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Social and Ecological Synergy: Local Rulemaking, Forest Livelihoods, and Biodiversity Conservation

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Causal pathways to achieve social and ecological benefits from forests are unclear, because there are few systematic multicountry empirical analyses that identify important factors and their complex relationships with social and ecological outcomes. This study examines biodiversity conservation and forest-based livelihood outcomes using a data set on 84 sites from six countries in East Africa and South Asia. We find both positive and negative relationships, leading to joint wins, losses, and trade-offs depending on specific contextual factors; participation in forest governance institutions by local forest users is strongly associated with jointly positive outcomes for forests in our study.

Human-dominated forested landscapes in tropical developing countries provide many different and important ecosystem services and also sustain the livelihoods of large numbers of poor peoples (1). Recognition of the diverse socioeconomic and ecological contributions of forests has prompted many governments to pursue policies for improved livelihoods and conservation outcomes. Notable are forest policy decentralization reforms that transfer ownership and management responsibilities to local forest user organizations (2, 3). Such policies have been introduced in more than two-thirds of the developing world (4), including 35 of 51 countries in sub-Saharan Africa (5), and apply to an estimated one-third of forests in developing countries globally (6).

Formalized local participation in forest governance via decentralization is often viewed as a key mechanism to provide incentives to local communities to use forests sustainably through en-

hanced local knowledge, stronger accountability, and perceived legitimacy of forest rules (2, 3). Its effectiveness is also debated because of fears that decentralization could lead to resource capture by local elites and remain ineffectual without extensive devolution of rights to local participants and functional linkages between local decentralized institutions and well-crafted macro-level governance institutions (7).

More broadly, policy pathways toward joint improvements in sustainable livelihoods and biodiversity conservation continue to be unclear. Despite the inherent complexity of social-ecological contexts for forest systems, current policy responses, particularly in terms of explicit management for trade-offs or synergies across multiple social and ecological goals, are seldom based on careful analysis or evidence of factors that lead to improvements across desired sets of social and ecological outcomes together (8, 9).

In scholarly research, relationships between human livelihoods and biodiversity conservation are often conceptualized as diametrically opposite (10, 11), but more studies that undertake explicit quantitative analysis of this relationship are needed (12). There is evidence of trade-offs, but case studies also reveal the potential for synergies (13). However, previous work tends to focus anal-
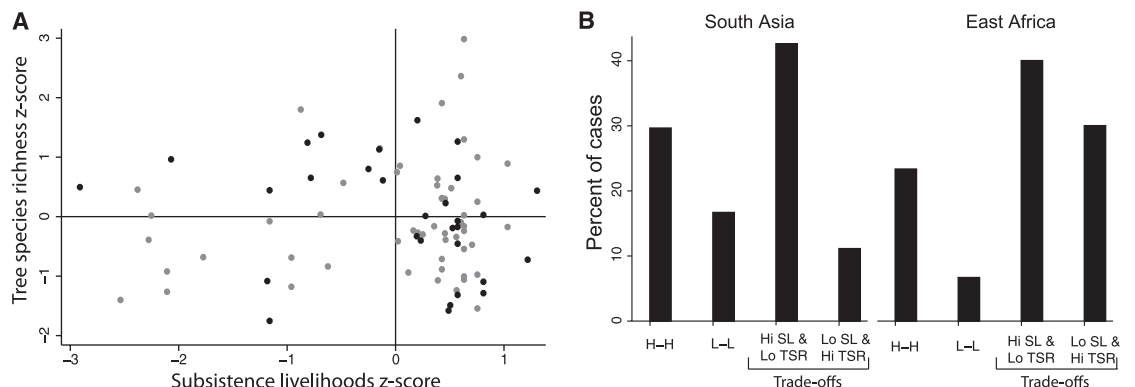
ysis on these social and ecological outcomes in isolation from each other, rather than in tandem as a single outcome constructed across both social and ecological dimensions. Here we analyze patterns of outcome relationships between forest-based household livelihoods and biodiversity conservation in 84 study sites, and the potential explanations associated with the joint production of these two forest benefits.

Our analysis draws on a global data set of social, ecological, and governance data on a wide range of representative forests in human-dominated tropical landscapes that has been compiled by the International Forestry Resources and Institutions (IFRI) research program (14, 15). The 84 cases are drawn from six countries in East Africa (6 in Kenya, 7 in Tanzania, and 17 in Uganda) and South Asia (2 in Bhutan, 27 in India, and 25 in Nepal). We use the nonparametric Chao-1 estimator of tree species richness as an indicator of forest biodiversity. We use the percent of households that depend substantially on the forest for subsistence livelihoods as an indicator of livelihood contributions of the same forest (16).

We classify the outcome relationships between tree species richness and forest-based subsistence livelihoods into categories on the basis of above- or below-average levels for each of our two indicator variables, relative to other forests in the same forest type in the data set (16). Our approach focuses on three joint-outcome categories where (i) species richness and livelihoods contributions are both above average (sustainable forest systems); (ii) species richness and livelihoods are both below average (unsustainable forest systems); and (iii) either species richness is above average relative to other forests and livelihoods are below average, or species richness is below average but livelihoods are above average (trade-off forest systems).

We find that all possible combinations of relationships between forest-based subsistence livelihoods and tree species richness are present in the data (Fig. 1A). The existence of multiple patterns of relationships underscores the relevance of analyses that seek to identify factors responsible for facilitating or impeding trade-offs and

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Fig. 1. (A) Tree species richness and subsistence livelihoods z scores, standardized within each forest type. Black circles indicate East African cases (n = 30), and gray circles indicate South Asian cases (n = 54). **(B)** Distribution of sustainable, unsustainable, and trade-off outcomes, by region. H-H, above-average standardized values for tree species richness and subsistence livelihoods; L-L, below-average standardized values for tree species richness and subsistence livelihoods; SL, subsistence livelihoods; TSR, tree species richness.

synergies across social and ecological outcomes. Most of our 84 cases (60%) are characterized by trade-off relationships, although jointly positive outcomes across biodiversity and livelihoods are also well represented (27% of cases). Jointly negative outcomes are less common (13% of cases) (Fig. 1B). The distribution of outcomes across all possible categories suggests that there is no universally applicable positive or negative association between livelihoods and biodiversity to be found in the studied forests. Outcomes are similarly distributed across the two regions covered in our study (likelihood-ratio $X^2 = 2.77$, df = 2, $P = 0.251$), and region was not a significant predictor of outcomes.

We also examined how a set of hypothesized social and ecological mediating factors affects the observed outcomes, using ordered logistic regression analysis to identify important predictors of

the likelihood of obtaining jointly negative, trade-off, or positive outcomes. Our model included three independent variables that are a focus of much theoretical and empirical work related to biodiversity conservation and sustainable livelihoods outcomes: forest size, formal participation (as conferred through policy) of local forest users in forest rulemaking (hereafter, "rulemaking participation"), and dependence on the forest for extractive commercial livelihoods (in our data, primarily charcoaling, small-scale timber harvesting, fuelwood, and collection of nontimber forest products for cash income). Forest patch size is a key factor relating to potential species richness, as well as to prospects for sustainable forest management due to monitoring and enforcement challenges related to scale (17); rulemaking participation is highlighted as important for obtaining local knowledge necessary to improve forest resources,

promoting legitimacy over forest rules, and engendering management accountability (18); a high level of commercial extractive forest use may be viewed as reducing the likelihood of sustainable forest outcomes across subsistence livelihoods and species richness, due to higher access inequities for poor households and negative impacts on biodiversity objectives (19–22).

Our results indicate that forest systems are more likely to have sustainable outcomes (above-average tree species richness and subsistence livelihoods) when local forest users participate in forest rulemaking ($z = 2.21$, $P = 0.027$), whereas unsustainable forest system outcomes are more likely when users do not participate in rulemaking ($z = -2.62$, $P = 0.009$; Tables 1 and 2). The size of the forest and the extent to which the forest provided commercial livelihoods to households are also important factors associated with

Table 1. Marginal effects of ordered logit regression (rulemaking participation held at its median value, all other variables at their means). Dependent variable: tree species richness and subsistence livelihoods joint outcome, with three categories: low-low, trade-off, or high-high. $N = 84$. Wald test $X^2(3) = 9.33$, $P = 0.0252$, pseudo $R^2 = 0.0903$. Independent variables: "forest size," logarithm of forest size (ha); "rulemaking participation," local forest user participation in forest rulemaking (0 = No, 1 = Yes); "commercial livelihoods" (percent of local forest users who depend substantially on the forest for cash income).

Independent variable	Marg. effect	Std. error	z	P > z	[95% CI]		X
Outcome category: low-low (unsustainable forest systems)							
Forest size	−0.036	0.019	−1.820	0.069	−0.074	0.003	5.821
Rulemaking participation	−0.119	0.045	−2.620	0.009	−0.208	−0.030	0.000
Commercial livelihoods	−0.215	0.122	−1.750	0.080	−0.456	0.026	0.207
Outcome category: trade-offs							
Forest size	0.001	0.014	0.070	0.943	−0.027	0.029	5.821
Rulemaking participation	−0.158	0.101	−1.570	0.117	−0.355	0.039	0.000
Commercial livelihoods	0.006	0.087	0.070	0.944	−0.164	0.177	0.207
Outcome category: high-high (sustainable forest systems)							
Forest size	0.035	0.018	1.980	0.048	0.003	0.068	5.821
Rulemaking participation	0.277	0.125	2.210	0.027	0.031	0.522	0.000
Commercial livelihoods	0.209	0.092	2.270	0.023	0.028	0.390	0.207
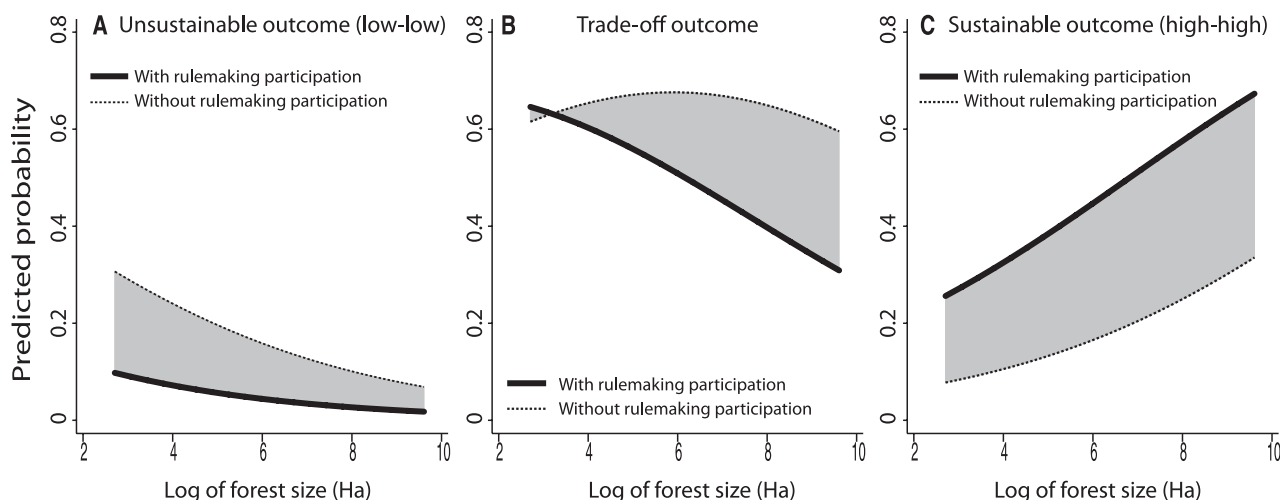
Fig. 2. Predicted probabilities of (**A**) unsustainable, (**B**) trade-off, and (**C**) sustainable forest system outcomes when local forest users participate in forest rulemaking (solid black line) and when they do not participate in forest rulemaking (dashed black line), as forest size increases. The gray shaded area between probability curves in each panel shows the decrease in the predicted probabilities of unsustainable forest systems and trade-offs, and the increase in the predicted probability of sustainable forest systems, when local forest users participate in forest rulemaking.

Table 2. Predicted probabilities of obtaining unsustainable, trade-off, or sustainable forest system outcomes as local forest users gain participation in forest rulemaking.

Outcome category	Predicted probability of outcome (%): Forest rulemaking participation by local forest users		Change in probability as local forest users gain rulemaking participation (95% CI)
	No	Yes	
Unsustainable outcome (low-low)	0.17	0.05	−0.12 (−0.21, −0.03)
Trade-off outcomes	0.68	0.52	−0.16 (−0.32, 0.00)
Sustainable outcome (high-high)	0.16	0.44	0.28 (0.07, 0.48)

obtaining either sustainable or unsustainable forest system outcomes, with a higher likelihood of sustainable outcomes as forest size and commercial livelihoods dependence increase [Table 1; note that the amount of benefits from commercial livelihoods, though important at the individual level, constitutes a small proportion of livelihoods for many households and is relatively low overall for our data (*16*)].

To better understand how interactions between forest size and rulemaking participation together affect the likelihood of obtaining jointly positive outcomes, we examined how the predicted probability of each of the three outcomes varies across the range of forest sizes in our data set, in the presence and absence of rulemaking participation by local forest users (Fig. 2). We find that rulemaking participation is associated with a lower probability of less desirable outcomes (unsustainable forest systems and those characterized by trade-offs) and a higher probability of sustainable forest system outcomes, across smaller and larger forests. But our results suggest that participation in rulemaking may be especially important in promoting positive outcomes in small forest fragments, where greater challenges to achieving jointly positive outcomes across biodiversity and livelihoods already exist (Fig. 2). We conclude that working toward formal participation of local forest users in rulemaking processes for use and management of forests from which they draw their livelihoods (irrespective of whether such activities are sanctioned under prevailing rules) is an important way to increase the probability of obtaining more positive outcomes across social and ecological dimensions.

Further work is needed to understand the causal mechanisms that underlie such outcomes. One proposed mechanism is that rulemaking participation provides an opportunity for local forest users to contribute more specific and locally relevant information on forest resources and dynamics of use for a given forest, which in turn leads to the construction of rules that are viewed as legitimate and better suited for local forest conditions. Rulemaking participation may also help shift incentive structures for forest users to undertake decisions aimed toward a more balanced prioritization between activities that maintain good forest conditions and benefit flows over longer time horizons (hence biodiversity conservation indirectly) and shorter-term livelihoods benefits.

In constructing our model, we also tested for the significance of additional variables, particularly market distance and population density, which have been found in prior work to be associated with biodiversity and livelihoods when treated as independent outcomes. However, we do not find a statistically significant association between these other factors and our joint outcome categories (*16*). Species richness does not encompass all facets of biodiversity, and species composition is also particularly important for assessing biodiversity conservation (*9*). Our use of tree species richness as an indicator of biodiversity is supported by a strong positive correlation of this variable with an abundance-based similarity index of tree species composition calculated for each of our cases in comparison with a minimally disturbed reference forest within the same forest type (*16*).

There are some important regional differences in the broader set of biophysical, socioeconomic, and institutional factors associated with the East African versus South Asian cases (table S2). Forests are larger on average in East Africa, and a greater proportion of households rely on the forests for commercial income. We also find differences in the strength of association of some of these explanatory and broader contextual factors between the two regions, even as overall patterns of outcomes in the relationship between tree species diversity and subsistence livelihoods are similar. We suggest that this may point to the likelihood of multiple pathways for achieving these outcomes, differentiated, for instance, across varied regional contexts and key factors that also likely operate at broader scales.

Recognition that forested ecosystems simultaneously generate multiple services is embodied in forestry policy decentralization reforms that have doubled the area of forest land under community ownership or management in the past 15 years (*6*). These efforts rest on an assumption that synergies across multiple forest outcomes can be achieved, yet existing scholarship provides only limited guidance on avenues by which policies might better promote these synergies. Our data and analysis from a large number of cases from different countries, forest types, and social contexts suggest that trade-offs favoring forest conservation objectives or immediate human livelihoods, as well as jointly positive or negative results, are each possible across the many different contexts

that comprise the human-dominated forested landscapes of East Africa and South Asia. Although achieving desirable outcomes across potentially competing social and ecological objectives is a complex process, our analysis suggests that jointly positive outcomes are far more likely when forest users participate in rulemaking aspects of forest governance. Our findings are particularly relevant for small forest patches in human-dominated landscapes (especially forests under 200 ha), which often present a particular challenge for achieving jointly positive results.

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