Pro-poor child nutrition gains from decentralised forest governance

Supplementary information

Contents

Supplementary Discussion

1. Main-effects-only model

Our primary analysis includes an interaction term between Community Forestry coverage and baseline poverty. We can remove this interaction term to focus exclusively on the effect of Community Forestry on socioeconomic deprivation. The results indicate that, controlling for confounders, including baseline poverty, Community Forestry was associated with declines in household socioeconomic deprivation (**Figure 1**).

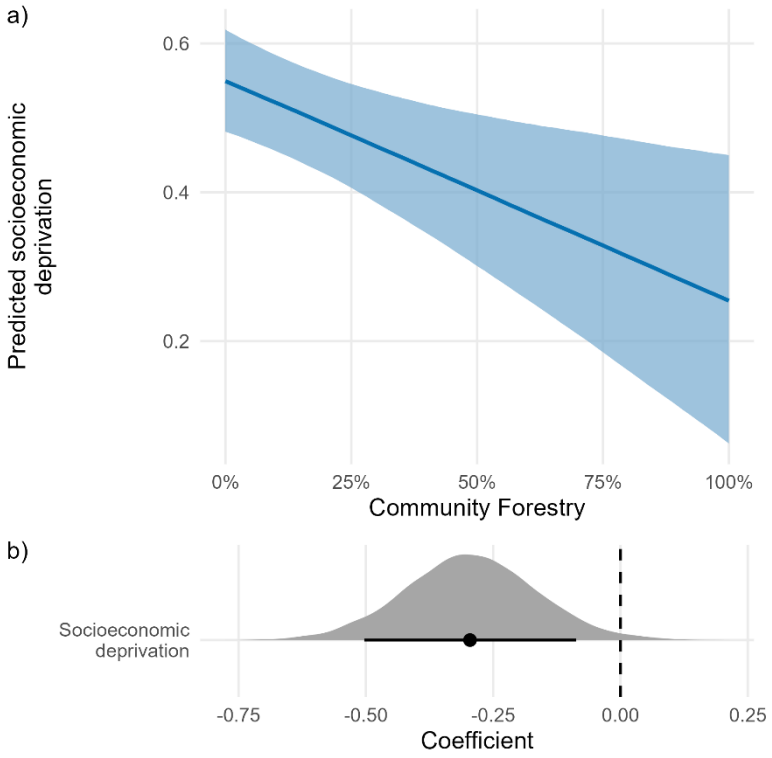


Figure 1. Posterior estimates from the Bayesian mediation analysis. Panel (a) shows the effect of Community Forestry (percentage of Village Development Committee area under Community Forestry) on household socioeconomic deprivation. The solid line is the posterior median, and the light blue band shows the 89% credible interval. Panel (b) shows posterior distributions for the estimated associations of Community Forestry on socioeconomic deprivation. Grey densities show posterior distributions, points show posterior medians, and black bars show 89% credible intervals on the odds-ratio scale. Values above 1 indicate higher predicted odds of the outcome, while values below 1 indicate lower odds.

2. Caste and ethnicity

Substantial evidence shows that, within communities, households with greater political, social, or economic advantage tend to disproportionately benefit from Community Forestry[1–4]. We sought to evaluate this through a sub-analysis that substituted baseline Village Development Committee-level multidimensional poverty with an indicator of household-level ethnicity and caste, defined as the majority ethnic or caste group among household members.

Following DHS classifications and recent empirical work[1,5], households were assigned to four groups: Brahman/Chhetri/Newar (BCN), Janajati (excluding Newar), Dalit, and other minority groups (Table 1). These categories reflect established differences in social and economic position in Nepal. BCN groups have historically held a relatively advantaged economic, social, and political status[1,6]. In contrast, Dalit castes and Janajati groups (state-recognised indigenous and ethnic minority groups) have experienced persistent marginalisation and worse socioeconomic outcomes[1,7]. Other minority groups, including Muslims and Tarai/Madhesi castes, also face marginalisation linked to caste/ethnic status and regional exclusion[1,7].

Table 1. Ethnicity/caste classification used in analysis, following[1,5].

Analytical group	**DHS major groups**	**Subgroups**
Brahman/Chhetri/Newar (BCN)	Brahman/Chhetri (Hill and Tarai/Madhesi)	Hill Brahman; Hill Chhetri; Thakuri; Sanyasi; Tarai Brahman; Rajput; Kayastha; Bhumihar
	Newar	All Newar
Dalit	Dalit	Hill Dalit (e.g. Kami, Damai, Sarki); Tarai Dalit (e.g. Chamar, Musahar, Tatma)
Janajati	Janajati (excluding Newar)	Hill/Mountain Janajati (e.g. Magar, Gurung, Rai, Limbu, Tamang); Tarai Janajati (e.g. Tharu, Rajbanshi)
Other minority	Muslim	Hill and Tarai Muslim groups
	Tarai/Madhesi other castes	Non-Brahman/Chhetri Tarai caste groups (e.g. Yadav, Teli, Kurmi, Koiri)
	Other minorities	Remaining caste and ethnic groups

The association between Community Forestry and household deprivation varied by caste/ethnicity (**Figure 2**). The strongest negative association was estimated for Dalit households, for whom predicted socioeconomic deprivation declined substantially as Community Forestry coverage increased. Janajati households showed a weaker negative association, while BCN households showed little change across the Community Forestry gradient. These results – specifically the strongest treatment effect for Dalit households – were unexpected, as there is strong and consistent evidence of elite capture within Community Forestry in Nepal[1–4]. One plausible explanation is that if BCN households already have lower deprivation, there may be less scope for socioeconomic deprivation to decline (**Figure 3**). In contrast, Dalit households may have higher baseline deprivation, so even small improvements in living conditions or education could produce a larger change in socioeconomic deprivation. Elite capture of

the broad suite of benefits from Community Forestry by BCN households might be occurring simultaneously with the alleviation of severe deprivation among Dalit households.

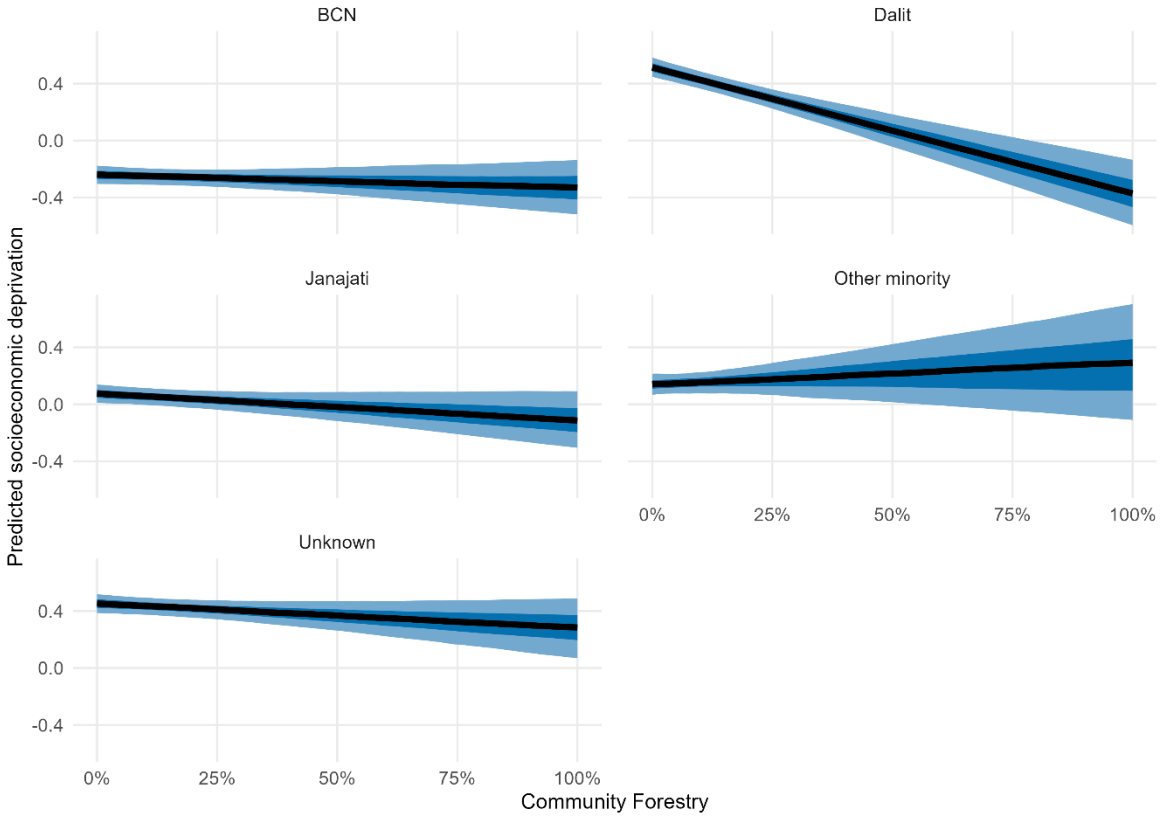


Figure 2. Posterior estimates from the Bayesian mediation analysis, with Community Forestry moderated by caste/ethnicity. The marginal effect of Community Forestry (percentage of Village Development Committee area under Community Forestry) on household socioeconomic deprivation across Brahman/Chhetri/Newar (BCN), Janajati (excluding Newar), Dalit, other minority, and unknown groups. The solid line is the posterior median; dark and light blue bands show 50% and 89% credible intervals.

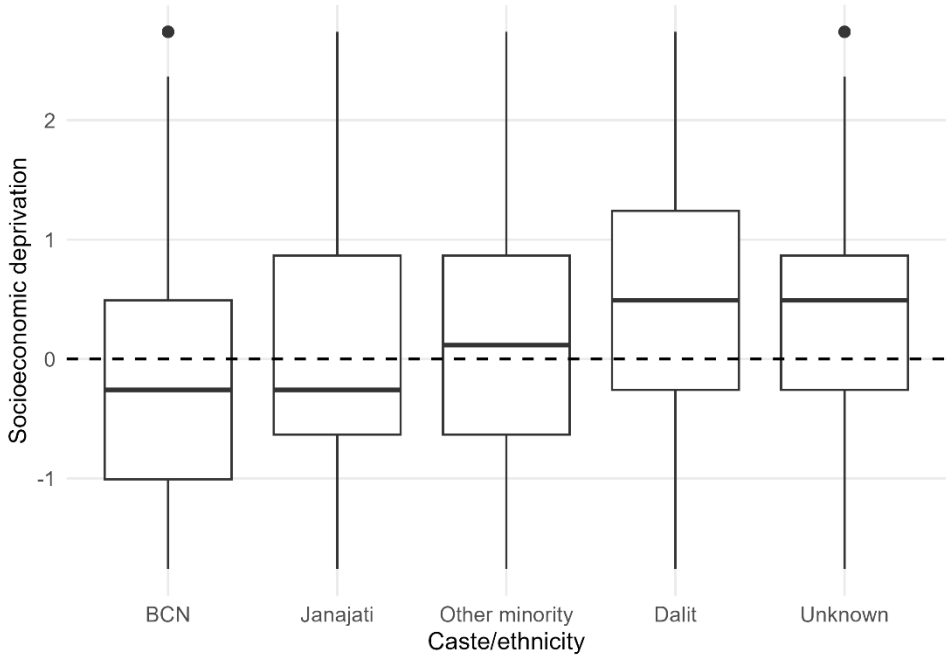


Figure 3. Distribution of socioeconomic deprivation scores between Brahman/Chhetri/Newar (BCN), Janajati (excluding Newar), Dalit, other minority, and unknown ethnicity/caste groups.

3. Dietary diversity

Dietary diversity is a core component of diet quality[8]. We constructed a child dietary diversity indicator following Rasolofoson et al.[9] using DHS child-feeding variables from the previous day. This approach is an adaption of the food grouping recommended by the United Nations Food and Agriculture Organization[10]. Food items were grouped into 10 dietary categories: cereals; vitamin A-rich vegetables; roots and tubers; dark green leafy vegetables; vitamin A-rich fruits; other fruits and vegetables; meat, fish, and organ meats; eggs; legumes, nuts, and seeds; and dairy products. A point was given whenever one or more food items within a given category were consumed, with the individual child dietary diversity score calculated as the sum of these ten group indicators (ranging from 0 to 10). Following Rasolofoson et al.[9], and to ensure comparability across Nepal DHS phases, we used the score for living children aged 12-23 months with valid feeding data. In addition to the individual-level indicator, we also calculated mean household scores. This resulted in observations from 2,618 children (aged 12-23 months) from 1,685 households. As an exploratory analysis, we repeated the primary analysis, substituting socioeconomic deprivation for dietary diversity scores. A full structured exercise to identify potential confounding variables for Community Forestry, dietary diversity, and child nutritional outcomes was not feasible. Therefore, we assumed that the same confounding variables likely to be associated with socioeconomic deprivation might also be associated with dietary diversity. Community Forestry showed a positive but statistically uncertain association with dietary diversity, possibly due to the relatively small household sample size (**Figure 4**). Dietary diversity was more strongly associated with nutritional outcomes.

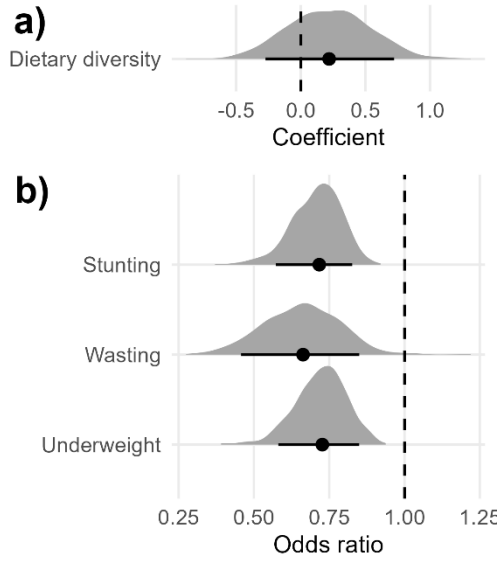


Figure 4. Posterior estimates from Bayesian models of the dietary diversity pathway. Panel (a) shows the association between Community Forestry (percentage of Village Development Committee area under Community Forestry) and household dietary diversity score. Panel (b) shows the associations between individual dietary diversity and child nutritional outcomes. Densities show posterior distributions, points show posterior medians, and black bars show 89% credible intervals.

4. Community-level deprivation

The primary mediator between Community Forestry and health outcomes in our analysis was household-level socioeconomic deprivation. However, some communities direct Community Forestry revenues to public goods like schools, irrigation, and community buildings[11]. These community-level characteristics can be important determinants of health outcomes, including those that were not strongly associated with household socioeconomic deprivation in our analysis, like anaemia, diarrhoea, and infant mortality[12–15]. Consequently, future research could explore community-level pathways through which decentralised natural resource management can affect public health outcomes. Such analyses could combine DHS Service Provision Assessments (although these are only available for 2015 and 2021) with indicators of community water, sanitation, and other public infrastructure. As an exploratory analysis, we used mean household socioeconomic deprivation within each DHS survey cluster as a proxy for community-level socioeconomic conditions. We then examined whether Community Forestry coverage was associated with this proxy and, in turn, whether this proxy was associated with each health outcome. This analysis is exploratory because it is a composition of household characteristics rather than true community-level infrastructure. Nevertheless, we found that Community Forestry had a strong negative association with Community socioeconomic deprivation; indeed, this relationship was stronger than that observed at the household level (**Figure 5**). Community socioeconomic deprivation, in turn, was associated with depression, stunting, underweight, and, to a lesser extent, wasting and anaemia. Consequently, the total effect of Community Forestry on health outcomes, which encompasses both household-level and community-level social determinants, may be larger than observed in our current analysis.

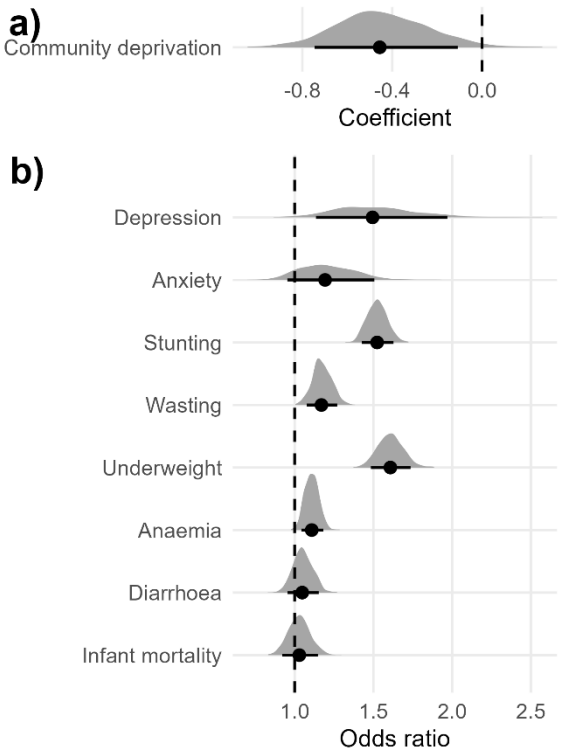


Figure 5. Posterior estimates from Bayesian models of the community socioeconomic deprivation pathway. Panel (a) shows the association between Community Forestry (percentage of Village Development Committee area under Community Forestry) and community deprivation (derived from aggregating household deprivation within DHS survey clusters). Panel (b) shows the associations between community deprivation and health outcomes. Densities show posterior distributions, points show posterior medians, and black bars show 89% credible intervals.

5. Identification diagnostics

Unmeasured confounding

We identify and adjust for plausible confounders through a structured evidence review and workshop with expert co-authors. One plausible confounder of the relationship between Community Forestry and socioeconomic deprivation was baseline local governance capacity. However, we were unable to adjust for this because comprehensive baseline data were unavailable. To quantify how strong such a confounder would need to be to invalidate our result, we conducted a formal sensitivity analysis using the sensemakr package following Cinelli and Hazlett[16]. We were unable to precisely replicate our Bayesian moderation analysis using the package or alternative software. Therefore, we fitted a frequentist linear regression version of the socioeconomic deprivation model, retaining the same confounder variables and including district and survey phase as fixed effects (rather than varying intercepts). The Village Development Committee and cluster varying intercepts could not be included, as Community Forestry coverage is constant within these units. Our primary results indicate that Community Forestry has stronger treatment effects within the poorest regions of Nepal. Therefore, in order to test the sensitivity of our headline results to unmeasured confounding, we centred the baseline poverty value at the 75th percentile. Consequently, the Community Forestry coverage coefficient in the following sensitivity analysis represents the effect in high-poverty areas.

The effect of Community Forestry coverage on socioeconomic deprivation was negative and statistically significant (coefficient = −0.34, 95% confidence interval = -0.45 to -0.22), but it only explained a small share of outcome variance (partial $R^2 = 0.0014$). The corresponding robustness value was 0.037, meaning that an unobserved confounder would need to explain at least 3.7% of the residual variance in both Community Forestry coverage and socioeconomic deprivation to reduce the coefficient estimate to zero. We explored whether any unobserved confounders as strong as our measured confounders would be strong enough to do so, but none appeared to do so: a confounder with three times the explanatory power of baseline agricultural effort (the most influential benchmark) shifted the estimate only from -0.34 to -0.29, which remained statistically distinguishable from zero (95% confidence interval: -0.40 to -0.17). Other benchmarks (e.g., based on baseline forest cover and travel time to population centres) also had insufficient effects. These results indicate that the estimated pro-poor effect is robust to confounders comparable in strength to measured structural covariates. However, given the small share of variance explained, our results may be sensitive to a sufficiently strong unmeasured confounder, potentially including baseline local governance capacity.

Positivity check for continuous Community Forestry exposure

To help evaluate the positivity assumption, we examined whether Village Development Committees with near-zero Community Forestry coverage had similar characteristics to Village Development Committees with positive coverage (**Figure 6**). To do this, we constructed a dataset by retaining one observation per Village Development Committee-phase combination and taking the mean of the covariates within each. We classified Village Development Committees as having near-zero Community Forestry coverage (≤1% of Village Development Committee area) or positive coverage (>1%) as a binary variable. We then fitted a Bayesian logistic model to predict positive Community Forestry coverage using the same covariates as the primary model between Community Forestry and socioeconomic deprivation. This is equivalent to estimating propensity scores for a binary treatment, where each predicted probability represents the estimated probability that a Village Development Committee had positive Community Forestry coverage, given its observed characteristics. We compared these predicted probabilities between Village Development Committees with near-zero and positive observed coverage. The two groups overlapped across much of the predicted probability range, suggesting that many Village Development Committees with and without Community Forestry coverage were comparable and providing partial support for the positivity assumption. However, the distributions were not identical, as Village Development Committees with positive Community Forestry coverage were more common at higher predicted probabilities. This indicates that estimates for these areas involve some extrapolation, meaning the model must infer the near-zero-Community Forestry counterfactual from Village Development Committees with less-similar observed characteristics.

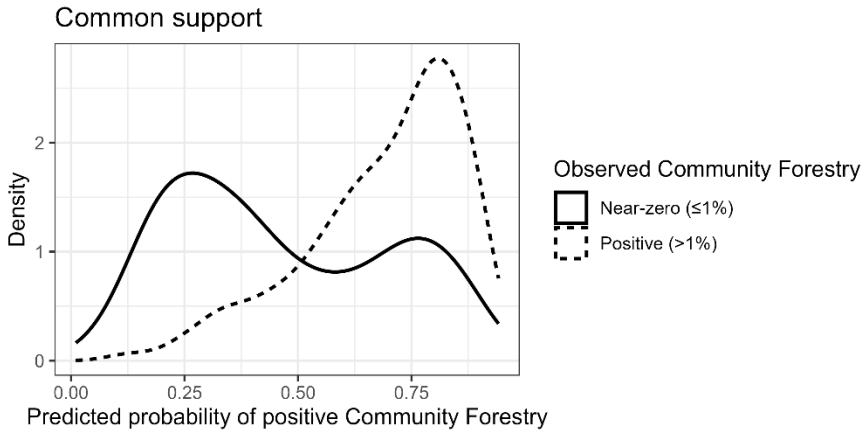


Figure 6. Predicted probabilities of positive Community Forestry coverage in areas with near-zero (≤ 1%) versus positive (>1% coverage) observed coverage at the Village Development Committee level.

Spatial and temporal dependence

We assessed residual spatial autocorrelation in the Community Forestry and socioeconomic deprivation model, where spatially structured confounding was most plausible (Figure 7). Residuals were calculated as observed socioeconomic deprivation minus predicted socioeconomic deprivation and aggregated to the DHS cluster-phase level (to avoid treating households within the same displaced cluster as independent spatial locations). Moran's I was then calculated separately for each survey phase. Residual spatial autocorrelation was weak. Moran's I was close to zero and non-significant in 2006 (I = 0.009, p = 0.426) and 2022 (I = -0.017, p = 0.360), but weakly positive in 2011 (I = 0.036, p = 0.009) and 2016 (I = 0.063, p = 0.003). This suggested there was negligible spatial autocorrelation.

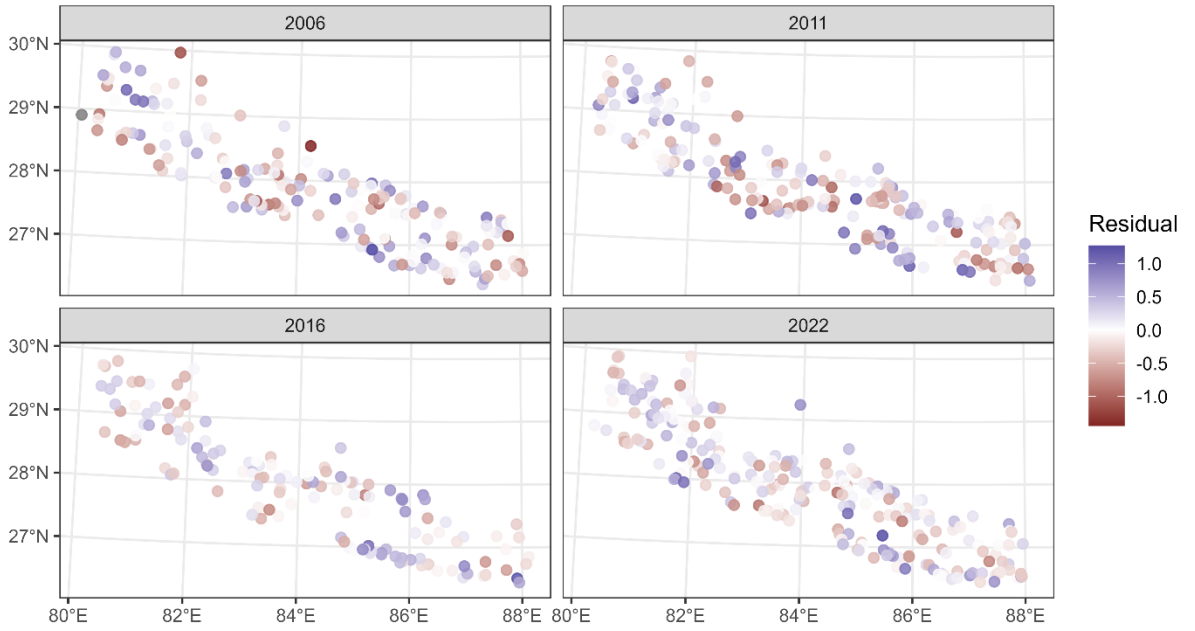


Figure 7. Spatial patterns of residuals from the Community Forestry and socioeconomic deprivation model.

We also sought to assess possible temporal dependence in model residuals. However, only 55 Village Development Committees (8.4% of all) were observed across more than one survey phase, so there were comparatively few repeated observations to robustly evaluate potential temporal dependencies. Among these repeated Village Development Committees, residuals showed no evidence of positive temporal persistence after accounting for the random effects. We therefore interpret this diagnostic as providing no clear evidence of temporal residual dependence, but note that the small repeated sample limits the strength of this conclusion.

6. Study phase

The Community Forestry model, and its role and importance within rural Nepali communities, has changed over time. Crucially, changes in livelihoods and increased remittance from out-migration have reshaped relationships between forests and people in many communities, reducing incentives to participate in Community Forestry[17]. Therefore, we sought to explore whether the treatment effect varied by survey phase. The results suggest that the strongest treatment effect was observed in 2006, with the treatment effect becoming weaker and more uncertain in later survey phases (**Figure 8**). This suggests that the greatest public health benefits might have been realised in the earlier years of the Community Forestry programme, with benefits attenuating in later years.

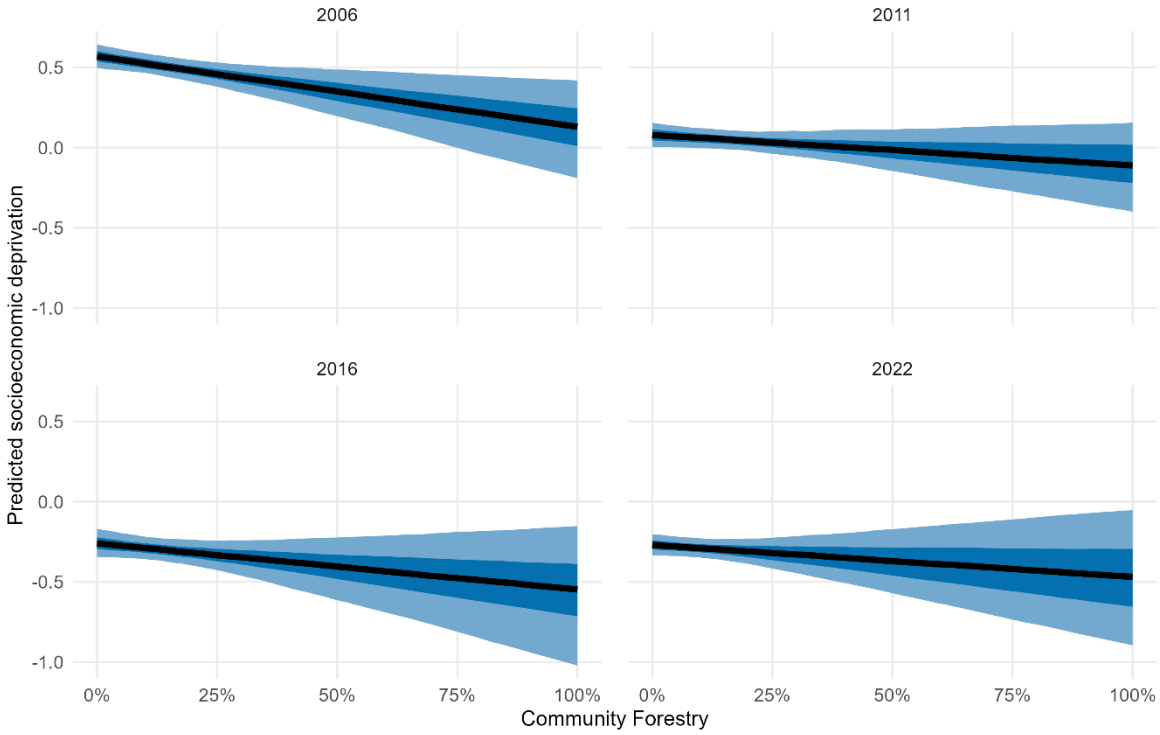


Figure 8. Posterior estimates from the Bayesian mediation analysis, with Community Forestry moderated by DHS phase. The marginal effect of Community Forestry (percentage of Village Development Committee area under Community Forestry) on household socioeconomic deprivation across DHS phases. The solid line is the posterior median; dark and light blue bands show 50% and 89% credible intervals.

Additionally, in 2013, Nepal introduced its National Health Insurance Program, which aimed to increase affordable access to healthcare[18]. After initial piloting in 2016, the programme has expanded to the national level. The programme heavily subsidises the premiums to certain vulnerable groups, including the very poor[18]. Consequently, it represents a potential time-varying moderator variable between household socioeconomic deprivation and health outcomes, as extremely poor households could avail of the programme and thus attain comparatively better health outcomes. This effect is not a confounder, as the ability to avail of subsidies is a consequence rather than a cause (i.e., is downstream) of household socioeconomic deprivation. Nevertheless, to explore this effect, we repeated the analysis of health

outcomes, including an interaction term between socioeconomic deprivation and a dummy variable identifying observations in the 2006-2011 and 2016-2022 phases. The results suggest relatively consistent associations between socioeconomic deprivation and health outcomes across the two phase groups (**Figure 9**).

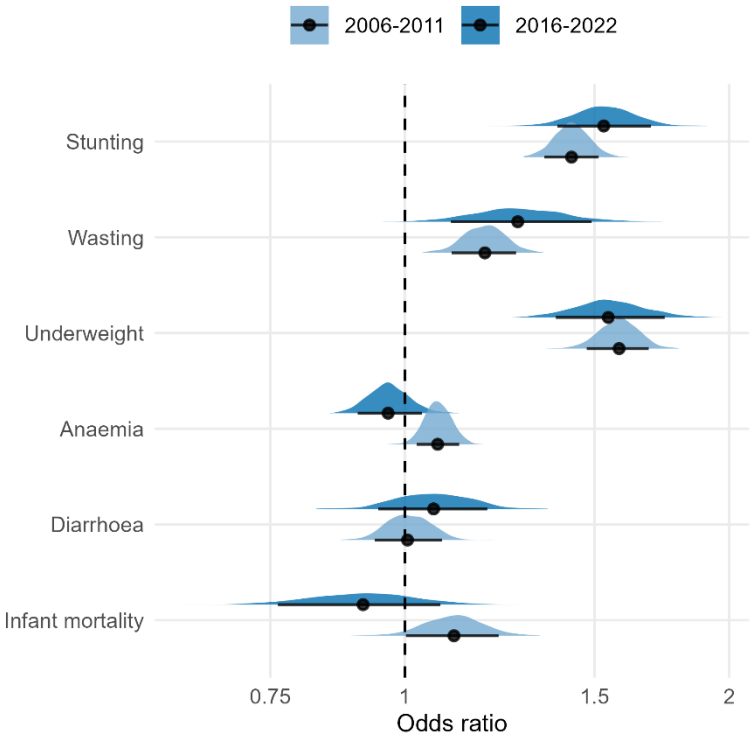


Figure 9. Posterior estimates from the Bayesian mediation analysis, with Community Forestry moderated by pre- and post-2016 phases. Posterior distributions for the estimated associations of socioeconomic deprivation on binary health outcomes in 2006-2011 (light blue) and 2016-2022 (dark blue) phases. Densities show posterior distributions, points show posterior medians, and black bars show 89% credible intervals on the odds-ratio scale. Values above 1 indicate higher predicted odds of the outcome, while values below 1 indicate lower odds.

7. DHS sampling approach

The DHS Program seeks nationally and sub-nationally representative estimates for key demographic and health indicators. To achieve this, the DHS Program uses multistage probability samples, following these steps:

1. An initial sampling frame (a complete list of all sampling units covering the target population) is defined. This is typically based on a recent population census, which provides a complete list of enumeration areas (usually geographic areas that group several households for census purposes).
2. Each enumeration area is classified into strata by administrative region and by urban or rural residence.
3. Enumeration areas within each strata are sampled using 'probability proportional to size', where the size is the census count of households or population within the enumeration areas. This sample of enumeration areas is called the primary sampling units and forms the survey cluster.
4. Field teams visit each primary sampling unit and prepare a fresh, complete list of all households. This list represents the second sampling frame (i.e., the sampling frame used in the second sampling stage).
5. Within this second sampling frame, a fixed number of households (commonly 20 to 30) is selected systematically with equal probability from the survey cluster.
6. Within each sampled household, a series of Household, Women's, Men's, and other surveys are conducted.

Sample weights are the overall probability that a household is sampled, which is the product of the first- and second-stage sampling probabilities. The inverse of this probability forms the sample weights. These sample weights are needed when calculating national descriptive statistics based on the sampled households. However, they are not needed for the current analysis.

8. DHS spatio-temporal structure

DHS data are available for multiple years. During DHS data collection, field teams use GPS receivers to georeference population centres in survey clusters. Within publicly available datasets, a “random direction, random distance” displacement process is carried out as follows:

- Urban clusters are displaced up to two kilometres.
- Rural clusters are displaced a distance up to five kilometres, with a further, randomly selected 1% of the rural clusters displaced a distance up to ten kilometres.

This random displacement is expected to add noise, increasing uncertainty but not adding bias to the analysis.

9. Data exclusions

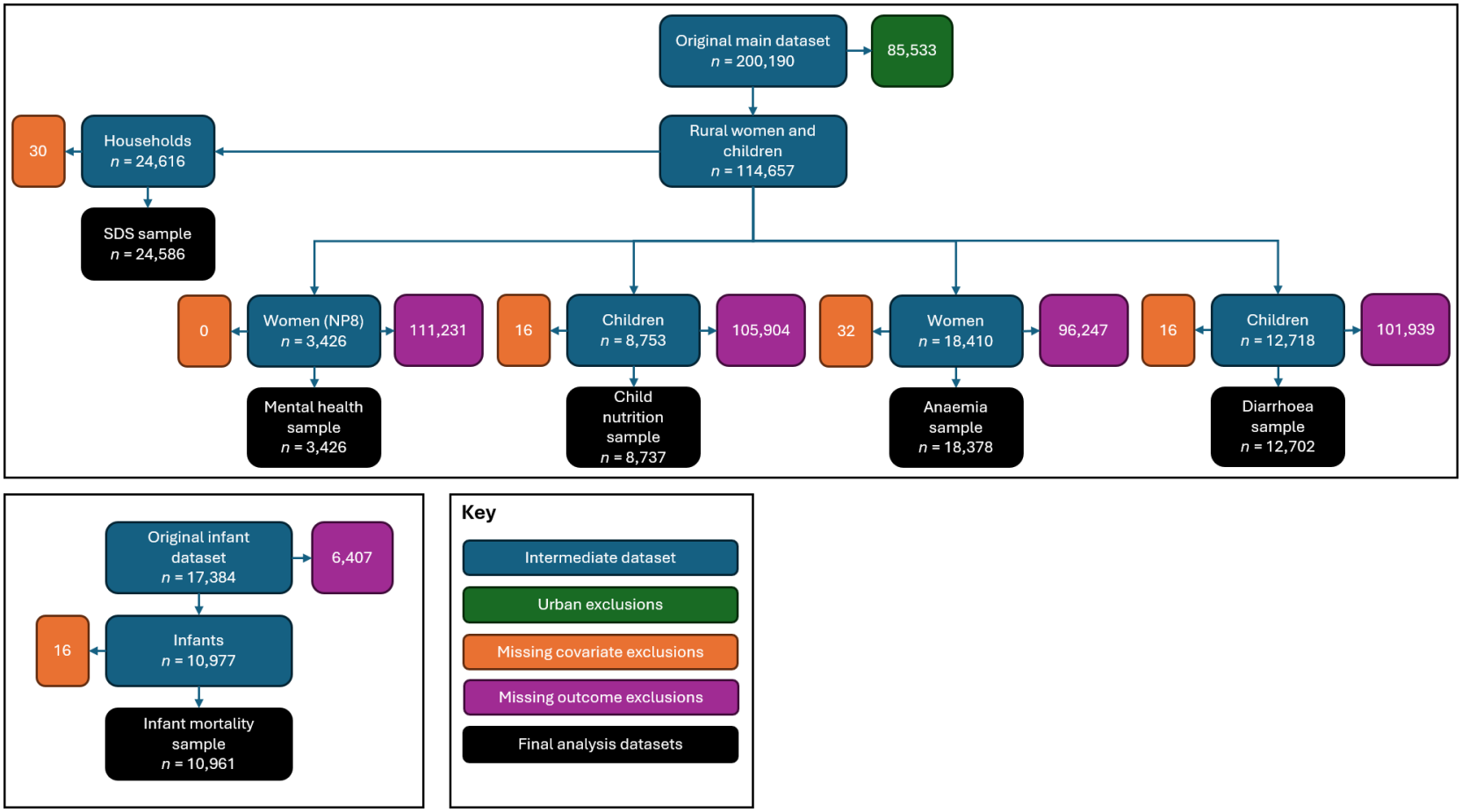


Figure 10. Graphical illustration of how observations were filtered from the original main and infant datasets to the final analytic samples. Most exclusions were due to the removal of urban observations and outcome-specific DHS systematic sampling methods. Exclusions due to missing covariate data were minimal across all models.

10. Treatment variable calculation

The response variable is derived from the analysis by Clark et al.[19], who compiled Community Forestry records from the non-governmental organisation, ForestAction Nepal. A 2017 dataset comprises 19,914 observations of Community Forest areas across all Village Development Committees. To align these with spatial units, each combined district and Village Development Committee name was matched to its polygon in the Global Administrative Boundaries Database using Levenshtein string matching. Records lacking a clear match were discarded under the assumption of random distribution and negligible bias. Finally, the total Community Forest area was divided by the Village Development Committee's total area to calculate the proportion of the Village Development Committee managed under Community Forestry.

Additionally, the 2017 dataset includes all Community Forests recorded as active up to that year. As operational plans are renewed every 10 years, these forests are assumed to remain active through to 2027. However, forests established between 2017 and 2022 are not captured. This likely underestimates Community Forestry coverage in the 2022 survey and may misclassify some areas as less exposed. This may bias the treatment effect towards zero (i.e. making the estimated treatment effect more conservative).

11. Confounder evidence pack

Summary

This document is intended to accompany the workshop for the project, "Health Impacts of Community Forestry in Nepal," scheduled for 20 January 2026. Please read this document in preparation for the workshop.

The workshop has three objectives:

a) Discuss the modelling framework in general.
b) Identify confounding variables for the links between:
    a. Community Forestry and household socioeconomic deprivation
    b. Household socioeconomic deprivation and health outcomes
    c. Community Forestry and health outcomes
c) Discuss the list of health outcomes (based on what is available in the DHS data) that we want to focus on.

This document is specifically focused on goal b) – identify confounding variables. If you are short on time, I would focus on reviewing the variables flagged as **Possibly** confounders in the tables below.

Recap of research questions

As a reminder, we aim to evaluate the effect of Community Forestry on health outcomes nationwide in Nepal between 2006 and 2022.

To meet this aim, we have the following research questions:

1) How does Community Forestry coverage (percentage of Village Development Committee area under Community Forestry) affect rural household socioeconomic deprivation, and how does this effect vary with baseline poverty?
2) How does rural household socioeconomic deprivation affect mental health, nutritional status, anaemia, infant mortality, and child diarrhoeal disease?

What are confounders?

A confounder is a factor that influences both the exposure(s) and the outcome we care about. If we do not control for confounders in the analysis, our estimated effects of the exposure(s) on the outcome will be biased.

In this project, we want to understand whether Community Forestry influences socioeconomic deprivation and, through this, influences health. However, some Village Development Committees may have characteristics that make them more likely to adopt Community Forestry and also more likely to have better socioeconomic deprivation or health, regardless of Community Forestry. These factors are confounders.

Identifying and adjusting for these confounders will allow us to isolate just the effect of Community Forestry on socioeconomic deprivation and health outcomes.

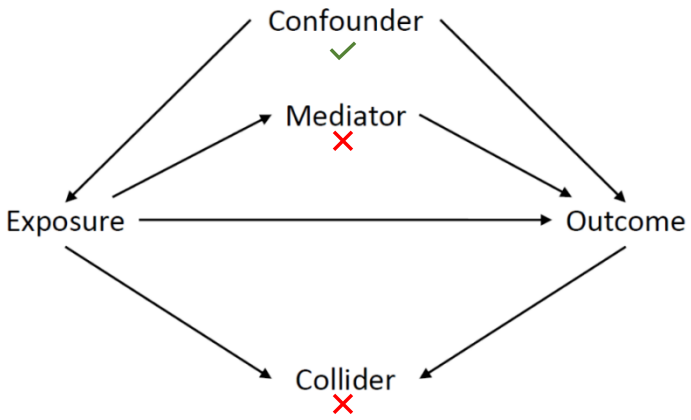
How could we identify confounders?

There are several things we need to avoid when identifying confounders, which can risk biasing our estimates:

- Overadjustment bias: We should avoid adjustment for downstream mediators that lie on the causal pathway from the exposure to the outcome variable.
- Collider bias: We must avoid including variables that are affected by both the treatment and outcome variables.
- Post-treatment bias: We should also avoid including variables that were measured after the treatment started (i.e., after 2001).

To identify factors that are confounders, and hence must be controlled for, we might use expert judgement (e.g., personal experience), peer-reviewed academic literature (e.g., academic papers), and grey literature (e.g., studies by governments).

Finally, some variables will have plausible bidirectional or timing-dependent relationships. Below, these are flagged with "[unpick causal sequence]" as we need to discuss these further together and decide how to handle them. Additionally, some variables might possibly be confounders, but we would need more evidence to decide either way. These are flagged with "[evidence needed]", which we also need to discuss.



Evidence: Community Forestry and Socioeconomic Deprivation

For the Community Forestry model, we prioritise pre-existing, community-level characteristics that could shape both uptake and household socioeconomic deprivation. Household-level factors are not treated as confounders of Village Development Committee-level coverage unless there is a plausible pathway to adoption.

Unit of analysis: Household

Exposure: Village Development Committee-level Community Forestry coverage (% area)

Outcome: Household socioeconomic deprivation

Variable	Confounder status	Causal rationale
Baseline community distance to protected areas	Yes	Proximity affects governance regimes, funding flows, enforcement capacity, and tourism opportunities linked to Community Forestry engagement [20] and has independent effects on household socioeconomic deprivation[21–23].
Baseline local governance capacity	Yes [unmeasured]	Likely to influence collective action capacity needed for Community Forestry adoption[24–28] and to support cooperation and information sharing that affect household socioeconomic deprivation (e.g., via wealth-generating activities) ([e.g., 29,30]).
Baseline population density	Yes	Influences forest pressure and incentives for collective action[31], and household socioeconomic deprivation via resource scarcity and employment opportunities ([e.g., 32])[33].
Baseline precipitation	Yes	Shapes forest conditions and agricultural suitability relevant to both Community Forestry engagement[20] and socioeconomic deprivation[34,35].
Baseline slope and elevation	Yes	Affects land use (including agriculture), forest condition, and livelihood opportunities relevant to participation and socioeconomic deprivation[20,36].
Baseline agricultural effort	Yes	Shapes forest condition and opportunity costs of Community Forestry engagement through competing land and labour demands[24,25,37,38] and influences agricultural productivity and thus socioeconomic deprivation[39,40].
Baseline forest cover	Yes	Determines the biophysical feasibility (i.e., absence of forests prevents establishment) of Community Forestry establishment[20] and the scale of forest-based livelihood opportunities contributing to socioeconomic deprivation[41–43].
Out-migration	Yes	Affects participation through labour availability and opportunity costs[17,20,38,44], while remittances influence household wealth, and thus socioeconomic deprivation[45,46]. Patterns of migration have substantially changed over time, suggesting migration may be a time-varying confounder.
Baseline poverty	Yes	Poorer communities are more reliant on forest resources and face constrained economic alternatives, increasing both incentives for Community Forestry engagement[20,26,41–43] and constraints on subsequent household socioeconomic deprivation.
Travel time to population centres	Yes	Accessibility alters opportunity costs of participation[37] and independently improves employment access and other opportunities shaping socioeconomic deprivation[47].

Baseline training and support opportunity (e.g., NGO support)	Possibly [unpick causal sequence]	Some evidence of effects on participation at the household level[38]. But, unlikely to affect socioeconomic deprivation except through Community Forestry participation; adjusting would risk post-treatment or overadjustment bias.
Baseline forest dependence	Possibly [evidence needed]	Complex links between forest dependence and participation[24,25] and socioeconomic deprivation[41–43] at the household level. Reflects household-level livelihood strategies shaped by underlying geography and opportunity costs already controlled for; adjusting risks overadjustment bias (by conditioning on pathways through which Community Forestry affects socioeconomic deprivation).
Elite capture and caste	Possibly [evidence needed]	Strongly associated with participation[24,25,37,48–50] and socioeconomic deprivation[51] at the household level, but evidence for causal effects of community-level caste composition uptake is limited.
Age	No [implausible]	Predicts socioeconomic deprivation over the life course[52] and household participation[49,50], but does not plausibly influence community-level Community Forestry establishment.
Baseline distance to forests	No [implausible]	Some evidence of effects on participation[38] and socioeconomic deprivation[42] at the household level. But there is limited evidence that it shapes community-level Community Forestry adoption, once forest cover is controlled for.
Community Forest area	No [implausible]	Some evidence of effect of protected area size on socioeconomic outcomes[20,53]. But no clear causal pathway linking area size to household socioeconomic deprivation after accounting for coverage and geography.
Gender	No [implausible]	Strong evidence of effects of gender-differentiated participation at the individual level[25,37,49,50] and predicts household socioeconomic deprivation[54,55]. But does not plausibly influence community-level Community Forestry establishment.
Household size	No [implausible]	Some evidence of effects on participation[24,37,38] and socioeconomic deprivation[56] at the household level. However, unlikely to affect community-level Community Forestry participation.
Baseline education	No [overadjustment bias]	Education facilitates organisation and capacity for Community Forestry engagement[24,37,49] and is associated with household wealth accumulation, and thus socioeconomic deprivation[41–43]. However, education is already included as an indicator within the baseline Village Development Committee-level poverty variable, so including it would introduce multicollinearity and overadjustment.

Evidence: Community Forestry, Socioeconomic Deprivation and Health

For health outcome models, we focus on upstream determinants of both household socioeconomic deprivation and each health outcome.

Mental health: depression and anxiety

Unit of analysis: Individual

Exposure: Household socioeconomic deprivation & Community Forestry

Outcome: Depression and anxiety

Variable	Confounder status	Causal rationale
Childhood and early life adversity	Yes [unmeasured]	Occurs prior to and influences adult socioeconomic deprivation (e.g., [57]) and has long-lasting effects on mental health[58–60].
Ethnoracial discrimination	Yes	Constrains socioeconomic opportunities (e.g., [61]) and independently increases mental health risk[58–60,62].
LGBTQ+ discrimination	Yes [unmeasured]	Constrains socioeconomic opportunities (e.g., [61]) and independently increases mental health risk[58,59,62].
Disaster and conflict	Yes	Impacts household socioeconomic deprivation through asset loss and livelihood disruption[63,64] and directly threatens mental health via trauma, displacement, and chronic stress[65,65,66]. A notable disaster with potential mental health implications is the 2015 earthquake in Nepal.
Neighbourhood socioeconomic disadvantage	Yes	Constrains household opportunities, impacting socioeconomic deprivation[67], and exposure to chronic stressors[58,59,62].
Women's age	Yes	Associated with both socioeconomic deprivation accumulation, shaping socioeconomic deprivation, and mental health risk[68,69].
Employment/earning control	Yes	Individual engagement in paid work may increase household socioeconomic deprivation while enhancing financial autonomy and control, which is associated with reduced mental health risks[62,70].
Travel time to population centres	Yes	Improves employment access and socioeconomic deprivation[47] and access to healthcare services.
Baseline population density	Yes	Influences forest pressure and incentives for collective action[31], and household stressors (potentially linked to mental health risk) via resource scarcity and employment opportunities (e.g., [32])[33].
Baseline agricultural effort	Yes	Shapes forest condition and opportunity costs of Community Forestry engagement through competing land and labour demands[24,25,37,38] and influences agricultural productivity and thus household stressors (potentially linked to mental health risk)[39,40].

Baseline forest cover	Yes	Determines the biophysical feasibility (i.e., absence of forests prevents establishment) of Community Forestry establishment[20] and the scale of forest-based livelihood opportunities contributing to household stressors (potentially mental health risk)[41–43].
Out-migration	Yes	Affects participation through labour availability and opportunity costs[17,20,38,44], while remittances influence household wealth, and thus household stressors (potentially mental health risk)[45,46]. Patterns of migration have substantially changed over time, suggesting migration may be a time-varying confounder.
Baseline neighbourhood social capital	Possibly [unpick causal sequence]	Can influence socioeconomic deprivation through cooperation and mutual support[24–28] and mental health through social support and collective efficacy[58,59,62]. But, poverty and poor mental health can also erode social capital, making causal direction ambiguous.
Loneliness and social isolation	Possibly [unpick causal sequence]	May influence socioeconomic deprivation through social support and mental health through psychosocial stress, but is also plausibly a consequence of both poverty and poor mental health, creating feedback loops[58–60,62].
Individual migration	Possibly [unpick causal sequence]	May affect socioeconomic deprivation via remittances and labour availability and mental health via stress and the drivers of migration (e.g., escaping conflict)[58–60,62], with context-specific effects that vary by migration type and timing relative to socioeconomic deprivation measurement.
Substance/alcohol use and partner substance/alcohol	Possibly [unpick causal sequence]	Bidirectionally linked with both poverty[71–74] and mental health[75,76], as economic stress may increase substance use while substance use can impair income generation and worsen mental health outcomes.
Sex-based inequalities (decision-making power)	No [implausible]	Evidence of gendered effects on socioeconomic deprivation[54,55] and mental health[58–60,62]. But the sample is restricted to women, so individual-level sex variation is removed.
Access and use of healthcare services	No [overadjustment bias]	Evidence of effect on mental health[59,62]. But, primarily a consequence of socioeconomic deprivation and education (alongside other factors we are controlling for); adjusting risks overadjustment bias.
Food insecurity	No [overadjustment bias]	Evidence of effect on mental health[59,62,77,78]. But food insecurity is primarily a manifestation of household socioeconomic deprivation; adjusting risks overadjustment bias.
Intimate partner violence	No [implausible]	Strongly associated with mental health outcomes[79]. But evidence that it independently determines household socioeconomic deprivation is limited.
Women's education	No [overadjustment bias]	Affects socioeconomic deprivation and independently improves mental health through improved coping skills, health literacy, and access to support[80,81]. However, already partially captured in the socioeconomic deprivation measure, so including a separate variable is redundant.

Child nutrition: stunting, wasting, underweight

Unit of analysis: Individual (child)

Exposure: Household socioeconomic deprivation & Community Forestry

Outcome: Child nutritional status

Variable	Confounder status	Causal rationale
Household size	Yes	Affects socioeconomic deprivation through resource use (i.e., number of working adults vs dependents) and labour availability[56] and influences per-capita resources and caregiving time available for child nutrition[82].
Neighbourhood socioeconomic disadvantage	Yes	Constrains household opportunities shaping socioeconomic deprivation[67] and local food, health, and sanitation environments that influence child nutrition independently of household socioeconomic deprivation[83–85].
Baseline population density	Yes	Influences forest pressure and incentives for collective action[31], and household food security via resource scarcity and employment opportunities[33].
Baseline precipitation	Yes	Shapes agricultural suitability relevant to both socioeconomic deprivation[34,35] and agricultural productivity, which can influence food availability.
Baseline slope and elevation	Yes	Affects land use (including agriculture)[20,36] and agricultural productivity, which can influence food availability[86] and socioeconomic deprivation.
Baseline agricultural effort	Yes	Influences household socioeconomic deprivation[39,40] and food availability[86].
Baseline forest cover	Yes	Determines the biophysical feasibility (i.e., absence of forests prevents establishment) of Community Forestry establishment[20] and the scale of forest-based livelihood opportunities that can shape food availability[9,41–43].
Out-migration	Yes	Affects participation through labour availability and opportunity costs[17,20,38,44], while remittances influence household wealth, and thus food availability[45,46]. Patterns of migration have substantially changed over time, suggesting migration may be a time-varying confounder.
Travel time to population centres	Yes	Improves employment access and wealth, shaping socioeconomic deprivation[47] and access to healthcare services.
Child age and sex	No [implausible]	Evidence of effects on child nutrition[82,83], but does not plausibly influence household socioeconomic deprivation.
Maternal education	No [overadjustment bias]	Affects socioeconomic deprivation and influences caregiving practices, nutrition knowledge, and maternal decision-making that shape child nutritional status[82,83,87,88]. However, already captured in the socioeconomic deprivation measure, so including a separate variable is redundant.
Feeding practices	No [overadjustment bias]	Evidence of effects on child nutrition[82,83]. But feeding practices are largely shaped by household wealth, maternal education, and food availability; adjusting risks overadjustment bias.
Food insecurity	No [overadjustment bias]	Evidence of effects on child nutrition[89–92]. But food insecurity is primarily a manifestation of household socioeconomic deprivation; adjusting risks overadjustment bias.

Low birthweight	No [overadjustment bias]	Evidence of effects on child nutrition[82,83,87]. Determined by prenatal conditions correlated with poverty and maternal health, but unlikely to influence subsequent household socioeconomic deprivation; adjusting risks overadjustment bias.
Maternal nutritional status	No [overadjustment bias]	Evidence of effects on child nutrition[83,93]. But maternal nutritional status is largely shaped by household socioeconomic deprivation and food access; adjusting risks overadjustment bias.
Recent child illness (e.g. diarrhoea)	No [overadjustment bias]	Evidence of effects on child nutrition[83,93]. But it is itself shaped by socioeconomic deprivation and care access; adjusting risks overadjustment bias.
Sanitation	No [overadjustment bias]	Evidence of effects on child nutrition[82–85,87,93]. However, already partially captured in the socioeconomic deprivation measure, so including a separate variable is redundant.
Water source	No [overadjustment bias]	Evidence of effects on child nutrition[82–85,87,88,93]. However, already partially captured in the socioeconomic deprivation measure, so including a separate variable is redundant.

Women's health: anaemia

Unit of analysis: Individual (women)

Exposure: Household socioeconomic deprivation & Community Forestry

Outcome: Anaemia status

Variable	Confounder status	Causal rationale
Neighbourhood socioeconomic disadvantage	Yes	Constrains household wealth opportunities shaping socioeconomic deprivation[67] and access to food, health services, and infrastructure that influence anaemia risk independently of household socioeconomic deprivation[14].
Women's age	Yes	Associated with life-course wealth accumulation, shaping socioeconomic deprivation[52], and biological anaemia risk[14,94].
Reproductive parity (number of births)	Yes	May both influence (e.g., more children requiring resources) and be influenced by (e.g., poorer women more likely to have more children) household socioeconomic deprivation[95], and affects anaemia risk through cumulative nutritional depletion[14,94,96–98]. However, in general, reproductive parity is more likely to be upstream of both household socioeconomic deprivation and anaemia risk.
Baseline population density	Yes	Influences forest pressure and incentives for collective action[31], and household food security via resource scarcity and employment opportunities[33].
Baseline precipitation	Yes	Shapes agricultural suitability relevant to both wealth accumulation[34,35] and agricultural productivity, which can influence food availability, in turn influencing anaemia risk[86,99].
Baseline slope and elevation	Yes	Affects land use (including agriculture)[20,36] and agricultural productivity, which can influence food availability, in turn influencing anaemia risk [86,99] and socioeconomic deprivation.
Baseline agricultural effort	Yes	Influences household socioeconomic deprivation[39,40] and food availability[86], in turn influencing anaemia risk[99].
Baseline forest cover	Yes	Determines the biophysical feasibility (i.e., absence of forests prevents establishment) of Community Forestry establishment[20] and the scale of forest-based livelihood opportunities that can shape food availability[9,41–43].
Out-migration	Yes	Affects participation through labour availability and opportunity costs[17,20,38,44], while remittances influence household wealth, and thus food availability[45,46]. Patterns of migration have substantially changed over time, suggesting migration may be a time-varying confounder.
Travel time to population centres	Yes	Improves employment access and wealth, shaping socioeconomic deprivation[47] and access to healthcare services.
Food insecurity	No [overadjustment bias]	Evidence of effect on anaemia risk[99]. But food insecurity is primarily a manifestation of household socioeconomic deprivation; adjusting risks overadjustment bias.
Health service and supplement use	No [overadjustment bias]	Evidence of effect on anaemia risk[96,97]. But service and supplement use are largely determined by socioeconomic deprivation; adjusting risks overadjustment bias.

Marital status	No [implausible]	Well-evidenced effects on household socioeconomic deprivation in some contexts[100,101]. But independent effects on anaemia beyond parity, age, and socioeconomic deprivation are unclear (but see [14]).
Women's education	No [overadjustment bias]	Precedes socioeconomic deprivation and influences diet quality, health literacy, and access to care, which are relevant to anaemia risk[14,94,96]. However, already partially captured in the socioeconomic deprivation measure, so including a separate variable is redundant.
Maternal nutritional status	No [overadjustment bias]	Evidence of effect on anaemia risk[96]. But largely shaped by household socioeconomic deprivation and food security; adjusting risks overadjustment bias.
Recent illness	No [overadjustment bias]	Evidence of effect on anaemia risk[94,97]. But, predicted by other upstream factors (e.g., socioeconomic deprivation, diet, and healthcare access) that we either include as confounders or exclude for other reasons; adjusting risks overadjustment bias.
Sanitation	No [overadjustment bias]	Evidence of effect on anaemia risk[96]. However, already captured in the socioeconomic deprivation measure, so including a separate variable is redundant.

Infant mortality: Infant mortality

Unit of analysis: Individual (infant)

Exposure: Household socioeconomic deprivation & Community Forestry

Outcome: Infant mortality (the risk of a child born in the preceding 12–59 months[1] who dies before reaching their first birthday).

Variable	Confounder status	Causal rationale
Maternal age	Yes	Associated with both socioeconomic deprivation[52] and infant mortality risk[15,102,103].
Neighbourhood socioeconomic disadvantage	Yes	Constrains household wealth opportunities linked to socioeconomic deprivation[67] and access to quality maternal and neonatal care, health infrastructure, and emergency services that influence infant survival independently of household socioeconomic deprivations[15].
Reproductive parity (number of births)	Yes	May both influence and be influenced by socioeconomic deprivation[95] and affect infant mortality through birth spacing, maternal depletion, and care allocation[15,102,104]. However, in general, reproductive parity is more likely to be upstream of both household socioeconomic deprivation and infant mortality risk.
Travel time to population centres	Yes	Improves employment access and socioeconomic deprivation[47] and access to healthcare services.
Baseline population density	Yes	Influences forest pressure and incentives for collective action[31], and access to healthcare services.
Out-migration	Yes	Affects participation through labour availability and opportunity costs[17,20,38,44], while remittances influence household income that could be used to purchase better healthcare[45,46]. Patterns of migration have substantially changed over time, suggesting migration may be a time-varying confounder.
Substance use	Possibly [unpick causal sequence]	Bidirectionally linked with socioeconomic deprivation[71–74] and adverse infant outcomes[15,103], as economic stress may increase substance use while substance use can impair caregiving, health-seeking, and income generation.
Maternal education	No [overadjustment bias]	Affects socioeconomic deprivation and improves care-seeking, health knowledge, and newborn care practices that reduce infant mortality risk[15,102]. However, already partially captured in the socioeconomic deprivation measure, so including a separate variable is redundant.
Maternal mortality and morbidity	No [overadjustment bias]	Severe or chronic maternal conditions can reduce household economic capacity and directly increase infant mortality risk[102]. E.g., HIV/AIDs[105,106], though HIV is rare in Nepal[107]. Other potentially confounding illnesses include severe diabetes and mental disorders, though the evidence is limited. However, maternal health is largely shaped by household socioeconomic deprivation; adjusting risks overadjustment bias.

[1] To avoid right-censoring of infant mortality, the analysis was restricted to children born 12–59 months before the survey interview. This restriction ensures that all included children were fully observed over the risk period. I.e., we were not including infants who were less than 12 months old, who are still at risk of death before their first birthday.

Arsenic exposure	No [implausible]	Evidence of effect on infant mortality[103]. But arsenic exposure is geographically determined and unlikely to influence household socioeconomic deprivation, limiting its role as a confounder.
Feeding practices	No [overadjustment bias]	Evidence of effect on infant mortality[15,102,103,108]. But feeding practices are largely shaped by household socioeconomic deprivation and maternal education; adjusting risks overadjustment bias.
History of perinatal loss	No [implausible]	Evidence of effect on infant mortality [103,104]. But, unlikely to affect socioeconomic deprivation.
Intimate partner violence	No [implausible]	Evidence that poorer women are at greater risk[109] and associated with infant outcomes[15,102,110]. But evidence that it independently determines household socioeconomic deprivation is limited.
Low birthweight	No [overadjustment bias]	Evidence of effect on infant mortality[102–104]. But largely downstream consequences of maternal health and socioeconomic conditions; adjusting risks overadjustment bias.
Maternal nutritional status	No [overadjustment bias]	Evidence of effect on infant mortality[103]. But, primarily a consequence of socioeconomic deprivation; adjusting risks overadjustment bias.
Mode of delivery	No [overadjustment bias]	Evidence of effect on infant mortality[15,104,111]. But healthcare utilisation is primarily determined by wealth, education, and access; adjusting risks overadjustment bias.
Multiple gestation	No [implausible]	Evidence of effect on infant mortality[104]. But, no plausible causal effect on household socioeconomic deprivation.
Occupational status	No [overadjustment bias]	Occupation is a manifestation of socioeconomic position and risks overadjustment bias or collinearity with socioeconomic deprivation.
Place of delivery	No [overadjustment bias]	Evidence of effect on infant mortality[15,108,112]. But healthcare utilisation is primarily determined by wealth, education, and access; adjusting risks overadjustment bias.
Prenatal and antenatal care utilisation	No [overadjustment bias]	Evidence of effect on infant mortality[15,102–104,108]. But healthcare utilisation is primarily determined by wealth, education, and access; adjusting risks overadjustment bias.
Preterm birth	No [overadjustment bias]	Evidence of effect on infant mortality[102–104]. But largely downstream consequences of maternal health and socioeconomic conditions; adjusting risks overadjustment bias.
Primiparity (first pregnancy)	No [implausible]	Evidence of effect on infant mortality[104]. But, no plausible causal effect on household socioeconomic deprivations.

Child diarrhoea disease

Unit of analysis: Individual (child)

Exposure: Household socioeconomic deprivation & Community Forestry

Outcome: Diarrhoeal disease (children under age 5 with diarrhoea at any time in the 2 weeks preceding the survey).

Variable	Confounder status	Causal rationale
Household size	Yes	Affects socioeconomic deprivation through resource use (i.e., number of working adults vs dependents) and labour availability[56] and increases person-to-person transmission risk due to crowding[12,13,113].
Maternal age	Yes	Associated with life-course wealth accumulation, shaping socioeconomic deprivation, and caregiving experience[113].
Neighbourhood socioeconomic disadvantage	Yes	Constrains household wealth opportunities shaping socioeconomic deprivation[67] and community-level sanitation, water infrastructure, and environmental contamination that influence diarrheal risk independently of household socioeconomic deprivation[12,13].
Travel time to population centres	Yes	Improves employment access and socioeconomic deprivation[47] and access to healthcare services.
Baseline precipitation	Yes	Shapes agricultural suitability relevant to socioeconomic deprivation[34,35], and patterns of rainwater run-off and pollution[114,115].
Baseline slope and elevation	Yes	Affects land use (including agriculture)[20,36] and agricultural productivity, which can influence socioeconomic deprivation and patterns of rainwater run-off and pollution.
Baseline agricultural effort	Yes	Influences household socioeconomic deprivation[39,40] and environmental surface water contamination[116].
Baseline forest cover	Yes	Determines the scale of forest-based livelihood opportunities contributing to socioeconomic deprivation[41–43] and the buffering effect of vegetation on surface water contamination[117].
Baseline population density	Yes	Influences household socioeconomic deprivation via resource scarcity and employment opportunities (e.g., [32,33]) and risk of surface water contamination[118].
Domestic animals	No [overadjustment bias]	Associated with household socioeconomic deprivation through livestock-based livelihoods[39,40] and increases diarrheal risk via fecal contamination of local environments[119]. But primarily shaped by household socioeconomic deprivation; adjusting risks overadjustment bias.
Child age and sex	No [implausible]	Evidence of effect on diarrhoea risk [12,113]. But, no plausible causal effect on household socioeconomic deprivation.
Maternal education	No [overadjustment bias]	Affects socioeconomic deprivation and influences preventive hygiene practices, caregiving behaviours, and timely care-seeking that reduce diarrhoeal risk[12,13,113,120]. However, already partially captured in the socioeconomic deprivation measure, so including a separate variable is redundant.

Child nutritional status	No [overadjustment bias]	Bidirectionally linked with diarrhoea[13,83,93,121], but primarily shaped by household socioeconomic deprivation and prior illness; adjusting risks overadjustment bias.
Feeding practices	No [overadjustment bias]	Evidence of effect on diarrhoea risk[12,122]. But feeding practices are largely shaped by household socioeconomic deprivation, maternal education, and food availability; adjusting risks overadjustment bias.
Healthcare access and use	No [overadjustment bias]	Evidence of effect on diarrhoea risk[113]. But healthcare utilisation is primarily determined by wealth, education, and access; adjusting risks overadjustment bias.
Hygiene practices	No [overadjustment bias]	Evidence of effect on diarrhoea risk[12,113,120,121,121]. But hygiene practices are largely a consequence of wealth, education, and infrastructure; adjusting risks overadjustment bias.
Low birthweight	No [overadjustment bias]	Evidence of effect on diarrhoea risk[121]. But largely downstream of maternal health and socioeconomic conditions; adjusting risks overadjustment bias.
Occupational status	No [overadjustment bias]	Occupation is a manifestation of socioeconomic position and risks overadjustment bias or collinearity with socioeconomic deprivation and domestic animal ownership.
Preterm birth	No [overadjustment bias]	Evidence of effect on diarrhoea risk[121]. But largely downstream of maternal health and socioeconomic conditions; adjusting risks overadjustment bias.
Sanitation	No [overadjustment bias]	Evidence of effect on diarrhoea risk[12,13,113,120,121]. However, already captured in the socioeconomic deprivation measure, so including a separate variable is redundant.
Water source	No [overadjustment bias]	Evidence of effect on diarrhoea risk [12,13,113,121]. However, already captured in the socioeconomic deprivation measure, so including a separate variable is redundant.

12. Description of mental health outcomes

The PHQ-9 is based on the Diagnostic and Statistical Manual of Mental Disorders criteria for the diagnosis of depression[123]. The PHQ-9 is a widely used, reliable and valid measure of depressive symptom severity[124–126]. The PHQ-9 has nine items, each corresponding to one diagnostic criterion for depression (e.g. “Little interest or pleasure in doing things,” “Feeling down, depressed, or hopeless”). Responses are given on a four-point Likert scale (4-point Likert (0 = “Not at all,” 1 = “Several days,” 2 = “More than half the days,” 3 = “Nearly every day”). Responses for each item are totalled; total scores of 10 are generally considered a threshold score (with good sensitivity and specificity) for major depression.

The GAD-7 is designed to measure the main feature of anxiety: persistent and impairing worry[127]. The GAD-7 also captures characteristics of three other common anxiety disorders: panic disorder, social anxiety disorder, and posttraumatic stress disorder. The scale has good reliability and validity, and has been used across diverse contexts[128,129]. The GAD-7 has seven items, addressing key anxiety symptoms (e.g. “Feeling nervous, anxious or on edge,” “Worrying too much about different things,” “Feeling restless”). Responses are given on a four-point Likert scale (4-point Likert (0 = “Not at all,” 1 = “Several days,” 2 = “More than half the days,” 3 = “Nearly every day”). Responses for each item are totalled; total scores of 10 are generally considered a threshold score (with good sensitivity and specificity) for general anxiety disorder.

13. Out-migration

The primary analysis used time-varying out-migration, linearly interpolated to 2005, 2010, 2015, and 2021 from Nepal census data for 2001[130], 2011[131], and 2021[132]. This assumes that Community Forestry did not substantially affect patterns of out-migration, which could lead to post-treatment bias. To evaluate this, we repeated the analysis using only the 2001 census data. The results were almost identical to the primary analysis, indicating that using time-varying out-migration is unlikely to have introduced post-treatment bias (Figure 11).

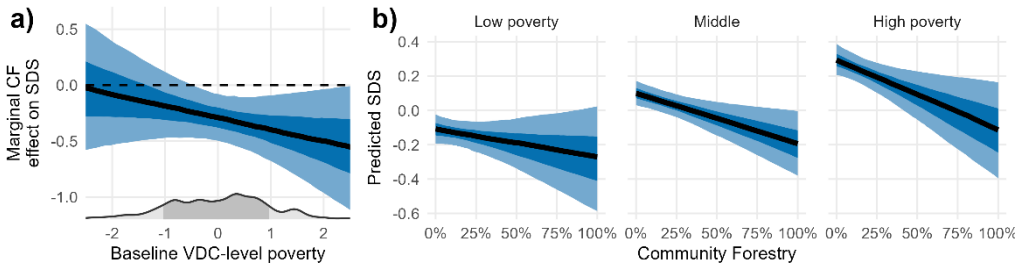


Figure 11. Posterior estimates from the Bayesian mediation analysis, including baseline out-migration. Panel (a) shows the marginal effect of Community Forestry (percentage of Village Development Committee area under Community Forestry) on household socioeconomic deprivation across baseline Village Development Committee-level poverty, with baseline (2001) out-migration. The solid line is the posterior median; dark and light blue bands show 50% and 89% credible intervals. The grey density at the base shows the observed distribution of baseline Village Development Committee-level poverty, with shaded regions indicating the central 1 and 2 SDs. Panel (b) shows predicted socioeconomic deprivation across the CF gradients for low-, middle-, and high-poverty Village Development Committees.

14. WAMBS-checklist

We assessed the fitted Bayesian models using the WAMBS checklist points 1-6 and 10[133]. We do not assess points 7-9 as our analysis used only weakly informative priors.

Point 1: Do you understand the priors?

Yes. We inspected the priors using the model prior summaries and prior plots. We specified weakly informative priors across all models: Normal(0, 2) for regression coefficients and Exponential(0.5) for group-level standard deviations. Intercepts were assigned Normal(0, 4) priors in the Gaussian model and Normal(0, 2) in the Bernoulli models, with an Exponential(0.5) prior on the Gaussian residual standard deviation.

Point 2: Does the trace-plot exhibit convergence?

Yes. We inspected trace plots for fixed effects, group-level standard deviations, and residual standard deviations. The trace plots showed clear chain convergence.

Point 3: Does convergence remain after doubling the number of iterations?

Yes. We re-estimated the models with doubled iterations and compared the results with the original models. The doubled-iteration models did not substantively change the findings.

Point 4: Does the histogram have enough information?

Yes. We inspected posterior histograms for fixed effects, group-level standard deviations, and residual standard deviations. The histograms contained ample information and were smoothly shaped.

Point 5: Do the chains exhibit a strong degree of autocorrelation?

No. We inspected autocorrelation plots for fixed effects, group-level standard deviations, and residual standard deviations. Some parameters showed autocorrelation, but this was not a concern because the models converged and effective sample sizes were sufficient.

Point 6: Does the posterior distribution make substantive sense?

Yes. We inspected posterior histograms. These were smooth and made substantive sense.

Point 10: Is the Bayesian way of interpreting and reporting model results used?

Yes. Results were interpreted using posterior summaries, credible intervals, and the estimated probability of direction.

Supplementary Tables

Table 2. Total scenario differences in expected adverse health cases. Values compare observed Community Forestry coverage with a counterfactual zero-Community-Forestry scenario. Negative values indicate fewer expected cases under observed Community Forestry. Probable depression and probable anxiety are only estimated for 2022, since mental health data were only collected in that survey phase.

Outcome	Year	Observations	Expected case difference (89% CI)	Percentage change (89% CI)	PD
Probable depression	2022	3281	-6.09 (-19.37 to 7.54)	-4.0% (-11.4% to 4.9%)	74.2%
Probable anxiety	2022	3281	-5.49 (-20.28 to 11.40)	-2.8% (-9.1% to 6.1%)	71.8%
Stunting	2006	4293	-59.33 (-96.69 to -19.09)	-2.5% (-4.1% to -0.8%)	99.2%
Stunting	2011	1964	-36.90 (-59.55 to -12.33)	-4.2% (-6.6% to -1.4%)	99.2%
Stunting	2016	1059	-13.13 (-21.40 to -4.84)	-3.2% (-5.1% to -1.2%)	99.2%
Stunting	2022	1295	-8.53 (-13.98 to -3.07)	-2.4% (-3.9% to -0.9%)	99.2%
Wasting	2006	4293	1.66 (-17.63 to 19.27)	0.4% (-3.4% to 4.1%)	57.6%
Wasting	2011	1964	0.94 (-10.43 to 11.59)	0.5% (-5.2% to 6.4%)	57.4%
Wasting	2016	1057	0.20 (-2.67 to 2.78)	0.3% (-3.1% to 3.6%)	55.8%
Wasting	2022	1296	0.13 (-1.58 to 1.70)	0.2% (-2.2% to 2.4%)	56.2%
Underweight	2006	4293	-52.99 (-92.88 to -7.42)	-3.2% (-5.4% to -0.4%)	96.6%
Underweight	2011	1964	-28.81 (-50.94 to -4.24)	-5.5% (-9.2% to -0.8%)	97%
Underweight	2016	1062	-9.47 (-16.80 to -1.77)	-3.7% (-6.2% to -0.7%)	97.2%
Underweight	2022	1300	-4.88 (-8.40 to -0.83)	-2.5% (-4.3% to -0.4%)	97%
Anaemia	2006	7974	-29.05 (-86.34 to 28.56)	-1.1% (-3.2% to 1.1%)	78%
Anaemia	2011	4520	-21.27 (-65.18 to 20.39)	-1.5% (-4.4% to 1.5%)	78.4%
Anaemia	2016	2261	-8.29 (-24.98 to 7.99)	-0.9% (-2.7% to 0.9%)	78.8%
Anaemia	2022	3370	-7.47 (-22.67 to 6.96)	-0.8% (-2.2% to 0.7%)	78.8%
Diarrhoea	2006	4144	-3.15 (-20.37 to 12.24)	-0.9% (-5.5% to 3.7%)	65.4%
Diarrhoea	2011	3945	-4.64 (-30.45 to 16.93)	-1.2% (-7.5% to 5.1%)	65.4%
Diarrhoea	2016	1965	-0.66 (-4.35 to 2.61)	-0.9% (-5.4% to 3.5%)	65.8%
Diarrhoea	2022	2414	-0.84 (-5.50 to 3.32)	-0.6% (-3.8% to 2.4%)	65.8%
Infant mortality	2006	3643	-3.04 (-10.60 to 3.78)	-2.4% (-7.9% to 2.9%)	78.6%
Infant mortality	2011	3373	-4.08 (-14.72 to 5.10)	-3.7% (-11.9% to 4.3%)	78.6%
Infant mortality	2016	1683	-1.04 (-3.72 to 1.16)	-2.4% (-7.9% to 2.8%)	79%
Infant mortality	2022	2064	-0.72 (-2.54 to 0.85)	-1.7% (-5.6% to 2.0%)	78.8%

Table 3. Socioeconomic-deprivation-mediated scenario differences in expected adverse health cases. Values compare observed Community Forestry coverage and predicted socioeconomic deprivation with observed Community Forestry coverage but socioeconomic deprivation predicted under the zero-Community-Forestry scenario. Negative values indicate fewer expected cases through the socioeconomic-deprivation-mediated pathway. Probable depression and probable anxiety are only estimated for 2022, since mental health data were only collected in that survey phase

Outcome	Year	Observations	Mediated expected case difference (89% CI)	Percentage change (89% CI)	PD
Probable depression	2022	3281	-0.51 (-1.33 to -0.04)	-0.3% (-0.8% to 0.0%)	95.8%
Probable anxiety	2022	3281	-0.83 (-1.86 to -0.18)	-0.4% (-1.0% to -0.1%)	97.4%
Stunting	2006	4293	-11.98 (-20.52 to -2.90)	-0.5% (-0.9% to -0.1%)	98%
Stunting	2011	1964	-7.65 (-13.01 to -2.44)	-0.9% (-1.5% to -0.3%)	97.8%
Stunting	2016	1059	-2.98 (-5.15 to -0.91)	-0.8% (-1.3% to -0.2%)	98.4%
Stunting	2022	1295	-1.87 (-3.20 to -0.60)	-0.5% (-0.9% to -0.2%)	98.4%
Wasting	2006	4293	-2.02 (-3.86 to -0.45)	-0.4% (-0.8% to -0.1%)	97.6%
Wasting	2011	1964	-1.30 (-2.43 to -0.34)	-0.7% (-1.3% to -0.2%)	97.8%
Wasting	2016	1057	-0.35 (-0.66 to -0.10)	-0.4% (-0.8% to -0.1%)	98.4%
Wasting	2022	1296	-0.20 (-0.38 to -0.05)	-0.3% (-0.5% to -0.1%)	98.4%
Underweight	2006	4293	-13.25 (-21.78 to -3.62)	-0.8% (-1.3% to -0.2%)	97.8%
Underweight	2011	1964	-7.53 (-12.01 to -2.34)	-1.4% (-2.4% to -0.5%)	97.8%
Underweight	2016	1062	-2.64 (-4.39 to -0.74)	-1.0% (-1.7% to -0.3%)	98.4%
Underweight	2022	1300	-1.30 (-2.17 to -0.41)	-0.7% (-1.1% to -0.2%)	98.4%
Anaemia	2006	7974	-1.62 (-4.75 to 0.11)	-0.1% (-0.2% to 0.0%)	93.2%
Anaemia	2011	4520	-1.29 (-3.65 to 0.07)	-0.1% (-0.3% to 0.0%)	93%
Anaemia	2016	2261	-0.56 (-1.53 to 0.02)	-0.1% (-0.2% to 0.0%)	93.6%
Anaemia	2022	3370	-0.50 (-1.38 to 0.02)	-0.1% (-0.1% to 0.0%)	93.6%
Diarrhoea	2006	4144	-0.13 (-0.87 to 0.42)	0.0% (-0.3% to 0.1%)	67.6%
Diarrhoea	2011	3945	-0.20 (-1.27 to 0.60)	-0.1% (-0.4% to 0.2%)	67.6%
Diarrhoea	2016	1965	-0.03 (-0.23 to 0.10)	0.0% (-0.3% to 0.1%)	68.4%
Diarrhoea	2022	2414	-0.04 (-0.28 to 0.13)	0.0% (-0.2% to 0.1%)	68.2%
Infant mortality	2006	3643	-0.17 (-0.60 to 0.14)	-0.1% (-0.5% to 0.1%)	80.4%
Infant mortality	2011	3373	-0.22 (-0.83 to 0.19)	-0.2% (-0.8% to 0.2%)	80.4%
Infant mortality	2016	1683	-0.05 (-0.23 to 0.04)	-0.1% (-0.5% to 0.1%)	79.6%
Infant mortality	2022	2064	-0.04 (-0.16 to 0.03)	-0.1% (-0.4% to 0.1%)	79.8%

Table 4. Directs scenario differences in expected adverse health cases. Values compare observed Community Forestry coverage under observed socioeconomic deprivation with observed Community Forestry coverage under a fixed zero level of socioeconomic deprivation, isolating the component of the Community Forestry effect that does not operate through household socioeconomic deprivation. Negative values indicate fewer expected cases via this direct pathway. Probable depression and probable anxiety are only estimated for 2022, since mental health data were only collected in that survey phase.

Outcome	Year	Observations	Direct expected case difference (89% CI)	Percentage change (89% CI)	PD
Probable depression	2022	3281	-5.40 (-18.56 to 8.15)	-3.6% (-10.6% to 5.5%)	71.4%
Probable anxiety	2022	3281	-4.48 (-19.12 to 11.85)	-2.3% (-8.6% to 6.9%)	68.4%
Stunting	2006	4293	-46.63 (-87.01 to -8.08)	-2.0% (-3.6% to -0.3%)	97%
Stunting	2011	1964	-28.68 (-53.92 to -5.00)	-3.3% (-5.9% to -0.6%)	97%
Stunting	2016	1059	-10.13 (-19.00 to -1.71)	-2.5% (-4.5% to -0.5%)	97%
Stunting	2022	1295	-6.56 (-12.24 to -1.10)	-1.9% (-3.4% to -0.3%)	97%
Wasting	2006	4293	3.51 (-15.57 to 21.54)	0.7% (-3.1% to 4.8%)	63.8%
Wasting	2011	1964	2.17 (-9.13 to 12.97)	1.2% (-4.7% to 7.3%)	63.8%
Wasting	2016	1057	0.54 (-2.27 to 3.13)	0.6% (-2.7% to 4.1%)	63.8%
Wasting	2022	1296	0.31 (-1.33 to 1.90)	0.5% (-1.9% to 2.8%)	63.8%
Underweight	2006	4293	-40.76 (-79.52 to 4.29)	-2.5% (-4.6% to 0.3%)	93%
Underweight	2011	1964	-21.73 (-42.71 to 2.29)	-4.2% (-8.0% to 0.5%)	93%
Underweight	2016	1062	-6.91 (-14.02 to 0.69)	-2.7% (-5.3% to 0.3%)	93%
Underweight	2022	1300	-3.54 (-7.03 to 0.37)	-1.9% (-3.7% to 0.2%)	93%
Anaemia	2006	7974	-26.91 (-84.11 to 29.74)	-1.0% (-3.1% to 1.1%)	76%
Anaemia	2011	4520	-19.61 (-62.43 to 21.31)	-1.4% (-4.3% to 1.6%)	76%
Anaemia	2016	2261	-7.57 (-23.77 to 8.38)	-0.8% (-2.6% to 0.9%)	76%
Anaemia	2022	3370	-6.82 (-21.56 to 7.37)	-0.7% (-2.2% to 0.8%)	76%
Diarrhoea	2006	4144	-2.91 (-19.99 to 12.39)	-0.9% (-5.5% to 3.6%)	64%
Diarrhoea	2011	3945	-4.30 (-30.35 to 17.00)	-1.2% (-7.4% to 5.1%)	64%
Diarrhoea	2016	1965	-0.58 (-4.32 to 2.64)	-0.8% (-5.3% to 3.5%)	64%
Diarrhoea	2022	2414	-0.77 (-5.44 to 3.42)	-0.6% (-3.8% to 2.4%)	64%
Infant mortality	2006	3643	-2.91 (-10.51 to 3.93)	-2.4% (-7.8% to 3.1%)	77.4%
Infant mortality	2011	3373	-3.92 (-14.44 to 5.18)	-3.6% (-11.5% to 4.7%)	77.4%
Infant mortality	2016	1683	-0.95 (-3.62 to 1.24)	-2.3% (-7.6% to 2.9%)	77.4%
Infant mortality	2022	2064	-0.65 (-2.54 to 0.93)	-1.6% (-5.5% to 2.1%)	77.4%

Table 5. Observed Community Forestry minus zero-Community-Forestry differences in predicted household socioeconomic deprivation categories. Values are percentage-point differences (pp), followed by household-count differences and the probability of direction. Negative values indicate fewer households in the category under observed Community Forestry. Socioeconomic deprivation categories are derived from Dirksen et al.[134].

SDS category	Year	Difference, pp (89% CI)	Difference, households (89% CI)	PD
Non-deprived (<0.25)	2006	1.7 (-1.6 to 5.5)	104 (-102 to 346)	76%
Non-deprived (<0.25)	2011	7.2 (1.6 to 13.0)	556 (123 to 995)	98.2%
Non-deprived (<0.25)	2016	3.8 (0.0 to 6.7)	147 (0 to 264)	94.4%
Non-deprived (<0.25)	2022	1.8 (0.0 to 4.1)	115 (0 to 262)	91.8%
Less deprived (0.25-<0.50)	2006	1.8 (-0.9 to 4.6)	110 (-54 to 289)	86.6%
Less deprived (0.25-<0.50)	2011	-3.7 (-8.3 to -0.4)	-283 (-639 to -32)	96.4%
Less deprived (0.25-<0.50)	2016	-3.0 (-5.9 to 0.0)	-118 (-233 to 1)	90.8%
Less deprived (0.25-<0.50)	2022	-1.4 (-3.3 to 0.0)	-86 (-208 to 0)	89.8%
Deprived (0.50-<0.75)	2006	0.0 (-3.3 to 3.1)	-2 (-208 to 197)	50.2%
Deprived (0.50-<0.75)	2011	-2.5 (-5.1 to 0.0)	-195 (-395 to -1)	94.8%
Deprived (0.50-<0.75)	2016	-0.7 (-1.5 to 0.0)	-29 (-60 to 0)	54.8%
Deprived (0.50-<0.75)	2022	0.0 (-1.4 to 0.0)	0 (-87 to 0)	49.4%
Extremely deprived (>=0.75)	2006	-3.5 (-7.2 to -0.6)	-217 (-452 to -35)	96.4%
Extremely deprived (>=0.75)	2011	-0.5 (-2.1 to 0.0)	-41 (-160 to 0)	64%
Extremely deprived (>=0.75)	2016	0.0 (-0.8 to 0.0)	0 (-30 to 0)	12.4%
Extremely deprived (>=0.75)	2022	0.0 (0.0 to 0.0)	0 (0 to 0)	0.4%

Table 6. Full household socioeconomic deprivation category results, for every survey year. Columns report the percentage of households in each deprivation category (with 89% CI) under the zero-Community-Forestry counterfactual, under observed Community Forestry coverage, and their difference in percentage points

Socioeconomic deprivation category	Year	Zero CF (%, 89% CI)	Observed CF (%, 89% CI)	Difference (pp, 89% CI)
Non-deprived (<0.25)	2006	6.9 (2.2 to 13.7)	9.1 (3.3 to 14.8)	1.7 (-1.6 to 5.5)
Non-deprived (<0.25)	2011	59.2 (49.2 to 69.5)	66.9 (57.9 to 75.1)	7.2 (1.6 to 13.0)
Non-deprived (<0.25)	2016	85.9 (80.6 to 91.8)	90.3 (85.0 to 94.0)	3.8 (0.0 to 6.7)
Non-deprived (<0.25)	2022	87.1 (81.5 to 92.5)	89.0 (83.9 to 93.2)	1.8 (0.0 to 4.1)
Less deprived (0.25-<0.50)	2006	21.3 (16.0 to 27.1)	23.3 (17.6 to 29.1)	1.8 (-0.9 to 4.6)
Less deprived (0.25-<0.50)	2011	26.9 (20.6 to 33.7)	23.0 (16.6 to 30.0)	-3.7 (-8.3 to -0.4)
Less deprived (0.25-<0.50)	2016	11.8 (6.7 to 16.3)	8.2 (5.2 to 12.6)	-3.0 (-5.9 to 0.0)
Less deprived (0.25-<0.50)	2022	11.2 (6.4 to 15.6)	9.7 (5.7 to 13.8)	-1.4 (-3.3 to 0.0)
Deprived (0.50-<0.75)	2006	34.4 (29.8 to 40.1)	34.5 (29.4 to 39.9)	0.0 (-3.3 to 3.1)
Deprived (0.50-<0.75)	2011	11.3 (7.2 to 15.0)	8.4 (5.2 to 11.9)	-2.5 (-5.1 to 0.0)
Deprived (0.50-<0.75)	2016	2.3 (0.8 to 4.5)	1.5 (0.3 to 3.0)	-0.7 (-1.5 to 0.0)
Deprived (0.50-<0.75)	2022	1.5 (0.1 to 3.4)	1.4 (0.0 to 2.4)	0.0 (-1.4 to 0.0)
Extremely deprived (>=0.75)	2006	36.4 (27.9 to 46.3)	33.4 (24.0 to 41.4)	-3.5 (-7.2 to -0.6)
Extremely deprived (>=0.75)	2011	2.1 (1.1 to 4.7)	1.6 (0.5 to 3.2)	-0.5 (-2.1 to 0.0)
Extremely deprived (>=0.75)	2016	0.0 (0.0 to 0.8)	0.0 (0.0 to 0.8)	0.0 (-0.8 to 0.0)
Extremely deprived (>=0.75)	2022	0.0 (0.0 to 0.6)	0.0 (0.0 to 0.6)	0.0 (0.0 to 0.0)

Table 7. Extrapolated total differences in expected cases of stunting, wasting, and underweight among children under 5, with households weighted by DHS sampling weights. Negative values indicate fewer expected cases under observed Community Forestry coverage relative to a zero-Community-Forestry counterfactual.

Outcome	Year	Observations	Under-5 population	Zero CF expected cases	Observed CF expected cases	Difference (89% CI)
Stunting	2006	4293	3,137,848	1,650,513	1,606,851	-42,384 (-69,219 to -13,275)
Stunting	2011	1964	3,004,148	1,243,653	1,202,094	-43,203 (-69,473 to -14,425)
Stunting	2016	1059	2,999,716	1,121,006	1,089,583	-31,256 (-50,765 to -11,622)
Stunting	2022	1295	2,702,573	705,133	687,394	-16,488 (-27,236 to -5,900)
Wasting	2006	4293	3,137,848	1,217,548	1,181,746	-36,823 (-64,362 to -4,449)
Wasting	2011	1964	3,004,148	801,977	768,322	-33,335 (-59,203 to -4,926)
Wasting	2016	1062	2,999,716	741,630	718,491	-22,092 (-38,822 to -4,150)
Wasting	2022	1300	2,702,573	401,746	393,083	-9,447 (-16,085 to -1,565)
Underweight	2006	4293	3,137,848	1,650,513	1,606,851	-42,384 (-69,219 to -13,275)
Underweight	2011	1964	3,004,148	1,243,653	1,202,094	-43,203 (-69,473 to -14,425)
Underweight	2016	1059	2,999,716	1,121,006	1,089,583	-31,256 (-50,765 to -11,622)
Underweight	2022	1295	2,702,573	705,133	687,394	-16,488 (-27,236 to -5,900)

Table 8. Annualised 2006–2022 differences in stunting and underweight among children under five, scaled nationally relative to a zero-Community-Forestry counterfactual. Values report prevalence reductions per 1,000 children under five and expected cases avoided nationally per year; positive values indicate fewer expected cases under observed Community Forestry coverage.

Outcome	Prevalence reduction per 1,000 children under five (89% CI)	Expected cases avoided nationally per year (89% CI)
Stunting	11.3 (3.9 to 18.3)	33,965 (11,639 to 54,899)
Underweight	8.5 (1.3 to 14.9)	25,490 (3,887 to 44,789)

Supplementary References

1. Cook, N. J. *et al.* Effects of forestry decentralization on rural inequality in Nepal. *Nature Sustainability* 1–10 (2026) doi:10.1038/s41893-025-01729-z.
2. Iversen, V. *et al.* High value forests, hidden economies and elite capture: Evidence from forest user groups in Nepal's Terai. *Ecological Economics* **58**, 93–107 (2006).
3. Paudel, G., Carr, J. & Munro, P. G. Community forestry in Nepal: A critical review. *International Forestry Review* **24**, 43–58 (2022).
4. Dahal, G. R. & Chapagain, A. Community forestry in Nepal: Decentralized forest governance. in *Lessons from Forest Decentralization* 65–79 (Routledge, 2008).
5. Bennett, L., Dahal, D. R. & Govindasamy, P. Caste, ethnic, and regional identity in Nepal: Further analysis of the 2006 Nepal Demographic and Health Survey. https://dhsprogram.com/publications/publication-fa58-further-analysis.cfm (2008).
6. Cook, N. J. Experimental evidence on minority participation and the design of community-based natural resource management programs. *Ecological Economics* **218**, 108114 (2024).
7. Bennett, L., Tamang, S., Onta, P. & Thapa, M. Unequal citizens: Gender, caste and ethnic exclusion in Nepal. *Department for International Development and The World Bank, Kathmandu* 1–142 (2006).
8. Verger, E. O. *et al.* Dietary diversity indicators and their associations with dietary adequacy and health outcomes: A systematic scoping review. *Advances in Nutrition* **12**, 1659–1672 (2021).
9. Rasolofoson, R. A., Hanauer, M. M., Pappinen, A., Fisher, B. & Ricketts, T. H. Impacts of forests on children's diet in rural areas across 27 developing countries. *Science Advances* **4**, eaat2853 (2018).
10. Kennedy, G., Ballard, T. & Dop, M. *Guidelines for Measuring Household and Individual Dietary Diversity*. https://www.fao.org/4/i1983e/i1983e00.pdf (2011).
11. Pokharel, R. K. Development of community infrastructure through community forestry funds: What infrastructure gets priority? *Banko Janakari* **20**, 44–50 (2010).
12. Worede, E. A. *et al.* Prevalence of diarrheal diseases and associated factors among under five children in Africa: A meta-analysis. *PLOS ONE* **20**, e0326501 (2025).
13. Tag, Z. M., Alashwal, H., Chemaitelly, H. & Abu-Raddad, L. J. Global childhood diarrhoea prevalence and its determinants: A systematic meta-analytic assessment, 1985–2024. *eBioMedicine* **121**, 105956 (2025).
14. Worku, M. G. *et al.* Multilevel analysis of determinants of anemia among young women (15-24) in sub-Sahara Africa. *PLOS ONE* **17**, e0268129 (2022).
15. Reno, R. & Hyder, A. The evidence base for social determinants of health as risk factors for infant mortality: A systematic scoping review. *Journal of Health Care for the Poor and Underserved* **29**, 1188–1208 (2018).
16. Cinelli, C. & Hazlett, C. Making sense of sensitivity: Extending omitted variable bias. *Journal of the Royal Statistical Society Series B: Statistical Methodology* **82**, 39–67 (2020).
17. Cook, N. J., Khatri, D. B., Poudel, D. P., Paudel, G. & Acharya, S. Dropping out of environmental governance: Why Nepal's community-based forestry program is losing participants. *Elementa: Science of the Anthropocene* **13**, 00059 (2025).
18. Bharati, R. *et al.* Experiences and effect of implementing social health insurance (SHI) program in Nepal-A mixed method study. *PLOS Global Public Health* **5**, e0003492 (2025).
19. Clark, M. *et al.* Community management and wellbeing increase the resilience of Nepali forests to climate change. Preprint at https://doi.org/10.21203/rs.3.rs-6413705/v1 (2025).
20. Oldekop, J. A., Sims, K. R. E., Karna, B. K., Whittingham, M. J. & Agrawal, A. Reductions in deforestation and poverty from decentralized forest management in Nepal. *Nature Sustainability* **2**, 421–428 (2019).
21. Oldekop, J. A., Holmes, G., Harris, W. E. & Evans, K. L. A global assessment of the social and conservation outcomes of protected areas. *Conservation Biology* **30**, 133–141 (2016).
22. Kandel, P., Pandit, R., White, B. & Polyakov, M. Do protected areas increase household income? Evidence from a Meta-Analysis. *World Development* **159**, 106024 (2022).

23. Stoudmann, N. *et al.* Overview of evidence on mechanisms affecting the outcomes of terrestrial multiple-use protected areas. *One Earth* **6**, 492–504 (2023).
24. Agrawal, A. & Gupta, K. Decentralization and participation: The governance of common pool resources in Nepal's Terai. *World Development* **33**, 1101–1114 (2005).
25. Oli, B. N. & Treue, T. Determinants of participation in Community Forestry in Nepal. *The International Forestry Review* **17**, 311–325 (2015).
26. Olson Jr, M. *The Logic of Collective Action: Public Goods and the Theory of Groups, with a New Preface and Appendix*. vol. 124 (Harvard University Press, 1971).
27. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*. (Cambridge University Press, Cambridge, United Kingdom, 1990).
28. Pretty, J. Social capital and the collective management of resources. *Science* **302**, 1912–1914 (2003).
29. Bisung, E., Elliott, S. J., Schuster-Wallace, C. J., Karanja, D. M. & Bernard, A. Social capital, collective action and access to water in rural Kenya. *Social Science & Medicine* **119**, 147–154 (2014).
30. Ahmad, N. & Sadaqat, M. Social capital household welfare and poverty: Evidence from Pakistan. *The Pakistan Development Review* **55**, 467–482 (2016).
31. Cafaro, P., Hansson, P. & Götmark, F. Overpopulation is a major cause of biodiversity loss and smaller human populations are necessary to preserve what is left. *Biological Conservation* **272**, 109646 (2022).
32. Muyanga, M. & Jayne, T. S. Effects of rising rural population density on smallholder agriculture in Kenya. *Food Policy* **48**, 98–113 (2014).
33. Duranton, G. Growing through cities in developing countries. *The World Bank Research Observer* **30**, 39–73 (2015).
34. Malla, G. Climate change and its impact on Nepalese agriculture. *Journal of Agriculture and Environment* **9**, 62–71 (2008).
35. Paudel, B., Zhang, Y., Li, S. & Wu, X. Spatiotemporal reconstruction of agricultural land cover in Nepal from 1970 to 2010. *Regional Environmental Change* **17**, 2349–2357 (2017).
36. Nelson, A. & Chomitz, K. M. Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: A global analysis using matching methods. *PLOS ONE* **6**, e22722 (2011).
37. Chhetri, B. B. K., Johnsen, F. H., Konoshima, M. & Yoshimoto, A. Community forestry in the hills of Nepal: Determinants of user participation in forest management. *Forest Policy and Economics* **30**, 6–13 (2013).
38. Bista, R., Graybill, S., Zhang, Q., Bilsborrow, R. E. & Song, C. Influence of rural out-migration on household participation in community forest management? Evidence from the middle hills of Nepal. *Sustainability* **15**, 2185 (2023).
39. Gautam, Y. & Andersen, P. Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *Journal of Rural Studies* **44**, 239–249 (2016).
40. Tiwari, M. Land ownership and nutrition in Nepal. *Review of Development Economics* **28**, 1838–1870 (2024).
41. Levang, P., Dounias, E. & Sitorus, S. Out of the forest, out of poverty? *Forests, Trees and Livelihoods* **15**, 211–235 (2005).
42. Sapkota, I. P. & Odén, P. C. Household characteristics and dependency on community forests in Terai of Nepal. *International Journal of Social Forestry* **1**, 123–144 (2008).
43. Cheng, S. H. *et al.* What is the evidence for the contribution of forests to poverty alleviation? A systematic map protocol. *Environmental Evidence* **6**, 10 (2017).
44. Poudyal, B. H., Khatri, D. B., Paudel, D., Marquardt, K. & Khatri, S. Examining forest transition and collective action in Nepal's community forestry. *Land Use Policy* **134**, 106872 (2023).
45. Anwar, A., Mang, C. F. & Plaza, S. Remittances and inequality: A meta-analytic investigation. *The World Economy* **47**, 2664–2705 (2024).
46. Koirala, S. & Bashyal, S. The land left behind: A systematic review of transnational migration-induced change and its implication for rural sustainability in Nepal. *Humanities and Social Sciences Communications* **12**, 38 (2025).

47. Weiss, D. J. *et al.* A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature* **553**, 333–336 (2018).
48. Gautam, N. P. *et al.* Nepal's community forestry: critical reflection from the governance perspective. *Scandinavian Journal of Forest Research* **38**, 529–541 (2023).
49. Timilsina, S., Sharma, G. B., Poudel, P. & Timilsina, A. Users' participation in community forest management: A comparative study. *Journal of Resources and Ecology* **15**, 1335–1343 (2024).
50. Subedi, M. R. & Timilsina, Y. P. Evidence of user participation in community forest management in the mid-hills of Nepal: A case of rule making and implementation. *Small-scale Forestry* **15**, 257–270 (2016).
51. Atreya, K. *et al.* Dalit's livelihoods in Nepal: Income sources and determinants. *Environment, Development and Sustainability* 1–29 (2022) doi:10.1007/s10668-022-02582-2.
52. Varghese, J. S. *et al.* Changes in asset-based wealth across the life course in birth cohorts from five low- and middle-income countries. *SSM - Population Health* **16**, 100976 (2021).
53. Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A. & Robalino, J. A. Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences* **105**, 16089–16094 (2008).
54. Deere, C. D. & Doss, C. R. The gender asset gap: What do we know and why does it matter? *Feminist Economics* **12**, 1–50 (2006).
55. Fisher, B. & Naidoo, R. The geography of gender inequality. *PLOS ONE* **11**, e0145778 (2016).
56. Jolliffe, D. & Tetteh-Baah, S. K. Identifying the poor – Accounting for household economies of scale in global poverty estimates. *World Development* **179**, 106593 (2024).
57. Kinyanda, E. *et al.* Poverty, life events and the risk for depression in Uganda. *Social Psychiatry and Psychiatric Epidemiology* **46**, 35–44 (2011).
58. Huggard, L., Murphy, R., O'Connor, C. & Nearchou, F. The social determinants of mental illness: A rapid review of systematic reviews. *Issues in Mental Health Nursing* **44**, 302–312 (2023).
59. Kirkbride, J. B. *et al.* The social determinants of mental health and disorder: Evidence, prevention and recommendations. *World Psychiatry* **23**, 58–90 (2024).
60. Alon, N. *et al.* Social determinants of mental health in major depressive disorder: Umbrella review of 26 meta-analyses and systematic reviews. *Psychiatry Research* **335**, 115854 (2024).
61. Lippens, L., Vermeiren, S. & Baert, S. The state of hiring discrimination: A meta-analysis of (almost) all recent correspondence experiments. *European Economic Review* **151**, 104315 (2023).
62. Lund, C. *et al.* Social determinants of mental disorders and the Sustainable Development Goals: A systematic review of reviews. *The Lancet Psychiatry* **5**, 357–369 (2018).
63. Arouri, M., Nguyen, C. & Youssef, A. B. Natural disasters, household welfare, and resilience: Evidence from rural Vietnam. *World Development* **70**, 59–77 (2015).
64. Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M. & Beaudet, C. From poverty to disaster and back: A review of the literature. *Economics of Disasters and Climate Change* **4**, 223–247 (2020).
65. Makwana, N. Disaster and its impact on mental health: A narrative review. *Journal of Family Medicine and Primary Care* **8**, 3090–3095 (2019).
66. Amsalem, D. *et al.* The effects of war-related experiences on mental health symptoms of individuals living in conflict zones: A longitudinal study. *Scientific Reports* **15**, 889 (2025).
67. Galster, G. C. The mechanism(s) of neighbourhood effects: Theory, evidence, and policy implications. in *Neighbourhood Effects Research: New Perspectives* (eds van Ham, M., Manley, D., Bailey, N., Simpson, L. & Maclennan, D.) 23–56 (Springer Netherlands, Dordrecht, 2012). doi:10.1007/978-94-007-2309-2_2.
68. Solmi, M. *et al.* Age at onset of mental disorders worldwide: large-scale meta-analysis of 192 epidemiological studies. *Molecular Psychiatry* **27**, 281–295 (2022).
69. McGrath, J. J. *et al.* Age of onset and cumulative risk of mental disorders: A cross-national analysis of population surveys from 29 countries. *The Lancet Psychiatry* **10**, 668–681 (2023).

70. Katiyar, J. & Keynejad, R. Gender-specific economic interventions for women's mental health and well-being in South Asia: A systematic review. *Social Psychiatry and Psychiatric Epidemiology* https://doi.org/10.1007/s00127-026-03074-8 (2026) doi:10.1007/s00127-026-03074-8.
71. Antón, J.-I., Ponce, J. & Muñoz de Bustillo, R. Road to perdition? The effect of illicit drug use on labour market outcomes of prime-age men in Mexico. *Economics & Human Biology* **55**, 101415 (2024).
72. Karriker-Jaffe, K. J. Areas of disadvantage: A systematic review of effects of area-level socioeconomic status on substance use outcomes. *Drug and Alcohol Review* **30**, 84–95 (2011).
73. Manhica, H., Straatmann, V. S., Lundin, A., Agardh, E. & Danielsson, A. Association between poverty exposure during childhood and adolescence, and drug use disorders and drug-related crimes later in life. *Addiction* **116**, 1747–1756 (2021).
74. Manhica, H., Straatmann, V. S., Lundin, A., Agardh, E. & Danielsson, A.-K. Poverty in adolescence and later drug use disorders: Understanding the mediation and interaction effects of other psychiatric disorders. *BJPsych Open* **8**, e71 (2022).
75. Turner, S., Mota, N., Bolton, J. & Sareen, J. Self-medication with alcohol or drugs for mood and anxiety disorders: A narrative review of the epidemiological literature. *Depression and Anxiety* **35**, 851–860 (2018).
76. Hansen, E. R. *et al.* Adolescent substance use patterns and subsequent risk of mental and behavioural disorders, substance use, and suicidal behaviour: A cohort study. *The Lancet Public Health* **10**, e578–e587 (2025).
77. Myers, C. A. Food insecurity and psychological distress: A review of the recent literature. *Current Nutrition Reports* **9**, 107–118 (2020).
78. Pourmotabbed, A. *et al.* Food insecurity and mental health: A systematic review and meta-analysis. *Public Health Nutrition* **23**, 1778–1790 (2020).
79. Oram, S. *et al.* The Lancet Psychiatry Commission on intimate partner violence and mental health: Advancing mental health services, research, and policy. *The Lancet Psychiatry* **9**, 487–524 (2022).
80. Kondirolli, F. & Sunder, N. Mental health effects of education. *Health Economics* **31**, 22–39 (2022).
81. Magakwe, T. S. S. *et al.* Association between educational attainment and mental health conditions among Africans working and studying in selected African countries. *Scientific Reports* **15**, 20578 (2025).
82. Katoch, O. R. Determinants of malnutrition among children: A systematic review. *Nutrition* **96**, 111565 (2022).
83. Akombi, B. J. *et al.* Stunting, wasting and underweight in Sub-Saharan Africa: A systematic review. *International Journal of Environmental Research and Public Health* **14**, 863 (2017).
84. Larsen, D. A., Grisham, T., Slawsky, E. & Narine, L. An individual-level meta-analysis assessing the impact of community-level sanitation access on child stunting, anemia, and diarrhea: Evidence from DHS and MICS surveys. *PLOS Neglected Tropical Diseases* **11**, e0005591 (2017).
85. Alao, R. *et al.* Economic inequality in malnutrition: A global systematic review and meta-analysis. *BMJ Global Health* **6**, e006906 (2021).
86. Morioka, M. & Kondo, T. Agricultural productivity growth and household food security improvement in Nepal. *Review of Development Economics* **21**, e220–e240 (2017).
87. Li, Z., Kim, R., Vollmer, S. & Subramanian, S. V. Factors associated with child stunting, wasting, and underweight in 35 low- and middle-income countries. *JAMA Network Open* **3**, e203386 (2020).
88. Kartinah, N. T., Putri, S. I., Hedo, D. J. P. K., Simarmata, N. & Sianipar, I. R. Estimating pathways affecting stunting in families with children under aged 5 years. *Journal of Public Health Research* **14**, 22799036251397751 (2025).
89. Moradi, S. *et al.* Food insecurity and the risk of undernutrition complications among children and adolescents: A systematic review and meta-analysis. *Nutrition* **62**, 52–60 (2019).
90. de Oliveira, K. H. D. *et al.* Household food insecurity and early childhood development: Systematic review and meta-analysis. *Maternal & Child Nutrition* **16**, e12967 (2020).

91. Patriota, É. S. O. *et al.* Association between household food insecurity and stunting in children aged 0−59 months: Systematic review and meta-analysis of cohort studies. *Maternal & Child Nutrition* **20**, e13609 (2024).
92. Yadav, S. S., Matela, H., Panchal, P. & Menon, K. Household food insecurity, dietary diversity with undernutrition among children younger than five years in Indian subcontinent–a narrative review. *The Lancet Regional Health - Southeast Asia* **26**, 100426 (2024).
93. Humphrey, J. H. Child undernutrition, tropical enteropathy, toilets, and handwashing. *Lancet* **374**, 1032–1035 (2009).
94. Ali, S. A., Khan, U. & Feroz, A. Prevalence and determinants of anemia among women of reproductive age in developing countries. *Journal of the College of Physicians and Surgeons* **30**, 177–186 (2020).
95. Sagalova, V., Nanama, S., Zagre, N. M. & Vollmer, S. Long-term consequences of early marriage and maternity in West and Central Africa: Wealth, education, and fertility. *Journal of Global Health* **11**, 13004 (2021).
96. Owais, A., Merritt, C., Lee, C. & Bhutta, Z. A. Anemia among women of reproductive age: An overview of global burden, trends, determinants, and drivers of progress in low- and middle-income countries. *Nutrients* **13**, 2745 (2021).
97. Fite, M. B., Assefa, N. & Mengiste, B. Prevalence and determinants of anemia among pregnant women in sub-Saharan Africa: A systematic review and Meta-analysis. *Archives of Public Health = Archives Belges De Sante Publique* **79**, 219 (2021).
98. Karami, M., Chaleshgar, M., Salari, N., Akbari, H. & Mohammadi, M. Global prevalence of anemia in pregnant women: A comprehensive systematic review and meta-analysis. *Maternal and Child Health Journal* **26**, 1473–1487 (2022).
99. Moradi, S., Arghavani, H., Issah, A., Mohammadi, H. & Mirzaei, K. Food insecurity and anaemia risk: A systematic review and meta-analysis. *Public Health Nutrition* **21**, 3067–3079 (2018).
100. Aderemi, T. & Ogebe, J. Widowhood and multidimensional poverty: Evidence from Nigeria. *South African Journal of Economics* **92**, 386–412 (2024).
101. Fagbamigbe, A. F., Adeniji, F. I. P. & Morakinyo, O. M. Factors contributing to household wealth inequality in under-five deaths in low- and middle-income countries: Decomposition analysis. *BMC Public Health* **22**, 769 (2022).
102. Kefale, B. *et al.* Risk factors of under-five and infant mortality: An umbrella review of systematic reviews and meta-analyses. *Journal of Global Health* **14**, 04260 (2024).
103. Kefale, B. *et al.* Risk factors for neonatal mortality: An umbrella review of systematic reviews and meta-analyses. *eClinicalMedicine* **88**, 103525 (2025).
104. Tiruneh, D., Assefa, N. & Mengiste, B. Perinatal mortality and its determinants in Sub Saharan African countries: Systematic review and meta-analysis. *Maternal Health, Neonatology and Perinatology* **7**, 1 (2021).
105. Kurewa, E. N. *et al.* Effect of maternal HIV status on infant mortality: Evidence from a 9-month follow-up of mothers and their infants in Zimbabwe. *Journal of Perinatology* **30**, 88–92 (2010).
106. Hecht, R. *et al.* Putting it together: AIDS and the Millennium Development Goals. *PLOS Medicine* **3**, e455 (2006).
107. Paudel, T. *et al.* Epidemiology of HIV, programmatic progress and gaps in last 10 years in Nepal. *Journal of Virus Eradication* **2**, 35–40 (2016).
108. Jena, B. H., Jaldo, M. M., Demesa, Y. Y., Kebede, B. A. & Melaku, L. M. Magnitude of neonatal mortality and its association with maternal and child health care in sub-Saharan africa: A systematic review and meta-analysis. *Archives of Public Health = Archives Belges De Sante Publique* **83**, 219 (2025).
109. Coll, C. V. N., Ewerling, F., García-Moreno, C., Hellwig, F. & Barros, A. J. D. Intimate partner violence in 46 low-income and middle-income countries: An appraisal of the most vulnerable groups of women using national health surveys. *BMJ Global Health* **5**, e002208 (2020).

110. Dadi, A. F. *et al.* Intimate partner violence and childhood health outcomes in 37 sub-Saharan African countries: An analysis of demographic health survey data from 2011 to 2022. *The Lancet Global Health* **12**, e1785–e1793 (2024).
111. Boerma, T. *et al.* Global epidemiology of use of and disparities in caesarean sections. *The Lancet* **392**, 1341–1348 (2018).
112. Chaka, E. E., Mekurie, M., Abdurahman, A. A., Parsaeian, M. & Majdzadeh, R. Association between place of delivery for pregnant mothers and neonatal mortality: A systematic review and meta-analysis. *European Journal of Public Health* **30**, 743–748 (2020).
113. Azanaw, J., Malede, A., Yalew, H. F. & Worede, E. A. Determinants of diarrhoeal diseases among under-five children in Africa (2013–2023): A comprehensive systematic review highlighting geographic variances, socioeconomic influences, and environmental factors. *BMC Public Health* **24**, 2399 (2024).
114. Dimitrova, A., Gershunov, A., Levy, M. C. & Benmarhnia, T. Uncovering social and environmental factors that increase the burden of climate-sensitive diarrheal infections on children. *Proceedings of the National Academy of Sciences* **120**, e2119409120 (2023).
115. Dimitrova, A., McElroy, S., Levy, M., Gershunov, A. & Benmarhnia, T. Precipitation variability and risk of infectious disease in children under 5 years for 32 countries: A global analysis using Demographic and Health Survey data. *The Lancet Planetary Health* **6**, e147–e155 (2022).
116. Zhang, T. *et al.* The impacts of animal agriculture on One Health—Bacterial zoonosis, antimicrobial resistance, and beyond. *One Health* **18**, 100748 (2024).
117. Herrera, D. *et al.* Upstream watershed condition predicts rural children's health across 35 developing countries. *Nature Communications* **8**, 811 (2017).
118. Greenwood, E. E. *et al.* Mapping safe drinking water use in low- and middle-income countries. *Science* **385**, 784–790 (2024).
119. Zambrano, L. D., Levy, K., Menezes, N. P. & Freeman, M. C. Human diarrhea infections associated with domestic animal husbandry: A systematic review and meta-analysis. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **108**, 313–325 (2014).
120. Alebel, A. *et al.* Prevalence and determinants of diarrhea among under-five children in Ethiopia: A systematic review and meta-analysis. *PLOS ONE* **13**, e0199684 (2018).
121. Kyu, H. H. *et al.* Global, regional, and national age-sex-specific burden of diarrhoeal diseases, their risk factors, and aetiologies, 1990–2021, for 204 countries and territories: A systematic analysis for the Global Burden of Disease Study 2021. *The Lancet Infectious Diseases* **25**, 519–536 (2025).
122. Miatton, A. *et al.* The global burden of suboptimal breastfeeding from 1990 to 2019: Results and insights of the Global Burden of Disease. *European Journal of Pediatrics* **184**, 448 (2025).
123. Kroenke, K., Spitzer, R. L. & Williams, J. B. W. The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine* **16**, 606–613 (2001).
124. Ajele, K. W. & Idemudia, E. S. Charting the course of depression care: A meta-analysis of reliability generalization of the patient health questionnaire (PHQ- 9) as the measure. *Discover Mental Health* **5**, 50 (2025).
125. Carroll, H. A. *et al.* Establishing reliability and validity for mental health screening instruments in resource-constrained settings: Systematic review of the PHQ-9 and key recommendations. *Psychiatry Research* **291**, 113236 (2020).
126. Negeri, Z. F. *et al.* Accuracy of the Patient Health Questionnaire-9 for screening to detect major depression: Updated systematic review and individual participant data meta-analysis. *BMJ* **375**, n2183 (2021).
127. Spitzer, R. L., Kroenke, K., Williams, J. B. W. & Löwe, B. A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine* **166**, 1092–1097 (2006).
128. Plummer, F., Manea, L., Trepel, D. & McMillan, D. Screening for anxiety disorders with the GAD-7 and GAD-2: A systematic review and diagnostic metaanalysis. *General Hospital Psychiatry* **39**, 24–31 (2016).
129. Löwe, B. *et al.* Validation and standardization of the Generalized Anxiety Disorder Screener (GAD-7) in the general population. *Medical Care* **46**, 266–274 (2008).

130.Central Bureau of Statistics, Nepal. National Population Census 2001. (2002).
131.Central Bureau of Statistics, Nepal. National Population and Housing Census 2011. (2015).
132.National Statistics Office, Nepal. National Population and Housing Census 2021. (2023).
133.Depaoli, S. & Van de Schoot, R. Improving transparency and replication in Bayesian statistics: The WAMBS-Checklist. *Psychological Methods* **22**, 240–261 (2017).
134.Dirksen, J. *et al.* Exploring the potential for a new measure of socioeconomic deprivation status to monitor health inequality. *International Journal for Equity in Health* **21**, 56 (2022).