


Aligning conservation efforts with resource use around protected areas

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Abstract A large number of economically disadvantaged people live around protected areas. Conservation efforts that focus on poverty alleviation, work on the premise that an increase in household wealth decreases use of forest resources. We surveyed 1222 households across four tiger reserves to test the paradigm that an increase in assets leads to reduced forest use and we also assess the effects of other socio-economic factors. We find that increase in assets may reduce Non-timber Forest Product (NTFP) collection, but may not necessarily reduce livestock numbers or use of wood as a cooking fuel. Households that faced more economic setbacks were more likely to state that they wanted more livestock in the future. Education is positively associated with choosing Liquefied Petroleum Gas as a cooking fuel in the future. We find site and resource-specific variation. Fifty percent of all households (range across sites: 6–98) want to collect NTFP while 91% (range: 87–96) want to retain or own more livestock over the next 5–10 years. Understanding current and future resource use will help plan context-specific conservation efforts that are better aligned with reducing specific pressures around protected areas.

Keywords Livelihoods · Protected areas · Resource extraction

INTRODUCTION

Poverty and biodiversity often coexist in developing tropical nations, and a large proportion of economically

disadvantaged households depend on natural resources for subsistence and income. For instance, 40% of India's poor live on the periphery of forests and these forests are important to people for firewood, Non Timber Forest Products (NTFP) and livestock grazing (Nayak et al. 2012). The direct dependence of economically disadvantaged households on natural capital has led to a slew of initiatives that seek to alleviate poverty (through socio-economic development) while also reducing pressures on forest resources (McShane et al. 2011). The conceptual paradigm behind such programs is that wealth creation—including through the provision of economic assets—leads to reduced dependence and extractive pressures on forests, and a shift away from forest-based livelihoods (Macura et al. 2016). Increasingly, however, recognition is growing that such win-win situations (that simultaneously secure human welfare as well as biodiversity) are likely to be special cases (Salafsky 2011).

More commonly, there are trade-offs between poverty alleviation efforts and biodiversity conservation (McShane et al. 2011), and site-specific socio-political and economic contingencies can—and do—complicate relationships between economic mobility and biodiversity conservation. For instance, the ownership of assets, which serves as an indicator of wealth, is correlated with lower reliance on forests (Angelsen et al. 2014), the exploitation of forest-based resources in itself might act as a springboard enabling asset accumulation and escape from poverty (Wright et al. 2016). Further, income setbacks (e.g., from floods, droughts, crop disease) can increase dependence on forest-based resources as an economic buffer, especially for marginalized communities such as small-holder farmers and the landless (Shackleton and Pandey 2014). The degree of reliance on forest-based resources for subsistence and income is likely to be an outcomes that is constrained by

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factors such as social status, the resource in question and household education (Davidar et al. 2008).

To design effective human welfare and biodiversity conservation programs, therefore, requires an understanding of the household-level factors and constraints determining current patterns of forest-based resource dependence, as well as potential changes in the use of forest-based resources in the future. For instance, with increasing urbanization and non-agricultural economic opportunities, people may become less reliant on forest-based resources in the near future for both subsistence and wealth creation (Parry et al. 2014; Singh et al. 2017). It is therefore crucial to evaluate relationships between wealth and dependence on forest resources, and how such relationships are likely to be modulated by social, economic and political factors (Mascia et al. 2014) such as livelihood diversity and access to markets (Belcher et al. 2015). Interpreting such relationships would therefore be the first step in: (a) understanding the socio-economic and political contexts in which people living around forests are likely to reduce extractive pressures on forests, and (b) identifying socio-economically vulnerable groups with high reliance on natural resources that might be most vulnerable to resource use restrictions (Wright et al. 2016) and/or who might benefit most from livelihood-focused interventions (Kaaya and Chapman 2017). Such poverty alleviation efforts and livelihood-focused interventions are implemented in many parts of Asia (Macura et al. 2016), South America (Parry et al. 2014), and Africa (Kaaya and Chapman 2017).

Here, we examine current and future correlates of forest dependence (separately for NTFP, fodder, and cooking fuel) in communities living around four Indian PAs that not only differ amongst themselves, but also encompass heterogeneous socio-economic and political groups. Such work is crucial to establishing baselines and foreseeing future pressures on forests, especially in developing bio-diverse tropical countries that are poised to have multiple pathways to transformations in forest cover and degradation (Singh et al. 2017). We addressed two specific questions: (1) does current and predicted future forest use vary with household wealth; and (2) do socio-economic and political contingencies (income setbacks, livelihood diversification, political representation) correlate with current and future forest use? Predicted forest use assumed that an interviewee was able to assess internal and external changes and opportunities that would be available to a household in the next 5–10 years and base their choice of future use of forest accordingly. We expected that a household's current collection efforts and future use of forests will: (a) in general, be negatively correlated with household wealth (an asset-consumption metric was used; see methods), and if not explained by assets alone,

(b) income setbacks, livelihood diversification, livelihood type, political representation, and proximity to forests are likely to play an important role.

MATERIALS AND METHODS

Study site

We selected four tiger reserves (Corbett, Kanha, Pakke, and Bilgiri Ranga Swamy Temple (BRT) Tiger Reserve; Fig. 1) that maybe representative of tiger reserves in India. These four tiger reserves represent diverse socio-economic and cultural settings, important biodiversity values and different management histories. Two of the four states in which these tiger reserves are located have significant tribal populations (greater than 10% consists of Scheduled Tribe, a term used in the Indian Constitution to represent tribes, tribal communities or parts or groups within such tribes or tribal communities) (Maity 2017). Scheduled Tribe is used as an umbrella term for a heterogeneously diverse group of people (104 million) in India, which has the second highest tribal population in the world (Anderson et al. 2016). Further, these tiger reserves spanned different management histories ranging from older (Corbett and Kanha) to recently declared tiger reserves (Pakke and BRT).

These tiger reserves have important biological values. Corbett has high tiger densities and other species of important biodiversity values (Verma et al. 2015). Kanha Tiger Reserve is also a strong hold for tigers as well as the Hard-ground Barasingha *Rucervus duvaucellii branderi* (a sub-species of the Swamp Deer) (Verma et al. 2015). BRT is a bridge between the Eastern and Western Ghats in Karnataka state that has one of the largest contiguous wild tiger populations and many endemic species of the Western Ghats. Pakke is part of the Eastern Himalaya Biodiversity Hotspot and along with a breeding tiger population, hosts globally important species such as the White-winged Wood Duck *Asarcornis scutulata*.

The communities living around these tiger reserves are diverse. The Van Gujjars, Gonds, Baigas, Nyishis, Akas, Puroiks, and Soligas are Scheduled Tribes that live around these four tiger reserves. Around Corbett the non-tribal groups are the Joshis, Negis and Jats while the tribal Van Gujjar community live in certain pockets. The numerical majority of people living around Pakke Tiger Reserve belong mostly to the Nyishi and Aka tribe while non-resident settlers also live in the area. In Kanha, the Gonds and Baigas are the two main tribes and the Pawar, Marar, Lodhi, Aahir, and Yadavs are the major non-tribal communities. In BRT, Soligas are the numerical majority living in the tiger reserve while the non-tribal Lingayats and Brahmins inhabit areas in and around BRT.

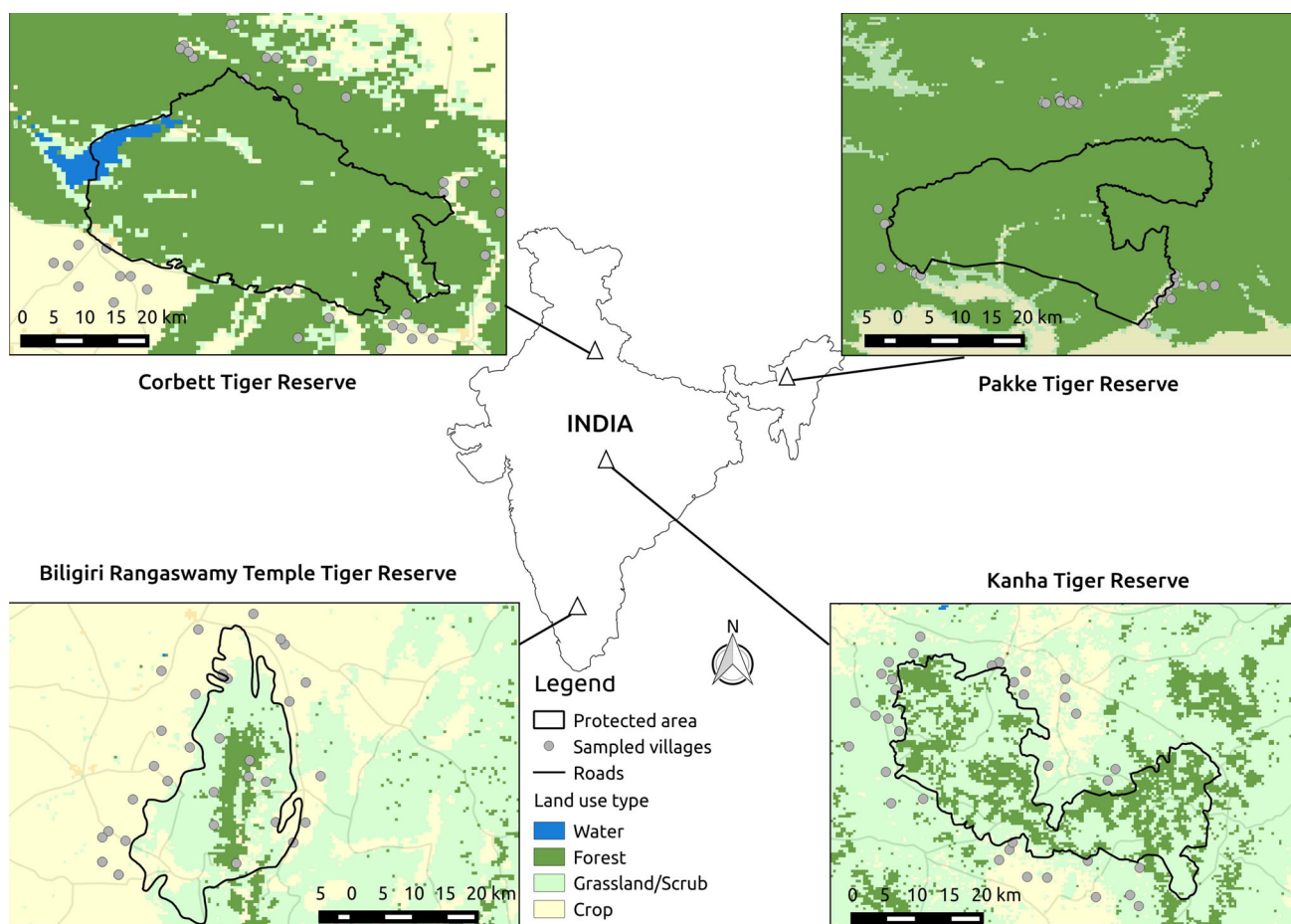


Fig. 1 Map of the study area where we sampled 1222 households across 135 villages (grey dots) in and around four Indian tiger reserves. The grey lines depict the road network and land-use classification (0.5 km MODIS-based Global Land Cover Climatology, Broxton et al. 2014)

The residents living around these tiger reserves use the forest in different ways. Practices vary across the different tiger reserves and across communities. Residents mostly from the Van Gujjar community around Corbett use firewood ($25\text{--}40\text{ kg household}^{-1}\text{ day}^{-1}$), fodder and NTFP (Irengbam et al. 2017) while dead wood is provided monthly to some villages in the buffer zone (Verma et al. 2015). Day-to-day needs of people around Kanha is met by forests in multiple ways. Bamboo (*Dendrocalamus* spp.) is useful for construction of homes; *amla* (*Phyllanthus emblica*), *harra* (*Terminalia chebula*), *behera* (*Terminalia bellerica*), *tendu* (*Diospyros melanoxylon*), and *mahua* (*Madhuca longifolia*), among others are used for medicinal purposes, sold at markets and/or to cooperatives (Agarwala et al. 2016). In BRT, the Soligas collect NTFPs that are sold to the Large Adivasi Multipurpose Cooperative Society (LAMPS) (Setty et al. 2008) and recently there have been honey value addition centres that are independent of LAMPS (Tatpati and Pathak-Broome 2016). In Pakke Tiger Reserve, there are no settlements within the

park. Hence people collect NTFP from the few accessible areas inside the core and from the adjacent forests. Current NTFP collection efforts during our study were representative of the main species mentioned in Table 1.

Livestock rearing patterns differ across sites. One strategy is to allow livestock to graze during the day and return in the evening. Many residents pay a person to graze livestock during the day. Some communities in Corbett collect fodder for livestock from the forest to stall-feed cattle, yet adjacent pastoral communities graze livestock themselves (and also collect fodder while grazing their livestock) at the household level or a group of households. Fodder collection efforts were mostly observed in and around Corbett Tiger Reserve. The semi-domesticated *mithun* (*Bos frontalis*) is found around Pakke Tiger Reserve and is unique to our sample of tiger reserves. These animals are left to forage in the forests and owners would go and check on these animals periodically. The fodder requirement for livestock is lower than what is available in India, and 199.6 million livestock depend on forests for

Table 1 Site wise differences across the four tiger reserves. The upper section of the table contains a summary of the details of the four different sites. *Source* Census of India (2011) and 19th Livestock Census (2012). The second half of the table contains the mean and standard deviation across households at each site

Study area details	BRT	Corbett	Kanha	Pakke
Core area (km ²)	359.1	Corbett (520.8), Sonanadi Wildlife Sanctuary (301.1)	Kanha (940), Phen Wildlife Sanctuary (110)	861.9
Buffer area (km ²)	215.7	466.3	1009.0	608.2
District average of human density (per km ²)	180.7	386.9	183.0	15.1
District average tribal population (%)	11.7	< 1	40.1	73.6
District average livestock density (per km ²)	91.3	144.6	97.1	18.5
Commonly harvested NTFPs	<i>Phyllanthus emblica</i> , <i>P. indofischeri</i> , <i>Acacia sinuata</i> , <i>Sapindus laurifolius</i> , lichen, honey	<i>Grewia optiva</i> , <i>Artemisia maritima</i> , <i>A. nilagirica</i> , <i>A.</i> <i>parviflora</i> , <i>A.</i> <i>sacrorum</i>	<i>Canarium resiniferum</i> , <i>Thysolina maxima</i> , <i>Stenochlaena</i> <i>palustris</i> , <i>Livistona</i> <i>jenkinsiana</i> , <i>Musa</i> spp., cane, bamboo	<i>P. emblica</i> , <i>Terminalia</i> <i>chebula</i> , <i>T. bellerica</i> , <i>Madhuca longifolia</i> , <i>Diospyros</i> <i>melanoxylon</i> . bamboo
Household characteristics (mean ± SD)				
Asset	3.7 ± 1.8	5.1 ± 1.9	1.4 ± 1.3	3.7 ± 2.2
Proportion of jobs availed	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.13 ± 0.1
Income setbacks	3.23 ± 1.8	4.52 ± 1.9	5.47 ± 1.4	5.53 ± 2.3
Education in years	11.0 ± 5.4	15.5 ± 4.4	10.0 ± 4.2	14.3 ± 4.3
Land in acres	1.3 ± 1.3	2.0 ± 4.0	1.8 ± 2.6	2.6 ± 5.6

fodder (Nayak et al. 2012). The dependence of livestock on forests across the four states where these four tiger reserves are located ranges from 53.6 to 95.2% (Forest Survey of India 2011). Thus, we used livestock number as a proxy for grazing pressure.

Data collection

We surveyed 1222 households across 135 villages across these four tiger reserves (39.8% of villages in our sampling frame; Census of India 2011). Across sites we sampled a range of household parameters, with no significant differences in the distribution of these parameters across sites (see Fig. S1). We selected villages using Census of India 2011 data and after our pilot study, we included relocated villages, villages that did not have land deeds and some forest and revenue villages that were not on our initial map. We selected villages within and around the reserve (for BRT) and within a 5–8 km buffer around the tiger reserve for the other three sites. We did a cluster analysis (using R package *cluster*) to select villages that encompassed a variation in distance from forest, road, nearest city or town, and tiger reserve boundary. We obtained five clusters (which explained > 75% of the variance) and selected five to six

villages within each cluster. Villages were initially selected in a randomized manner. During our pilot survey, a few villages that were difficult to access and/or find were substituted by villages from the same cluster.

From December 2016 to May 2017, we visited multiple areas, conducted a pilot study, tested our questionnaire, and had training sessions for larger teams of data collectors. We collected data using in-depth interviews of people living around these areas (approved IRB protocol is AAAR2467). In each village, we obtained a geographical representation of households through a random start point and walked in different cardinal directions where we sampled eight to 12 households per village. We tried to sample three to four households in each cardinal direction by separating every 3rd or 4th household, but in some smaller villages we sampled nearly all households. While this may have resulted in clustering within a village, given that we selected a different random start point for each village, we expect that within-site across-village bias would be minimized. Households were represented by various demographic profiles that spanned different castes, religious groups, livelihood patterns, education levels and relationship to their respective protected areas. We either spoke to the head of the household or any adult in the

household who was willing to speak with the interviewer (45.9% were males). Each interview lasted between 40 and 60 minutes. We assume that the individual interviewee was represented to speak about a household's overall forest use. In some cases, predictors were relevant only to a particular site (e.g., fodder was not collected in all sites). Interviews were conducted during a time that was convenient for the residents and there was broad temporal overlap in data collection across all sites. If the interviewee consented to be interviewed, the interview was conducted in Hindi, Assamese, or Kannada.

The questionnaire was structured to collect information around the two main questions: (i) the currently use of forests (NTFP and fuelwood collection effort and livestock numbers) and how future use is likely to change with respect to collecting NTFP, wanting livestock and cooking fuel choices over the next 5–10 years; (ii) how does forest use in the future correlate with socio-demographic characteristics and household income strategies? For the first response variable of current use, we collected data on the household effort spent over the last 7 days collecting firewood, NTFP and fodder and livestock numbers. Our second response variable was future use of forests, and the preference for resource use over the next 5–10 years was used as a proxy to assess future forest use. The question on future resource use assumed that an interviewee was able to assess changing opportunities (with respect to intrinsic household factors as well as external economic forces) in the next 5–10 years and would be able to make a choice on future resource use given the household's present situation. Respondents replied as yes or no or both (if they preferred using Liquefied Petroleum Gas (LPG) as well as firewood). For the second question on wealth, we used an asset-consumption metric for each household where we summed 14 different assets and 19 consumption variables over the last 7 days as a proxy for household wealth (Appendix S2). For other socio-demographic characteristics, we calculated the relative measure of the proportion of livelihood opportunities (the number of different income occupations in a household divided by the total number of recorded occupations across all communities in that site) in which each household was engaged. Education of the household was defined as the maximum education that was obtained at the household level. In terms of the generation of our interviewee, grandfather would be 1st generation and grand-son would be 3rd generation. Livestock rearing effort was considered as cattle grazing and fodder collection efforts. For a measure of forest use, effort was calculated as the hours spent collecting different NTFPs, firewood, fodder and multiplied by the frequency of visits in the last week. We defined income setbacks as environmental, social or other setbacks where the interviewee felt that a loss changed the relationship between their assets and their

household income in the last 5 years. We enumerated 15 income setbacks apart from other setbacks that interviewees stated (Appendix S2 has questionnaire of variables used in this study). During the course of the study, Indian currency of a particular value was demonetized. Although demonetization was listed as an income-setback, it is likely to be an under-representation as data collection protocols were already in place during the early effects of demonetization. Within the setbacks, the livestock that households lost were classified as killed in wildlife-conflict, died, got lost or were stolen in the last 5 years. Political representation was coded as yes or no at the first level and if yes was further categorized into whether the household was represented at the village level (village head, council, sangha), or included elected representatives at the ward, block, district, a local party member, a party campaigner, an assembly-elected leader or others. Distance to protected area was used as a predictor with the assumption that closer to a protected area there would be stricter enforcement versus further away (but we did not characterize the type of enforcement at each site).

Data analysis

We used Program R (R Core Team 2017) for all analyses. We constructed three models to evaluate the factors that explain current use of forests, separately for each forest resource (NTFP collection effort, firewood collection effort and livestock number). We used Poisson Generalised Linear Mixed Models (with site—the four tiger reserves—as a random effect) to investigate the relationship between our response variables and predictor variables. We coded each response in which interviewees seemed unsure, uncomfortable or confused about a certain question but responded nevertheless as NA. We scaled all predictor variables to enable comparisons of coefficient values across predictors. We classified caste into three levels: General, Scheduled Caste (SC)/Other Backward Class (OBC) and Scheduled Tribe (ST). We also constructed three models to evaluate preference for future forest use (over the next 5–10 years) for NTFP collection, livestock and choice of cooking fuel. We used binomial Generalised Linear Mixed Models with site as a random effect to investigate whether people wanted to collect NTFP (yes: 1, or no: 0) in the next 5–10 years as a function of our predictor variables. To evaluate a household's future livestock use, our response was coded as zero if a household wanted to reduce livestock numbers, or '1' if a household wanted to retain current livestock numbers, or own more livestock in the future. For choice of cooking fuel over the next 5–10 years, our response was whether a household wanted to use LPG (0) or firewood and a combination of firewood and LPG (1). In total, therefore, we evaluated six models

(one for current and future use for each of three forest use variables). Before model construction, we examined correlation coefficients between our predictor variables, as well as variance inflation factors (in the package *usdm*), to check for collinearity between predictors. Our predictors were not collinear (min R : -0.00 , max R : 0.46 , variance inflation factors < 1.4), and we therefore retained all predictors in our model. We calculated marginal R^2 and cumulative R^2 to assess the variance explained by fixed and random effects for each model.

RESULTS

Current and future resource use varies across sites and also depends on the resource type. Mean livestock holding per household was 2.6 (range across sites: 2.1–3.4). The effort households spent collecting NTFP per week was lower (4.2 h per week; range: 2.0–5.1) compared with fuelwood (7.8 h per week; range: 2.9–12.8). Roughly half of all households want to continue to collect NTFP in the future (50.6%; range: 6.9–98.6), while the rest (49.3%; range: > 1 –93.0%) prefer not to collect NTFP in the future. Overall, 91.4% (range: 87.6–96.9) wanted to either retain current livestock numbers or own more livestock in the future, while 8.6% (range: 3.1–12.3%) wanted to reduce livestock over the next 5–10 years. Across sites, 27.7% want to use only LPG (range: 15.0–38.8) while 72.2% (range: 61.1–84.9) want to retain firewood use or a combination of firewood and LPG (firewood and LPG together: 61.8%; range: 51.0–84.4) over the next 5–10 years.

Model performance

NTFP, livestock, and fuelwood models performed differently, in terms of the proportion of variance explained by fixed effects (marginal R^2), and fixed and random effects together (conditional R^2). Our selected predictors explained 26.8% of variation in NTFP collection effort, while site-level variation in addition accounted for 47.9% of variation in NTFP collection effort. Our predictors explained a higher percentage of the variation related to future NTFP collection (marginal $R^2 = 44.7\%$; conditional $R^2 = 69.6\%$). In general, livestock models (current and future) were less explanatory (current: marginal $R^2 = 19.5\%$; conditional $R^2 = 27.7\%$; future: marginal $R^2 = 29.7\%$; marginal $R^2 = 37.2\%$). Models attempting to explain current fuelwood dependence and future consumption varied in explanatory power (current: marginal $R^2 = 21.4\%$; conditional $R^2 = 56.8\%$; future: marginal $R^2 = 12.2\%$; conditional $R^2 = 21.9\%$).

Relationships between wealth (asset ownership) and forest use

Households with more assets spent significantly less time collecting NTFP (i.e., 95% CIs not overlapping zero; dotted line in Fig. 2a), and this was similarly negative for future NTFP collection (Fig. 2b). However, wealthier households currently owned a greater number of livestock (Fig. 2c), and were also more likely to want to retain or increase their current livestock holdings in the next 5–10 years, albeit this trend was weaker (Fig. 2d). The current effort spent collecting firewood showed a decreasing trend with increasing assets (Fig. 2e); however, more assets were with a higher probability for retaining firewood as a cooking fuel (firewood in combination with LPG was the most preferred method for cooking) as opposed to just using LPG over the next 5–10 years (Fig. 2f).

Other predictors of current and future forest use

Household occupation was the most significant predictor that explained current efforts and future NTFP collection (Fig. 3; 95% CI not overlapping zero). Another common factor to both current and future NTFP use was how far a household was located from a forest; the greater the distance from a forest, the lower the NTFP collection effort presently and the probability of wanting to collect NTFP in the future. Further, the greater the number of livelihoods in a household, the more the time spent NTFP collecting currently.

Political representation (although, 95% CI overlapped zero) showed a positive qualitative trend with current NTFP collection efforts. Households that had lower NTFP collection efforts were those with higher education and greater social disadvantage (whether an Other Backward Castes (OBC), Scheduled Castes (SC) and Scheduled Tribes (ST) compared to the General Category). However, households with a greater social disadvantage (when compared with General Category) were more likely to prefer collecting NTFP over the next 5–10 years (Fig. 3).

Few variables (fixed effects) were significantly related to current livestock holding size (95% CI did not overlap the zero dotted line in Fig. 3). Households with larger land holdings, those that faced a greater number of livestock-related calamities, spent greater effort rearing livestock, and availed a greater proportion of governmental schemes, were more likely to own a greater number of livestock (Fig. 4). Households living further away from PAs were more likely to own fewer livestock (Fig. 4). Compared with general caste households, SC and OBC households owned more livestock, as did those households that listed livestock as an occupation (Fig. 4). Only three of the fixed effects

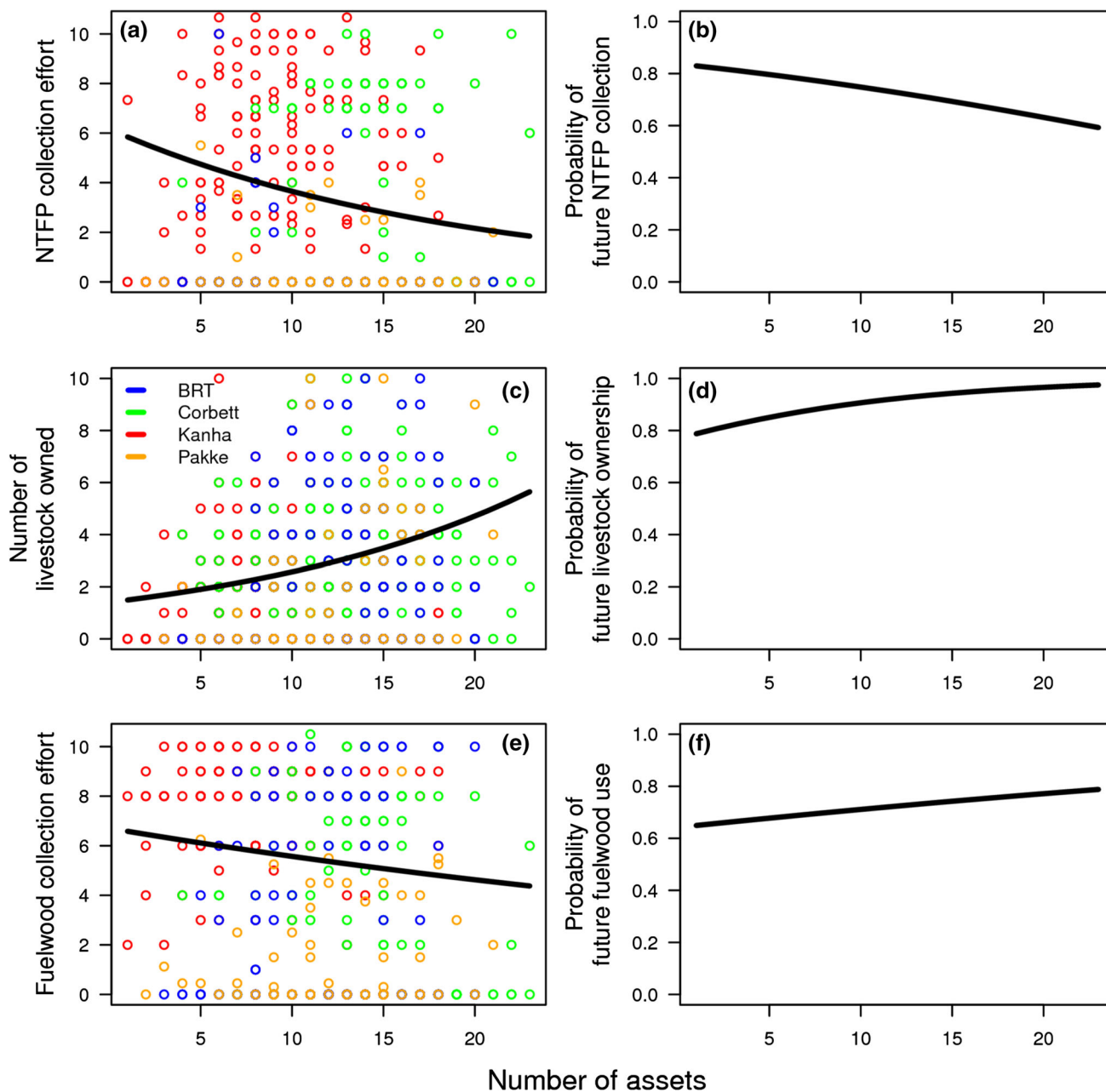


Fig. 2 Predicted relationship between assets and current and future resource use. The open coloured circles (left panel are from each site) are raw data points. The black line is the modeled trend line

were significantly related to desire to own more livestock in the future (Fig. 4). Households with larger families, those that suffered a greater number of income setbacks and reared livestock as an occupation were more likely to want to increase their livestock holdings in the next 5–10 years.

Type of cooking fuel (especially if it included using solely LPG or a combination of LPG and firewood) was an important negative predictor of current firewood collection effort, as well as increased the probability of choosing LPG in the future. Other factors that explained decreasing

firewood collection effort were increasing distance to forest, larger land holdings, education and gender (male respondents) (Fig. 4). Similar to trends with NTFP collection effort, larger families and households with a greater number of livelihoods spent more time collecting fuelwood currently; interestingly, these households were not likely to want to use firewood in the future (Fig. 5). Households that spent a substantial effort collecting firewood currently were more likely to retain firewood (in isolation or in combination with LPG) as a cooking fuel in the next 5–10 years (Fig. 5).

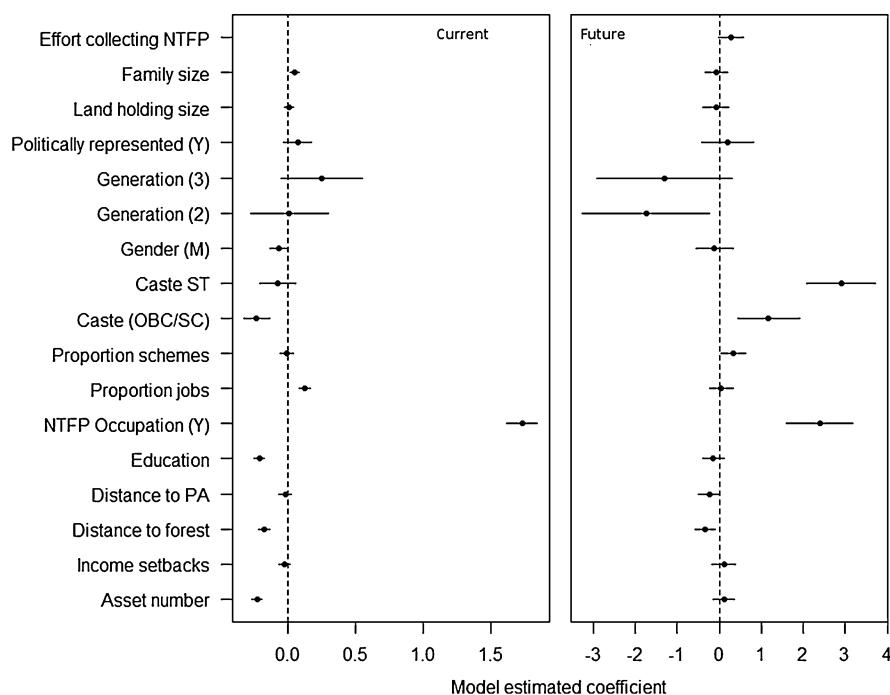


Fig. 3 The modeled predictors from the two separate NTFP models for current and future use. Each predictor (and their 95% CI) that overlaps zero (the dotted line) indicate no effect. The significant predictors to the left of the dotted line are those that are likely to decrease current and future NTFP collection

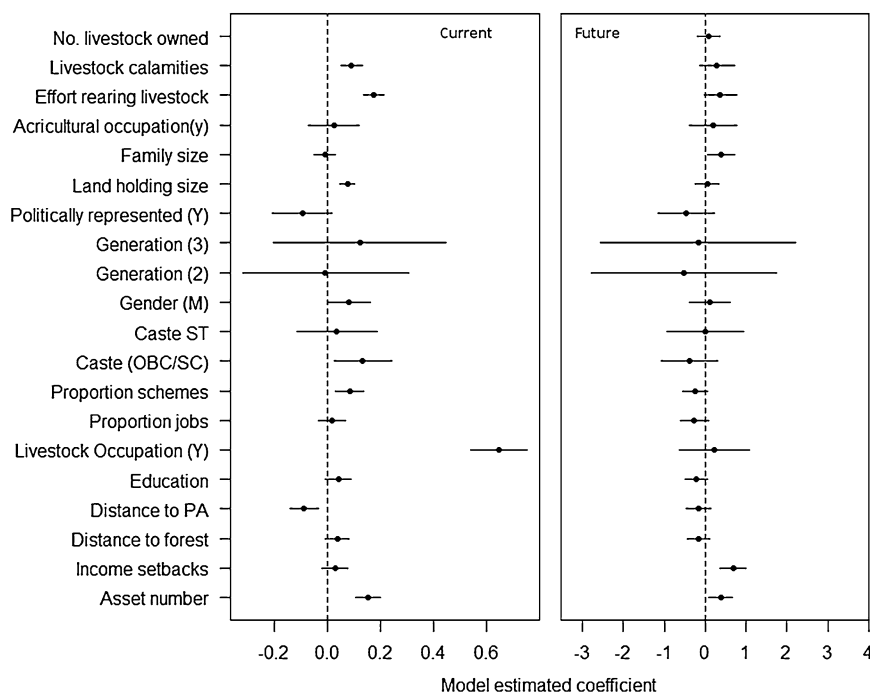


Fig. 4 The modeled predictors (and 95% CI) for the two separate livestock models (left panel: current livestock number and right panel: probability of wanting livestock in the future)

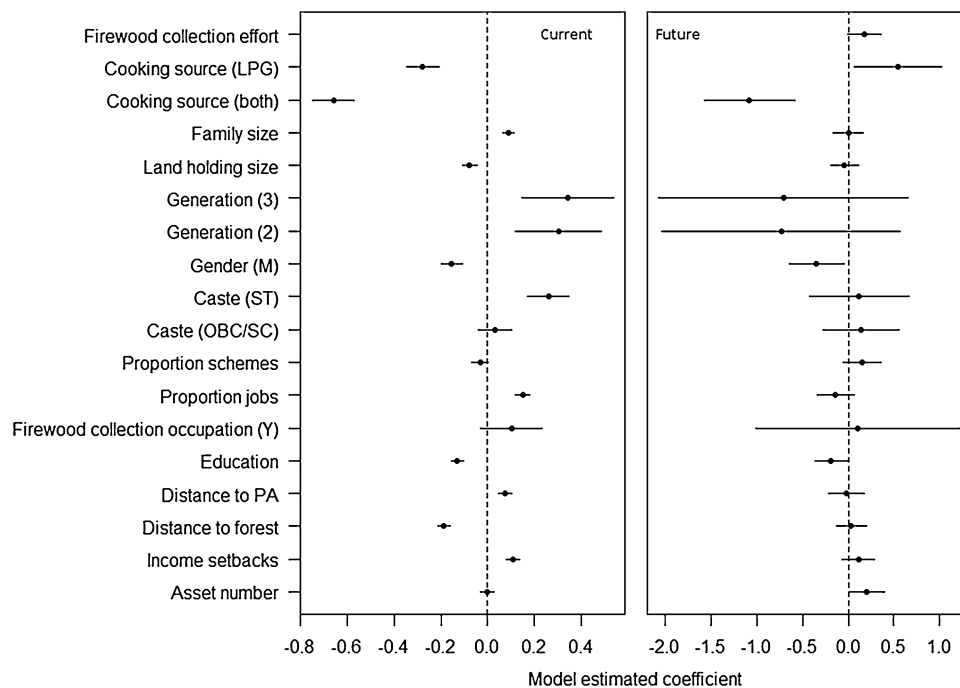


Fig. 5 The modeled predictors (and 95% CI) for the two separate models (left panel: current fuelwood collection efforts and right panel: future choice of cooking fuel)

DISCUSSION

We find that household wealth (specifically defined as an asset-consumption metric) predicts current and future resource use around India's PAs depending on the resource type. For instance, NTFP collection (at present and in the future) as well as current fuelwood collection efforts decreased with increasing assets. While firewood collection decreases with household wealth, wealthier households do not necessarily want to shift entirely to LPG, preferring to use both LPG and firewood for future cooking. Similarly wealthier households had greater livestock numbers and showed a similar trend (but weaker relationship) of wanting more livestock in the future. This may point to the important role of livestock as an asset to rural households or in enabling asset accumulation. Thus, the relationship between assets and current and future resource use is complex and nuanced and not simply a question of the substituting forest products with wealth. While a more top-down view posits that poorer households have a higher reliance on forest-based resources, we show that current and future resource use will vary depending on other factors (diversity of livelihoods, occupation) and particular forest-based resource. Our study is a starting point to investigate other factors such as the reliability of LPG supply to forest areas and/or an expansion in household energy demand.

Hence, programs that provide substitutes or asset-transfer for forest-based resources or Alternate Livelihood

Programs (Wright et al. 2016) alone—for instance, substitutions of LPG with firewood—may not always yield the desired result(s) of reducing pressures on forest resources. The type of cooking fuel used at present may be important in decreasing current fuelwood collection efforts and increasing a household's likelihood of using LPG in the future. The Pradhan Mantri Ujjwala Yojana provides LPG connections to rural women living below poverty line across India. While this scheme is also operational in rural forested areas, it may need to be tailored to a different set of requirements if rural development programs also seek to try and better natural resource management (e.g., reduce firewood dependence). Efforts that get households to choose LPG in the future maybe more effective if they also focus on education and gender, both important factors that are likely to predict a decrease in fuelwood collection currently and an increased likelihood of choosing LPG in the future.

A multitude of governmental and non-governmental initiatives occur in rural India; in some cases, they may directly or indirectly lead to a reduced extraction of natural resources. The idea that rural development (e.g., through the Mahatma Gandhi National Rural Employment Guarantee Act 2005) can better natural resource management (via the creation of 'green jobs' that work on drought proofing and water conservation, among others) has been receiving increasing attention (Shome 2014). However, we find that the number of schemes that a household is involved in does not show any predictable relationship with

a decrease in reliance on natural resources. Thus, existing or future schemes that may be implemented with households around PAs may also need to factor PA-specific factors (such as forest-based occupations, collection effort of forest products, distance to forest and protected areas of each household).

Although benefits may be diffused across beneficiary groups, livelihood-targeted interventions may help communities in different ways (e.g., with developing resilience; Patnaik and Das 2017). Often, the mandates of such livelihood-based programs (e.g., Skills India) have focused on training for livelihood diversification. From our study, households with a greater number of livelihoods might have a greater dependence on forests presently for all three resources. However, those households that had a greater number of livelihoods were less likely to state that they wanted to collect NTFP and use firewood for cooking over the next 5–10 years. This may point to NTFP collection being a livelihood option engaged in out of ‘desperation’ to diversify livelihoods presently (Barrett et al. 2001), with many of these households being from vulnerable groups, but perhaps not a choice that would be necessarily opted for in the next 5–10 years. However, livelihood diversification did not appear to be associated with lower livestock numbers and a decrease in the probability of a household wanting less livestock in the future. In other words, livelihood diversification alone does not necessarily equate to lowered dependence on all natural resources and a consequent reduction of pressures on PAs and natural habitats. Other factors, such as the type of livelihood (whether livestock rearing is an occupation) are also important. Current occupation (e.g., NTFP collection) also plays an important role in present community–PA relationships (Liu et al. 2010).

Several other aspects related to social and/or economic power and exclusion might affect current and future resource extraction efforts. While such evaluations help in establishing baselines and/or to imagine the future environmental impacts, they also help understand the social acceptability of any planned conservation intervention (Bennett 2016). We found that people from a more vulnerable social status (OBC/SC/ST compared to the General Category) spent lower time collecting NTFP presently (probably due to restrictions) but these vulnerable groups were most likely to state that they wanted to collect NTFP over the next 5–10 years. Trying to reduce NTFP collection pressure in and around a protected area may be desirable from the point of view of reducing pressure on natural resources but it may not be a socially acceptable given the vulnerability of such social groups and/or use of certain type of enforcement methods. Often, these trade-offs are rooted in competing social, economic and biodiversity

goals (McShane et al. 2011) and it is important to characterize the socio-economic drivers of resource use before planning conservation efforts (Mascia et al. 2014). In a similar vein, while households that spend the most effort rearing livestock may currently have the largest livestock numbers, simply restricting collection efforts may not lead to households wanting to reduce their livestock numbers in the future. This also requires an understanding of other household vulnerabilities such as income setbacks (e.g., droughts, livestock killed/stolen and other losses) in the last five years. Finally, although 16% of all households were politically represented, we found that such representation may have important qualitative trends with resource use. For instance, current NTFP collection efforts was positively correlated (qualitatively) with whether a household was politically represented. While it is not possible to tease out the causal links between current NTFP use and political representation, management decisions related to banning NTFP collection have affected vulnerable social groups that collect NTFP as one of their livelihood sources in the past (Madegowda and Rao 2013). Our study is a starting point that illustrates the need to understand perspectives from the ground that may vary by site and/or by resource.

These assessments could be further used to assess the type of planned inputs, activities, and outputs required to build management capacity on the ground (Mascia et al. 2014). Most studies have examined impact evaluations of eco-development schemes and livelihood-focused interventions post-implementation and have found mismatches between outcomes and mandates and/or limited reach (Gubbi et al. 2008; Macura et al. 2016). There is evidence from around the Serengeti that in addition to community-level benefits, providing such household-level benefits are also important to reduce poaching pressures (Kaaya and Chapman 2017). In India, such programs reach approximately only 10% of all households of targeted villages around a tiger reserve (Macura et al. 2016). Many of these interventions are now focused around notified buffer-zones of tiger reserves that aim to recognize livelihoods, development, and social and cultural rights of residents through eco-development and poverty-alleviation measures, while also ensuring safeguards to dispersing tigers. Thus gaining an understanding of ambient conditions would help identify priorities and choose among potential strategies before implementation of a conservation program (Mascia et al. 2014). For instance, an intervention focused on improving household wealth may not necessarily overlap with parallel goals to reduce pressure for all forest-based resources. We show that bottom-up perspectives from around protected areas and towards a particular forest-based resource are an important first step, as current and future use of forests are likely to differ by resource and location as well as

contextual household factors. Such approaches will help plan site-specific conservation efforts aligned with current and future use of resources and potentially improve conservation outcomes.

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REFERENCES

- Agarwala, M., R.S. DeFries, Q. Qureshi, and Y.V. Jhala. 2016. Changes in the dry tropical forests in Central India with human use. *Regional Environmental Change* 16: 5–15.
- Anderson, I., B. Robson, M. Connolly, F. Al-Yaman, E. Bjertness, A. King, M. Tynan, R. Madden, et al. 2016. Indigenous and tribal peoples' health (*The Lancet*–Lowitja Institute Global Collaboration): A population study. *The Lancet* 388: 131–157.
- Angelsen, A., P. Jagger, R. Babigumira, B. Belcher, N.J. Hogarth, S. Bauch, J.B.C. Smith-Hall, and S. Wunder. 2014. Environmental income and rural livelihoods: A global-comparative analysis. *World Development* 64: 12–28.
- Barrett, C.B., T. Reardon, and P. Webb. 2001. Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics, and policy implications. *Food Policy* 26: 315–331.
- Belcher, B., R. Achdiawan, and S. Dewi. 2015. Forest-based livelihoods strategies conditioned by market remoteness and forest proximity in Jharkhand, India. *World Development* 66: 269–279.
- Bennett, N.J., 2016. Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology* 30: 582–592.
- Broxton, P.D., X. Zeng, D. Sulla-Menashe, and P.A. Troch. 2014. A global land cover climatology using MODIS data. *Journal of Applied Meteorology Climatology* 53: 1593–1605.
- Census of India. 2011. District Census handbook. The Registrar General & Census Commissioner, New Delhi. Retrieved March 1st, 2018, from <https://www.censusindia.gov.in/2011census/dchb/DCHB.html>.
- Davidar, P., M. Arjunan, and J.P. Puyravaud. 2008. Why do local households harvest forest products? A case study from the southern Western Ghats, India. *Biological Conservation* 141: 1876–1884.
- Forest Survey of India. 2011. Socio-economic contribution of forests: Production & consumption of forest resources in India. Pages 67–79 in India State of Forest Report. New Delhi, Ministry of Environment and Forests, Government of India.
- Gubbi, S., M. Linkie, and N. Leader-Williams. 2008. Evaluating the legacy of an integrated conservation and development project around a tiger reserve in India. *Environmental Conservation* 35: 331–339.
- Irengbam, M., P. Dobriyal, S.A. Hussain, and R. Badola. 2017. Balancing conservation and development in Nandhaur Wildlife Sanctuary, Uttarakhand, India. *Current Science* 112: 1187.
- Kaaya, E., and M. Chapman. 2017. Micro-credit and community wildlife management: Complementary strategies to improve conservation outcomes in Serengeti National Park, Tanzania. *Environmental Management* 60: 464–475.
- Liu, J., Z. Ouyang, and H. Miao. 2010. Environmental attitudes of stakeholders and their perceptions regarding protected area-community conflicts: A case study in China. *Journal of Environmental Management* 91: 2254–2262.
- Livestock Census of India. 2012. 19th Livestock Census. Ministry of Agriculture and Farmers Welfare, Department of Animal Husbandry, Dairying and Fisheries. Retrieved March 1st, 2018, from <https://data.gov.in/catalog/livestock-and-poultry-livestock-census>.
- Macura, B., L. Secco, E. Pisani, A.S. Pullin, and V. Reyes-García. 2016. All that glitters is not gold: The effect of top-down participation on conservation knowledge, attitudes and institutional trust in a Central Indian tiger reserve. *Regional Environmental Change* 16: 125–140.
- Madegowda, C., and C.U. Rao. 2013. The ban of Non-Timber Forest Products collection effect on Soligas migration in Biligiri Rangaswamy Temple Wildlife Sanctuary, India. *Antrocom* 9: 105–114.
- Maity, B. 2017. Comparing health outcomes across Scheduled Tribes and Castes in India. *World Development* 96: 163–181.
- Mascia, M.B., S. Pailler, M.L. Thieme, A. Rowe, M.C. Bottrill, F. Danielsen, J. Geldmann, R. Naidoo, A.S. Pullin, and N.D. Burgess. 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. *Biological Conservation* 169: 258–267.
- McShane, T.O., P.D. Hirsh, T.C. Trung, A.N. Songorwar, A. Kinzig, B. Monteferri, D. Mutekanga, and H.V. Thanh. 2011. Hard choices: Making trade-offs between biodiversity conservation and human well-being. *Biological Conservation* 144: 966–972.
- Nayak, B.P., P. Kohli, and J.V. Sharma. 2012. *Livelihood of local communities and forest degradation in India: Issues for REDD+*. New Delhi: The Energy and Resources Institute.
- Parry, L., J. Barlow, and H. Pereira. 2014. Wildlife harvest and consumption in Amazonia's urbanized wilderness. *Conservation Letters* 7: 565–574.
- Patnaik, U., and P.K. Das. 2017. Do development interventions confer adaptive capacity? Insights from rural India. *World Development* 97: 298–312.
- R Core Team. 2017. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>.
- Salafsky, N. 2011. Integrating development with conservation: A means to a conservation end, or a mean end to conservation? *Biological Conservation* 144: 973–978.
- Setty, R.S., K. Bawa, T. Ticktin, and C. Gowda. 2008. Evaluation of a participatory resource monitoring system for nontimber forest products: The case of *amla* (*Phyllanthus* spp.) fruit harvest by Soligas in South India. *Ecology and Society* 13: 19.

- Shackleton, C.M., and A.K. Pandey. 2014. Positioning non-timber forest products on the development agenda. *Forest Policy and Economics* 38: 1–7.
- Shome, S. 2014. Inclusive rural development through green jobs: The NREGA example. *Productivity* 3: 266–275.
- Singh, M.P., P.P. Bhojvaid, W. de Jong, J. Ashraf, and S.R. Reddy. 2017. Forest transition and socio-economic development in India and their implications for forest transition theory. *Forest Policy and Economics* 76: 65–71.
- Tatpati, M., and N. Pathak-Broome. 2016. Emerging paradigms under the Forest Rights Act. In *Land rights in India: Policies, movements and challenges*, ed. V. Bhagat-Ganguly, 195–211. London: Routledge.
- Verma, M., D. Negandhi, C. Khanna, A. Edgaonkar, A. David, G. Kadekodi, R. Costanza, G. Kadekodi, and R. Singh. 2015. *Economic valuation of tiger reserves in India: A VALUE+ approach*. Bhopal: Indian Institute of Forest Management.
- Wright, J.H., N.A.O. Hill, D. Roe, J.M. Rowcliffe, N.F. Kümpel, M. Day, F. Booker, and E.J. Milner-Gulland. 2016. Reframing the concept of alternative livelihoods. *Conservation Biology* 30: 7–13.
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