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Forest restoration for environment and well-being is associated with empowered local governance over long time horizons

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Abstract

Forest restoration is widely recognized as a global priority to sequester carbon, conserve biodiversity, and support the livelihoods of rural and indigenous people. Contemporary interventions often target landscapes with a substantial human presence, and they regularly call for stakeholder participation during project implementation. However, there is a lack of empirical evidence linking local involvement with multiple forest benefits over long time horizons. Using a unique dataset of four decades of government-sponsored tree planting in North India, we find that both substantive local influence over planning projects and sustained control over management into the present—a favorable combination of long-term, empowered local governance—is associated with greater livelihood benefits and improvements in forest canopy cover over time. Our work points toward complex socio-ecological relationships, which may be explained by a positive interaction between empowered local governance, interventions that align with local needs, and long-term local care for planted forests. This implies that current financial commitments may need to be accompanied by institutional reforms that give communities meaningful control over planning and build capacities for self-governance that can endure into the future. In light of this work, we suggest that a paradigm of 'people-centered restoration' may offer the best opportunity to support long-term environmental goals in densely settled landscapes in the Global South.

1. Introduction

Restoring forests has become a global policy objective [1–3]. During the UN climate conference (COP-26), 140 world leaders committed to end and reverse forest loss by 2030 [4]. This commitment joins a wide range of existing efforts at global, regional, and national scales, including the UN's 'Decade of Ecosystem Restoration', the World Economic Forum's '1 Trillion Tree' initiative (1 t.org), the African restoration initiative (AFR 100), and the Bonn Challenge of 2016 [5, 6]. India has pledged to increase tree cover with the goal of sequestering an additional 2.5–3 billion tons of CO2 by 2030 [7]. Tree planting is one of

the primary ways in which governments, organizations, and private actors pursue forest restoration targets [8–10].

Proponents argue that forest restoration can sequester carbon and preserve biodiversity [11, 12], while also contributing to the well-being of rural and indigenous people [13, 14]. An estimated 1.8 billion people live on lands needed to sustain key biodiversity goals globally [15]. However, research shows that the impacts of restoration interventions are variable. Many tree planting programs emphasize numerical targets for trees planted rather than long-term forest regrowth [16], resulting in low survival rates and limited forest cover change [9, 17, 18]. Globally, natural biodiverse landscapes risk being transformed into monoculture tree plantations [19]. Several recent reviews show that socio-economic benefits are also highly uneven [20, 21], and a growing body of research shows that tree planting interventions can have negative impacts on local people [22–24]. As tree planting grows rapidly, there is a need for better evidence to support policy design that can promote human and environmental objectives over the long term.

Stakeholder participation is widely viewed as an essential component of restoration policy [25–27]. Greater participation may help ensure that interventions respond to local needs and that people are invested in caring for planted forests [28, 29]. A well-established body of research shows that rural communities often manage forest resources effectively over long time horizons [30, 31], and that policies that promote community forest governance can support favorable outcomes for both human and environmental objectives [32–34]. However, research also shows that participatory resource management interventions are often tokenistic [35, 36]. Even where participation exists, it is often hard to sustain it beyond the project cycle [37]. Current discussions recognize that governance challenges are complex [38, 39]. Still, there remains a dearth of empirical evidence exploring the links between local participation and outcomes over long time horizons, especially in restoration projects [40]. This is a significant gap in scientific knowledge, given the rapid growth in tree planting targets that aspire to support sustainability goals into the future.

Our work fills this gap using a unique time-series dataset of 430 government-sponsored tree plantations created over the past forty years in Northern India. We complement this with survey data from 2400 quasi-randomly sampled households who use the plantations, along with in-depth interviews with key informants who are knowledgeable about the plantations. Our survey data includes detailed information on local participation in plantation planning and management over time as well as plantations' contributions to rural livelihoods. We use remote sensing to track forest cover change over time.

We hypothesize that where communities gain meaningful influence over plantation planning and management over extended time periods, there is a greater likelihood of sustained human and environmental gains. Planted forests take time to mature; where communities are involved in management, they may be better able to set rules, regulate use, and care for forests as they grow. At the same time, where planted forests respond to local needs and priorities, people may be more motivated to continue to manage forests over time, particularly if they expect future benefits as forests grow. To study this, we created a variable which we refer to as 'continuous participation'. Continuous participation indicates that local forest users were involved in decision-making at the time of plantation (for example, by selecting species or location) and that they continue to exercise de facto control over management at the time of our surveys (2018).

Importantly, our variable 'continuous participation' does not refer to a specific institutional arrangement or bundle of management rights. It is a measure that signifies long-term, *de-facto* influence on plantation planning and management. Our data shows that continuous participation exists under a variety of conditions and in the context of different tree planting initiatives—including, in a few cases, projects without a planned participatory component. As we describe below, we thus understand continuous participation less as the direct result of planned interventions, but as part of a broader set of organic social interactions at the intersection of state and society. This variable offers a unique opportunity to study the relationship between empowered local governance and human-environmental outcomes over time.

We find that continuous participation is associated with greater livelihood contributions from forest plantations as well as greater improvement in forest cover. Our work points towards complex and multidirectional interactions between local involvement and long-term human and ecological outcomes. We suggest these outcomes may be the result of the ways that local influence can bring external interventions into alignment with local needs and interests, thus supporting greater local investment in plantation care and management over time.

These findings have important implications for forest restoration policy and nature-based climate solutions. At a time when tree planting is promoted as a short-term action for the current climate crisis, our work highlights the need for a longer-term view: sustained positive outcomes may require arrangements that support local people's ability to care for planted forests into the future. Drawing insights from our study, we discuss the need to move beyond 'best practice' principles for planned interventions toward a paradigm that supports sustained progress for human and environmental goals over long time horizons.

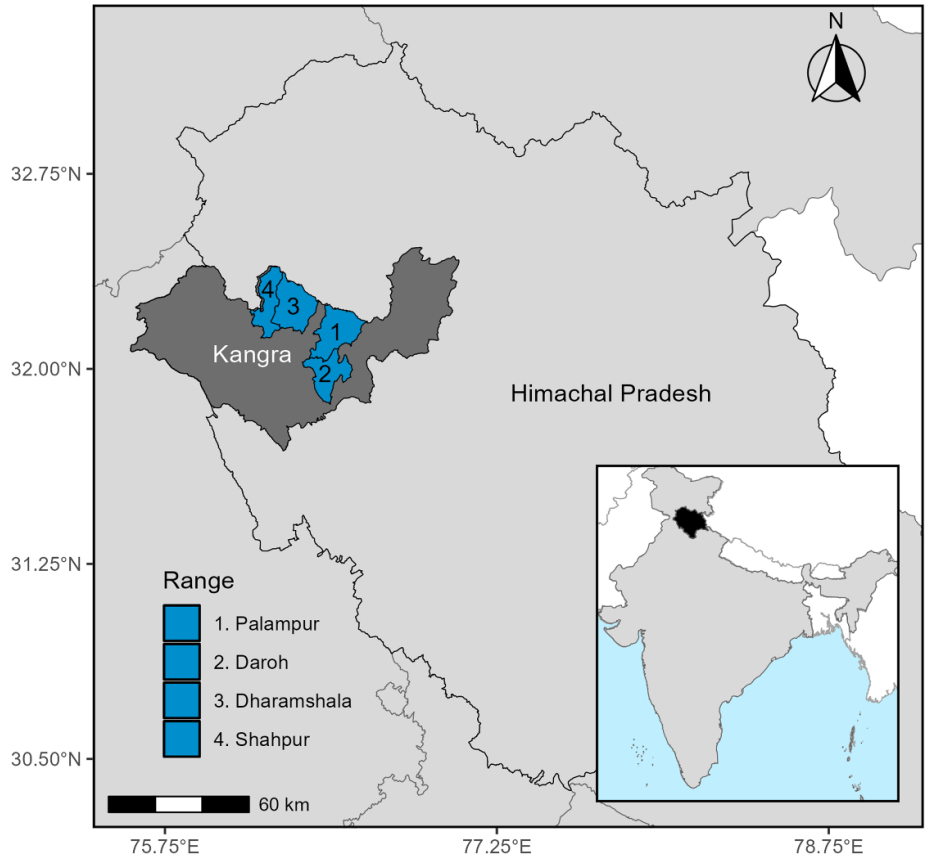

Figure 1. Map of our study context. Our sample includes 430 government-sponsored tree plantations undertaken over the past 40 years and 2400 rural households, nested within 60 *panchayats* (local government units) in the Palampur, Daroh, Dharamsala and Shahpur ranges (a forest sub-administrative unit) of the Kangra District, Himachal Pradesh, India.

2. Study area and data

India's history of large-scale tree planting makes it an excellent place to study long-term outcomes from restoration [41]. Our study area is in the Kangra District of Himachal Pradesh (figure 1). Himachal Pradesh has seen substantial tree planting—according to government records, an area equivalent to 845 188 hectares between 1979 and 2015 [42]—with a long history of policies for decentralized forest management [43]. Like many rural contexts targeted for restoration, the Kangra District is a densely settled rural landscape, where forest patches are interspersed with agriculture, grazing land, and human settlements (SI 0). See SI 1 for overarching details on our data collection. We briefly summarize important points here.

We collected data on 430 tree plantations planted from 1980 to 2018 in 60 randomly selected *panchayats* (local government units) in the Palampur, Daroh, Dharamsala and Shahpur *ranges* (a forest department sub-administrative unit). Based on satellite images, we estimate the percent of each plantation classified as '*dense forest canopy*' (canopy >40%) in six different years between 1991 and 2018 (SI 2). We also surveyed 2400 quasi-randomly selected households from the same 60 *panchayats* (40 households per panchayat). This provided data on the benefits households derive from plantations, including fuelwood, fodder, and land for animal grazing.

Our previous work from the study area has shown that tree plantations have not achieved statistically significant improvements in canopy cover nor great livelihood benefits on average [18]. However, growth trajectories vary across plantations in our dataset. Forest cover may grow more in plantations with certain characteristics and less (or even decline) in others, implying that a null trend on average masks informative variation. Moreover, 62.9% of our household sample used plantations for different needs. Products derived from planted forests contribute to many households' well-being both directly (by providing cooking and heating fuel, forest foods, fibers, and building materials) and indirectly (for example by feeding livestock, an important source of income and nutrition). Usage rates are higher for poorer and more marginal households (SI 3). They also vary with plantation characteristics like age and distance from the road [18].

This variation across our sample suggests that some plantings have been more effective at improving forest cover and supporting rural livelihoods.

We explore whether continuous participation helps explain some of this variation in outcomes.

3. 'Continuous participation' and tree planting outcomes

Contemporary policy discourse widely calls for stakeholder participation. However, several factors have interfered with accumulative learning about participation's role in human & environmental outcomes: the wide variety of ways participation occurs in practice, the difficulty of synthesizing available evidence, and the gap between participation's promise and tokenistic implementation [35, 36, 44]. Our dataset includes extensive details about local participation, thus providing a unique opportunity to study the role of actual community involvement over time: what we call 'continuous participation'.

There are many reasons that participation may not occur, even where projects have a 'participatory' component. Participation is often limited to notional attempts to solicit input, with limited opportunity to influence overall project goals [35]. External interventions can struggle to encourage local collective action where it does not already exist [45]. Even where participation does occur, local people often encounter costly 'frictions' that may dissuade them from continuing if they see no benefit from it [46, 47]. On the other hand, when local people choose to participate in planning and managing ecosystem interventions, it may signal a better fit between the intervention, the institutional context, and the community's needs [28, 48].

We define 'continuous participation' as any case where a community has some form of substantive influence over planning and management during initial planting stages and continues to exercise authority over management today. Two points are worth emphasis. First, 'substantive influence' implies that participation is *de facto* and not just *de jure*; communities are exercising real influence across a plantation's lifecycle, rather than having formal rights which they may not be able to take advantage of in practice [49]. Second, we assume there is no specific venue or forum in which participation must occur: local actors may sometimes participate through the local government, through local institutions with formal rights over forests, or through informal channels (e.g. connections with politicians or career bureaucrats). Theory suggests that resource management practices should adapt to local socio-ecological conditions [48], and the 'best' forum for participation may vary from site to site or even within a site over time. We thus do not assume that any observed form of influence is necessarily better.

We discuss our data collection, operationalization, and measurement of the variable *Continuous Participation* in SI 1 & SI 6. Briefly, we conducted interviews with key informants with direct, long-term knowledge about plantation and forest governance history, typically people in formal and/or customary positions of authority over forests (e.g. the *Rakha*, a traditional forest authority, elected forest committee member, or local forest guard). Our variables are constructed from several different survey questions that capture overarching aspects of plantation planning and management on our plantation-level survey, and we undertook rigorous field-testing to assess their viability in different contexts.

Continuous participation is constructed based on two separate variables derived from our plantation-level surveys—*initial participation* and *participation now*. We classify a plantation as having *initial participation* if, at the time of planting, the panchayat government, a co-management institution (e.g. a Joint Forestry Management institution, or co-operative forest society), or community members more broadly (a residual category capturing other kinds of informal participation) perceive that they had influence on the planting, either in choosing its location or species. We classify a plantation as having *participation now* if either a co-management institution or community members more broadly currently exercise *de facto* management authority. This may include defining use rules, regulating use, sanctioning of infractions, extinguishing fires, or other forms of management. (See SI 6 for further details).

We find that 333 of 430 plantations in our sample in which there was some kind of community participation during a past planting event (*initial participation*), and we identify 131 of 430 plantations that have some kind of substantive community participation now (*participation now*). We classify 113 plantations as having *continuous participation* for having both, suggesting long-term sustained influence on planting and management. Note that only 15 plantations have 'participation now' alone. Thus, the primary distinctions we can draw are between no participation, participation at planting alone, and sustained participation over time (but not participation during later management alone). However, these distinctions are also the most relevant to our theoretical arguments, allowing us to compare plantations with only initial participation to those with long-term participation in management.

4. Forest cover change

To study forest cover change, we estimate linear mixed effects regression models using our panel dataset of 430 plantations. The dependent variable is percent dense forest canopy (ranging from 0 to 100). The model includes controls for several relevant

Table 1. Tree planting, participation, and forest canopy cover. Coefficient estimates and Satterthwaite p-values from a linear mixed effect regression with plantation and year random effects. Observations are plantation areas observed at six different time points (1991, 1993, 1996, 1998, 2009, and 2018). The outcome is percent dense forest canopy cover within the plantation's boundaries (land area with canopy density >40%), ranging from 0–100. Each model controls for plantation area (log), elevation (log), slope (log), and distance from the road in minutes (square root), all mean-centered. The interaction term Continuous *x* Age indicates that plantations with substantive, long-term participation in plantation planning and management gain 0.249 percentage points more dense forest canopy every year (9.96 percentage points more after 40 years). This suggests that long-term empowered local governance is associated with greater improvements in forest canopy cover over time.

	Model (1) *Estimate (p-value)*
Plantation age	−0.069 (0.458)
Continuous participation	0.896 (0.754)
Continuous *x* Age	0.249* (0.031)
Intercept	51.676*** (<0.001)
Plantation controls	Yes
SD (intercept | plantation)	23.405
SD (intercept | year)	3.071
Years	6
Plantations	430
Observations	2580

$+p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

plantation characteristics (SI 7), a measure we call *Plantation Age* (years since a plantation was established, or 0 if it is not yet established), and crossed random intercepts for both plantations and years. We estimate a linear age trend (i.e. assuming forest cover increases at the same rate with each additional year of age) in the interest of more efficiently comparing average annual rates of forest growth in different groups of plantations.

Specifically, our regression model interacts *plantation age* with a binary indicator for *continuous participation*. This allows us to evaluate whether forest cover increases more quickly in plantations with long-standing participation. We are most interested in the slope coefficient for the interaction (*Continuous x Age*), representing the estimated difference in dense forest canopy trends between participatory and non-participatory plantations. See SI 7 and SI 12 for more details and SI 9 for summary statistics.

We find that dense forest canopy increased more quickly in plantations managed with continuous participation (Model 1 of table 1). In fact, in other plantations we estimate an average annual decline in forest cover (0.069 percentage points per year), though the effect is substantively small and not statistically significant. On the other hand, the annual dense forest canopy trend was +0.249 percentage points greater in plantations managed with continuous participation. This difference in trends is statistically significant. From the model parameters we estimate that over a span of 40 years, dense forest canopy in plantations with continuous participation increases by 9.96 percentage points more than it does in other plantations.[11] Results in SI 12–13 suggest that this finding may be attributable to the value-added of ongoing participation. This finding is also robust to alternative models (SI 14, SI 19).

Figure 2 illustrates our estimated differences in forest canopy cover between plantations with and without continuous participation. We plot the differences between predicted values of forest canopy for each of the plantation ages in our data, along with 95% confidence intervals. The average trends with and without continuous participation are statistically distinguished roughly 20 years after planting occurs. This implies that continuous participation is associated with long-term improvements in forest cover, which becomes pronounced as trees mature. We provide descriptive summaries across participation regimes in SI 19.

5. Modeling livelihood benefits

To test whether plantations with continuous participation provide greater livelihood benefits, we construct a dataset where each unit of observation is an individual household in our survey (2400 total) paired with each one of the plantations in their panchayat (*household-plantation pairs*). These data include 18 720 household-plantation pairs. On average, each household has the opportunity to use 7.8 (=18 720/2400) plantations within their panchayat (SI 3).

The dependent variable is a binary measure from our household survey indicating whether the household extracts any livelihood benefit from the plantation ($Y = 1$) or not ($Y = 0$). This may include fuelwood, fodder, or a variety of products (SI 16). We estimate two linear mixed effects regression models, each including crossed random intercepts for both panchayats and plantations. With a binary outcome, linear regression slope coefficients represent change in the probability of $Y = 1$ associated with a unit increase in a given independent variable.

The first model includes only a fixed intercept and a control for the number of plantations in a household's panchayat (grand mean centered). The second

[11] At the end of a 40−year period, we estimate that plantations with continuous participation see 7.2 percentage points more dense forest canopy on average, while others see 2.76 percentage points less.

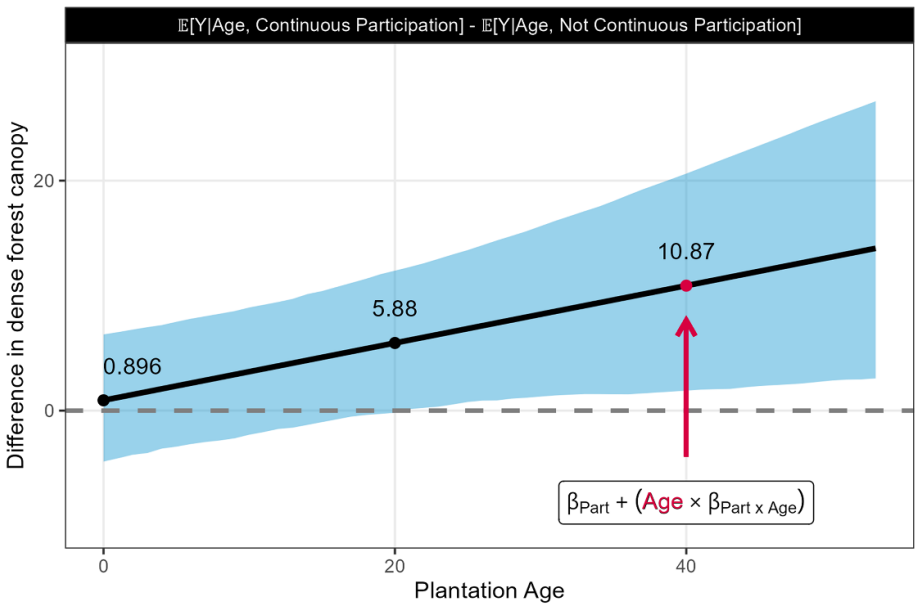

Figure 2. The differences in dense forest canopy trends between plantations with and without continuous participation. Based on model 1 in table 1, with 95% CIs (blue shaded region). *X*-axis is the number of years following a plantation event, and the *Y*-axis is the percentage point difference in forest canopy change between plantations with and without participation. The difference in trends becomes statistically distinguishable from zero after approximately 20 years, suggesting that gains associated with continuous participation become noteworthy through sustained continued care and management as trees mature over time. The value at Age = 0 represents the negligible (and statistically insignificant) average difference in dense forest canopy among sites just or not yet planted. Values at other ages add the estimated coefficient for continuous participation (β_{Part}) to the coefficient for the difference in trends associated with continuous participation ($\beta_{\text{Part x Age}}$), multiplied by the relevant plantation age.

Table 2. Tree planting, participation, and livelihoods. Coefficient estimates and Satterthwaite *p*-values from linear mixed effects regressions with plantation and panchayat random effects. Observations are households paired with each of our sample plantations in their locality (i.e. household-plantation pairs). The outcome is binary: whether a household uses a given plantation for any purpose (e.g. fuelwood, fodder, food, or other). All models control for the total number of plantations in a panchayat, including those outside our study sample. This control is mean-centered so that the intercept in model 1 represents an estimated baseline probability. Standard deviations of the plantation and panchayat random effects are in the footer. Model 2 suggests that an average household is 2.3 percentage points more likely to extract benefits from a plantation in their panchayat managed with substantive, long-term participation (continuous participation), relative to a baseline probability for other plantations of 3.7% (i.e. a 62.16% increase). The estimate is largely unchanged when introducing a battery of plantation, household, and panchayat controls. This implies that long-term empowered local governance is associated with greater livelihood benefits from plantations.

	Model (1) *Estimate (p-value)*	Model (2) *Estimate (p-value)*	Model (3) *Estimate (p-value)*
Intercept	0.043^{***} (<0.001)	0.037^{***} (<0.001)	0.002 (0.963)
Continuous participation		0.023^{**} (0.008)	0.021^{*} (0.012)
Additional controls	*No*	*No*	*Yes*
SD(intercept | plantation)	0.061	0.06	0.057
SD(intercept | panchayat)	0.032	0.032	0.030
Panchayats	60	60	60
Plantations	430	430	430
Observations	18 720	18 720	18 720

$+p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

adds our independent variable of interest: a binary indicator for whether a plantation has been managed with continuous participation. The third model adds a variety of controls for household socio-economic characteristics, plantation characteristics, and environmental characteristics of each panchayat (our covariates are discussed in SI 5). See SI 7 and SI 11 for more discussion of this analysis, and SI 8 & 10 for summary statistics.

We find that households are more likely to receive livelihood benefits from plantations that have been managed with continuous participation. Model 2 of table 2 shows that households are 2.3 percentage points more likely to derive livelihood benefits from

a plantation managed with continuous participation. The estimate for continuous participation represents a 62.16% increase relative to the baseline of 3.7%.[12]

Long-term participation in plantation planning and management is thus a strong predictor of livelihood benefits from planted forests. SI 11 and SI 13 also show that continuous participation is associated with an increase in use, and similar findings hold with household random effects (SI 18).

The association between continuous participation and the probability of livelihood benefits persists after introducing controls for a variety of household, plantation, and panchayat characteristics (model 2). Notably, we also find that the coefficient estimate for continuous participation is comparable to other variables associated with forest use, for example level of wealth, livestock ownership, and availability of alternative cooking fuels (SI 17). This implies that continuous participation is as strong a predictor of livelihood benefits as other socio-economic factors and rural livelihood needs.

6. Discussion

Amidst the growing global focus on forest restoration, there is an urgent need for knowledge of the conditions that support progress toward both human and environmental goals. While much current work offers short and medium-term policy guidance [25, 26], less remains known about the conditions that will support continued gains into the future. Our study offers a unique opportunity to fill this gap through original empirical data on tree planting over nearly four decades. We find that sustained, long-term local influence on planning and management is associated with positive gains for tree cover and livelihoods. These findings have implications for theory and practice.

We find that continuous participation is associated with long-term improvements in dense forest canopy cover. The gains were relatively modest: a 9.76 percentage point increase over a 40 year period, relative to a slight decline in plantations without continuous participation (−2.76 percentage points). This is not a large-scale expansion of forest cover projected by some aspirational projections [50, 51] but is comparable to observed outcomes in other contexts [52, 53]. Kangra may thus be similar to other agrarian landscapes globally [54, 55], where existing land uses mean that spaces for forest expansion are constrained [56]. We see a 9.76 percentage point difference as meaningful in the context of current global challenges, where any progress toward carbon sequestration can contribute to addressing climate change.

When considering livelihoods, we find a 62.16% increase above the baseline probability that a plantation will provide benefits. Notably, nearly two-thirds of households in our sample derive subsistence benefits from plantations, which contribute to well-being in multiple ways (SI 3). Our work thus shows that livelihood benefits of tree planting can be of broad local interest, and that greater contributions are associated with long-term local participation.

Our most significant finding is that it is substantive, long-term participation that shows an association with both forest cover and livelihood gains. Participation at the time of planting alone shows no such relationship. This finding stands in contrast with many tree planting programs at present, which often pursue participation within the bounds of planned projects and initial monitoring [26] but commonly fail to sustain local involvement over time [37]. As very few plantations in our study only have participation now, we cannot empirically distinguish between this and continuous participation. Even so, our findings still underscore that it is participation in management as a plantation grows, rather than initial participation alone, that is associated with forest cover and improved livelihoods.

These associations point toward complex socio-ecological relationships, and we therefore caution against mono-directional causal interpretation of our results. Existing research points to several different relationships that may explain this correlational finding, and we encourage future research that can credibly isolate them. First, local participation may simply make tree planting more effective. In densely settled landscapes such as Kangra, participation may help to connect tree planting with local needs and conditions. Existing research shows that forest officials often face pressure to fulfill targets yet have limited local land use knowledge, resulting in the planting of species that people do not value, in places where they may not grow, or where they face competition with other land uses [22, 24]. In contrast, local participation may enable people to influence planting according to their needs and local land-use dynamics [57]. While existing research shows that local users are often better placed to make time- and place-specific management decisions of existing forest commons [30], our work provides evidence that this may also hold for the recovery of forests through large-scale tree planting programs.

Second, there may be a relationship between long-term improvements in forest cover, local benefits, and continued involvement. The logic is simple: where people perceive benefits or anticipate them in the future, they may be more motivated to manage forests to sustain those benefits over time. This is one

[12] A majority of the households in our sample derive some livelihood benefits from tree planting, but most households use only one or two plantations. Meanwhile, most panchayats are host to many plantations, hence a low usage rate for any one plantation-household pair. Most households also do not report mean or high 'dependence' on plantations. See SI 3–4 for more.

reason that secure tenure may help to encourage local forest management [58], but it is also important that planted trees align with local priorities [16]. Where projects reflect local needs, this may encourage long-term care of planted trees, resulting in a positive feedback between rural benefits and long-term sustainability goals.

Our findings lend evidence for both relationships. 'Initial participation' indicates influence on species selection or location on the landscape (SI 6, figure S3a), which suggests that people have been able to incorporate local priorities and landscape knowledge into planning processes. Yet, this alone is not enough—continued *de facto* management ('Participation now') is also important. In practice, this could include a variety of activities including community involvement in defining rules, forest monitoring, enforcement, and fire extinguishing (SI 6, figure S3b). Interestingly, our data suggests that where there was no participation at the time of planting, it is uncommon to emerge later, which implies that initial influence and associated benefits may help incentivize management thereafter. Yet we also find a substantial portion of plantations for which participation occurred initially but is not sustained, and this points toward a deeper question: from where does participation come to begin with?

This is a key question, and ultimately our data is not able to pinpoint why participation has emerged in particular contexts or what sustains it over time. Importantly, continuous participation implies more than project-based forums; it signifies substantive *influence* over a longer time horizon. This suggests that there may be something more fundamental about how relationships between citizens and government officials take shape over time. Existing research suggests that policy arrangements that formally-recognize local institutions and designate authorities under their control can help to open up new opportunities for locally-driven governance [32, 59]. Research from the study area shows that local actors often rely on a wide range of other informal interactions—from personal relationships with low-level forest officers to broader political networks—to access and influence interventions [60]. In either case, building more empowered local governance is a long-term process as local actors become more skilled at advocating for their needs and administrative actors learn ways to respond [61]. Future research may better disentangle the relationship between socio-political context, institutional design, and long-term restoration gains.

Our findings are nevertheless important, since they point toward generalizable conditions under which tree planting may be more successful for both human and environmental outcomes. In current policy discussions, tree planting is often discussed as an immediate point of action for our present climate crisis, while the much larger process of decarbonizing our economies unfolds over time [50, 51]. Accordingly, recent years have seen very large tree planting and forest restoration commitments [4, 6] and a burgeoning body of scientific literature seeking to optimize these investments [25]. Our work, however, suggests that long-term outcomes are likely to require far more than well-crafted interventions in the present. To be successful, current financial outlays may need to be accompanied with institutional reforms and other strategies that provide a deeper redistribution of power and capacities to local actors to manage planted forests over the long-term. In other words, sustained community participation may be a crucial element of moving from policy's current emphasis on target-based tree planting toward a focus on long-term tree growing for multiple human and environmental goals [9].

Our work aligns with calls for a paradigm of 'people-centered restoration' [16, 28]. At present, tree planting efforts are targeting landscapes in the Global South, where millions of people live [54, 55]. Yet these investments continue to be motivated primarily as a response to urgent environmental crises, while livelihood contributions are often described as 'co-benefits' [62]. Our work implies the need to invert this focus: putting a focus on local people's needs first may offer a valuable opportunity to also encourage long-term environmental gains. Governance arrangements that provide rural and indigenous people rights and opportunities to manage local forests are not just ethically desirable; our work suggests that such arrangements may help to promote positive outcomes for both humans and the environment over time.

Data availability statement

The complete dataset from which this publication is derived is available at the University of Minnesota Data Repository: https://doi.org/10.13020/j6sj-jw18.

The data that support the findings of this study are openly available at the following URL/DOI: https://figshare.com/s/87bfcae7f5c8f93f5cb0.

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Ethics & inclusion

This project has complied with all relevant ethical regulations, including standards of informed consent. The project was reviewed by the University of Minnesota ethics board, IRB ID00002044. We strive for an inclusive authorship team, and we have involved multiple researchers from the study area who participated in the design, implementation, and development of outputs from this research.

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