e) further landscape change, including the conversion (and therefore the loss of conservation value) of "unprotected" lands. Through multiple iterations, it is possible to compare different pathways of protected area deployment.

an SCP module will select sites at each cycle based on the landscape predictions of an LSS module in the previous cycle (Figure 2). Such feedback is triggered by the response of land users to conservation policies, for which the other two insights – social context and human agency – are relevant.

Social context

Although the interactions between people and nature are fundamental to biodiversity conservation, SCP maintains an ecology-centric approach to conservation planning, and the incorporation of social data into SCP-based analyses has generally been limited (Knight *et al.* 2006; Stephanson and Mascia 2014). However, recent research highlights the importance of social context for conservation planning (Ban *et al.* 2013; Stephanson and Mascia 2014). To address this shortcoming, Stephanson and Mascia (2014) introduced the Putting People on the Map (P-MAP) approach, a hierarchical framework used to incorporate social datasets into conservation planning. P-MAP applies social attributes categorized into five domains (economic well-being, health, political empowerment, education, and culture) in order to (1) define conservation targets, (2) design conservation strategies, (3) explore socioecological relationships, and (4) practice adaptive management.

LSS offers both theories and datasets necessary to examine social factors affecting land change, encompassing such aspects of social context as land tenure and governance, demography, markets and prices, and livelihoods (Figure 3). For instance, the impacts on cropland abandonment after the collapse of communism in Eastern European countries were explored using a wide range of social variables – related to land ownership and management, demography, and infrastructure – in the Carpathian Mountains of Romania (Müller *et al.* 2009). In this way, LSS can inform SCP studies as to which aspects of social context are related to specific types of land change (eg deforestation), and illustrate how to elicit systematic information about specific social processes (eg through household surveys and use of census data). LSS has adopted and developed conceptual frameworks (eg immediate and underlying drivers of land change) and quantitative models (eg spatial regressions) for the application of such information.

Human agency

SCP often treats people as passive entities that are merely impacted by conservation interventions (eg establishment of protected areas) and do not actively change their behaviors in response to these interventions (eg by increasing the intensity of resource extraction). In reality, however, humans are autonomous agents who adapt to the new circumstances created by changes in policy environments, and actively shape these situations and policy environments themselves. Recently, LSS studies have started to model individual stakeholders' behavioral responses to changes in local conditions, including policy changes. For example, using agent-based modeling, Iwamura *et al.* (2016) developed a spatially explicit simulation model of the interactions between indigenous peoples' livelihood activities (hunting and agriculture) and wildlife populations in the Amazon. In this model, animal populations are affected by hunting, but are regulated through animal metapopulation dynamics, which interact with vegetation succession mechanisms to define habitat patches for each species (Figure 4). This simulation setting allowed the authors to explore interactions between changes in hunting pressure due to human population increase, which itself was affected by food aid policies, and changes in animal populations and vegetation cover.

The outcome of conservation actions based on SCP can be examined using similar spatially explicit models incorporating human agency (Figure 4). One can test the effectiveness of conservation interventions with or without the inclusion of compensation programs for the loss of livelihood options (eg hunting or agricultural opportunities). Tools to address human agency also enable SCP to incorporate the unintended displacement of resource extraction, such as deforestation or hunting pressure, from within a newly designated protected area to neighboring lands. An LSS model (eg agent-based model) can be used to estimate changes in land cover based on the behavioral responses of autonomous human agents, which in turn affect the status of species habitats in the landscape. The adjusted conservation benefits (eg the number of species protected) can then be used in the SCP process, modifying the selection of conservation investment in order to maximize the outcome.

Discussion

Implications for conservation science

The mission of SCP – ensuring species persistence in landscapes through ecologically interconnected networks of multiple protected areas – has been formulated on the basis of biological insights derived from landscape ecology and island biogeography (eg nonhomogenous distribution of species, complementarities, connectivity) (Margules and Pressey 2000). At the same time, SCP focuses on resource optimization from decision-making sciences (eg operational research) for the efficient use of available resources (Sarkar and Margules 2002). SCP treats human activities in the target area as a "cost" to conservation efforts, which may hinder its objectives (ie species persistence), and consequently focuses on minimizing such costs, often represented by surrogate data (Naidoo and Iwamura 2007) by choosing the areas with fewer human activities for protection. In this context, social complexity is often considered to be exogenous to the SCP framework and, as such, is treated as *uncertainty* with regard to political capacity or land availability (McDonald-Madden *et al.* 2008). This simplification creates gaps in the planning and implementation of SCP (Knight *et al.* 2006) and overlooks the importance of social processes (Ban *et al.* 2013). Incorporation of insights from LSS – summarized here as dynamic landscapes, social context, and human agency – into SCP approaches may assist in the development of more effective pathways for achieving SCP goals.

We have discussed dynamic landscapes as incorporating anthropogenic drivers of land change (eg human population increase) into SCP (Figure 2). Although the dynamic nature of ecological systems has been a main focus of landscape conservation (eg through the study of vegetation succession and gene flows), the implications of dynamic social systems in conservation sciences have received scant attention. By learning from LSS, SCP can incorporate underlying factors of land changes into a spatial optimization scheme of conservation planning for maximizing the chances of species persistence. Furthermore, such incorporation into SCP models may serve to simulate the impacts of social and ecological changes on conservation targets or on the effectiveness of conservation planning.

Incorporating social context into conservation science has been discussed extensively in the literature (Ban *et al.* 2013; Stephanson and Mascia 2014). LSS has developed theoretical and methodological approaches for studying the impacts of social context on land changes (Geist and Lambin 2002; Turner *et al.* 2007). By incorporating these, SCP may, for instance, be able to simulate the influence of governance type (eg cooperative land management or top-down, centralized decision making) on the long-term effectiveness of protected area networks. Theoretical advances in LSS, such as telecoupling, can also be directly applied to SCP to examine the impacts of remote drivers (eg increased demands for consumer products) on deforestation (Liu *et al.* 2013; Gasparri *et al.* 2016). SCP evaluation frameworks can support assessments of social impacts of land configurations (eg McIntosh *et al.* 2017).

The conservation literature often emphasizes the role of local stakeholders, including their reactions to conservation policies, in achieving successful conservation. LSS has addressed the issue of human agency by studying the implications of stakeholder preferences and decision making for land changes (Figure 4). Of particular interest in the case of SCP is the possibility of "leakage" – the displacement of an environmental impact due to a policy intervention, including protected areas, which can displace deforestation or hunting to surrounding areas (Ewers and Rodrigues 2008) – resulting from behavioral responses to new conservation interventions (le Polain de Waroux *et al.* 2017). LSS has developed ways of representing human decision making in formal models that could fulfill the need for a better representation of human agency in SCP, and help address issues such as leakage (Figure 5). SCP, with LSS, may therefore be able to develop the framework needed to incorporate stakeholders' behavior into the computation of land configurations.

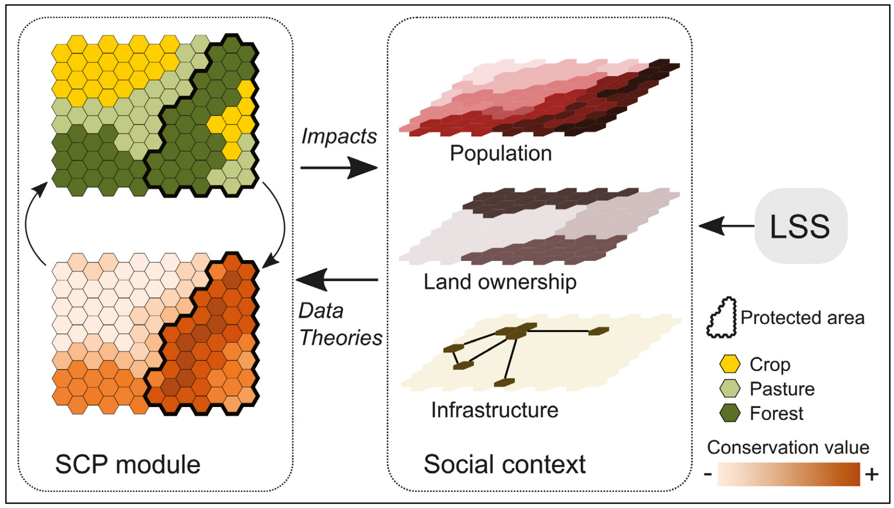

Figure 3. Contributions of LSS to characterizing social context for SCP. The SCP module develops a protected area network based on conservation values (eg biodiversity), taking into account elements of social context such as human population, land ownership, or infrastructure. After completion of the SCP process for resource allocation, the impacts from proposed land configurations are assessed based on both biological and social variables. Social context provides a set of parameters to evaluate the social impacts of SCP configurations. LSS can provide both data and theories relating to social context for SCP.

Implications for conservation practice

Because of its focus on long-term species persistence through networks of multiple protected areas, landscape conservation

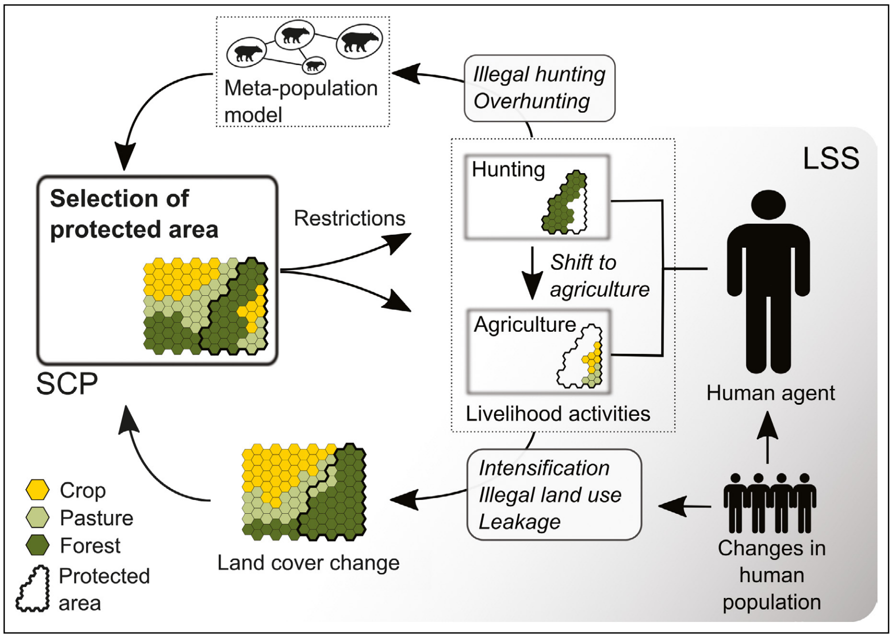

Figure 4. Representation of human agency in SCP using agent-based modeling of an indigenous community. Each household is represented as an agent achieving subsistence through hunting and/or agriculture. The selection of a protected area restricts certain practices (here, hunting and agriculture), causing human agents to modify their subsistence strategies, with consequences for fauna (through changes in hunting practices, such as illegal hunting or overhunting) and land cover (through changes in agricultural practices, such as intensification). The explicit representation of these social–ecological interactions can be incorporated to update the selection of protected areas through SCP processes.

has shifted conservation resources away from site-based local habitat protection (eg ICDPs). Historically, SCP has helped advance landscape conservation projects by providing effective tools for designing optimal protected area networks. However, this also means that SCP has largely overlooked local human communities, their social contexts and dynamics, and their responses to conservation policies (Ban *et al.* 2013; Stephanson and Mascia 2014). We argue that the integration of insights from LSS, in addition to improving computed conservation plans, can help SCP to minimize the gap between these plans and their implementation.

SCP practitioners often struggle to incorporate changing baselines for their conservation plans, such as increasing populations or agricultural expansion that may cause future habitat loss. Understanding such shifting social baselines is crucial for achieving adaptive management (Lee 2001) within the SCP framework. Since conservation plans (or any policy changes) take time to implement, the ability to track the evolution of underlying drivers of future landscape change is extremely valuable. Using LSS methods to estimate future land changes due to shifting social baselines, conservation practitioners may conduct more timely conservation decisions.

Selection of conservation areas is the product of a negotiation involving different groups of stakeholders operating in a specific social and political environment (Knight *et al.* 2006). Although failure to take underlying social contexts (eg types of governance, land ownerships, demography) into account can lead to ineffective conservation policies, SCP software does not consider such implications when selecting "optimal" sites for protection. However, long-term conservation success may depend on equal conservation investment across various types of land ownership. In this case, implementation of conservation plans will be easier if SCP incorporates information on land tenure during the selection process (Step 8 in WebTable 2 and WebPanel 1) in order to distribute resources among different land owners. LSS provides not only the relevant social parameters but also the concepts that are required for SCP to address the social context. By incorporating insights from LSS, SCP can assist in the selection of sites that better reflect the social reality within which conservation is taking place, thereby potentially improving the efficacy of the selection process.

Finally, major changes in conservation outcomes may result when stakeholders, either individual land users or large-scale enterprises, decide to change their behaviors. For example, farmers may change crop types in response to changes in commodity prices or the prospect of future productivity under a changing climate. Such decisions may alter their behavior in ways that run against a certain conservation policy (eg expansion of agricultural lands, more intensive crop production, increased pesticide use). LSS has already developed novel methodological and theoretical frameworks to understand what motivates or facilitates land changes (eg agent-based modeling; Parker *et al.* 2003). We believe that the recognition and study of human agency and decision making can provide effective avenues for improving SCP processes under realistic scenarios, including predicting stakeholder responses to conservation policies.

Conclusions

Although the importance of incorporating people and social processes into biodiversity conservation has been long recognized, integration of these factors into conservation efforts has not always been implemented. Landscape conservation, while promoting long-term species persistence, shifts investment resources away from local projects that focus on people and social processes. SCP has advanced landscape conservation by providing a cost-effective method for identifying optimal land configurations but it has largely neglected social processes. By integrating insights from LSS, SCP has the potential to provide a framework that explicitly incorporates people and social processes at the landscape level. These efforts represent a first step for SCP to reinvent itself as a tool that helps to reconcile landscape-level species persistence with social needs.

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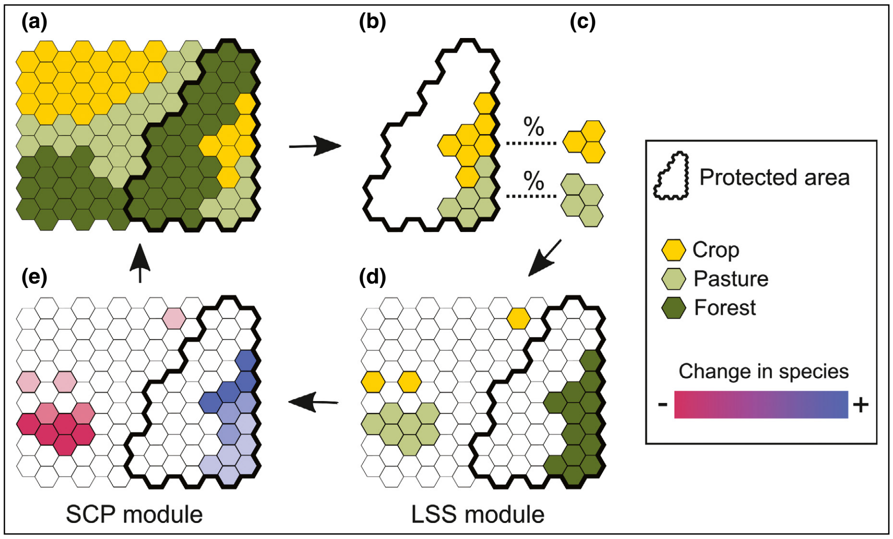

Figure 5. Incorporation of land-use leakage in SCP. The designation of (a) a protected area restricts land uses, some of which (b) may be leaked to other areas. (c) The amount of leaked land use is estimated based on empirical evidence, scenarios, or simulations (eg agent-based modeling). (d) A land-use change model reallocates these quantities. Based on the updated land-cover map, (e) gain and loss of species within and outside the protected area are calculated, and used to assess conservation impacts. Steps (a–e) can be repeated with different siting choices to compare alternative protected area designations.

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