Environmental Degradation in One's Own Backyard: Who Gains and Who Loses from Sand Mining in India *

Sushant Banjara†, Claire Fan‡, Varun Kapoor §& Katie Zhang¶

November 7, 2026

Preliminary draft

Click here for latest version

Abstract

In the context of sand mining in India, we study why environmentally damaging natural resource extraction can persist despite substantial costs to nearby communities. Using a difference-in-differences design, we find that sand mining causes both environmental damage and local economic expansion. Near mines, the share of land inundated during the monsoon increases by 25% and satellite-measured vegetation declines by 2.8%, while nighttime light intensity rises by 12%. We then quantify the distribution of these costs and benefits. Asset gains are concentrated among socially and politically dominant groups. A survey of nearly 8,000 households across 210 mining and nearby non-mining villages reveals that only 9.0% of households in mining villages earn income from mining, with 1% of households receiving 53.8% of total mining income. Compensation for environmental damage is rare, and household profits from mining are insufficient to cover measured environmental losses in two-thirds of mining villages. To rationalize these findings, we develop a model of communal policymaking in which each household's support for resource extraction depends on its private net gains from extraction. Giving households that earn income from mining greater influence over decisions can sustain extraction in 78% of villages, including those where aggregate local losses exceed gains. Our findings highlight a political economy mechanism through which concentrated economic benefits can sustain extraction despite widespread, uncompensated environmental damage.

Keywords: sand mining, environmental degradation, resource extraction, distributive conflict, political influence, caste

JEL codes: D72, D74, J15, O13, Q34, Q56

*We thank Oeindrila Dube, and seminar audiences at Development Workshop at UChicago, MWIEDC (UIUC) 2025, Interdisciplinary PhD Workshop in Sustainable Development (Columbia) 2025, LSE Environment Camp 2025 and Workshop on Contemporary Political Economy at APU for helpful comments and feedback. Rajiv Kumar and Aritra Majumdar provided excellent research assistance. We are deeply indebted to the field team in Bihar led by Abhinash Mauar and Gufran Ahmad. This work would not have been possible without helpful discussions with Abhinash Mauar, Randheer Kumar, Rajiv Kumar and Aritra Majumdar. The project was funded by the Weiss Fund, Development Economics Research Fund at UChicago, Energy Policy Institute at UChicago and the Pearson Institute. The IRB approval for this project was provided by University of Chicago and Harvard University.

†University of Chicago Harris School of Public Policy. Email: sbanjara@uchicago.edu

‡University of British Columbia. Email: claire.fan@ubc.ca

§Harvard University. Email: varun_kapoor@fas.harvard.edu (corresponding author)

¶Harvard University. Email: katiezhang@g.harvard.edu

1 Introduction

Environmental damage from economic activities such as mining is often visible and concentrated among nearby communities. Yet extraction often continues, sometimes with support or participation from members of the same communities. Why does environmentally damaging extraction persist despite these local costs?

Several explanations could account for this coexistence of economic gains and environmental damage. First, extraction may generate local economic benefits that exceed its environmental costs. Under suitable property rights and low transaction costs, bargaining could allow beneficiaries to compensate those harmed (Coase, 1960). However, an efficient bargain may fail when those controlling decisions cannot credibly commit to future actions or compensation (Acemoglu, 2003). Second, the distribution of gains and losses may matter independently of their magnitudes. Households benefiting from extraction may be better organized or more politically influential than those bearing its costs, allowing extraction to persist even when aggregate local losses exceed gains (Olson, 1965; Boyce, 1994). Third, non-local firms and the state may benefit from extraction while affected communities lack the authority or institutional capacity to restrict it.

These explanations raise distinct questions about the economic and political consequences of extraction. Do the economic gains accruing to nearby households exceed the environmental losses they bear? Even if they do, are those harmed compensated? If local losses exceed gains, can the unequal distribution of benefits and political influence nevertheless sustain extraction? Addressing these questions requires moving beyond aggregate measures of economic activity and environmental damage to examine who benefits, who bears the costs, and whose interests carry weight in decisions. Social hierarchies may shape both access to economic gains and political influence. Moreover, because firms and the state control extraction, its persistence need not reflect the interests of nearby communities.

We study these questions through river sand mining in Bihar, India. Sand is a key input in construction, with global use estimated at approximately 50 billion tonnes annually (United Nations Environment Programme, 2026). Unlike higher-value minerals, sand is bulky and inexpensive relative to its transport costs. Extraction therefore tends to occur near construction markets, often close to rural settlements, farmland, and water sources. Sand mining thus brings the economic benefits of development into close proximity with its environmental costs. Bihar provides a particularly informative setting: its rivers supply sand for construction, while nearby communities depend heavily on agriculture and face substantial flood risks.

In Bihar, the state government authorizes sand mining at specified locations for fixed periods. However, authorization alone does not give mining companies unrestricted control over operations. Transporting sand often requires access through land owned by nearby households, which companies must negotiate with landowners. Residents can also earn income from mining and transport activities. At the same time, mining is subject to legal and environmental regulations that residents can invoke to report violations, demand compensation, and press officials to enforce restrictions. Nearby households therefore have opportunities both to benefit from mining

and to influence how it operates. These opportunities differ across households, however, and continued extraction need not reflect the preferences of a village majority.

Our empirical analysis combines government mining records, satellite data, existing household surveys, and a new survey of communities near rivers. Official district reports identify authorized mines and other locations considered suitable for extraction. We digitize these records and validate them against satellite imagery. We then link mining locations and approval dates to satellite measures of flooding, vegetation, and nighttime lighting. We use the National Family Health Survey to examine changes in household assets and housing conditions. Our field survey covers 8,203 households in 214 villages, including 137 villages near authorized mines and 77 comparison villages selected for their similarity to mining villages. It records household earnings from mining and related activities, land payments, environmental damage and associated monetary losses, compensation, support for extraction, and households' reported ability to object to or influence mining decisions. Together, these sources allow us to examine both the effects of mining and the distribution of its economic benefits and environmental costs.

We incorporate these data into a staggered difference-in-differences framework using authorized mines and their surrounding villages as the treated group, and suitable sites within the same district and along the same river, that are not authorized for mining during the study period, as the control group. Our identification strategy requires that, in the absence of mining, outcomes at authorized and comparison sites would have followed similar trends. We provide support for this assumption by showing parallel pre-trends in a variety of outcomes and covariates.

We begin by quantifying the environmental impacts of sand mining. Our estimates confirm the increase in flooding that is widely associated with sand mining. Within 500 metres of mines, the share of land inundated during the monsoon increases by 2.5 ppt, or 25% relative to its pre-mining level. The share of monsoon months experiencing flooding also rises by 3.7 ppt. The impacts extend to key inputs for agriculture. Groundwater levels, as reported by village leaders, see a greater decline in mining villages than in nearby control villages. Accordingly, we find that sand mining leads to a 2.8% decline in the Enhanced Vegetation Index, a satellite-based proxy for agricultural production, during the growing season.

Mining also generates local economic gains, but these are unevenly distributed across social groups. Using nighttime lighting as a proxy for economic activity (Román et al., 2018), we find that light intensity in villages within 1 km of mines increases by 12% following mining authorization. Mining thus brings local economic expansion alongside environmental damage. Whether these gains outweigh the losses borne by nearby households depends on their magnitude and distribution.

The economic gains from mining are unevenly distributed across social groups. Using two rounds of the National Family Health Survey, we compare changes in household assets near operating mines with those in comparison areas. Because the survey draws independent household samples in each round, our estimates capture changes in group averages rather than changes within the same households. We examine differences by caste, which shapes access to land and

economic opportunities. The survey distinguishes Upper-caste households, Other Backward Classes (OBC), and Scheduled Castes and Scheduled Tribes (SC/ST), the latter having historically faced severe social exclusion. Measured in standard deviations of the household asset index within the state, the estimated gain is 0.26 for Upper-caste and OBC households combined, compared with 0.01 for SC/ST households. The difference is 0.24 standard deviations and is significant at the 10% level. These results indicate unequal gains in household assets, but do not establish whether households are better off after accounting for environmental losses or whether those benefiting from mining have greater political influence.

Our field survey of households reveals that the economic benefits of mining are highly concentrated. Income from mining accruing to villagers, whether in the form of wages or payments for land access, is all earned by only 9.0% of households. The 1% of households who earn the most from sand mining account for 53.8% of the total earnings accruing to villagers. The distribution of these earnings reflects existing social and economic inequalities. Upper-caste households receive a disproportionately large share of mining income, as do farmland owners. The survey also distinguishes Backward Classes (BC) and Extremely Backward Classes (EBC) within the broader OBC category, allowing us to examine differences across four caste groups: Upper-caste, BC, EBC, and SC/ST.

The survey also examines whether households receive compensation for environmental damage and whether they can influence mining operations. Compensation for land damage is rare. To examine whether payments could change local support, we ask households whether they would accept continued mining in exchange for a hypothetical annual payment, randomly varying the amount offered. Larger payments increase stated acceptance, suggesting that compensation can influence households' preferences. Other responses reveal conflicting interests within communities. Participation in sand-related work is associated with greater support for mining, while greater reported environmental damage is associated with stronger preferences for restrictions. Although residents can raise objections, many consider public protests unsafe or doubt that complaints will prompt official action. Thus, households have opportunities to influence mining, but their ability to translate preferences into decisions may be limited.

To examine how these competing economic interests could shape the persistence of mining, we construct a measure of each household's economic stake in extraction. For each household we subtract annual monetary losses from environmental damage attributable to mining from annual mining profits, including land rents. Wage workers in mining could otherwise earn the local farm wage, so for them we count only the premium of the sand wage over it. Losses cover crop damage, deeper digging for water and flooding; road damage, road accidents, and dust and pollution affect the village as a whole and are left out of the household account. For flooding and groundwater depletion, we use river-specific estimates from the observational data analysis to attribute only a portion of reported losses to mining. A positive economic stake indicates that measured mining profits exceed attributable environmental losses, while a negative stake indicates the reverse. We construct these accounts for 5,293 households in 126 villages with current or past mining activity.

These measures capture the distribution of economic gains and losses associated with mining relative to a counterfactual without extraction.

We aggregate these household accounts to assess whether local mining profits cover local environmental costs. Averaging across households within each village and giving villages equal weight, annual profits are Rs. 1,890 per household, compared with measured costs of Rs. 2,627. Costs therefore exceed profits on average, by Rs. 738 per household, although the average net gain is close to zero among villages with currently operating mines. This average also masks substantial variation: profits cover costs in only 25 of 126 villages. In the remaining villages, redistributing the measured gains cannot compensate all households that lose from mining while leaving beneficiaries better off. Where gains exceed losses, compensation is financially possible but need not occur. The accounts and the limited compensation reported in the survey thus reveal two distinct obstacles to a compensating bargain: insufficient local gains in many villages and limited transfers to those harmed.

We next assess whether concentrated beneficiary interests could favour extraction despite a negative measured local surplus. In the model, households' net gains generate supporting pressure and their net losses generate opposing pressure. Political weights allow the same monetary stake to carry different weight across sixteen groups defined by caste, farmland ownership and receipt of mining profits. Each group retains the same multiplier across villages. Requiring one common rule makes the explanation more demanding than selecting a different pattern of influence for every location. The exercise establishes how far unequal effectiveness can reconcile local stakes with extraction.

With equal multipliers, the local balance is nonnegative in the 25 villages where measured profits cover losses. Allowing weights to differ between households with and without mining income substantially expands the model's explanatory scope. When the largest influence weight is at most ten times the smallest, a common set of weights can favour mining in 63 villages. Raising this limit to one hundred increases the number to 76. Distinguishing only households with and without mining income already reaches 74, so further differences by landownership and caste add little. In 39 of the remaining villages, no group has a positive net stake after summing its members' gains and losses. Reweighting these groups therefore cannot produce a political balance in favour of extraction. Unequal influence can thus reconcile mining with aggregate local losses in 51 of the 101 villages where losses exceed gains, but cannot account for extraction everywhere under this grouping of households.

Caste shapes these economic stakes through access to land, mining income and exposure to environmental damage. Upper-caste households constitute 16.4% of households but receive 41.1% of positive net gains. Their contribution to modelled supporting pressure remains disproportionate when households in the same landownership and profit-receipt position receive equal multipliers across castes. Unequal economic opportunities can therefore make caste relevant to the political balance even without an additional caste advantage in effectiveness. Allowing caste-specific multipliers produces a much wider range of possible pressure shares, showing that compatibility with

extraction alone places limited restrictions on actual caste influence.

Survey evidence on political responses complements these results. Within the same village, Upper-caste respondents are more likely than SC/ST respondents to report influence over mining decisions, even after accounting for farmland ownership and receipt of mining profits. Villages with larger losses among Upper-caste households are more likely to report real instances of opposition against mining in the village. These correlations are consistent with a political process shaped by unequal access to mining returns, differences in influence across castes, and conflicting economic interests within them.

Literature and contributions. This paper contributes to the literature on the political economy of environmental regulation by examining conflicts of interest within communities exposed to environmental harm. Existing research shows how local officials' incentives affect deforestation (Burgess et al., 2012), how conflicts of interest undermine environmental auditing (Duflo et al., 2013), and how mining booms affect political selection and politicians' wealth accumulation (Asher and Novosad, 2023). We complement this work by examining the interests of nearby households. Residents can bargain over land access and press for enforcement, but some also receive substantial returns from extraction. Their shared exposure to environmental damage therefore need not translate into a common interest in restricting mining. We combine estimates of mining's effects with household evidence on earnings, losses, compensation, and political responses to examine how these competing local interests could sustain environmentally damaging extraction.

We also contribute to research on resource extraction and local development, within the broader literature on development and environmental quality (Greenstone and Jack, 2015; Jayachandran, 2022). Prior studies document income gains from mining's demand for local inputs (Aragón and Rud, 2013), agricultural productivity losses from mining pollution (Aragón and Rud, 2016), and household wealth gains alongside adverse health outcomes (von der Goltz and Barnwal, 2019). Our contribution is to connect these opposing consequences to the distribution of households' net economic stakes. We combine estimates of environmental and economic effects with household accounts of mining profits and attributable monetary losses. These accounts assess whether measured gains accruing to nearby households are sufficient to cover their measured losses and identify who gains and loses within the same communities. Together with evidence on compensation, they distinguish economic expansion from a positive local surplus, and the financial feasibility of compensation from its actual provision.

These comparisons speak to longstanding questions about bargaining over externalities (Coase, 1960) and collective governance of shared resources (Ostrom, 1990). The concentration of benefits and unequal asset ownership can shape incentives for collective action (Olson, 1965; Bardhan et al., 2007), while unequal control and constraints on transfers can distort collective decisions (Banerjee et al., 2001). Building on the idea that environmental outcomes depend on the relative power of net winners and losers (Boyce, 1994), we assess how far unequal influence could reconcile extraction with a negative measured local surplus. We allow influence to vary

across groups defined by caste, landownership, and receipt of mining profits, subject to explicit bounds on its inequality. Crucially, the same pattern of influence must apply across villages. This restriction makes the explanation more demanding than assigning a separate pattern of power to fit each location. The exercise quantifies the scope and limits of an explanation based on unequal local influence, rather than estimating the political power households actually exercise.

Finally, we connect research on environmental inequality (Banzhaf et al., 2019) to work on social hierarchy and political power. Evidence from Indian villages links landownership and social dominance to elite political control (Anderson et al., 2015), while lobbying models show how wealth can distort public resource allocation (Esteban and Ray, 2006). We distinguish caste-related differences in economic stakes from additional differences in influence among households with the same landownership and mining-income status. Upper-caste households account for a disproportionate share of modelled pro-mining pressure even when influence weights depend only on these economic characteristics. Caste can therefore shape the political balance through unequal access to land and mining returns, without requiring a separate caste advantage in influence. Allowing caste-specific weights then assesses what this additional channel can explain. Evidence on reported influence and opposition complements the model, revealing political differences across castes as well as conflicting economic interests within them.

The remainder of the paper proceeds as follows. Section 2 describes sand mining institutions and the Bihar setting. Section 3 presents the data, the approach to estimating mining's effects, and evidence supporting that approach. Section 4 reports environmental and economic effects, including caste differences in asset gains. Section 5 examines household earnings, environmental damage, compensation, preferences, and the ability to object to or influence decisions. Section 6 combines household gains and losses with the political model to evaluate explanations for mining and caste's role in support and opposition. Section 7 concludes.

2 Background and Institutional Setting

River sand mining connects construction demand to the livelihoods and environmental conditions of nearby rural communities. In Bihar, extraction takes place along rivers bordered by villages, farmland and water sources. The state allocates mining rights, operators negotiate with households over labour and land access, and residents seek to influence operations and enforcement.

2.1 Bihar's sand economy

Sand is a basic input into concrete and other construction materials. Our study focuses largely on mining districts south of the Ganga, including those along the Sone, a major tributary whose construction-grade yellow sand is particularly valued. Extraction areas, commonly called sand ghats, lie on riverbanks, exposed riverbeds and floodplain islands, within a landscape also used for agriculture. Extraction ranges from manual digging and loading to operations using excavators. Sand moves by boat, tractor and truck, either directly to construction markets or through

traders and storage depots (Khan, 2022). Figure 1 illustrates mechanized extraction and site alteration; Appendix Figure A-4 shows transport.

Local households can supply mine labour, operate or own vehicles and machinery, manage loading and transport, or provide land. In our fieldwork, operators negotiated payments for private land used for access, storage and the movement of sand. These arrangements are distinct from the government's grant of mineral rights. Control over land needed by an operator can generate both rent and bargaining power, while households supplying labour occupy a different economic position. Bihar's 2019 rules require owners' consent for sand extraction on private land and provide for compensation to surface occupiers (Government of Bihar, 2019, Rules 29A, 29H and 83).

Caste and landholding shape access to resources and local influence (Anderson et al., 2015). The paper distinguishes Upper-caste households, Other Backward Classes (OBC), and the historically marginalized Scheduled Castes and Scheduled Tribes (SC/ST). Within OBC, our field survey separates Bihar's Backward Classes (BC) and Extremely Backward Classes (EBC). These categories do not identify a single economic interest: households within a caste differ in landownership, mining participation and exposure to damage. A household can earn from extraction while also losing crops, land or access to water.



(a) Excavation and truck loading

(b) A cordoned-off mining area

Figure 1: Sand extraction and site alteration in Bihar

Notes: Panel (a) is a field photograph from Patna, March 2023. Panel (b) is Google Maps imagery captured in 2023.

2.2 Mining rights and environmental safeguards

Ordinary sand is a minor mineral under India's Mines and Minerals (Development and Regulation) Act, 1957. State governments regulate minor-mineral concessions and illegal extraction, transport and storage (Government of India, 1957, Sections 3(e), 15 and 23C). In Bihar, the Mines and Geology Department administers the sector through district authorities, including the District Magistrate/Collector and district mining officers. Mining rights are awarded through auctions for fixed terms, generating settlement payments and other state receipts. Arrangements have changed over time: the five-year settlements for 2015–2019 were extended while new auctions

were delayed.[1]

The award of a concession, environmental clearance and the start of extraction need not coincide. District Survey Reports (DSRs) inventory resources and identify existing leases, potential mining areas and locations where extraction should be prohibited. The regulatory framework requires a DSR before auctioning mining areas, and an approved mining plan and prior environmental clearance before operations. The Ministry of Environment, Forest and Climate Change's 2016 management guidelines and 2020 enforcement guidelines address replenishment, extraction boundaries and depth, riverbank and infrastructure protection, permitted methods, and monsoon restrictions (Ministry of Environment, Forest and Climate Change, 2016, 2020). The National Green Tribunal (NGT), a specialized environmental tribunal, has reviewed compliance with this framework; the guidelines themselves are issued by the ministry.

Permission does not establish compliance. Extraction can occur outside approved boundaries or without required clearances, as an official audit documented at sampled Bihar sand sites (Comptroller and Auditor General of India, 2022, Chapter 4). We study mining associated with permitted sites, whose operations may include violations of spatial, seasonal or other conditions. Conversely, a proposed site in a DSR is a candidate for mining, not evidence that extraction has begun. These distinctions motivate the administrative records and image checks described in Section 3.1.

2.3 Environmental exposure and compensation

Sand mining can reduce agricultural productivity by altering the connection between river water and groundwater. Excavation deepens the riverbed and can lower the river's water level. Where the river and groundwater are connected, water in surrounding sediments can drain toward the lowered channel, pulling down the local water table. Wells may then yield less water or require deepening, raising irrigation costs and limiting crop production (Kondolf, 1997; Rentier and Cammeraat, 2022).

Excavation can also increase erosion and flood exposure. Removing sediment that supports riverbanks and flood embankments can undercut their slopes and make them more prone to collapse. Bank erosion destroys adjacent land, while a breach in a flood embankment allows high flows to inundate farms and settlements (Kondolf, 1997; Wang et al., 2012). The net effect on flooding depends on where extraction occurs and how the channel and its banks respond.

Other harms arise from excavation and transport. Digging, loading and truck traffic disperse dust that nearby residents inhale and that settles on crops. Inhaled dust can irritate airways, while deposits on leaves can impair photosynthesis and crop growth (Rentier and Cammeraat, 2022; Farmer, 1993).

Transport also brings heavy vehicles onto village roads, increasing residents' exposure to col-

[1]The 2015–2019 settlements operated under the 2013 Sand Policy and the Bihar Minor Mineral Concession Rules, 1972, as amended in 2014. Auctions initiated in 2019 for 2020–2024 stalled over incomplete District Survey Reports, and earlier settlements were extended in stages through 2021 (Comptroller and Auditor General of India, 2022, Chapter 2).

lisions. At the extraction site, deep pits can remain hidden underwater, creating sudden drops in depth and drowning hazards for people bathing in or crossing the river (ActionAid India, 2016).

Legal provisions for compensation and environmental relief coexist with public funds benefiting mining-affected people and areas (Government of Bihar, 2019; Government of India, 2010). Bihar's District Mineral Foundations are intended to finance public services and restoration, which differ from reimbursing individual losses. The official audit found substantial balances remaining unspent in the audited districts in September 2021 (Comptroller and Auditor General of India, 2022, Chapter 5). Mining earnings, land rent, compensation for environmental damage and state disaster assistance are therefore distinct sources of household receipts.

2.4 Community participation and voice

Residents have formal opportunities to raise concerns. Draft DSRs invite public comments, and residents can participate in public consultation where required for environmental clearance. The requirement depends on project category and applicable rules rather than extending to every individual lease. The 2020 enforcement guidelines also prescribe a committee of three local residents, nominated by the District Magistrate, to participate in environmental audits (Ministry of Environment, Forest and Climate Change, 2016, 2020). These procedures allow affected people to provide information and seek safeguards, while lease allocation remains an administrative decision rather than a village vote.

Influence can also operate during extraction. Residents can approach village leaders and elected representatives, negotiate with contractors, complain to mining officials or the police, and organize petitions, protests or blockades. Environmental disputes can reach the courts or the NGT, which has powers concerning relief and compensation (Government of India, 2010). Landowners and mining participants may have direct relationships with operators, while other residents depend more heavily on collective action and official enforcement.

The availability of these channels does not ensure safe or effective objection. Reporting from the Sone floodplain documents intimidation, violence and conflicts over extraction, alongside workers' dependence on mining income (Jha and Yousaf, 2023). Local disputes can concern environmental protection, access to earnings, or both. Contractors also earn returns and the state receives revenues beyond the household gains measured in nearby villages. Continued mining can therefore reflect overlapping interests; it does not by itself establish community agreement or that nearby households' gains exceed their losses. The household survey examines these economic stakes, experiences of objection and perceptions of influence directly. Appendix A.2 summarizes the legal provisions for compensation and complaint and describes cases in which residents and organizations have appealed.

3 Data and Empirical Strategy

3.1 Data

3.1.1 Sand mine locations and permit dates

We use District Survey Reports (DSRs) to identify sand-mining sites and construct a comparison group of locations suitable for extraction. Prepared under the *Sustainable Sand Mining Management Guidelines 2016*, these reports list existing mining leases and identify potential sites for future extraction. Potential sites are geographically delineated areas that have undergone feasibility assessments and been identified for future auctions. The guidelines require DSRs to document existing leases and available sand resources, and specify that mining should occur only in areas identified as suitable in these reports. The DSRs therefore allow us to draw comparison sites from locations assessed as suitable for mining, rather than from river stretches with no identified mining potential. For both existing and potential mines, the DSRs report the coordinates that delineate the boundary of the mine.

Our database covers 18 of Bihar's 21 districts containing major rivers, out of 38 districts statewide. It initially contains 1,745 active and potential mining sites and covers nearly all districts south of the Ganga River. This region supplies golden-yellow sand that is highly valued for construction, in contrast to the less valuable white sand found in northern Bihar.

We digitize the DSRs to extract site boundaries and, for active mines, reported lease and operation dates. Appendix Figure A-1 illustrates the format of these records. We convert each site's boundary coordinates into a polygon and classify it as an active or potential mine. For active mines, we also assign a treatment date using the administrative records. Where lease dates are unavailable in the DSRs, we supplement them with publicly available auction documents and use the auction date as a proxy for treatment timing.

We refine the comparison group in two stages. First, we exclude potential-mine polygons with more than 20% overlap with existing mines. This restriction reduces spatial overlap between treated and comparison sites and leaves 1,529 polygons across the same 18 districts, before the additional exclusions described below. This dataset is used as input for our analysis.

Second, we use historical Google Earth imagery to assess whether the administrative classifications and dates correspond to observed extraction. We compile image sequences for all sites in the sample districts using imagery dating back as far as 2010. The resulting collection contains more than 30,000 screenshots. Research assistants manually examine these images and record whether mining activity is visible. This exercise checks both whether potential sites remained unmined during the study period and whether extraction at active sites was visible before their assigned treatment dates. Table 1 summarizes the findings.

For most sites classified as active mines, the available imagery shows mining at or near the designated location only after the assigned treatment date. For most potential sites, we find no visible evidence of extraction during the study period. We exclude the small subset of potential sites with observed mining from the main analysis. The dataset at the end of this removal is used

as the final set of mines in our analysis. We do an additional refinement to avoid counting the same area as part of our analysis more than once. Some active mines may be close to each other, and therefore when we create a buffer of 500 meter around these mines (for creating a measure of inundation or vegetation) some buffers may overlap. Therefore, we fuse mines with overlapping buffers into one and consider them as one mine. After this cleaning, we exclude proposed mines located within 500 meters of an active mine from our sample to prevent spillover effects from existing mines.

Figures 2a and 2b illustrate an active mine and a potential site without visible mining, respectively. These checks provide evidence on the correspondence between administrative records and actual extraction, subject to the availability and clarity of historical imagery. Appendix Section A.1 provides further details on data construction and validation.

Table 1: Checks with Google Earth

Mining Activity	**% Existing**	**% Proposed**
Mining before official date	10.9	–
No mining before official date	89.1	–
Mining during sample period	–	36.8
No mining during sample period	–	63.2
Number of mines	1012	517



(a) Example of active mining



(b) Example of no mining on potential mine

Figure 2: Examples of Google Earth satellite imagery of locations with and without a sand mine

3.1.2 Flooding

Our flood measure comes from the JRC Monthly Water History dataset (Pekel et al., 2016), which provides a monthly binary measure of pixel inundation. To define the area surrounding each mine for assessing flooding impacts, we begin by creating a 500-meter radius buffer around the centroid of each mine. However, when mines are located close to one another, their buffers may overlap, leading to potential double counting of affected areas. To prevent this, we merge all contiguous overlapping buffers into a single, unified observation unit. For example, if mines A, B, and C are in proximity and the buffers of A and B as well as A and C overlap, we consolidate all three into a single merged shape, ensuring that each affected area is counted only once. To prevent spillover

effects from existing mines, we exclude proposed mines located within 500 meters of an active mine from our sample.

We measure flooding in two ways. Within the truncated circle around each potential or existing sand mine, we calculate the percentage of 30m x 30m cells inundated each month, among the cells with a valid observation that month; months with no valid observation because of cloud cover are left out. Our first measure, an area-based flooding metric, is the average inundation rate for the months from June to October, the monsoon and post-monsoon months when flooding occurs.

Our second, month-based measure records flooding incidents. To establish a baseline, we calculate each site's mean inundation rate for each calendar month over 2004–2010, before any mine in our sample received a permit. For each month-year combination, we classify a site as flooded if the inundation rate is at least 20% higher than its baseline for that calendar month (Patel, 2024) and at least 10% of the area is inundated. The second condition keeps small changes at sites that are almost never inundated from counting as floods; a month at a site with no inundation at all is not a flood. The annual measure is the share of observed months from June to October in which the site is flooded. Our analysis uses the years 2011–2021. Our empirical analysis uses panel data at the mine × year level.

3.1.3 Nightlights data

We obtain monthly gridded nightlights data for 2012-2023 at the 15 arc-second (approximately 0.5km) resolution from NASA's Black Marble product. Black Marble is derived from the satellite imagery collected by the VIIRS instrument, but compared to previous VIIRS nightlight products, it is better-suited for tropical low and middle-income countries like India where cloud cover is persistent and many areas have low nightlight intensity. In particular, it has improved sensitivity to low-intensity lights, better accounts for seasonal variation, and employs "temporal-gap filling" to reduce persistent data gap (Román et al., 2018).

For the village-level nightlights analysis, the sample consists of villages within 1 km of a mine in our final set of mines: we draw a circle of 1 km radius around each mine's centroid and keep every village that overlaps it. A village is treated if the circle around at least one existing mine overlaps it, and its treatment year is the earliest start year among those mines. Villages overlapped only by circles around proposed mines form the comparison group. We exclude villages with more than 15,000 residents in the 2011 Census. Within each village, we exclude cells with centroids inside active sand mines. We then average the remaining cells within each village to create a village × month panel of nightlights. Finally, we aggregate the data from monthly to yearly values.

3.1.4 Vegetation data

To measure agricultural production, we obtain gridded data of the Enhanced Vegetation Index (EVI) at a 16-day, 250m resolution, from 2012-2024, from the MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid data product, Version 6.1 (Didan, 2021). Where granular data on

agricultural production is not available, vegetation indices are a commonly used proxy (Didan et al., 2015; Burke and Lobell, 2017). Among vegetation indices, the EVI has several advantages over the Normalized Difference Vegetation Index (NDVI), including better differentiating vegetation levels in areas with either high biomass or sparse vegetation, and correcting for the influence of aerosols and haze (Huete et al., 2002). For the 500m buffer around each mine centroid and each 16-day window, we extract the average EVI by taking the mean value of all 250m cells overlapping with the buffer. The 16-day values are then aggregated to the annual level.

3.1.5 Other data

Village-level polygons, Census data, and elections data were downloaded from the Socioeconomic High-resolution Rural-Urban Geographic Platform for India (Asher et al., 2021).

3.1.6 Field survey

Sampling of villages. We conducted fieldwork between June and October 2026 in 214 villages across seven districts of Bihar. These districts were chosen on the basis of intensity of mining. We identified mining villages as those within 1 km of a permitted mine and matched them to comparison villages along the same river, within the same district and no more than 7 km away, using demographic, agricultural and infrastructure characteristics from the 2011 Census. Comparison villages were drawn from river-adjacent settlements and need not contain a proposed mine. We randomly selected mining villages together with their matched comparison villages for fieldwork. Matching allowed a comparison village to serve more than one mining village, yielding 137 mining villages and 77 comparison villages.

Household and community surveys. Within each hamlet, we randomly selected 10% of households for the household survey and interviewed the household's senior most earning member. The completed sample contains 8,203 households. These interviews measure households' economic circumstances, mining-related earnings and environmental losses, compensation, and preferences concerning extraction. A separate community survey targeted 5% of households and examined local institutions, political influence and the ability to object to mining. Most community interviews were conducted in households included in the household survey, with some additional households interviewed separately.

Village leader surveys. We also conducted interviews with elected representatives and residents knowledgeable about farming, and other local conditions. We refer to this instrument as the village-head survey. Their reports provide village-level information, including the groundwater histories. Supervisors also documented mining activity and its history, including whether extraction was continuing or had ceased, and local opposition or disputes. These assessments drew on conversations with residents across hamlets and caste groups.

Reference periods. Household economic measures refer principally to 2025, while reported environmental losses cover 2021–25. Retrospective questions record earlier livelihoods and environmental experiences, including changes over 2011–15, 2016–20 and 2021–25. Village informants report groundwater depth for 2010, 2015, 2020 and 2025. Historical comparisons therefore use recalled information.

3.2 Identification strategy

We identify the effects of sand mining in Bihar by comparing changes in outcomes around permitted mines with changes around proposed mining sites that remain unpermitted during the study period. District Survey Reports (DSRs) provide the basis for this comparison. As described in Section 3.1, these reports identify both existing mining leases and potential sites for future mining. The regulatory framework requires the identification of suitable mining areas before leases are granted, taking account of sand deposition, erosion, and proximity to infrastructure. Proposed sites therefore provide a comparison group drawn from locations identified as suitable for mining, helping us distinguish the effects of mining from differences between locations with and without mineable sand.

This institutional feature motivates the comparison but does not establish that the allocation or timing of permits is random. Our identifying assumption is that, conditional on the controls described below, outcomes around permitted and proposed sites along the same river and within the same district would have followed parallel trends in the absence of mining. This assumption allows the two groups to differ in their initial outcome levels, but rules out differences in their counterfactual trends associated with whether or when mining begins. Identification also requires no anticipation of treatment and no spillovers large enough to affect the comparison group's outcomes. The spatial exclusions and satellite-image checks described above help limit contamination from nearby or unrecorded extraction. The following subsection examines evidence relevant to parallel trends using the spatial distribution of sites, baseline characteristics, and changes before mining began.

The unit of observation depends on the outcome. For flooding and vegetation, we measure outcomes in the areas surrounding mining sites, using the geographic units defined in Section 3.1. For nightlights, we use villages within 1 km of permitted or proposed mines. Village-level aggregation captures changes in residential and commercial activity that may occur beyond the immediate vicinity of extraction. We exclude mine areas and their buffers from the village nightlights measure, as described above.

Let G_i denote the recorded treatment year for unit i, associated with river r and district d, and let $G_i = \infty$ for comparison units associated with proposed sites that remain unpermitted during the sample period. Our treated sample comprises the 2016–2020 cohorts. Treatment dates use the administrative information described above, including recorded operation or lease dates and, where necessary, auction dates. These dates approximate the onset of extraction; satellite-image checks and alternative sample definitions help assess sensitivity to discrepancies between

recorded dates and actual mining activity.

Our static specification is

$$Y_{irdt} = \alpha_i + \delta_{rdt} + X'_{it}\gamma + \beta\,\mathbf{1}\{t \geq G_i\} + \varepsilon_{irdt}, \tag{3.1}$$

where $\mathbf{1}\{t \geq G_i\}$ equals one for a permitted unit in its treatment year and after, and zero for comparison units in all years. α_i denotes unit fixed effects, and δ_{rdt} denotes district-by-river-by-year fixed effects. These absorb permanent differences across units and annual shocks shared by locations along the same river within a district. The vector X_{it} contains outcome-specific controls: precipitation and temperature for the environmental outcomes, and baseline village characteristics interacted with year for nightlights. We also report specifications using district-by-year fixed effects.

Under the identifying assumptions, β is the average effect of mining over the post-treatment years included in each outcome's estimation window.

To examine the evolution of outcomes around treatment, we express effects in event time:

$$Y_{irdt} = \alpha_i + \delta_{rdt} + X'_{it}\gamma + \sum_{\substack{\tau \in \mathcal{T} \\ \tau \neq -1}} \beta_\tau \mathbf{1}\{t - G_i = \tau\} + \varepsilon_{irdt}, \tag{3.2}$$

where τ measures years relative to treatment, $\mathcal{T}$ contains the event times in the outcome-specific estimation window, and the event-time indicators are zero for comparison units. The year immediately before treatment, $\tau = -1$, is the omitted period. Each β_τ is the average effect of mining τ years after treatment. Pre-treatment coefficients provide evidence on differential trends and anticipation, while post-treatment coefficients trace the evolution of mining's effects. These comparisons use proposed sites that remain unpermitted as the untreated reference group.

3.3 Support for parallel trends assumption

To empirically assess the plausibility of the parallel trends assumption, we begin by mapping the sites with existing and proposed leases. Figure 3 maps the centroids of existing and proposed sand mines in Bihar. Within any given district, the existing and proposed mines are well-interspersed, so it does not appear to be the case that timing of leases correlates with potential confounders such as being more up- or downstream along the river or distance from markets or urban areas.

Next, we check for pre-trends in economic and demographic variables in the villages around existing and proposed mines. We use the Socioeconomic High-resolution Rural-Urban Geographic Platform for India (Asher et al., 2021) to access village-level Population Census Abstract data from the 1991, 2001, and 2011 Censuses. For different demographic and public goods variables at the village level we perform two kinds of comparisons between villages which had an operational mine by 2020 and those which had a potential mine. First, we compare the cross-sectional differences on these variables in 2011 (see Figure 4a). The treated and control villages are similar across most variables. Then in Figure 4b, we compare the change in these variables

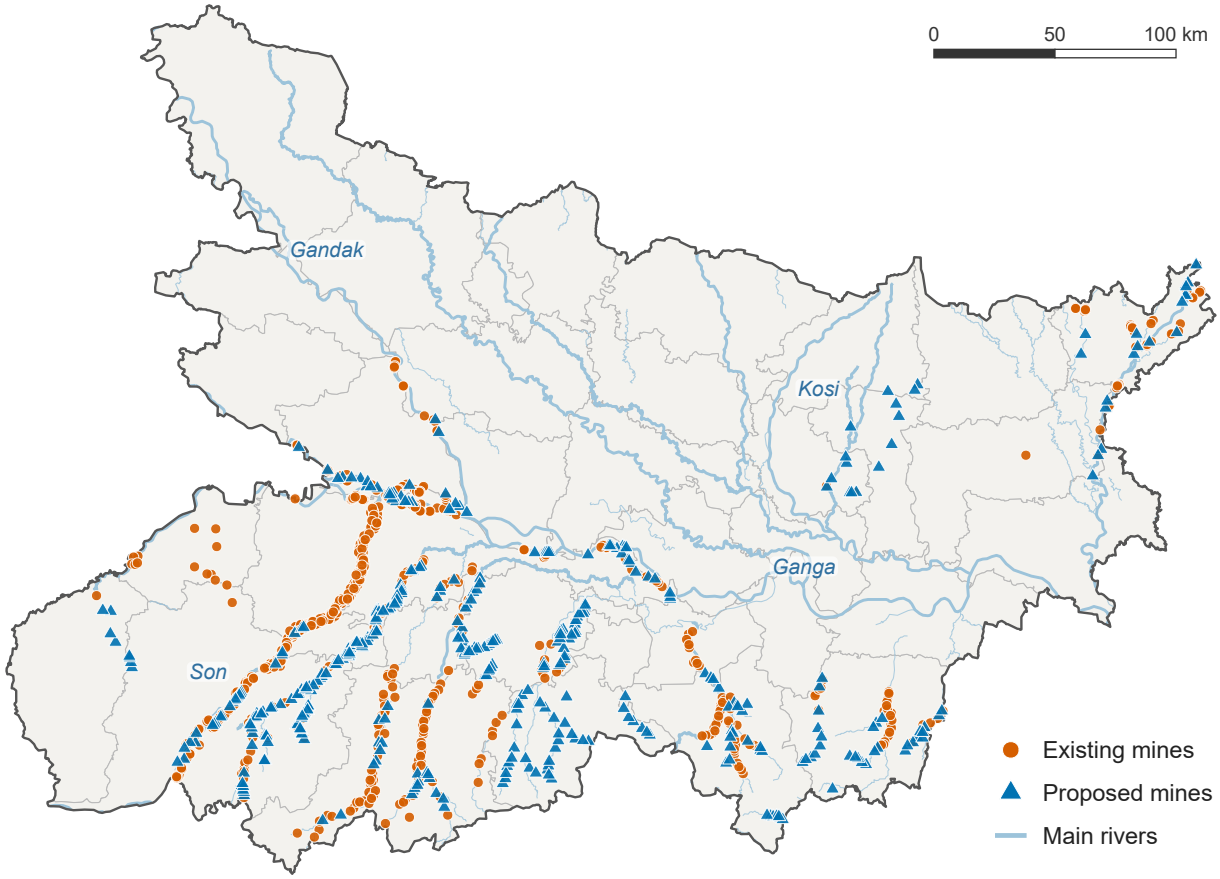


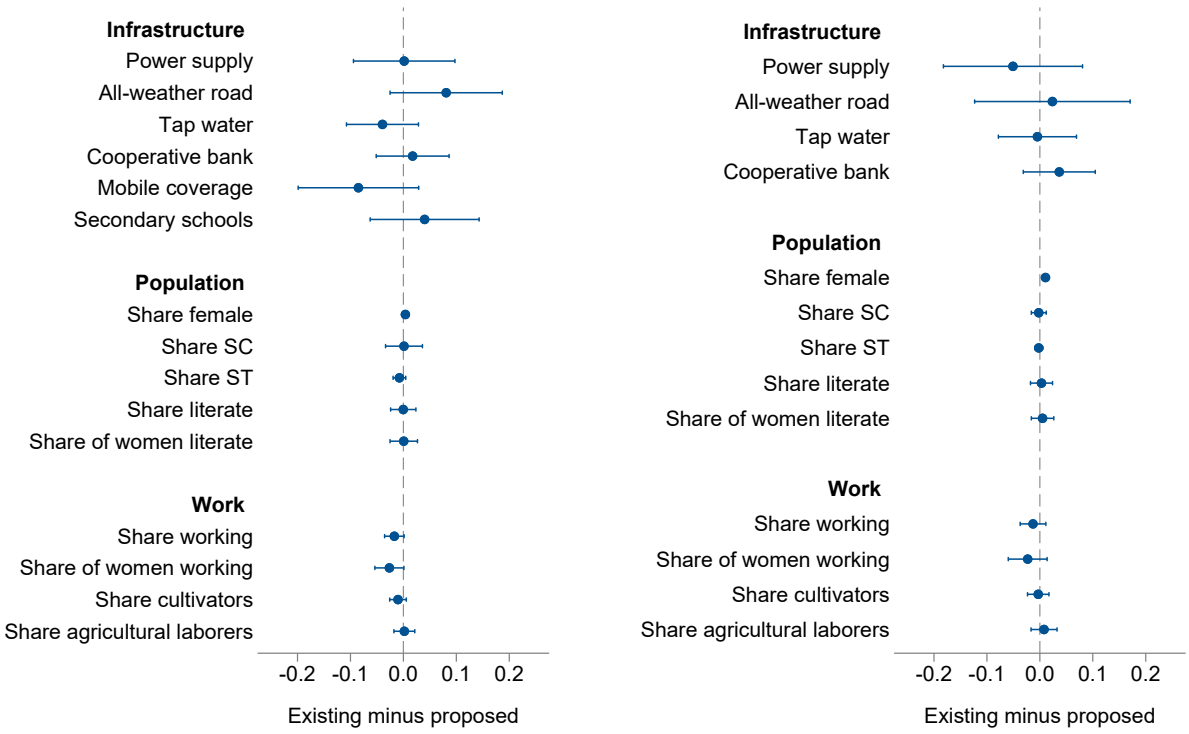
Figure 3: Centroids of existing and proposed sand mines in Bihar

Notes: Each marker is the centroid of a sand mine polygon from the District Survey Reports. Thin gray lines are district boundaries. Blue lines are rivers from OpenStreetMap; the main rivers are drawn thicker.

between 2001 and 2011 across the two types of villages. The figure clearly illustrates that the trend in change for the decade was not different between the treatment and control village.

Finally, one may be concerned that the timing of when a sand mining permit is granted in a village could be related to the village's political connections, posing a threat to the parallel trends assumption. Although we cannot test for balance in a comprehensive way - for example, we do not know of any publicly available data on district government officials' villages of origin, we can check for balance on state assembly election outcomes. Although sand mining sites are chosen and auctioned off by the district government rather than the legislative assembly, it is possible that members of the legislative assembly (MLAs) hold some informal influence over these decisions.

Bihar held state assembly elections in 2015 and 2020. In our sample of existing and proposed mines, 96% of existing mines received their permit in 2016-2020, so we check for balance based on 2015 election results. In that election, the parties winning the most assembly constituency (AC) seats were the RJD, JD(U), and BJP, in that order. The RJD, JD(U), and INC formed the ruling coalition that held a majority in the assembly. In July 2017, that coalition fell apart and a new



(a) Levels in 2011

(b) Change from 2001 to 2011

Figure 4: Balance in observable characteristics

Notes: Panel (a) plots coefficients from separate regressions of each 2011 village characteristic on an indicator for proximity to a treated mine, with villages near potential mines as the comparison group. Panel (b) uses the change in each characteristic between 2001 and 2011 as the dependent variable. All regressions include district-by-river fixed effects.

ruling coalition formed between the JD(U), BJP, and LJP.

Appendix Table B-1a shows mine-level correlations between the party of the elected MLA and sand mine permit status. There is no significant correlation between MLA party affiliation and either the probability of having been treated (i.e. granted a permit) by 2021, when our DSR data was published, or the year in which treated mines were granted their permits. In Appendix Table B-1b, we aggregate the mines to the AC level. We find that among the 78 ACs containing any existing or proposed mines, the party of the elected MLA is not significantly correlated with the total number of existing and proposed mines, the share of existing mines in that total, or the timing of existing mines' permits. Although the coefficient on RJD in Column (1) is large, this is to be expected as the RJD's support base is primarily cultivators who tend to live near rivers, where sand mining is more prominent for purely geographical reasons. As such, many of the prime locations for sand mining happen to be in RJD ACs. There is also no significant or consistent correlation between the number of sand mine permits an AC receives in a given year and whether the MLA's party is in the ruling coalition during that year.

4 Effects of Sand Mining on Environmental and Economic Outcomes

4.1 Effects on flooding

In this section we present static and dynamic difference-in-differences estimates of the effect of sand mining on flooding. Table 2 reports the static estimates. Within 500 m of a mine, the stacked difference-in-differences estimate shows that mining raises the share of the area inundated in June–October by 2.5 ppt (column 1), a 25% increase over the pre-mining mean of 9.9% among mines that began operating. The interaction-weighted estimate is 1.3 ppt (column 3). The share of June–October months with a flood rises by 3.7 ppt (column 5), 32% of the pre-mining mean of 11.4%; the interaction-weighted estimate is 2.3 ppt (column 7). Figure 5 shows the event study estimates. Inundation rises after mines begin operating: the largest stacked estimate is 3.9 ppt, in year 3, and the largest interaction-weighted estimate is 3.8 ppt, in year 4. For the probability of flooding, the largest estimates are 4.6 ppt in year 3 (stacked) and 7.5 ppt in year 4 (interaction-weighted).

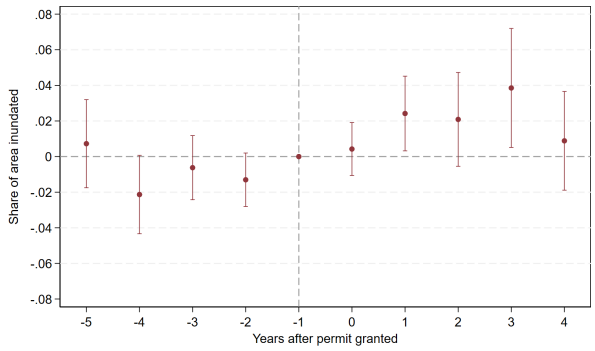
Table 2: Effect of mining on flooding

	Share of area inundated				Probability of flooding			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated mines	0.025**	0.019**	0.013*	0.010*	0.037***	0.029***	0.023**	0.013
	(0.010)	(0.008)	(0.007)	(0.006)	(0.012)	(0.011)	(0.011)	(0.009)
Observations	12,596	13,304	5,329	5,549	12,596	13,304	5,329	5,549
Mean Dep variable	0.099	0.099	0.099	0.099	0.114	0.114	0.114	0.114
Method	Stacked	Stacked	Sun-Abraham	Sun-Abraham	Stacked	Stacked	Sun-Abraham	Sun-Abraham
Fixed Effect	Dist*River	District	Dist*River	District	Dist*River	District	Dist*River	District

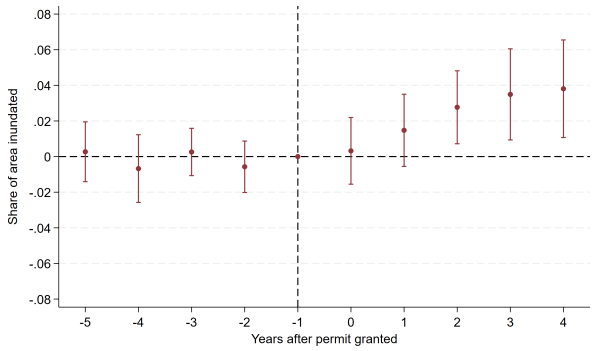
Notes: The dependent variables are the share of the area within 500 meters of the mine inundated in June–October (columns 1–4) and the share of June–October months with a flood (columns 5–8), as defined in Section 3.1. Estimates are from the staggered difference-in-differences specification in Equation 3.1, using yearly data. Columns (1), (2), (5) and (6) use stacked difference-in-differences and columns (3), (4), (7) and (8) the interaction-weighted estimator of Sun and Abraham (2021), both with proposed mines that were never permitted as the comparison group. Odd-numbered columns include year-by-district-by-river fixed effects and even-numbered columns year-by-district fixed effects; all columns include mine fixed effects and control for precipitation and temperature in the year, and the interaction-weighted columns also control for the number of mines in the area, interacted with year. The sample excludes proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. We use 5 years before and 4 years after a mine started operations. The mean of the dependent variable is for mines that began operating, in the years before they did. Standard errors, in parentheses, are clustered at the mine level. * p < 0.10, ** p <0.05, *** p<0.01.

4.2 Effects on village-level mean nightlights

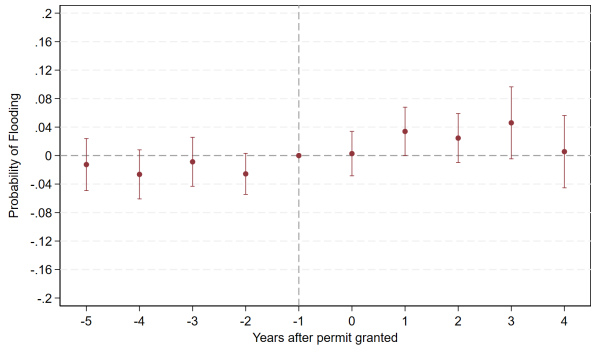
In our main nightlights specification, we exclude towns and cities with populations over 15,000, as larger urban areas are unlikely to be affected by nearby sand mines in the same way as rural villages. We limit the sample to the four years before and after the year a mine is allotted.



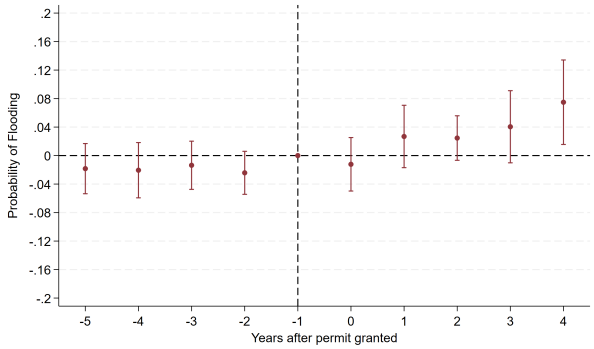
(a) Share of area inundated: stacked difference-in-differences



(b) Share of area inundated: interaction-weighted estimator



(c) Probability of flooding: stacked difference-in-differences



(d) Probability of flooding: interaction-weighted estimator

Figure 5: Dynamic effects of sand mining on flooding

Notes: This figure presents event study estimates of the effect of sand mining on flooding within 500 meters of the mine, following Equation 3.2. Panels (a) and (b) show the share of the area inundated in June–October, and panels (c) and (d) the share of June–October months with a flood, as defined in Section 3.1. Panels (a) and (c) use stacked difference-in-differences and panels (b) and (d) the interaction-weighted estimator of Sun and Abraham (2021), both with proposed mines that were never permitted as the comparison group. All estimates use yearly data and include mine and year-by-district-by-river fixed effects and controls for precipitation and temperature in the year; the interaction-weighted estimates also control for the number of mines in the area, interacted with year. The sample excludes proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. We show 5 years before and 4 years after a mine started operations. Each dot is an estimated coefficient and vertical lines show 95% confidence intervals; the year before operations began is the omitted period. Standard errors are clustered at the mine level.

Table 3 reports static estimates for villages with populations below 15,000. With the stacked difference-in-differences estimator, nightlights rise by 1.10 (column 1), 12% of the pre-mining mean of 8.94 in villages near mines that began operating. The interaction-weighted estimate is 1.20, or 13% of the pre-mining mean (column 3). Figure 6 presents the dynamic effects, comparing villages near mines that began operating with villages near proposed mines that were never permitted. The largest stacked estimate is 1.49 in year 3 after operations began, 17% of the pre-mining mean; the largest interaction-weighted estimate is 1.69 in year 3, 19% of the pre-mining mean.

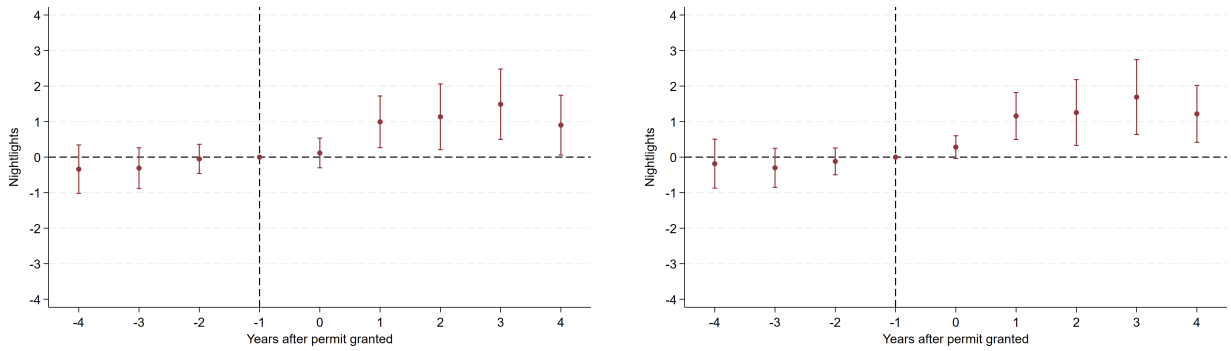
Table 3: Effects of sand mining on village-level mean nightlights

	Nightlights			
	(1)	(2)	(3)	(4)
Treated mines	1.099**	0.809*	1.197***	1.078***
	(0.482)	(0.416)	(0.400)	(0.345)
Observations	22,858	25,051	10,077	10,769
Mean Dep variable	8.94	8.94	8.94	8.94
Method	Stacked	Stacked	Sun-Abraham	Sun-Abraham
Fixed Effect	Dist*River	District	Dist*River	District

Notes: The dependent variable is mean nightlights in villages within 1 km of a mine, with existing mines and a 25 m buffer around them removed. Villages with more than 15,000 residents are excluded. Estimates are from the staggered difference-in-differences specification in Equation 3.1, using yearly data. Columns (1) and (2) use stacked difference-in-differences and columns (3) and (4) the interaction-weighted estimator of Sun and Abraham (2021), both with villages near proposed mines that were never permitted as the comparison group. Columns (1) and (3) include year-by-district-by-river fixed effects and columns (2) and (4) year-by-district fixed effects; all columns include village fixed effects and the 2011 Census village population, SC/ST share, area and number of main workers, each interacted with year. The sample excludes villages near proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. We use 4 years before and 4 years after a mine started operations. The mean of the dependent variable is for villages near mines that began operating, in the years before they did. Standard errors, in parentheses, are clustered at the village level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.3 Effects on agriculture

Sand mining may affect agricultural production through several possible channels, such as substitution of land or labor from agriculture to sand mining, decreased productivity due to flooding, or increased productivity due to mechanization, irrigation, or other investments funded with sand mining-derived capital. To measure the net effect of sand mining on agricultural production, we use EVI as an outcome variable. Table 4 shows that within 500 m of the mine, sand mining lowers EVI by 0.007 with the stacked difference-in-differences estimator (column 1), 2.8% of the



(a) Stacked difference-in-differences (b) Interaction-weighted estimator

Figure 6: Village-level dynamic effects of sand mining on nightlights

Notes: This figure presents event study estimates of the effect of sand mining on mean nightlights in villages within 1 km of a mine, following Equation 3.2. Existing mines and a 25 m buffer around them are removed from each village, and villages with more than 15,000 residents are excluded. Panel (a) uses stacked difference-in-differences and panel (b) the interaction-weighted estimator of Sun and Abraham (2021), both with villages near proposed mines that were never permitted as the comparison group. All estimates use yearly data and include village and year-by-district-by-river fixed effects and the 2011 Census village population, SC/ST share, area and number of main workers, each interacted with year. The sample excludes villages near proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. We show 4 years before and 4 years after a mine started operations. Each dot is an estimated coefficient and vertical lines show 95% confidence intervals; the year before operations began is the omitted period. Standard errors are clustered at the village level.

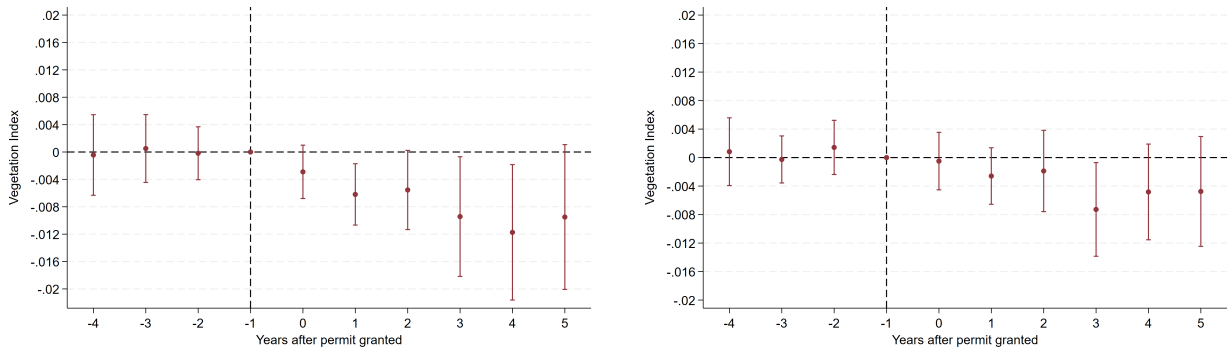
pre-mining mean of 0.257 among mines that began operating. The interaction-weighted estimate is a decline of 0.003, or 1.3% of the pre-mining mean (column 3). Figure 7 plots the dynamic effects. The largest stacked estimate is a decline of 0.012 in year 4 after operations began, 4.6% of the pre-mining mean; the largest interaction-weighted estimate is a decline of 0.007 in year 3, 2.8% of the pre-mining mean.

The flooding, nightlights and vegetation results are robust to including all mines listed in the District Survey Reports (Appendix Tables B-2, B-3 and B-4), and the nightlights and vegetation results hold when control villages are drawn from the sampling frame of our household survey (Appendix Figures B-5 and B-8).

Table 4: Effects of sand mining on mine-level vegetation

	Vegetation index			
	(1)	(2)	(3)	(4)
Treated mines	-0.007**	-0.007***	-0.003	-0.005***
	(0.003)	(0.002)	(0.002)	(0.002)
Observations	16,857	17,969	6,518	6,820
Mean Dep variable	0.257	0.257	0.257	0.257
Method	Stacked	Stacked	Sun-Abraham	Sun-Abraham
Fixed Effect	Dist*River	District	Dist*River	District

Notes: The dependent variable is the growing-season vegetation index (EVI) within 500 meters of the mine. Estimates are from the staggered difference-in-differences specification in Equation 3.1, using yearly data. Columns (1) and (2) use stacked difference-in-differences and columns (3) and (4) the interaction-weighted estimator of Sun and Abraham (2021), both with proposed mines that were never permitted as the comparison group. Columns (1) and (3) include year-by-district-by-river fixed effects and columns (2) and (4) year-by-district fixed effects; all columns include mine fixed effects and control for precipitation and temperature in the year. The sample excludes proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. We use 4 years before and 5 years after a mine started operations. The mean of the dependent variable is for mines that began operating, in the years before they did. Standard errors, in parentheses, are clustered at the mine level. * p $<$ 0.10, ** p $<$0.05, *** p$<$0.01.



(a) Stacked difference-in-differences

(b) Interaction-weighted estimator

Figure 7: Dynamic effects of sand mining on vegetation

Notes: This figure presents event study estimates of the effect of sand mining on the growing-season vegetation index (EVI) within 500 meters of the mine, following Equation 3.2. Panel (a) uses stacked difference-in-differences and panel (b) the interaction-weighted estimator of Sun and Abraham (2021), both with proposed mines that were never permitted as the comparison group. All estimates use yearly data and include mine and year-by-district-by-river fixed effects and controls for precipitation and temperature in the year. The sample excludes proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. We show 4 years before and 5 years after a mine started operations. Each dot is an estimated coefficient and vertical lines show 95% confidence intervals; the year before operations began is the omitted period. Standard errors are clustered at the mine level.

4.3.1 Effects on groundwater

Groundwater availability provides another potential link between sand mining and agricultural production. We examine this channel using the village-head survey described in Section 3.1.6. Village leaders report the minimum depth to groundwater in 2010, 2015, 2020 and 2025. We retain respondents who report all four years and average their responses within each village. We then compare changes in mining villages with those in their matched survey controls, including village and matched-group-by-period fixed effects and clustering standard errors by matched group. The omitted year is 2015. This comparison uses common calendar years, rather than aligning observations to each mine's permit date; each period in the figure spans five years.

Figure 8 shows little evidence of a differential change between mining and control villages before 2015. The 2020 estimate is also small and statistically indistinguishable from zero. By 2025, however, the water table in mining villages has deepened by an additional 9.4 feet relative to 2015, compared with the change in matched control villages (standard error: 4.0; significant at the 5% level). This pattern is consistent with reduced groundwater availability as a channel connecting mining to agricultural losses and higher costs of obtaining water.

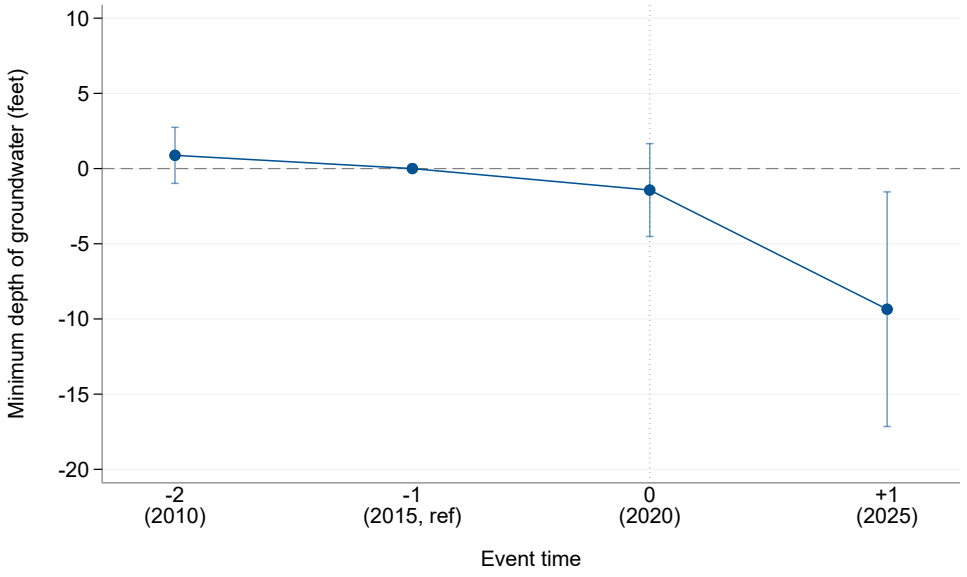


Figure 8: Effect of sand mining on groundwater depth: village survey

Notes: This figure presents event study estimates comparing treated and matched control villages, using village heads' reports of the minimum depth to groundwater (in feet) in 2010, 2015, 2020 and 2025, averaged within each village. Depth is entered as a negative number, so a negative coefficient indicates a deeper water table in treated villages. Event time is measured relative to 2020 (period 0); 2015 (period -1) is the omitted period. The regression includes village and matched-group-by-period fixed effects. Vertical lines indicate 95% confidence intervals; standard errors are clustered at the matched-group level.

4.4 Heterogeneity by caste

In this subsection, we examine the distributional effects of sand mining by assessing its effects on household assets using NFHS data, disaggregated by caste.

Table 5: Effect of sand mining on household assets

	All (1)	Upper-caste + OBC (2)	SC/ST (3)	All (4)
Post × Treated	0.147*	0.260**	0.006	-0.027
	(0.081)	(0.101)	(0.116)	(0.117)
Post × Treated × (Upper-caste + OBC)				0.244*
				(0.137)
Observations	9,726	7,059	2,629	9,688
Control mean (pre)	.102	.254	-.338	.103
District FE	Yes	Yes	Yes	Yes
River FE	Yes	Yes	Yes	Yes
Caste FE	Yes	No	No	Yes

Notes: Estimates use the difference-in-differences specification in Equation 4.1, pooling rural households in Bihar from NFHS-4 (pre) and NFHS-5 (post). The dependent variable is the NFHS wealth index score for rural Bihar, standardised within each round. A cluster is treated if it lies within 2 km of a mine that had begun operating by 2018; all other clusters within 5 km of a mine are controls. Mines that began operating in 2019 or 2020 are excluded. The sample is restricted to districts with both treated and control clusters. Column (1) includes all households, column (2) Upper-caste and OBC households, and column (3) SC/ST households. Column (4) adds the interaction of Post × Treated with an indicator for Upper-caste + OBC households. All columns control for distance to the nearest mine and include district and river fixed effects; columns (1) and (4) also include caste fixed effects. The control mean is the NFHS-4 mean among control clusters. Standard errors, clustered at the NFHS cluster level, are in parentheses. * p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01.

In Table 5, we analyse the effects of sand mining on household assets using two rounds of the National Family Health Survey (NFHS): NFHS-4 (2015–16) and NFHS-5 (2019–21). The outcome is the NFHS wealth index score for rural Bihar, standardised within each round. Our analysis is at the level of the NFHS cluster, which we locate using its GPS coordinates. A rural cluster is treated if it lies within 2 km of a mine that had begun operating by 2018. All other rural clusters within 5 km of a mine form the control group: they lie 2 to 5 km from a treated mine, or within 5 km of a proposed mine or of a mine that began operating in 2021 or later. We exclude mines that began operating in 2019 or 2020, while NFHS-5 was in the field. Because the NFHS samples a different set of clusters in each round, we estimate a repeated cross-section difference-in-differences:

$$W_{hct} = \beta\,\text{Post}_t \times \text{Treated}_c + \gamma\,\text{Treated}_c + \delta\,\text{Post}_t + \theta\,\text{Dist}_c + \mu_d + \rho_r + \kappa_k + \varepsilon_{hct}, \qquad (4.1)$$

where W_{hct} is the wealth score of household h in cluster c in round t, Post_t equals one for NFHS-5, Treated_c indicates a treated cluster, Dist_c is the distance from the cluster to the nearest mine, and μ_d, ρ_r and κ_k are district, river and caste-group fixed effects. We restrict the sample to districts that

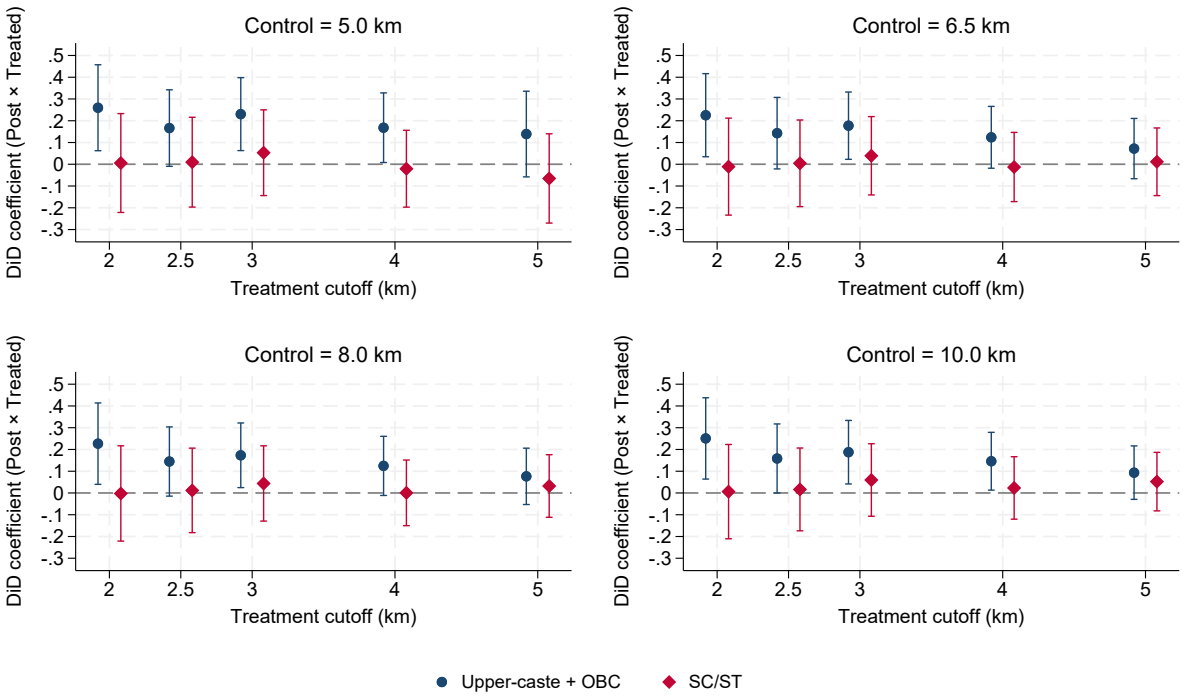


Figure 9: Effect of sand mining on household assets: sensitivity to distance cutoffs

Notes: Each panel holds fixed the radius that defines the control group (5, 6.5, 8 or 10 km) and varies the radius within which a cluster is treated (2, 2.5, 3, 4 or 5 km). Each point is the Post × Treated coefficient from Equation 4.1, estimated separately for Upper-caste + OBC and SC/ST households with district and river fixed effects, as in columns (2) and (3) of Table 5. Vertical lines show 95% confidence intervals; standard errors are clustered at the NFHS cluster level.

have both treated and control clusters, and cluster standard errors at the NFHS cluster level.

Across all households, assets in treated clusters rise by 0.15 standard deviations relative to control clusters, significant at the 10% level (column 1). The increase is concentrated among Upper-caste and Other Backward Class (OBC) households, whose assets rise by 0.26 standard deviations, significant at the 5% level (column 2). For Scheduled Caste and Scheduled Tribe (SC/ST) households, the estimate is 0.01 standard deviations and not statistically significant (column 3). In column (4), we interact the treatment effect with an indicator for Upper-caste + OBC households. The difference between the two groups is 0.24 standard deviations, significant at the 10% level. The OBC category contains groups with different economic and social positions. NFHS does not distinguish Backward Classes from Extremely Backward Classes, so these estimates cannot establish whether the gains are concentrated among particular OBC groups or shared more broadly within that category. The household survey in Section 5 provides this finer caste distinction and measures the mining-related earnings and losses that can underlie unequal asset gains.

Figure 9 shows how these results change with the distance cutoffs. We re-estimate columns (2) and (3) with treatment radii from 2 to 5 km and control radii from 5 to 10 km. The Upper-caste + OBC estimate is positive in 20 of the 20 combinations and significant at the 5% level in 10 of

them, while the SC/ST estimate is significant at the 5% level in none of them. Appendix Table B-5 shows that the estimates are essentially unchanged when wealth is standardised over both rounds pooled rather than within each round.

NFHS cluster coordinates are randomly displaced to protect respondents' confidentiality (Burgert et al., 2013). Because treatment status depends on distance to a mine, this displacement can move clusters across our treatment and control cutoffs. We therefore use Monte Carlo simulations to assess whether the estimated caste pattern is sensitive to further perturbations of the reported cluster locations. Appendix Figure B-9 re-estimates columns (2) and (3) 500 times after moving each cluster's coordinates in a random direction by up to 2 km (up to 5 km for 1% of clusters) and recomputing treatment status: the Upper-caste + OBC estimate averages 0.209 and is positive in 99.8% of draws, while the SC/ST estimate averages -0.026. With the larger distances that DHS uses to displace rural clusters, up to 5 km (up to 10 km for 1% of clusters; Appendix Figure B-10), the Upper-caste + OBC estimate averages 0.130 and is positive in 90.2% of draws, while the SC/ST estimate averages 0.013.

The asset results therefore document unequal gains across broad caste categories, with a positive estimate for Upper-caste and OBC households and no statistically detectable improvement for SC/ST households. They motivate two further questions: whether caste differences reflect access to mining income and the returns from particular economic positions, and whether political effectiveness differs beyond those economic stakes. Sections 5 and 6 examine these questions using the household survey and the common political-weighting model.

5 Evidence from a Survey of Mining Villages

Section 4 shows that sand mining raises economic activity and worsens environmental outcomes near mines. To examine how mining-related earnings and reported harms are distributed across households, we conduct a household survey in 214 mining and non-mining villages. The central pattern indicates that the income from sand is concentrated, while reported damage extends beyond those who benefit.

The survey covers 8,203 households in 214 villages. 5,551 households live in 137 villages within 1 km of a permitted mine, which we call mining villages. 2,652 households live in 77 control villages, each matched to a mining village on 2011 Census characteristics, in the same district, along the same river and no more than 7 km away.[2] Section 3.1 describes the implementation of the survey in greater detail.

The empirical exercise in this section does two types of comparisons: i) households in mining villages with households in their matched control villages, and ii) Within mining villages we compare farmland owners and non-owners and those belonging to different social groups. For the

[2] A control village can be matched to more than one mining village.

first comparison we use the following specification:

$$y_{iv} = \beta \, \text{Mining}_v + \alpha_{g(v)} + \varepsilon_{iv}, \tag{5.1}$$

where y_{iv} is household i's outcome, Mining_v indicates a mining village and $\alpha_{g(v)}$ is a matched-group fixed effect. These comparisons describe differences between nearby matched villages. As control villages are also close to mines, the households in these villages may also be exposed to mining. We estimate Equation 5.1 for all households and separately for three caste groups and by farmland ownership. The caste groups are Upper-caste households, Other Backward Classes (OBC) and Scheduled Castes and Tribes (SC/ST). OBC combines Bihar's Backward Classes in our sample (Yadav, Koiri/Kushwaha, Kurmi and Sunar) with the groups on its Extremely Backward Classes list. Farmland ownership means owning cultivable land; non-owners may still own the land for their own house. Within mining villages, we compare these groups using village fixed effects:

$$y_{iv} = \gamma' D_i + \alpha_v + \varepsilon_{iv}, \tag{5.2}$$

where D_i contains indicators for OBC and SC/ST households, with Upper-caste households the omitted group (or, separately, an indicator for a household without farmland), and α_v is a village fixed effect.

5.1 Who earns from sand?

Few households report income from sand (Table 6, Panel A). The share with recorded involvement in sand work is 6.1 ppt higher in mining villages than in control villages, where it is 0.9%. Mine labour accounts for most of the difference (4.9 ppt); differences in transport and machine work are small and statistically insignificant. Land provides another income channel: 3.3 ppt more households have land used for sand work, and 2.2 ppt more receive rent. Annual income from sand work and land rent is Rs. 2,228 higher per household than in control villages, where it averages Rs. 756.

Within mining villages, caste groups earn from sand in different ways (Table 6, Panel B). OBC and SC/ST households are 4.4 and 8.4 ppt more likely than Upper-caste households to do mine labour, but 4.7 and 5.3 ppt less likely to receive land rent. Their annual income from sand is Rs. 3,961 and Rs. 4,491 lower than Upper-caste households' Rs. 6,777, although neither difference is statistically significant. Households without farmland are about as likely as owners to work in sand mining, but much less likely to receive land rent; their annual sand income is Rs. 3,326 lower than owners' Rs. 4,309. Thus participation in mine labour does not imply an equal share of mining income.

Income from sand is highly concentrated (Appendix Table B-8). Only 9.0% of households in mining villages receive any. The top 1% of households receive 53.8% of all income from sand, and the top 5% receive 91.6%. Upper-caste households are 15.7% of households in mining villages but receive 29.5% of income from sand; OBC households are 60.9% and receive 52.3%, and SC/ST

Table 6: Work, land and income from sand

	Control villages (1)	All (2)	Upper-caste (3)	OBC (4)	SC/ST (5)	Owns farmland (6)	No farmland (7)
A. Mining minus control villages							
Member works in sand mining (%)	0.9	6.1***	3.6***	5.2***	10.0***	5.7***	6.5***
		(0.9)	(0.8)	(0.9)	(1.7)	(0.9)	(1.1)
Mine labour (%)	0.3	4.9***	1.4***	4.3***	8.5***	4.4***	5.5***
		(0.8)	(0.5)	(0.8)	(1.6)	(0.7)	(1.0)
Transport (%)	0.3	0.1	0.5**	0.0	0.4**	0.0	0.3
		(0.1)	(0.2)	(0.2)	(0.2)	(0.1)	(0.2)
Machines or management (%)	0.2	0.1	-0.1	0.2	0.0	0.2	-0.1
		(0.1)	(0.4)	(0.1)	(0.1)	(0.1)	(0.1)
Land used for sand work (%)	0.5	3.3***	7.0***	2.7***	2.2**	4.6***	0.9***
		(0.5)	(1.4)	(0.5)	(1.0)	(0.6)	(0.3)
Receives land rent (%)	0.4	2.2***	5.7***	1.6***	1.8**	3.3***	0.4**
		(0.4)	(1.3)	(0.4)	(0.8)	(0.6)	(0.2)
Any income from sand (%)	1.2	7.3***	7.5***	5.9***	10.9***	7.6***	6.6***
		(1.0)	(1.5)	(1.0)	(1.9)	(1.0)	(1.1)
Income from sand (Rs. a year)	756	2,228***	6,697**	1,409***	2,522***	2,371***	1,490***
		(514)	(3,256)	(474)	(435)	(664)	(322)
B. Within mining villages: means (columns 3 and 6) and differences from them (columns 4, 5 and 7)							
Member works in sand mining (%)			4.5	4.3***	8.0***	6.7	0.7
				(1.0)	(1.7)		(0.9)
Mine labour (%)			1.9	4.4***	8.4***	4.6	1.3
				(1.0)	(1.7)		(0.9)
Transport (%)			0.3	0.5	0.2	0.5	0.0
				(0.4)	(0.4)		(0.2)
Machines or management (%)			0.2	0.1	-0.1	0.3	-0.3**
				(0.2)	(0.2)		(0.1)
Land used for sand work (%)			8.1	-5.4***	-6.3***	5.2	-5.0***
				(1.3)	(1.3)		(0.7)
Receives land rent (%)			6.2	-4.7***	-5.3***	3.7	-4.3***
				(1.2)	(1.3)		(0.7)
Any income from sand (%)			8.4	0.7	4.2**	8.8	-1.8*
				(1.4)	(1.9)		(1.0)
Income from sand (Rs. a year)			6,777	-3,961	-4,491	4,309	-3,326**
				(2,911)	(3,430)		(1,511)

Notes: All variables refer to 2025. Panel A: column (1) gives the control-village mean; columns (2)–(7) give mining-minus-control differences for the indicated groups, with matched-group fixed effects (Equation 5.1). Panel B: columns (3) and (6) give means for Upper-caste households and farmland owners in mining villages; columns (4) and (5) give OBC-minus-Upper-caste and SC/ST-minus-Upper-caste differences, estimated together, and column (7) the non-owner-minus-owner difference, with village fixed effects (Equation 5.2). The sand-work indicator records whether the household is involved in any kind of work in sand mining. Transport includes truck or tractor driving for sand transport. Machines or management includes machine operators and mine managers. Income from sand is sand-work income plus yearly land rent (Appendix B.6). Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

households are 23.2% and receive 18.2%. Households that own farmland are 63.7% of households and receive 76.0%. Separating OBC households into the Backward Classes (BC) and the Extremely Backward Classes (EBC) reveals differences within that group (Appendix Table B-9). Farmland ownership is also much more common in Upper-caste and OBC groups. These current-income comparisons complement Section 4's estimates of asset growth.

Income from sand is concentrated on the Sone (Appendix Table B-15), where 75 of the surveyed mining villages lie. On the Sone, 11.6% of households in mining villages have a member in sand work, 9.7 ppt more than in their control villages, 4.1% receive land rent, and annual income from sand is Rs. 3,779 higher. On other rivers, 1.7% have a member in sand work (1.3 ppt more than in control villages), 0.1% receive land rent, and income from sand is only Rs. 225 higher. Outside the Sone, mining brings almost no income to the surveyed households.

5.2 Who bears the costs?

Farming, dust and groundwater over time. Let t_{-1}, t_0 and t_1 denote the period before mining, the start period and the following period; for almost all mining villages these are 2011–15, 2016–20 and 2021–25. In the start period compared to period before mining, households in mining villages are 2.9 ppt more likely than control households to report falling farm income (control share: 12.2%) and 3.4 ppt more likely to report growing fewer crops per year (Table 7). Among those reporting lower farm income, 9.0 ppt more cite groundwater, dust or lack of irrigation. In the following window, mining households are 2.1 ppt less likely to report falling farm income (significant at the 10% level), but 1.8 ppt more report fewer crops.

Dust increases more in mining villages in both windows. Among households irrigating with a borewell, deepening is 0.8 ppt more common in the start period (not statistically significant) and 5.0 ppt more common in the following period (significant at the 1% level). These reports are consistent with the decline in vegetation and the deepening water table documented in Section 4.

Damage households attribute to mining. Households were asked an open ended question about the damage mining had caused in their village and, for the damage they named, its cost to their family over five years prior to the survey. Households in mining villages are much more likely than control households to name deeper digging for water (46.2 ppt), lower crop yields (30.8), dust and pollution (29.9) and road damage (23.5; Table 8). The difference for flooding is much smaller (1.9 ppt). The five-year loss from lower crop yields, road accidents and deeper digging for water together is Rs. 8,114 higher in mining villages; the control mean is Rs. 4,111. We do not total losses from road damage or dust and pollution, which affect the village as a whole rather than particular households. The cost of deeper digging for water enters only at mining's share of the 2020–25 fall in the water table on the village's river, from the village-head event study (Figure 8) estimated separately by river: 74.0% on the Sone and 1.9% on other rivers, where water tables in mining villages fell no more than in control villages. Annualising each household's reported losses and dividing by its positive 2025 income gives a difference of 2.0 ppt in the loss-to-income

Table 7: Reported changes in farming and dust, and borewell deepening around the start of mining

	Mining-start window		Following window	
	Control villages (1)	Mining minus control (2)	Control villages (3)	Mining minus control (4)
Farm income got worse (%)	12.2	2.9***	25.7	-2.1*
		(1.0)		(1.1)
names groundwater, dust or irrigation (%)	43.0	9.0**	26.5	6.8***
		(4.1)		(2.6)
Fewer crops per year (%)	4.6	3.4***	5.5	1.8***
		(0.7)		(0.6)
Dust increased (%)	14.0	9.2***	15.5	11.5***
		(1.4)		(1.7)
Borewell needed deepening (%)	8.7	0.8	18.2	5.0***
		(1.0)		(1.8)

Notes: The mining-start window compares the period before mining with the period containing the permit year; the following window compares that period with the next. For starts in 2016–20, these windows are 2011–15 to 2016–20 and 2016–20 to 2021–25. The first four rows record reported changes: farm income fell; among households reporting a fall, groundwater, dust or lack of irrigation was a reason; fewer crops were grown per year; and dust increased. The last row instead records whether an irrigation borewell needed deepening during the end period of each window, among households using a borewell in 2025. Columns (1) and (3) give control means for the two calendar windows above. Columns (2) and (4) give cohort-stacked mining-minus-control comparisons, with one stack per start period, all control villages in each stack, and stack-by-matched-group-by-window fixed effects. Villages without a surveyed pre-mining period are excluded. Farming questions were asked of households farming in 2025. Differences are in ppt. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

ratio. These capture costs attributed by households.

Within mining villages, Upper-caste households and farmland owners report larger losses (Appendix Table B-12). Five-year losses from crop yields, road accidents and deeper digging for water among OBC and SC/ST households are Rs. 7,944 and Rs. 11,832 lower than Upper-caste households' Rs. 19,294; non-owners' losses are Rs. 8,613 lower than owners' Rs. 15,032. The SC/ST and farmland differences remain when annualised losses are expressed as a share of household income; the OBC difference is then smaller and not statistically significant. Flood losses follow the same pattern. OBC and SC/ST households were less often flooded in 2021–25, by 3.6 and 3.1 ppt, and report Rs. 5,609 and Rs. 7,144 less in five-year flood losses (significant at the 10% level and significant at the 5% level, respectively); non-owners report Rs. 4,375 less than owners. This is consistent with greater asset exposure among households with more land, crops and borewells. The groups receiving more mining income also report larger losses.[3]

[3]Road accidents and drownings can be reported by several households, so we compare village-level reporting shares rather than count reports as separate incidents. The share reporting a road accident in the last two years is 10.0 ppt higher in mining villages (control mean: 30.3%); the share reporting a drowning death in the last five years is 26.9 ppt higher (control mean: 7.9%; Appendix Table B-14).

Table 8: Damage from mining: mining and control villages

	Control villages	Mining minus control villages					
		All	Upper-caste	OBC	SC/ST	Owns farmland	No farmland
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dust a serious problem (%)	11.8	14.5***	21.2***	13.5***	11.3***	14.5***	14.3***
		(1.7)	(3.7)	(1.7)	(2.5)	(1.9)	(2.0)
Names lower crop yields (%)	7.9	30.8***	34.8***	30.1***	30.7***	30.9***	30.1***
		(2.3)	(2.9)	(2.5)	(3.4)	(2.5)	(2.7)
Names road accidents (%)	3.4	9.1***	9.8***	9.0***	6.7***	7.5***	10.9***
		(1.4)	(2.4)	(1.6)	(1.5)	(1.3)	(2.0)
Names deeper digging for water (%)	28.3	46.2***	45.5***	46.0***	48.6***	43.0***	51.2***
		(2.5)	(4.5)	(2.8)	(3.0)	(2.4)	(3.3)
Names road damage (%)	10.5	23.5***	21.2***	24.3***	23.5***	23.1***	24.7***
		(2.0)	(3.7)	(2.2)	(2.4)	(2.1)	(2.4)
Names dust and pollution (%)	12.7	29.9***	32.4***	29.9***	27.3***	28.6***	30.1***
		(2.7)	(4.0)	(2.9)	(3.5)	(2.5)	(3.3)
Names more flooding (%)	0.7	1.9***	2.1**	2.1***	1.0	2.1***	1.7***
		(0.3)	(0.8)	(0.4)	(0.7)	(0.4)	(0.6)
Loss: lower crop yields (Rs.)	1,964	4,488***	5,594***	4,629***	3,734***	5,827***	2,147***
		(449)	(1,379)	(525)	(704)	(610)	(401)
Loss: road accidents (Rs.)	280	517***	157	581***	192	557***	296
		(113)	(462)	(139)	(264)	(170)	(192)
Loss: deeper digging for water, mining's share (Rs.)	1,867	3,109***	4,576***	3,304***	2,405***	3,671***	2,179***
		(373)	(958)	(476)	(398)	(480)	(287)
Loss: total of the three (Rs.)	4,111	8,114***	10,327***	8,515***	6,331***	10,055***	4,622***
		(716)	(1,990)	(880)	(1,063)	(994)	(506)
Total, % of yearly income	1.4	2.0***	2.0***	2.2***	1.6***	2.4***	1.4***
		(0.2)	(0.5)	(0.2)	(0.3)	(0.3)	(0.2)

Notes: Column (1) gives the control-village mean; columns (2)–(7) give mining-minus-control differences for the indicated groups, with matched-group fixed effects (Equation 5.1). The first row records serious or very serious dust in the village in 2021–25. "Names" records damage the household attributes to mining in the village. For five types of damage, follow-up questions ask the family's loss over the past five years. The table reports losses from lower crop yields, road accidents and deeper digging for water, and the total sums these three; losses from road damage and from dust and pollution, which affect the village as a whole, are not reported. A damage not named is assigned zero loss, as is a named damage whose amount the household did not know or refused to give. The cost of deeper digging for water counts at mining's share of the 2020–25 fall in the water table on the village's river, from the village-head groundwater event study estimated separately by river. Share differences are in ppt. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Sone and other rivers. Reported damage is larger on the Sone (Appendix Tables B-16 and B-17). Households in mining villages on the Sone are 45.2 ppt more likely than those in their control villages to name lower crop yields and 53.0 ppt more likely to name deeper digging for water, and their reported five-year losses are Rs. 14,419 higher. On other rivers, households also report damage: 37.0 ppt more name deeper digging for water, and reported losses are Rs. 8,219 higher, although mining brings them almost no income. These differences bear on how much of households' reported costs can be attributed to mining, which Section 6 takes up.

5.3 Are those who bear the costs compensated?

Separate compensation for reported land damage is shown in Table 9: only 9 of 1,553 affected households in mining villages received any (0.6%). Flood assistance is also uncommon. Of 1,470 households flooded in the last 15 years, 110 received compensation or financial assistance (7.5%); recipients reporting an amount received Rs. 5,432 on average over five years. This compensation comes from the state relief funds and not from mine owners. Only 7 of 129 mining villages have a village-head report of mine owners funding the development of the village. These measures show that there is little evidence of direct compensation for reported land damage or flood losses.

Table 9: Compensation, flood assistance and village-development funding

	Mining villages		Control villages	
	Mean	N	Mean	N
	(1)	(2)	(3)	(4)
Compensated for damage to land (%)	0.6	1,553	0.5	214
Received compensation or assistance after a flood (%)	7.5	1,470	3.2	378
Amount received, last 5 years (Rs., among those receiving)	5,432	107	3,750	12
Contractor funds village development (% of villages)	5.4	129	0.0	6

Notes: Columns (1) and (3) give means; columns (2) and (4) give the number of non-missing observations. The first row is among households reporting mining damage to their land; the second is among households flooded in the last 15 years; the third is among assistance recipients reporting an amount. The amount covers the past five years. The last row is the percentage of villages with at least one village-head respondent reporting that the mining company or contractor funds village development; its observation count is villages.

5.4 Do households attribute the damage to mining?

The preceding cost measures rely on damage households name in an open-ended question. We now examine responses to direct questions about mining's effects on specific environmental conditions, including among households that report no personal loss.

Figure 10 shows how households answer direct questions about mining's environmental effects. For each question, the figure reports the percentage answering "a little", "somewhat" or "a lot", rather than "not at all". In mining villages, 85.6% report that mining affects groundwater,

59.5% report an effect on crop yields, and 68.3% report an effect on roads, dust or accidents. The flooding question specifically asks whether mining increases flood risk: 17.6% of households in mining villages say it does.

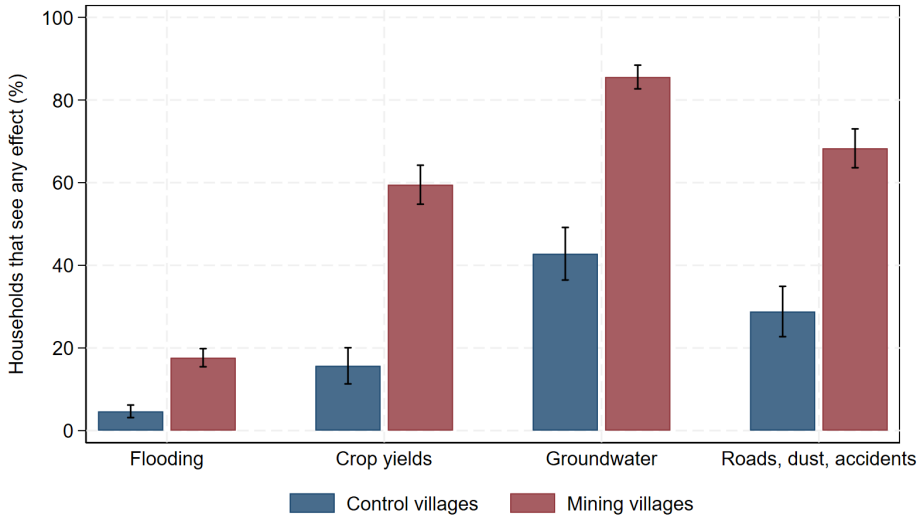


Figure 10: Households that think sand mining affects the village: mining and control villages

Notes: The flooding question asks how much mining increases flood risk; the other questions ask how much mining affects crop yields, groundwater, or roads, dust and accidents. Bars show the percentage answering a little, somewhat or a lot rather than not at all. "Don't know" and refusals are excluded. Vertical lines show 95% confidence intervals, with standard errors clustered by village.

Table 10 examines whether these beliefs differ with households' reported experiences. Column (2) compares households within the same mining village. Households that experienced flooding during 2021–25 are 17.9 ppt more likely than households that did not experience flooding to say that mining increases flood risk. Similarly, households reporting a dust problem are 19.9 ppt more likely than those reporting no dust problem to say that mining affects roads, dust or accidents. These numbers are differences between groups; the percentages in Figure 10 describe how common each belief is overall.

Column (3) of Table 10 instead compares households whose respondent or family was involved in sand mining during the previous ten years with households reporting no such involvement. For each of the four environmental domains, the estimated difference in the probability of reporting an effect is no more than 1.1 ppt in absolute value. None of these differences is statistically significant at the 10% level.

5.5 Support for mining and willingness to pay to stop it

Compensation could make mining more acceptable to nearby households, while households opposed to extraction might be willing to help finance restrictions. We examine both possibilities through hypothetical questions. One asks whether the household would support mining if its

Table 10: Beliefs, reported harm and sand involvement: correlations within mining villages

	Share in mining villages (1)	Reported the harm minus not (2)	Sand involvement in last 10 years minus not (3)
Flooding (%)	17.6	17.9***	-0.2
		(3.5)	(2.3)
Crop yields (%)	59.5	4.1**	1.1
		(1.7)	(2.0)
Groundwater (%)	85.6	-0.5	0.5
		(2.0)	(1.0)
Roads, dust and accidents (%)	68.3	19.9***	-0.4
		(1.6)	(1.9)

Notes: Mining villages only. Beliefs are defined in Figure 10; "don't know" and refusals are excluded. Column (1) gives the share holding each belief. Column (2) regresses each belief on the corresponding report of harm: flooding in 2021–25; lower farm income in 2021–25 than in 2016–20 (farming households); irrigation borewell deepening in 2021–25 (borewell users); or dust reported as at least a slight problem in the village/hamlet in 2021–25. Column (3) regresses each belief on any sand-mining involvement by the respondent or family in the last 10 years, including recorded sand work in 2025. Columns (2) and (3) come from separate regressions with village fixed effects and report differences in ppt. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

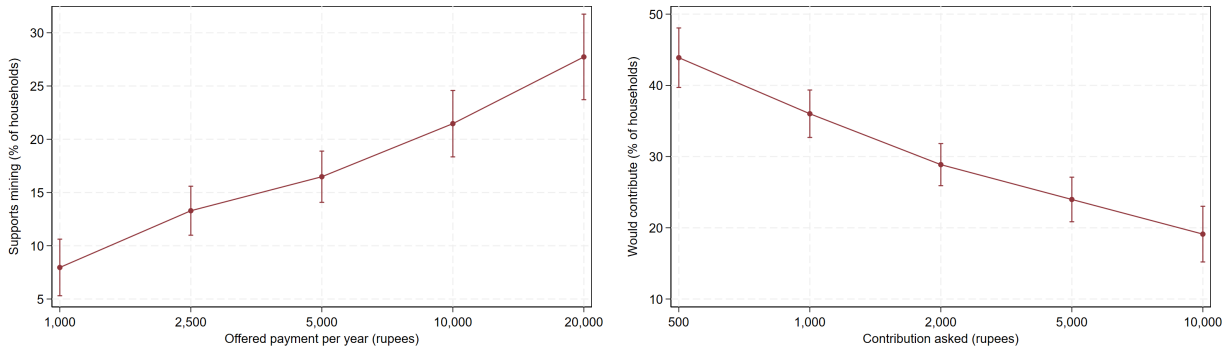
family received an annual payment. The other asks whether it would contribute money to stop or reduce mining. We randomly vary the amount offered or requested, allowing us to examine how stated choices respond to the size of the payment.

Larger compensation offers increase acceptance. Among households offered Rs. 1,000 per year, 8.0% say they would support mining; among those offered Rs. 20,000, the share is 27.7% (Figure 11, panel (a)). Compensation can therefore change stated support, although even the largest offer receives an affirmative response from fewer than one-third of households. Willingness to finance restrictions also depends on the amount involved. When asked to contribute Rs. 500 to stop or reduce mining, 43.9% agree, compared with 19.1% when the requested contribution is Rs. 10,000.

We next examine which households are more supportive of mining. We consider three responses: whether there should be a sand industry in the village, whether the household would support mining in exchange for the offered annual payment, and whether it would contribute the requested amount to stop or reduce extraction. For each response, we compare households living in the same mining village using

$$Y_{iv}^{q} = \alpha_{v}^{q} + X_{iv}'\beta^{q} + B_{iv}^{q\prime}\delta^{q} + \varepsilon_{iv}^{q}, \tag{5.3}$$

where i indexes households, v villages and q the three questions. The outcome Y_{iv}^{q} equals 100 for an affirmative answer and zero for every other response, including uncertainty and refusals. For the payment questions, the sample includes households assigned an amount, and B_{iv}^{q} contains indicators for that amount. These indicators allow us to compare households facing the same offer



(a) Accepts mining if paid this amount each year (b) Would contribute this amount to stop mining

Figure 11: Support for mining and willingness to pay to stop it, by randomly assigned amount: mining villages

Notes: Each point is the share of households in mining villages saying yes at the randomly assigned amount; every other answer, including "mining does not affect this village", "unsure" and refusals, counts as not yes. Vertical lines show 95% confidence intervals, with standard errors clustered by village.

or requested contribution. They are omitted for the general-support question. Village fixed effects, α_v^q, account for differences common to households in the same village. Coefficients measure ppt differences, and standard errors are clustered by village.

The household characteristics in X_{iv} depend on the comparison. Table 11 examines caste differences and, separately, differences between farmland owners and non-owners. Table 12 examines involvement in sand work, reported environmental harms, and both together. The latter comparison asks whether households connected to mining remain more supportive after accounting for the harms they report.

Within the same village, OBC and SC/ST households are more supportive of mining than Upper-caste households, and households without farmland are more supportive than farmland owners. They are also more willing to accept the offered payment and less willing to contribute to stopping mining (Table 11). These groups receive less mining income per household, but also report lower environmental losses (Sections 5.1 and 5.2). Their greater support is therefore consistent with facing lower costs despite receiving fewer direct benefits. This may also be driven by their overall lower income.

A household's own involvement in mining is nevertheless strongly associated with its preferences. After accounting for reported harms, households with a member in sand work are 12.6 ppt more likely than other households in the same village to favour a local sand industry. They are also more willing to accept payment and less willing to contribute to stopping extraction (Table 12, column (3)). Dust problems are associated with the opposite pattern: households reporting dust are less supportive of mining and 9.3 ppt more likely to contribute to stopping or reducing it. Households whose borewells needed deepening are also more willing to contribute.

Table 11: Support for mining: caste and farmland within mining villages

	Caste			Farmland	
	Upper-caste mean (1)	OBC minus Upper-caste (2)	SC/ST minus Upper-caste (3)	Owners mean (4)	Non-owners minus owners (5)
Should be a sand industry (%)	15.8	6.0***	9.9***	20.1	5.2***
		(2.0)	(2.5)		(1.6)
Supports mining if paid the offer (%)	13.1	5.2***	9.9***	16.9	6.2***
		(1.8)	(2.2)		(1.3)
Would pay the amount to stop mining (%)	40.6	-9.0***	-12.5***	33.6	-8.5***
		(2.0)	(2.3)		(1.4)

Notes: Mining villages only. Rows report the three responses defined in Section 5.5, in the order listed there. Columns (1) and (4) give unadjusted affirmative-response percentages among Upper-caste households and farmland owners, respectively. Columns (2) and (3) report OBC-minus-Upper-caste and SC/ST-minus-Upper-caste differences from Equation 5.3, with the two caste indicators included together. Column (5) reports the non-owner-minus-owner difference from a separate regression. The payment-response regressions include indicators for the assigned amount. Differences are in ppt. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.6 Can households object to mining?

Households have several avenues for voicing concerns about mining. Residents can approach village leaders or contractors, submit complaints to officials or the police, and organise petitions, protests or blockades. Our survey records the use of these channels and asks whether respondents feel safe objecting and expect their complaints to receive a response.

Residents do use these avenues to raise concerns. In the average surveyed mining village, 12.8% of households report that someone in their village or hamlet made a complaint, application, protest or objection in the preceding few years (Table 13, Panel A). This percentage measures awareness of an objection: several households may be describing the same event. Among households reporting an objection, the most frequently named channels are complaints to the police and protests or blockades (Panel B). The issues raised commonly concern illegal or excessive extraction, groundwater, road damage and truck traffic, and dust (Panel C).

The availability of these channels does not ensure that residents feel able to use them effectively. Among community-survey respondents in mining villages, 36.9% say they would feel safe protesting publicly. Only 20.2% believe that a complaint about harmful or illegal mining from someone like them would likely lead to action (Table 14, Panel A). These responses suggest limited confidence both in the safety of public objection and in the prospect of obtaining a response.

Evidence of differences across social groups is less clear. Among respondents linked to the household survey, those without farmland are 3.0 ppt less likely than farmland owners in the same village to feel safe protesting, although this estimate is imprecise. The estimated caste differences in perceived safety are also imprecise (Table 14, Panel B).

Village histories collected by field supervisors show that opposition can reflect different inter-

Table 12: Support for mining, sand involvement and reported harm: correlations within mining villages

	Sand work (1)	Reported harms (2)	Both (3)
A. Says there should be a sand industry in the village			
Household member in sand work, 2025	12.1***		12.6***
	(2.4)		(2.4)
Flooded, 2021–25		-0.1	-0.1
		(3.0)	(3.0)
Farm income got worse, 2021–25		-0.1	-0.1
		(1.9)	(1.9)
Borewell needed deepening, 2021–25		-2.2	-2.4
		(2.2)	(2.3)
Dust a problem, 2021–25		-3.2**	-3.4**
		(1.4)	(1.4)
Mean (%)	20.6	20.6	20.6
Households	5,317	5,317	5,317
B. Supports mining if paid the offered amount each year			
Household member in sand work, 2025	8.8***		9.3***
	(2.2)		(2.1)
Flooded, 2021–25		-0.2	-0.1
		(2.6)	(2.6)
Farm income got worse, 2021–25		0.9	0.8
		(1.8)	(1.8)
Borewell needed deepening, 2021–25		-3.2	-3.4
		(2.1)	(2.1)
Dust a problem, 2021–25		-4.3***	-4.4***
		(1.1)	(1.1)
Mean (%)	17.7	17.7	17.7
Households	5,317	5,317	5,317
C. Would contribute the asked amount to stop or reduce mining			
Household member in sand work, 2025	-6.4**		-7.3***
	(2.5)		(2.5)
Flooded, 2021–25		2.1	2.1
		(4.2)	(4.2)
Farm income got worse, 2021–25		0.9	1.0
		(1.9)	(1.9)
Borewell needed deepening, 2021–25		7.2***	7.3***
		(2.3)	(2.3)
Dust a problem, 2021–25		9.2***	9.3***
		(1.7)	(1.7)
Mean (%)	31.0	31.0	31.0
Households	5,317	5,317	5,317

Notes: Mining villages only. Panels A, B and C use the general-support, payment-acceptance and contribution responses defined in Section 5.5. Regressions follow Equation 5.3. Column (1) includes an indicator for a household member in sand work in 2025; column (2) includes the reported-harm indicators; column (3) includes both. Harms are household flooding, falling farm income relative to 2016–20, irrigation borewell deepening, and dust reported as at least a slight problem in the village or hamlet, all referring to 2021–25. Farm-income and borewell harms are coded zero when inapplicable; columns (2) and (3) also include indicators for households not farming in both periods and households without an irrigation borewell. Within each panel, all columns use the same sample with complete explanatory variables. The mean is the affirmative-response percentage in that estimation sample. Panels B and C include assigned-amount indicators. Coefficients are ppt differences. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 13: Complaints about sand mining: mining villages

A. Share of the village's households reporting a complaint	
Mean across villages (%)	12.8
Median across villages (%)	10.0
Villages where at least 10% report one (%)	54.7
Villages where at least 25% report one (%)	15.3
Villages where at least 50% report one (%)	1.5
Villages	137
B. How or to whom (% of households reporting a complaint)	
Verbal complaint to panchayat or village leaders	26.1
Written complaint or petition	29.3
Complaint to block or district officials	34.4
Complaint to police	41.5
Complaint to the mining department	22.0
Protest, dharna, road blockade or public demonstration	40.4
Court case or complaint to a tribunal	4.9
Complaint to the contractor or company	23.9
C. Main issue (% of households reporting a complaint)	
Flooding or waterlogging	3.8
Riverbank erosion	23.1
Crop or land damage	29.2
Dust or air pollution	31.8
Noise	7.8
Road damage or truck traffic	38.5
Groundwater or drinking water problems	42.0
Illegal or excessive mining	49.5
Lack of compensation	10.2
Exclusion from mining jobs or benefits	9.3
Households reporting a complaint	733

Notes: Mining villages only. Households were asked whether anyone in their village or hamlet made a formal complaint, application, protest or objection related to sand mining in the past few years; "unsure" and refusals count as no. Panel A computes, for each village, the share of its households reporting a complaint, and summarizes these shares across villages, with each village weighted equally. Panels B and C report, among households reporting a complaint, the share naming each channel and each issue; households could name several.

ests. Of the 111 mining villages with a recorded answer, 23 had experienced opposition, protest or dispute (Appendix Table B-21). Environmental damage and losses of land, crops or livelihoods were common reasons. Supervisors described some disputes as broad community concerns, others as struggles over control of sand, and others as a mixture of the two. Their records also mention violence, weapons, injuries, deaths, or police or court cases in 7 villages. Objection therefore includes both efforts to address mining's harms and conflicts over its economic benefits.

Explaining why mining persists requires connecting households' economic stakes to the decisions governing extraction. Local gains may be sufficient to compensate those harmed, making a mutually beneficial agreement possible. Where local losses exceed gains, continued extraction may instead reflect the greater influence of beneficiaries or the interests of contractors and the

Table 14: Safety of protesting and expected response to complaints: mining villages

A. Shares

	All respondents	Household-survey respondents
Feels safe protesting (%)	36.9	36.0
Expects action on a complaint (%)	20.2	19.9
Respondents	3,087	2,806
Villages	136	136

B. Caste and farmland within mining villages

	Caste			Farmland	
	Upper-caste mean	OBC minus Upper-caste	SC/ST minus Upper-caste	Owners mean	Non-owners minus owners
	(1)	(2)	(3)	(4)	(5)
Feels safe protesting (%)	39.1	-4.7	-3.3	39.1	-3.0
		(3.0)	(3.7)		(1.8)
Expects action on a complaint (%)	23.7	-3.1	-2.2	20.8	0.5
		(2.5)	(2.7)		(1.6)

Notes: Mining villages only. Answers come from the community survey: "Would you feel safe publicly protesting sand mining in this village?" (yes; no or not sure) and "If someone like you complains about harmful or illegal sand mining, how likely is it that action will be taken?" (likely or very likely; very unlikely, unlikely or not sure). Panel A: all respondents include respondents to the community survey who were not in the household survey; household-survey respondents are households that answered both surveys. Panel B uses household-survey respondents; Column (1) reports the mean among Upper-caste households and column (4) the mean among households that own farmland. Columns (2) and (3) report the coefficients on the OBC and SC/ST indicators in Equation 5.2, estimated together with Upper-caste households as the omitted group, and column (5) the coefficient on an indicator for a household without farmland, with village fixed effects. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

state. Section 6 examines these possibilities by first comparing household earnings with environmental losses, then asking how unequal political influence could shift the balance in favour of mining.

6 Why does mining persist?

The state allocates mining rights, but nearby households can influence operations through their participation, bargaining and objections. Continued extraction therefore need not imply agreement among residents. We ask how far local economic interests can help explain persistence, using measured gains and losses together with evidence on compensation and political voice. Four explanations guide the analysis.

The first is a *positive local economic surplus*: gains accruing to nearby households exceed their environmental losses. This establishes whether beneficiaries could compensate those harmed while retaining a gain.

The second explanation is a *compensated agreement*. Beneficiaries might use part of their gains to make households bearing the damage willing to accept mining. This explanation requires both sufficient resources to cover the losses and transfers that actually reach those harmed. If measured local gains are insufficient to make all local losers whole, better redistribution among local households alone cannot produce a fully compensated agreement.

The third explanation is *unequal local political influence*. Households obtaining mining income or controlling resources relevant to extraction may exert more effective pressure than households bearing losses. Mining could then be consistent with the local political balance even when its unweighted local surplus is negative. We examine this explanation by asking whether a common relationship between household characteristics and political effectiveness can reconcile mining with the measured gains and losses across villages. The key question is how much explanatory scope this unequal weighting provides, rather than whether one can select a separate set of convenient weights for every village.

The fourth explanation is an *advantage arising beyond the surveyed households*. Contractors, the state and other actors can benefit from extraction or influence permitting and enforcement, even when nearby households bear net losses. The decision to allow mining may therefore respond to interests that a local household account does not capture. This residual measures the limits of the specified local mechanism.

6.1 Measuring household level gains and losses

To assess whether local gains could compensate local losses, we first compare mining earnings and environmental damage within each household. This comparison also identifies the opposing economic interests that may shape support for extraction. For household i in village v, we define annual net gain as

$$g_{iv} = \pi_{iv} - C_{iv}, \qquad C_{iv} = C_{iv}^{N} + \gamma_{r(v)} C_{iv}^{G} + \phi_{r(v)} C_{iv}^{F}, \tag{6.1}$$

where π_{iv} combines annual sand-work earnings and rent from land used for mining or transport, which we treat as profit without deducting further expenses. Labourers, loaders, drivers and machine operators could earn the village farm wage without mining, so for them we count only the premium of their sand wage over that farm wage. Managers' earnings and land rent count in full. The cost measure distinguishes three components: C_{iv}^{N} is the crop loss attributed by households to mining; C_{iv}^{G} is the reported cost of digging deeper for water; and C_{iv}^{F} is total reported flood loss. Losses recalled for 2021–25 are divided by five to express them on an annual basis. Road accidents, road damage, and dust and pollution, which households also attribute to mining (Section 5.2), are left out of the household account: these harms fall on the village as a whole, so a household's own report does not measure its individual stake. A positive g_{iv} indicates a measured net gain from mining, while a negative value indicates a measured net loss. Receiving mining income therefore need not imply a net gain.

Flooding and groundwater decline also occur without mining. We therefore adjust their costs

to reflect mining's estimated contribution. For flood losses, we use satellite-based estimates of mining's effect on flood exposure, estimated separately for villages on the Sone and those on other rivers (Appendix Table B-17, Panel D). For river group r, we set $\phi_r = \widehat{\beta}_r/(\widehat{\mu}_r + \widehat{\beta}_r)$, where $\widehat{\mu}_r$ is the pre-mining flood probability in mining villages and $\widehat{\beta}_r$ is the estimated increase attributable to mining, obtained by comparison with matched villages near the river. The denominator thus approximates flood risk with mining. We use this share of flood risk to approximate the share of reported monetary losses attributable to mining: 25.8% on the Sone and 26.9% on other rivers. We apply the share for river group $r(v)$ to each household in village v.

For groundwater, we use village heads' reports of water-table depth to estimate how much of the decline in mining villages exceeds that in matched control villages. We estimate the event study underlying Figure 8 separately for the Sone and other rivers. The share γ_r is the excess decline between 2020 and 2025 divided by the total decline in mining villages over that period. We apply the resulting shares, 74.0% on the Sone and 1.9% on other rivers, to households' reported costs of digging deeper. Both attribution shares are bounded between zero and one. Appendix B.7.1 provides the construction, and Appendix Table B-30 examines alternative assumptions about flood and groundwater costs.

The earnings measure must also reflect the mining histories covered by these losses. The analysis includes 5,293 households in 126 villages, comprising 74 with active mines and 52 with previously operating mines. We assign earnings to sand workers who report no amount and, at active sites, allow for work during 2021–25 that ended before 2025. For previously operating sites, we average current sand-work earnings with earnings imputed from the household's pre-closure role, using the median earnings of active-site workers in that role, then add reported annual land rent. These adjustments, detailed in Appendix B.7.1, avoid treating current earnings as the only return from mining when the losses cover a longer period.

The comparison covers direct mining earnings and land rent, less the three measured loss components in Equation 6.1. Possible indirect gains to other local businesses and the environmental harms excluded above remain outside it. Net gains are measured before additional environmental compensation; land rent is already included in earnings.

We compare the gains and losses associated with mining with their absence over the period covered by the data. Because some damage has already occurred, this comparison does not measure the benefit of closing a mine today. We also report results for villages with active mines alone, separating the findings relevant to ongoing extraction from those using imputed earnings at previously operating sites.

6.2 From household stakes to an aggregation rule

Households may differ in their ability to influence mining decisions. Extraction could therefore continue despite a negative average net gain if those who benefit are more politically effective than those bearing losses. Following Boyce (1994), we represent this possibility by weighting households' net gains by their political effectiveness. Differences in resources may affect both

control over collective decisions and the ability to exert pressure (Banerjee et al., 2001; Esteban and Ray, 2006).

We represent household i's signed political pressure as $h_{k(i)}g_{iv}$, where $k(i)$ denotes its group and $h_k > 0$ measures the group's effectiveness per rupee of gain or loss. Positive stakes generate supporting pressure and negative stakes generate opposing pressure. The same multiplier applies to both within each group. This linear relationship is an assumption: the multipliers summarise how stakes enter decisions, without separately identifying households' efforts to exert pressure and officials' responses.

We form sixteen groups by crossing farmland ownership, four caste categories (Upper-caste, Backward Classes or BC, Extremely Backward Classes or EBC, and SC/ST), and receipt of positive mining profit. Receipt uses the earnings measure in Section 6.1 and is defined before environmental losses are deducted. A recipient can therefore contribute opposing pressure. BC and EBC retain separate multipliers even when we report their pressure shares together as OBC; Appendix Table B-23 reports all four caste categories separately.

Land ownership and profit receipt define households' economic positions. Caste may shape access to these positions as well as influence within them: land and social status can jointly sustain village political control (Anderson et al., 2015). Giving castes equal multipliers within an economic position still retains caste differences in access to land, mining earnings and environmental losses. To assess what separate caste multipliers add, we compare the sixteen-group model with specifications that pool caste categories within each position, including the eight-group rule that combines Upper-caste with BC and EBC with SC/ST. All comparisons use the same household gains and losses. This distinguishes caste's role through economic differences from any additional explanatory scope provided by differences in effectiveness within the same economic position.

To combine household pressures, let n_v denote the number of sampled households in village v and n_{vk} the number in group k. Define

$$U_{vk} = \frac{1}{n_v} \sum_{i:k(i)=k} g_{iv}, \qquad m_{vk} = \frac{n_{vk}}{n_v}. \tag{6.2}$$

The group contribution U_{vk} divides its total gain by the full village sample, incorporating both group size and the magnitude of members' stakes. The household share m_{vk} determines the group's contribution to the village's average multiplier. We express the local political balance as

$$P_v(h) = \frac{\sum_k h_k U_{vk}}{\sum_k h_k m_{vk}}. \tag{6.3}$$

Dividing average household pressure by the village's average multiplier leaves its sign unchanged and expresses $P_v(h)$ in annual rupees per household. This puts villages with different group compositions on a common scale, which we use in Section 6.6 to measure the additional advantage required when local household pressure alone does not support mining.

When all multipliers are equal, $P_v(h)$ reduces to average household gain, $S_v = n_v^{-1} \sum_i g_{iv}$. The

local-surplus benchmark is therefore a special case of the political rule. Equal multipliers give every rupee of gain or loss equal political weight; households still contribute different amounts of pressure when their stakes differ. A few large gains can consequently outweigh many small losses even under this benchmark.

For local household interests alone to support mining, the weighted balance must be nonnegative: $P_v(h) \geq 0$, equivalently $U_v h \geq 0$, where U_v is the vector of group contributions in village v. We require the *same* group multipliers across villages. The same group may gain in one village and lose in another, so a multiplier that strengthens support in one place can strengthen opposition elsewhere. A common rule must accommodate these differences rather than select a different pattern of influence for each village.

To assess how much inequality this explanation requires, we limit the ratio of the largest to the smallest multiplier to R. A cap of ten, for example, allows the most effective group at most ten times the multiplier of the least effective group. Because rescaling all multipliers leaves $P_v(h)$ unchanged, we can impose this cap as $1 \leq h_k \leq R$. For V villages, define

$$K(R) = \max_{1 \leq h_k \leq R} \sum_{v=1}^{V} \mathbb{1}\{U_v h \geq 0\}. \tag{6.4}$$

The quantity $K(R)$ is the largest number of villages in which one common rule can make the local political balance nonnegative. Comparing it with $K(1)$ shows how far unequal effectiveness can extend the explanation beyond the local-surplus benchmark. We choose a new common rule at each cap, so higher coverage need not retain the same set of villages. The mixed-integer linear programme is described in Appendix B.7.3.

The rule does not assume that residents vote on permits or control enforcement on their own. If no positive common multipliers satisfy every village condition, the mechanism cannot explain the full sample. When several rules attain the same coverage, the calculation does not identify which, if any, describes actual political power. The results are feasibility exercises conditional on the measured stakes and group definitions, rather than sampling-based significance tests.

6.3 Local surplus and compensation

The first explanation requires local gains to cover local losses. Only 25 of 126 villages meet this condition using the measured benefits and costs (Table 15). Giving each village equal weight, annual profit averages Rs. 1,890 per household and measured costs average Rs. 2,627, leaving an average net loss of Rs. 738. In most villages, the gains available to local beneficiaries are therefore insufficient to compensate all measured losses.

The same limitation appears among villages with active mines. Their average annual net gain is close to zero, at Rs. -22 per household, but only 21 of 74 villages have a nonnegative measured surplus (Appendix Table B-30). An average near zero across villages does not imply that compensation is feasible within most of them.

Table 15: Household gains, losses and the scope for compensation

	Amount or count	Share of total costs (%)
A. Sample		
Villages with a mine, active or closed	126	
of which mining active	74	
Households	5,293	
B. Annual household account (Rs), villages weighted equally		
Profit from sand	1,890	
Total environmental costs	2,627	100.0
Crop losses	1,330	50.6
Groundwater: deeper digging (attributed share)	933	35.5
Flood losses (attributed share)	364	13.9
Gain: profit minus costs	−738	
C. Who gains		
Households with a positive gain (%)	6.6	
Households with a negative gain (%)	46.3	
Households with a zero gain (%)	47.2	
Villages where the average gain is at least zero	25 of 126	
D. Compensation (Rs per household per year)		
Needed to make losers whole	2,424	
Gains of winners available to pay it	1,686	
Shortfall within villages	1,649	

Notes: Gains are annual profit minus the three cost components in Panel B, as in Equation 6.1. For wage workers, mining profit counts only earnings above the village farm-wage alternative. Managers' earnings and land rent enter in full, without deductions for other expenses. Road accidents, road damage, and dust and pollution are not in the household account. Groundwater costs count at mining's share of the decline on the village's river, and flood losses at the corresponding attributed share. Monetary means give each village equal weight. Each cost share is its equal-village mean amount divided by mean total costs; amounts and shares are calculated before rounding. The share column is blank for quantities outside the cost breakdown. Household proportions pool the complete accounting sample. Compensation amounts are per sampled household, including households with zero gains or losses. The local shortfall averages $[D_v - G_v]_+$ across villages.

Crop damage is the largest monetary cost, accounting for 50.6% of the total in Panel B of Table 15; deeper digging for water is also substantial. The groundwater adjustment in Section 6.1 materially affects the level of these costs. Counting reported digging costs in full would lower the average net gain from Rs. −738 to Rs. −2,063. Using the common stacked flood share instead of river-specific shares, while retaining the groundwater adjustment, gives an average net gain of Rs. −713 and leaves the number of villages with nonnegative gains unchanged (Appendix Table B-30). Even after allowing for non-mining causes of groundwater decline and flooding, local gains remain insufficient to cover losses in most villages.

Losses are also more widespread than gains. In the pooled household sample, 6.6% have a positive net gain, 46.3% a negative one, and 47.2% a zero measured net gain. Losers substantially outnumber winners, although they comprise fewer than half the sample. Whether the winners could compensate them depends on the size of their combined net gains relative to the combined net losses.

Could local beneficiaries compensate those who lose? To measure the resources needed for compensation and the gains available to finance it, define

$$D_v = \frac{1}{n_v}\sum_i [-g_{iv}]_+, \qquad G_v = \frac{1}{n_v}\sum_i [g_{iv}]_+. \tag{6.5}$$

Here $[x]_+ = \max\{x, 0\}$. The amount D_v is needed to eliminate negative measured net gains, while G_v is what winners could contribute while retaining a nonnegative gain. Both are expressed per sampled household, including households with zero gains or losses. Since $G_v - D_v = S_v$, transfers within a village could leave every household at least as well off as without mining precisely when $G_v \geq D_v$. Financial feasibility of compensation is therefore the same condition as the local-surplus benchmark.

Giving villages equal weight, the annual amount needed, D_v, averages Rs. 2,424 per household, while available gains, G_v, average Rs. 1,686 (Table 15, Panel D). A village with insufficient gains would need an additional $[D_v - G_v]_+$. Averaging these shortfalls gives Rs. 1,649 per household per year, substantially more than the absolute average net loss of Rs. 738. The difference arises because we consider compensation financed within each village: we calculate its shortfall before averaging, without using surpluses elsewhere to offset it.

Where $G_v < D_v$, making all measured losers whole would require resources beyond the gains of nearby households. Contractors, the state and sand users elsewhere may also benefit from extraction, but their returns are outside this calculation. A negative local surplus therefore leaves open whether mining's total benefits exceed its total costs; it establishes a limit on compensation financed by the surveyed households.

Even where local gains are sufficient, agreement is not assured: as Acemoglu (2003) emphasises, political actors may be unable to credibly commit to future actions or compensation. Section 5.3 finds compensation for land damage and flood assistance to be uncommon. Insufficient local resources and scarce evidence of damage payments thus limit the scope for explaining mining through compensated local agreement.

6.4 How much can unequal political weight explain?

Where local gains cannot finance compensation, extraction may still be sustained if the interests favouring it carry greater political weight. Using the rule in Section 6.2, we ask whether differences in effectiveness across household groups can make the local political balance nonnegative. Table 16 compares alternative groupings based on land ownership, caste and mining-profit receipt. All use the same measured household gains and losses, and each rule must apply across villages.

Distinguishing profit recipients from nonrecipients greatly expands the set of villages consistent with mining. At a highest-to-lowest multiplier ratio cap of 100, the land-and-caste rule accommodates 29 villages, compared with 25 under equal multipliers. A two-group rule separating recipients from nonrecipients accommodates 74. Adding land ownership and pooled caste categories to receipt gives eight groups and 75 villages; separating all four caste categories gives

Table 16: How many villages can one common weighting rule accommodate?

	Land and caste	Mining income	Pooled caste	Four castes
Groups	4	2	8	16
Villages with no positive group	75	47	41	39
Coverage at ratio 1	25	25	25	25
Coverage at ratio 2	27	38	38	38
Coverage at ratio 5	29	51	51	52
Coverage at ratio 10	29	63	63	63
Coverage at ratio 100	29	74	75	76
One rule fits all villages	No	No	No	No
Minimum ratio for all villages	None	None	None	None
Outside advantage, no ratio cap (Rs)	6,255	6,020	3,533	2,445
Outside advantage, ratio cap 100 (Rs)	6,349	6,020	3,545	2,581

Notes: A rule assigns one multiplier to each group, common across all villages. The first column uses farmland ownership and Upper-caste/BC versus EBC/SC; the second distinguishes positive mining-profit receipt; the third crosses both sets of characteristics. The last column separates Upper-caste, BC, EBC and SC/ST, crossed with ownership and receipt. $K(R)$ maximises village coverage subject to a highest-to-lowest multiplier ratio of at most R. Outside advantage is the smallest uniform ceiling permitting a common rule to accommodate all villages, in annual rupees per household, shown both with and without the ratio cap.

sixteen groups and 76 villages. Beyond receipt, land and caste add little coverage at this cap.

The importance of receipt reflects the concentration of mining returns. Only 8.7% of households receive positive mining profit, measured before environmental losses are deducted. This differs from the 9.0% with any sand income in Section 5.1: here, wage workers whose sand wage does not exceed the farm wage earn no profit, while earnings from sand work before 2025 count. Land-and-caste groups can therefore combine a small number of recipients with households that earn nothing from mining and may bear losses. Raising their shared multiplier increases the weight on both sides of the conflict. Separating receipt allows recipients' net gains and losses to carry a different weight from those of nonrecipients.

In the sixteen-group model, allowing a tenfold difference in effectiveness accommodates 63 villages; relaxing the cap to 100 raises this to 76 (Figure 12). Larger permitted disparities therefore bring additional villages into a nonnegative political balance, but their explanatory scope has a structural limit.

The 50 villages outside this rule fall into two groups. In 39 of them, every one of the sixteen groups has a nonpositive total net gain and the village total is negative. Their weighted sum consequently remains negative for any strictly positive multipliers. Individual households may still gain, but the rule gives them the same multiplier as others in their group. No increase in the permitted ratio can therefore make these villages satisfy the condition for local support. In the other 11, some group gains, but one rule cannot also accommodate them at the 100:1 cap. Even with a ratio cap of 10,000, the best common rule accommodates 82 of the 87 villages that some rule could in principle reach. Explaining extraction in the remaining villages requires stakes or political mechanisms beyond those represented by these household groups.

Caste can still shape this political balance through its association with land ownership, access

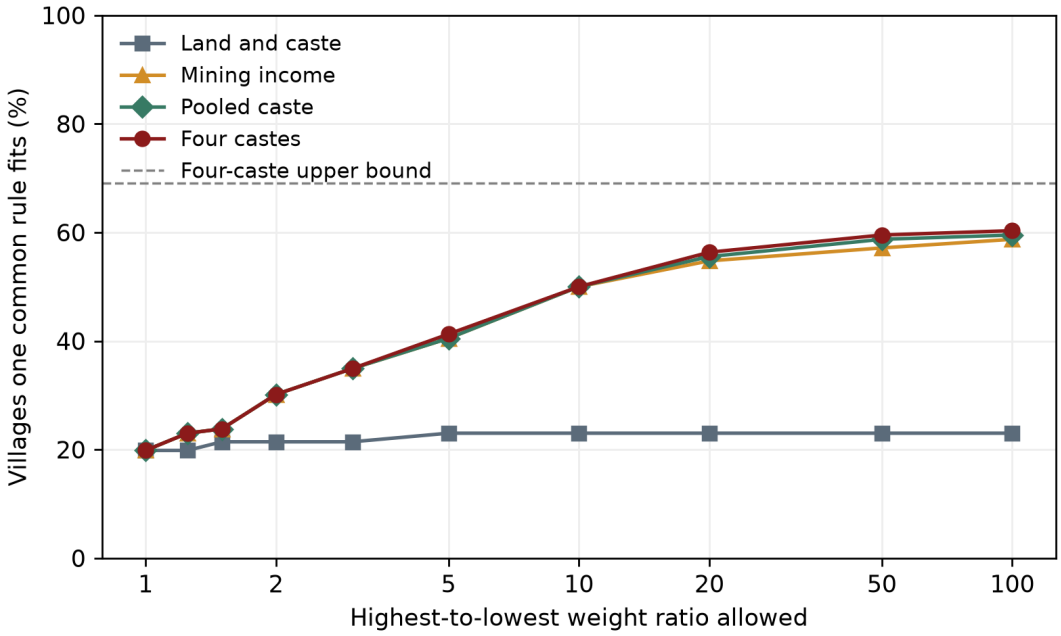


Figure 12: Compatibility as the permitted political-weight ratio increases

Notes: Each point solves Equation 6.4 using one set of group multipliers common across villages. The horizontal axis caps the highest-to-lowest multiplier ratio for the entire rule; the vertical axis reports the share of villages accommodated. Each specification uses household accounts from all 126 villages.

to mining income and environmental losses. Subsection 6.5 examines how these differences distribute supporting and opposing pressure across castes, alongside survey evidence on opposition and influence.

6.5 Caste and the distribution of political pressure

Caste can shape the political balance through differences in economic stakes and through differences in effectiveness among households occupying the same economic position. The first channel operates when caste is associated with access to mining income, landownership or exposure to losses. The second allows households with the same landownership and profit-receipt status to have different multipliers across castes. We distinguish these channels by examining whose gains and losses generate pressure before and after allowing separate caste multipliers.

Table 17 compares castes' shares of pressure with two benchmarks: their share of households in column (1), and their share of monetary gains or losses before political multipliers are applied, in column (2). Panel A uses positive net gains, after environmental losses have been deducted from earnings; Panel B uses the absolute size of net losses. Each caste's gains and losses are totalled separately, so its winners do not cancel its losers in these shares. Column (1) includes all households, including those with zero net gains, and is therefore the same in both panels. The pooling gives villages equal importance and households equal importance within villages, before applying any political multiplier.

Columns (3) and (4) translate monetary stakes into pressure using h_k, the political weight per rupee of gain or loss defined in Section 6.2. Column (3) allows four multipliers, one for each combination of farmland ownership and mining-profit receipt. For example, an Upper-caste landowner and an SC/ST landowner who both receive mining profit must have the same multiplier. Column (4) allows their multipliers to differ: it assigns a separate multiplier to each of the four caste categories within each position, giving sixteen groups. The OBC row combines BC and EBC contributions. In both specifications, the same group multiplier applies to gains and losses. A caste's pressure share divides its multiplied stakes by total supporting pressure in Panel A or total opposing pressure in Panel B.

The last two columns report ranges because several common rules can accommodate the same villages. At a highest-to-lowest multiplier ratio of at most 100, the best rule with equal caste multipliers accommodates 74 villages; separate caste multipliers reach 76 (Section 6.4). To compare the two columns over the same villages, we fix the set at these 74, which both specifications can accommodate. We retain all rules that accommodate them within the ratio cap, then find the smallest and largest share each caste can have. All 126 villages contribute to these shares, including the 39 whose balances remain negative under any multipliers and the 13 others outside the fixed set. The intervals describe possibilities within the model, rather than estimates of actual caste influence. Each endpoint is chosen separately and need not occur with the other endpoints under one rule; Appendix B.7.7 gives the calculation.

Table 17: Caste shares of net gains, net losses and model-implied pressure

	Household share (%)	Share of net gains or net losses (%)	Pressure-share range (%)	
			Equal caste multipliers within each position	Separate caste multipliers within each position
	(1)	(2)	(3)	(4)
A. Supporting pressure				
Upper-caste	16.4	41.1	40.9–44.3	29.4–70.7
OBC	59.9	46.9	45.6–47.0	19.9–63.2
SC/ST	23.8	12.0	10.2–12.1	4.1–19.8
B. Opposing pressure				
Upper-caste	16.4	24.5	11.5–15.2	6.9–35.7
OBC	59.9	61.1	63.5–66.0	38.8–84.7
SC/ST	23.8	14.4	19.6–23.5	7.5–39.8

Notes: OBC combines BC and EBC. Column (1) averages each caste's household share across villages, using all 5,293 households, including those with zero net gains, in both panels. Column (2) divides each caste's positive net gains (Panel A) or absolute net losses (Panel B) by the corresponding total across castes. Columns (3) and (4) first multiply each household's positive net gain (Panel A) or absolute net loss (Panel B) by its group's multiplier $h_{k(i)}$, then divide each caste's total by the corresponding total across all castes. Column (3) uses four groups: farmland ownership crossed with positive mining-profit receipt. Column (4) crosses these positions with Upper-caste, BC, EBC and SC/ST; the OBC row sums BC and EBC contributions. All shares use equal village base weights and equal household weights within villages, pooling amounts before the village-specific normalisation in Equation 6.3. Ranges minimise and maximise each share separately over common rules accommodating the 74 villages that the best equal-caste rule accommodates, with a highest-to-lowest multiplier ratio of at most 100. All 126 villages contribute to the shares.

Upper-caste households illustrate how unequal economic stakes can produce unequal supporting pressure. They represent 16.4% of households but receive 41.1% of positive net gains. Their share of supporting pressure remains above their household share throughout the 40.9–44.3% range in column (3). This pattern therefore does not require greater effectiveness for Upper-caste households within the same economic position: their overrepresentation is already present in the distribution of monetary gains. OBC and SC/ST households, in contrast, have supporting-pressure shares below their household shares throughout that column's ranges.

These differences also qualify the interpretation of the larger asset gains for Upper-caste and OBC households pooled together in Section 4. The pooled group represents 76.2% of households and carries 87.9–89.8% of supporting pressure under economic-position multipliers. But OBC households alone are underrepresented in support, and carry 63.5–66.0% of opposing pressure. The pooled group also bears 85.6% of net losses. The earnings and damage differences in Sections 5.1 and 5.2 thus generate substantial interests on both sides of extraction within this broad caste grouping.

Allowing separate caste multipliers makes the distribution of pressure much less determinate. For example, the OBC supporting share can range from 19.9% to 63.2% in column (4). Compatibility with mining alone therefore provides little basis for inferring a particular hierarchy of caste influence.

Reported conflict and influence. We next examine whether economic stakes are associated with reported resistance. Table 18 relates any reported opposition, protest or dispute in a village to gains and losses within each caste. Gains and losses enter separately as averages over all households of that caste with measured net gains, including zeros. The comparison separating Upper-caste from OBC covers 90 villages with at least one such household in each of the three caste categories. All specifications control for the daily flow of sand trucks from the village, whether its mines are on the Sone, its number of households and share of land sown in the 2011 Census, and the shares of Upper-caste and SC/ST households.

Opposition is more common where Upper-caste households have larger net losses. Holding the controls fixed, a Rs. 1,000 increase in their average annual net loss is associated with a 4.8 ppt increase in the probability of reported opposition (column 5; standard error 1.0). The same increase in SC/ST households' average positive net gains is associated with a 5.2 ppt decrease (standard error 1.8). Larger OBC gains are also associated with less opposition, but the estimate is statistically significant only with district fixed effects (column 6), and OBC losses are imprecisely estimated. The association with Upper-caste losses remains with district fixed effects and when gains and losses are measured by household shares. The association with SC/ST gains keeps its sign in these specifications but is less precisely estimated. With household shares, a larger share of Upper-caste households with positive net gains is also associated with less opposition (columns 7 and 8).

Substantial gains among some Upper-caste households thus coexist with losses among others

Table 18: Reported opposition and caste groups' gains and losses from mining

	Upper-caste and OBC together				Upper-caste and OBC separately			
	Rs. 1,000 a year		Share of households		Rs. 1,000 a year		Share of households	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Upper-caste and OBC: gaining	−0.1	0.0	−0.3	−0.9				
	(0.3)	(0.3)	(5.0)	(5.1)				
Upper-caste and OBC: losing	6.0***	6.0***	4.9**	6.1**				
	(1.3)	(1.7)	(2.4)	(3.0)				
Upper-caste: gaining					0.0	0.0	−6.0*	−9.0**
					(0.1)	(0.1)	(3.1)	(3.9)
Upper-caste: losing					4.8***	4.9***	3.4*	3.4*
					(1.0)	(0.9)	(2.0)	(2.0)
OBC: gaining					−2.1	−3.6**	7.2	10.5
					(1.4)	(1.7)	(6.6)	(7.5)
OBC: losing					−2.6	−3.0	−1.9	−0.8
					(2.3)	(2.7)	(2.5)	(2.8)
SC/ST: gaining	−4.7***	−4.1**	−6.5**	−5.6**	−5.2***	−3.7*	−3.9	−4.6
	(1.6)	(1.7)	(2.7)	(2.8)	(1.8)	(2.1)	(2.7)	(3.4)
SC/ST: losing	0.1	−0.8	0.3	−1.2	2.4	−1.4	1.6	−0.6
	(2.5)	(2.5)	(2.2)	(2.4)	(3.3)	(4.1)	(2.2)	(2.6)
Villages	119	119	119	119	90	90	90	90
R-squared	0.20	0.25	0.12	0.20	0.30	0.34	0.20	0.28
Mean of the outcome	24.4	24.4	24.4	24.4	23.3	23.3	23.3	23.3
District fixed effects	No	Yes	No	Yes	No	Yes	No	Yes

Notes: One observation per village with active or closed mining. The outcome is 100 if the field supervisor reports any opposition, protest or dispute over sand mining in the village at any time, and 0 otherwise. Supervisor reports are unavailable in 16 villages; there, the outcome is 100 if at least 20% of surveyed households report that someone in the village made a formal complaint, application or protest about mining in the past few years, and 0 otherwise. A household's net gain is g_{iv} in Equation 6.1. In columns (1), (2), (5) and (6), the gaining and losing rows are a group's averages of $[g_{iv}]_+$ and $[-g_{iv}]_+$ over all its households with a measured account in the village, in thousands of rupees a year. In columns (3), (4), (7) and (8), they are the shares of those households with a positive and with a negative net gain, in units of 10 ppt; households with a net gain of zero form the omitted category. Columns (1)–(4) combine Upper-caste and OBC households; columns (5)–(8) enter them separately. OBC includes BC and EBC. Each group must have at least one measured account in a village. All columns control for log(1 + daily trucks), from the supervisor's count of trucks a day while mining operates or, where it has closed, while it operated; an indicator for mines on the Sone; log households and the share of land sown in the 2011 Census; and the shares of Upper-caste and SC/ST households among surveyed households, with OBC omitted; their coefficients are not shown. Villages without a truck count are omitted. Columns (2), (4), (6) and (8) include district fixed effects and omit singleton districts. Coefficients are in ppt. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

that are associated with resistance. This connects the economic differences in Section 5 to reported conflict, without establishing which households mobilised or how their actions affected extraction.

The community survey asks directly about perceived influence over mining decisions. We use 2,611 observations with valid influence responses from people who answered both surveys. Upper-caste respondents are 11.9 ppt more likely than SC/ST respondents in the same village to report any influence. The gap remains 11.8 ppt after controlling for land-and-receipt position (standard error 4.0; Appendix Table B-27, Panel A). Pooling Upper-caste and all OBC households gives a smaller difference of 3.8 ppt ($p = 0.169$; Panel B). These reports suggest caste differences in perceived voice beyond broad economic position, but do not identify the model's multipliers or whether influence favours extraction or restraint. Appendix Table B-28 reports comparisons within economic positions and sensitivity to the influence measure and respondent linkage; Appendix Table B-29 gives linkage coverage and cell sizes.

6.6 Outside advantage and robustness

Section 6.4 identifies 39 villages where opposing pressure exceeds supporting pressure under any positive multipliers for the sixteen household groups. We now measure the additional advantage needed to make the political balance nonnegative in every village.

Let $b_v \geq 0$ denote an additional advantage in village v, so that mining is compatible with $P_v(h) + b_v \geq 0$. When $P_v(h) < 0$, opposing local pressure exceeds supporting pressure, and an addition of $-P_v(h)$ is needed to bring the balance to zero. When $P_v(h) \geq 0$, no addition is needed. The village's requirement is therefore $[-P_v(h)]_+$. We place a common ceiling b on these village-specific requirements and choose the local rule that makes this ceiling as small as possible. With multiplier-ratio cap R, this gives

$$b^*(R) = \min_{1 \leq h_k \leq R} \max_v [-P_v(h)]_+. \tag{6.6}$$

For a candidate ceiling b, feasibility requires $(U_v + bm_v)h \geq 0$ in every village. The normalisation in Equation 6.3 expresses both the local balance and the additional advantage in annual rupees per household. These units express an equivalent advantage in the political index, rather than an observed payment, contractor profit or compensation budget. Thus $b^*(R)$ measures the largest requirement under the rule that minimises it, rather than an amount required in each village. Appendix B.7.5 describes the calculation.

Under equal multipliers, this ceiling is Rs. 21,829. Allowing the sixteen-group rule with a 100:1 cap lowers it to Rs. 2,581; removing the cap lowers it further to Rs. 2,445. Unequal local effectiveness can therefore substantially reduce the additional advantage needed, but cannot eliminate it within the specified household groups. The ceiling is determined by the village requiring the greatest addition to its political balance, so it can greatly exceed the average household loss across villages.

This objective differs from maximising local coverage. Coverage depends only on whether a

balance crosses zero, whereas $b^*(R)$ depends on how negative the balances remain. Specifications can therefore accommodate the same number of villages yet require different outside ceilings, as Table 16 shows. The rule minimising this ceiling is chosen separately from the maximum-coverage rules underlying the pressure ranges in Table 17.

Caste differences in the required outside advantage. We hold the 100:1 ratio cap fixed and vary whether castes must have equal multipliers within the same land-and-receipt position (Table 19). Allowing separate caste multipliers lowers $b^*(100)$ from Rs. 5,836 under caste equality to Rs. 2,581 with sixteen groups, while raising local coverage only from 74 to 76 villages. Caste-specific effectiveness therefore mainly reduces the largest additional advantage required across villages, adding little to the number of villages local household stakes can accommodate.

Table 19: Additional caste effectiveness and model fit

Multipliers within each economic position	$K(100)$	$b^*(100)$ (Rs.)
Four separate castes (16 groups)	76	2,581
Upper-caste = BC; EBC = SC/ST (8 groups)	75	3,545
Upper-caste = BC = EBC; SC/ST separate (8 groups)	76	4,448
All castes equal (4 groups)	74	5,836

Notes: An economic position is a combination of farmland ownership and positive mining-profit receipt. Each programme chooses one common rule across all 126 villages, with a highest-to-lowest multiplier ratio of at most 100. $K(100)$ maximises the number of villages with a nonnegative local political balance. $b^*(100)$ minimises the largest additional advantage needed to make every village's balance nonnegative, in annual rupees per household in the normalised index of Equation 6.3. These objectives are optimised separately.

The institutional setting provides plausible sources of support beyond the surveyed households. The state awards mining rights through auctions and receives revenue from extraction, while operators earn returns from selling sand. Local households can bargain over access to their land and seek safeguards or changes in enforcement, but a village-wide agreement is not the basis on which leases are allocated (Section 2). Their ability to challenge harmful operations may also be constrained: only 36.9% of community-survey respondents in mining villages feel safe protesting publicly, and 20.2% expect a complaint from someone like them to lead to action (Section 5.6). These findings help explain how mining can continue despite local losses. They do not identify the source of the additional advantage in Equation 6.6, which may also reflect omitted local benefits or forms of influence absent from the household grouping.

Alternative flood-cost measures give the same qualitative result. Using a common attribution share from Section 4, whether stacked or interaction-weighted, or adding attributed flood-repair expenditure leaves a minority of villages with nonnegative local surplus and a larger, but incomplete, set compatible with unequal effectiveness. The groundwater adjustment matters more for the size of the remaining requirement. Counting reported groundwater costs in full lowers mean net gain to Rs. $-2{,}063$. Unequal multipliers still increase the number of compatible villages from 17 under equal effectiveness to 69 at the 100:1 cap, but the uncapped outside ceiling rises to

Rs. 10,174. The scope for a local political explanation remains substantial under these alternatives, while its inability to cover the full sample persists.

Interpreting measured losses as opposing pressure also requires residents to connect the harm they experience with mining. Appendix B.7.12 examines this connection. Within the monetary analysis, losses in domains that households do not explicitly connect to mining represent 9.1% of measured costs. Removing them would raise average annual net gain by Rs. 238 per household, leaving it negative. These responses qualify the relationship between measured and perceived stakes.

6.7 What the exercise establishes about persistence

The evidence supports different conclusions about the four explanations for persistence. Measured local gains cover losses in only 25 of 126 villages, including 21 of 74 villages with active mines. Redistributing these gains among nearby households therefore cannot fully compensate measured losses in most villages. A compensated agreement faces a further obstacle even where resources are sufficient: the survey finds little evidence of payments reaching households bearing environmental damage (Section 5.3).

Unequal political effectiveness provides a possible route through which concentrated gains can favour extraction despite larger aggregate losses. Requiring one rule across villages, the model accommodates 63 villages with up to tenfold differences in effectiveness and 76 with up to hundredfold differences. Much of this scope comes from distinguishing mining-profit recipients from nonrecipients. These calculations show that unequal effectiveness can reconcile extraction with the measured local stakes in a substantial part of the sample, while leaving its actual magnitude undetermined.

Caste remains central to this interpretation. Access to mining returns and exposure to losses differ across castes, so their contributions to supporting and opposing pressure differ even when households in the same economic position receive equal multipliers. Upper-caste respondents also report greater influence, while larger losses among Upper-caste households are associated with more reported opposition (Section 6.5). Together, these findings connect caste to both economic opportunities and political voice, without treating any caste as uniformly supportive of mining.

Local interests operate within a system in which the state authorises extraction and contractors receive returns beyond those measured among nearby households. Continued mining can therefore coexist with uncompensated local losses even where the specified local mechanism is insufficient. The additional advantage calculated in Section 6.6 measures that limitation. The resulting answer to the persistence question has two parts: concentrated benefits and unequal effectiveness can create local support despite aggregate losses, while state authority and interests beyond nearby households allow extraction to continue without a compensated community agreement.

7 Conclusion

This paper examines why environmentally damaging extraction can persist despite substantial costs to nearby households. Sand mining in Bihar increases flooding and reduces vegetation while stimulating local economic activity. Household asset gains are larger for Upper-caste and OBC households considered together than for SC/ST households, and direct mining income is concentrated among a small share of residents. These differences create conflicting interests within communities exposed to the same activity.

Economic expansion alone does not establish a broadly beneficial local agreement. Measured mining profits cover valued environmental losses in only 25 of 126 villages with current or past mining. Among the 74 villages with active mines, only 21 have a nonnegative measured surplus, despite an average net gain close to zero. Where losses exceed profits, redistribution among nearby households cannot fully compensate those harmed while leaving beneficiaries at least as well off as without mining. Where sufficient profits exist, scarce reported compensation presents a separate obstacle. These comparisons concern measured direct returns and selected environmental losses, rather than total social surplus.

Concentrated beneficiary interests nevertheless provide a possible basis for continued extraction. Under one political weighting rule common across villages, allowing up to tenfold differences in effectiveness makes the local balance nonnegative in 63 villages, compared with 25 under equal weights. A hundredfold limit raises coverage to 76. Much of this scope comes from distinguishing profit recipients from nonrecipients. The exercise establishes how far unequal local effectiveness can reconcile extraction with measured stakes under the specified model, while leaving actual political influence undetermined.

Caste matters through both economic opportunities and reported voice. Upper-caste households receive a disproportionate share of positive net gains and contribute disproportionately to supporting pressure even when households in the same economic position receive equal multipliers across castes. They also report greater influence after adjustment for landownership and mining-profit receipt. At the same time, their losses are associated with more reported opposition. Caste therefore shapes the distribution of interests and the ability to express them, without producing a uniform position on extraction within each group.

These local conflicts unfold within a system in which the state allocates mining rights, operators negotiate particular local inputs, and residents seek redress through bargaining, complaints and collective action. Limited confidence in official action and concerns about protest safety help explain why local losses need not translate into effective restrictions. Where the specified local mechanism is insufficient, contractor and state interests provide plausible additional explanations, although their contribution cannot be separated from omitted local returns or other forms of influence.

More broadly, environmental conflict is not simply a contest between firms and the communities exposed to their activities. Economic gains can create local support for environmentally damaging production even when its costs remain largely uncompensated. The distribution of

those gains, and the influence of those receiving them, can therefore matter independently of their aggregate size. Giving communities a role in environmental decisions does not by itself ensure that those bearing the costs are represented or compensated. Assessing extraction therefore requires attention to who receives its returns, who bears its costs, and how those interests enter the decisions governing its operation.

References

Acemoglu, Daron, "Why Not a Political Coase Theorem? Social Conflict, Commitment, and Politics," *Journal of Comparative Economics*, 2003, *31* (4), 620–652. 1, 6.3

ActionAid India, "Stolen Sand," Technical Report, Natural Resource Knowledge Activist Hub, ActionAid India, Bhubaneswar 2016. 2.3

Anderson, Siwan, Patrick François, and Ashok Kotwal, "Clientelism in Indian Villages," *American Economic Review*, 2015, *105* (6), 1780–1816. 1, 2.1, 6.2

Aragón, Fernando M. and Juan Pablo Rud, "Natural Resources and Local Communities: Evidence from a Peruvian Gold Mine," *American Economic Journal: Economic Policy*, 2013, *5* (2), 1–25. 1

_ **and** _ , "Polluting Industries and Agricultural Productivity: Evidence from Mining in Ghana," *The Economic Journal*, 2016, *126* (597), 1980–2011. 1

Asher, Sam and Paul Novosad, "Rent-Seeking and Criminal Politicians: Evidence from Mining Booms," *The Review of Economics and Statistics*, 2023, *105* (1), 20–39. 1

_ **, Tobias Lunt, Ryu Matsuura, and Paul Novosad**, "Development research at high geographic resolution: an analysis of night-lights, firms, and poverty in India using the shrug open data platform," *The World Bank Economic Review*, 2021, *35* (4). 3.1.5, 3.3

Banerjee, Abhijit, Dilip Mookherjee, Kaivan Munshi, and Debraj Ray, "Inequality, Control Rights, and Rent Seeking: Sugar Cooperatives in Maharashtra," *Journal of Political Economy*, 2001, *109* (1), 138–190. 1, 6.2

Banzhaf, Spencer, Lala Ma, and Christopher Timmins, "Environmental Justice: The Economics of Race, Place, and Pollution," *Journal of Economic Perspectives*, February 2019, *33* (1), 185–208. 1

Bardhan, Pranab, Maitreesh Ghatak, and Alexander Karaivanov, "Wealth Inequality and Collective Action," *Journal of Public Economics*, 2007, *91* (9), 1843–1874. 1

Boyce, James K., "Inequality as a Cause of Environmental Degradation," *Ecological Economics*, 1994, *11* (3), 169–178. 1, 1, 6.2

Burgert, Clara R., Josh Colston, Thea Roy, and Blake Zachary, "Geographic Displacement Procedure and Georeferenced Data Release Policy for the Demographic and Health Surveys," DHS Spatial Analysis Reports 7, ICF International, Calverton, Maryland September 2013. 4.4

Burgess, Robin, Matthew Hansen, Benjamin A. Olken, Peter Potapov, and Stefanie Sieber, "The Political Economy of Deforestation in the Tropics*," *The Quarterly Journal of Economics*, November 2012, *127* (4), 1707–1754. 1

Burke, M and D B Lobell, "Satellite-based assessment of yield variation and its determinants in smallholder African systems," *Proceedings of the National Academy of Sciences*, 2017, *114* (9), 2189–2194. 3.1.4

Cengiz, Doruk, Arindrajit Dube, Attila Lindner, and Ben Zipperer, "The Effect of Minimum Wages on Low-Wage Jobs*," *The Quarterly Journal of Economics*, August 2019, *134* (3), 1405–1454.

Central Pollution Control Board, "Report on Sand Mining at Different Ghats on River Son in Aurangabad and Rohtas Districts, Bihar," July 2020. Report of 27 July 2020 to the National Green Tribunal in Original Application No. 513 of 2019, Mohd. Imran Khan Kadri, Muslim Rashtriya Manch v. State of Bihar. A.2

Coase, Ronald H., "The Problem of Social Cost," *The Journal of Law and Economics*, 1960, *3*, 1–44. 1, 1

Comptroller and Auditor General of India, "Systems and Controls in Assessment and Collection of Mineral Receipts," Performance Audit Report 4 of 2022, Comptroller and Auditor General of India 2022. Government of Bihar; for the year ended 31 March 2021. 2.2, 1, 2.3

Didan, K, A B Munoz, R Solano, and A Huete, *MODIS Vegetation Index User's Guide (MOD13 Series)* 2015. 3.1.4

Didan, Kamel, "MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061," 2021. 3.1.4

Duflo, Esther, Michael Greenstone, Rohini Pande, and Nicholas Ryan, "Truth-telling by Third-party Auditors and the Response of Polluting Firms: Experimental Evidence from India," *The Quarterly Journal of Economics*, 2013, *128* (4), 1499–1545. 1

Esteban, Joan and Debraj Ray, "Inequality, Lobbying, and Resource Allocation," *American Economic Review*, 2006, *96* (1), 257–279. 1, 6.2

Farmer, A. M., "The Effects of Dust on Vegetation—A Review," *Environmental Pollution*, 1993, *79* (1), 63–75. 2.3

Government of Bihar, "Bihar Minerals (Concession, Prevention of Illegal Mining, Transportation & Storage) Rules, 2019," September 2019. Notification No. 4/V.Mu-20-93/18-3174/M, 17 September. 2.1, 2.3, A.2

Government of India, "The Mines and Minerals (Development and Regulation) Act, 1957," 1957. Act No. 67 of 1957, as amended; Sections 3(e), 15 and 23C. 2.2

_ , "The National Green Tribunal Act, 2010," 2010. Act No. 19 of 2010; Sections 14–18 and Schedule II. 2.3, 2.4, A.2

Greenstone, Michael and B. Kelsey Jack, "Envirodevonomics: A Research Agenda for an Emerging Field," *Journal of Economic Literature*, 2015, *53* (1), 5–42. 1

Huete, A, K Didan, T Miura, E P Rodriguez, X Gao, and L G Ferreira, "Overview of the radiometric and biophysical performance of the MODIS vegetation indices," *Remote Sensing of Environment*, 2002, *83* (1-2), 195–213. 3.1.4

India Legal, "Patna High Court Dismisses Petition Seeking to Take up Cudgels against the Mining Leases Granted by the State," September 2023. 16 September. A.2

Jayachandran, Seema, "How Economic Development Influences the Environment," 2022. 1

Jha, Monica and Shamsheer Yousaf, "The Crimes of Flood Plains," *Fountain Ink*, August 2023. 2.4

Khan, Mohd Imran, "'Digging your own grave': Illegal sand mining devastates Bihar's rivers," August 2022. 2.1

Kondolf, G. Mathias, "Hungry Water: Effects of Dams and Gravel Mining on River Channels," *Environmental Management*, 1997, *21* (4), 533–551. 2.3

Ministry of Environment, Forest and Climate Change, "Sustainable Sand Mining Management Guidelines, 2016," Technical Report, Government of India 2016. 2.2, 2.4

_ , "Enforcement & Monitoring Guidelines for Sand Mining," Technical Report, Government of India January 2020. 2.2, 2.4

National Green Tribunal, "Krishna Kumar Ram and Others v. State of Bihar, Original Application No. 587 of 2022: Joint Committee Report and Replies of the Respondents," 2023. Principal Bench, New Delhi. A.2

Olson, Mancur, *The Logic of Collective Action: Public Goods and the Theory of Groups*, Cambridge, MA: Harvard University Press, 1965. 1, 1

Ostrom, Elinor, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge: Cambridge University Press, 1990. 1

Patel, Dev, "Floods," 2024. 3.1.2

Pekel, Jean-Francois, Andrew Cottam, Noel Gorelick, and Alan S Belward, "High-resolution mapping of global surface water and its long-term changes," *Nature*, 2016, *540*, 418–422. 3.1.2

Rentier, ES and LH Cammeraat, "The environmental impacts of river sand mining," *Science of The Total Environment*, 2022, *838*, 155877. 2.3

Román, Miguel O, Zhuosen Wang, Qingsong Sun, Virginia Kalb, Steven D Miller, Andrew Molthan, Lori Schultz, Jordan Bell, Eleanor C Stokes, Bhartendu Pandey et al., "NASA's Black Marble nighttime lights product suite," *Remote Sensing of Environment*, 2018, *210*, 113–143. 1, 3.1.3

Sun, Liyang and Sarah Abraham, "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects," *Journal of Econometrics*, December 2021, *225* (2), 175–199. 2, 5, 3, 6, 4, 7, B-5, B-8

United Nations Environment Programme, "Sand and Sustainability: An Essential Resource for Nature and Development," Technical Report, United Nations Environment Programme 2026. 1

von der Goltz, Jan and Prabhat Barnwal, "Mines: The Local Wealth and Health Effects of Mineral Mining in Developing Countries," *Journal of Development Economics*, 2019, *139*, 1–16. 1

Wang, Zhuo-fu, Ji-yong Ding, and Gao-sheng Yang, "Risk Analysis of Slope Instability of Levees under River Sand Mining Conditions," *Water Science and Engineering*, 2012, *5* (3), 340–349. 2.3

Part I

Online Appendix

Table of Contents

A Data Appendix **62**

A.1 Data construction 62

A.2 Legal routes to compensation and complaint 65

B Additional Results and Robustness **67**

B.1 Balance 67

B.2 Flooding 69

B.3 Nightlights 70

B.4 Vegetation 73

B.5 Household assets 74

B.6 Survey of mining villages 77

B.7 Household accounts and political aggregation 92

A Data Appendix

अरवल जिलान्तर्गत पर्यावरणीय स्वीकृति प्राप्त बालूघाटों की विवरणी

क्र0सं0	बालूघाट का नाम	पूरा पता	नदी का नाम	रकवा (हे0 में)	GPS Coordomates(Latgitide &Longitude) (Latgitide &Longitude)			EC का पत्रांक एवं दिनांक	EC की वैधता की तिथि
1	मुरादपुर हुजरा	मुरादपुर हुजरा थाना–अरवल	सोन नदी	5	A	25° 14' 28.2397" N	84° 37' 55.5743" E	116 dt 16.03.2018	15.03.2024
					B	25° 14' 29.8595" N	84° 38' 1.3338" E		
					C	25° 14' 21.5127" N	84° 38' 3.6433" E		
					D	25° 14' 18.9588" N	84° 37' 57.1714" E		
				5	A	25° 14' 29.9815" N	84° 38' 2.8154" E		
					B	25° 14' 31.5059" N	84° 38' 7.4365" E		
					C	25° 14' 25.6215" N	84° 38' 13.9054" E		
					D	25° 14' 21.7375" N	84° 38' 5.7228" E		
				5	A	25° 14' 20.9216" N	84° 38' 7.9650" E		
					B	25° 14' 24.7778" N	84° 38' 14.7047" E		
					C	25° 14' 19.8157" N	84° 38' 19.7828" E		
					D	25° 14' 15.0806" N	84° 38' 13.5446" E		

Figure A-1: Example of mine details in a District Survey Report

Notes: The excerpt is from the District Survey Report (DSR) of Arwal district. The third column gives the river name; the fifth gives the mine coordinates as latitude and longitude; the sixth gives the date of Environmental Clearance (EC), used as the treatment date; and the seventh gives the EC expiry date.

A.1 Data construction

This section describes how we construct mining shapefiles from District Survey Reports (DSRs).

Step 1, DSR to raw shapefiles The coordinates of each mine are available in District Survey Reports (DSRs), which are available in PDF or scanned formats. The DSRs are prepared by each district in accordance with the Sustainable Sand Mining Management Guidelines 2016 and contain an exhaustive list of existing and potential mines in the district. In addition to the coordinates of the vertices of each mine, these reports also contain the date on which each mine was granted Environmental Clearance for operation, which we take as the official start date of the mine. Furthermore, these reports identify whether each mine is an active or potential mine at the time of DSR preparation. We extract the tables containing mine-related information using Optical Character Recognition (OCR) software. Because OCR is not 100% accurate, we manually verify the accuracy of the information for each mine. The final result is a list of 1,745 active and potential mines across 18 districts. Finally, using the extracted vertices, we construct mine shapefiles using the 'sf' package in R.



Figure A-2: Defining flooding area around a mine

Notes: This figure shows examples of mine polygons and the Area of Interest (AOI) for measuring floods. The orange rectangles represent mine polygons, each with two concentric circles centered at the mine centroid. The measurement area excludes the smaller circle. Contiguously overlapping larger circles are merged into a single observation area.

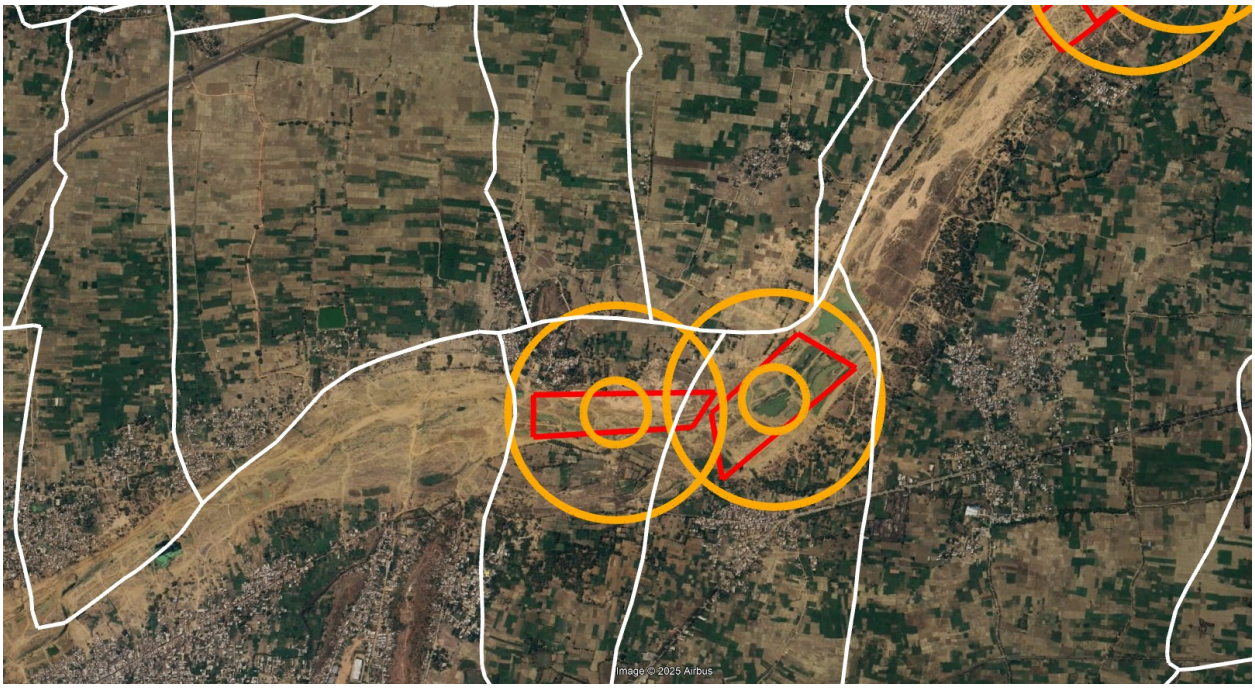


Figure A-3: Mine exposure areas and village boundaries

Notes: White lines mark village (shrid) boundaries. Mine polygons and exposure areas are defined as in Figure A-2.



(a) Sand being transported on boats



(b) Trucks lining up to transport sand at mine

Figure A-4: Sand transportation

Note: Panel a image was captured in March 2023. Panel b image is taken from Google Maps.

Step 2, exclusion of overlapping potential mines We take the output from Step 1 and identify cases where active (existing) and potential (proposed) mines overlap. This occurs because areas with active mining may be identified as potential mines for future leasing once the lease of the currently active mine expires. We exclude potential mines if they overlap significantly with active mines because such potential mines are still affected by mining activity and cannot be used as controls in our empirical strategy. We calculate the fraction of each active and potential mine that overlaps with a mine of the other type and exclude a potential mine if either **a)** it overlaps with more than 20 percent of an existing mine or **b)** an existing mine overlaps with more than 20 percent of the potential mine. The resultant file contains 1,529 mine polygons across 18 districts.

Step 3, manual verification of mining activity Output from **step 2** takes the information provided in the DSRs as given, i.e., mining starts only after the official clearance date, and there is no mining in potential mines. However, publishing DSRs became a requirement only after 2016, while sand mining had been taking place in rivers in Bihar well before then, albeit at a much lower intensity than in the post-2015 period. Therefore, active mining may have taken place in both active and potential mines before the DSRs were published. Furthermore, many parts of Bihar also experience illegal sand mining, so some potential mines may have active mining without official approval. In such cases, these mines cannot be used as controls in our empirical strategy. To construct the history of mining activity, we take Google Earth screenshots of all mines going back to 2010, resulting in over 30,000 screenshots. For each screenshot, we manually identify whether mining is taking place and visually estimate the approximate fraction of the mine polygon being mined. We then exclude potential mines if they experience high-intensity mining during our sample period, i.e., if more than 20% of the polygon is being actively mined. This results in 1,339 polygons across 18 districts. The data at the end of this step is the primary input for our analysis.

Step 4, creating buffers For mine-level analyses, we create buffers centred at the centroid of each mine. We create buffers with various radii (500m, 1000m, and 1500m) but exclude a smaller circle with a radius of 150m from the centre, thereby creating a doughnut. The logic behind this exclusion is to ensure that the flooding and EVI results are not driven by the mechanical impacts of higher-intensity extraction at the centre of the mine. Once we create the buffers, buffers of adjacent mines may overlap. If the overlapping buffers have the same active status (i.e., either all overlapping buffers are associated with active mines or all are associated with potential mines), we fuse the buffers together to create a single shapefile and avoid double-counting the overlapping region. If the overlapping buffers are associated with different types of mines, we exclude the buffers associated with potential mines and fuse the remaining buffers together. For 500m buffers, this results in 650 shapes for the version that excludes potential mines with active mining.

A.2 Legal routes to compensation and complaint

Bihar's mining rules give nearby residents several routes to compensation, and environmental law offers a further route through the National Green Tribunal. Table A-1 summarizes the main provisions of the Bihar Minerals (Concession, Prevention of Illegal Mining, Transportation and Storage) Rules, 2019 and the lease prescribed under them (Government of Bihar, 2019). The obligation to compensate is not limited to land occupied by the mine and the lease also covers damage to cultivable land and community property. Owner consent is not an absolute veto, however, since the State can order entry once fair compensation has been deposited.

Residents can also seek relief from the National Green Tribunal (Government of India, 2010). For disputes arising under the environmental laws listed in the Act, the Tribunal can order relief and compensation for victims of pollution and other environmental damage, restitution of damaged property, and restoration of the environment (Sections 14 and 15). Compensation can be

Table A-1: Provisions for compensation and redress under the Bihar mining rules

Situation	Provision	What it provides
Mine occupies land	Rule 83; lease, Part VII, clause 11D	The leaseholder pays the occupier of the land annual compensation set by the Collector. For agricultural land, it is based on the average annual net income from cultivating similar land over the previous three years; for other land, on its average annual letting value.
Sand extracted from private land	Rules 29A(2)(viii) and 29H	Quarrying on private land requires the consent of the owner or raiyat. Removing subsoil sand from raiyati land also requires adequately compensating the owner and must be included in the mining plan and environmental clearance.
Damage to people, property or cultivable land	Lease, Part VII, clauses 15 and 31	The leaseholder must pay reasonable compensation for all damage, injury or disturbance to persons or property. Clause 31 names individual, public and community property, cultivable land, and structures such as roads and places of worship; damage can also lead to cancellation of the lease and forfeiture of deposits.
Occupier refuses entry	Lease, Part VIII, clause 2	The leaseholder deposits the compensation offered with the State. If the State finds it fair, or after a further deposit, it can order the occupier to allow entry, assessing compensation by the principles of land acquisition law.
Operating restrictions violated	Rules 29A(2) and 47	Quarrying is barred within 300 m of railway and highway bridges and 100 m of other bridges, 50 m of public places, 5 m of riverbanks and 100 m of dams and weirs; near embankments, setbacks of 25–75 m come with depth limits of 1–2 m. The Collector can suspend or cancel a concession and forfeit its deposits after a hearing.

Notes: Provisions of the Bihar Minerals (Concession, Prevention of Illegal Mining, Transportation and Storage) Rules, 2019, as notified in September 2019, and of the mining lease prescribed in their Form B.

awarded under the heads listed in Schedule II, which include damage to private property, harm to crops and other flora, and loss of business or employment (Sections 15(4) and 17). An application can be made by an injured person, a property owner or any person aggrieved, including a representative body or organization (Section 18), so this route is not limited to landowners. Claims for compensation must be filed within five years of the cause first arising, and the claimant must show that the damage resulted from the activity.

Three cases illustrate how residents and organizations have used these routes.

Residents of Semra Labedaha, West Champaran. Residents of Semra Labedaha panchayat in Piprasi block applied to the National Green Tribunal, alleging illegal sand mining on the Gandak inside the eco-sensitive zone of the Valmiki Tiger Reserve. The Tribunal formed a joint committee in September 2022 and sought replies from the state's mining, pollution-control and forest authorities. Inspections in November 2022 and February 2023 found no ongoing extraction, although the complainants said mining had taken place months earlier. The District Magistrate then asked

the state environmental clearance authority to cancel the clearances of 16 sand ghats in the eco-sensitive zone, including Semra Labedaha (National Green Tribunal, 2023).

The Sone in Aurangabad and Rohtas. An application alleged illegal extraction from the Sone in Aurangabad and Rohtas, two of our survey districts. In February 2020 the Tribunal found the state pollution control board's report inconsistent with observations of the Patna High Court and ordered an inspection by the Central Pollution Control Board. Its July 2020 report found illegal mining near the Kesao ghat, tracks of heavy earth-moving machinery, and extraction near the pillars of the Sone bridge between the two districts, in violation of the 2019 Rules (Central Pollution Control Board, 2020).

Leases along the Kamla, Madhubani. A public interest petition asked the Patna High Court to investigate the officials who granted sand-mining leases on farmland along the Kamla river in Madhubani district, and alleged illegal extraction and transport. In September 2023 a Division Bench dismissed the petition with costs of Rs. 5,000, holding that it made broad allegations without specific complaints and did not join the officials or mining companies it accused (India Legal, 2023).

These appeals mainly seek enforcement against illegal mining. They can prompt inspections and administrative action, but in none of these cases do the available records show compensation paid to affected households.

B Additional Results and Robustness

B.1 Balance

Table B-1: Correlations between treatment status or timing and assembly election outcomes

(a) Mine-level correlations

	Treated (permit)			Permit year		
	(1)	(2)	(3)	(4)	(5)	(6)
RJD	-0.0481	0.00753	0.0531	0.0449	0.0875	0.210
	(0.104)	(0.0494)	(0.0448)	(0.469)	(0.240)	(0.305)
JD(U)	-0.185	-0.110	-0.00654	0.000497	0.203	1.011*
	(0.115)	(0.0696)	(0.0706)	(0.465)	(0.362)	(0.549)
BJP	-0.0593	0.0619	0.0577	0.623	0.262	0.503
	(0.0974)	(0.0529)	(0.0712)	(0.446)	(0.295)	(0.501)
Constant	0.664**	0.602**	0.560**	2018.7**	2018.7**	2018.4**
	(0.0870)	(0.0406)	(0.0415)	(0.394)	(0.225)	(0.320)
Observations	1,421	1,421	1,383	727	727	715
District FE		Yes			Yes	
District × river FE			Yes			Yes

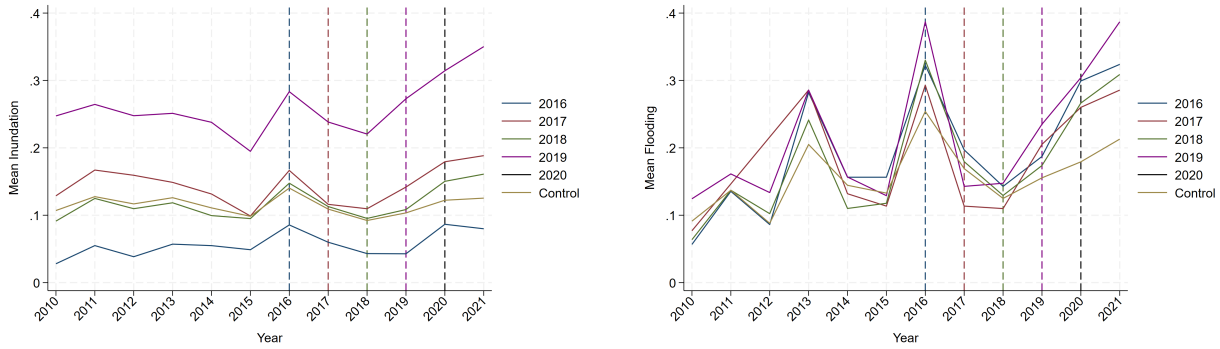
Notes: In Columns (1)–(3), the dependent variable is a binary indicator for whether the mine is existing, i.e. has a permit, rather than proposed. In Columns (4)–(6), the sample is restricted to existing mines, and the dependent variable is the year in which the mine's permit was granted. Standard errors in parentheses, clustered by AC. * $p < 0.10$, ** $p < 0.05$.

(b) AC-level correlations

	(1) Total mines	(2) % Existing	(3) Permit year	(4) Permits 2016–17	(5) Permits 2018–20
RJD	3.949	0.0396	-0.381		
	(5.599)	(0.105)	(0.709)		
JD(U)	-0.0162	-0.0114	-0.928		
	(6.070)	(0.114)	(0.742)		
BJP	-3.322	-0.0283	0.263		
	(6.297)	(0.118)	(0.762)		
Ruling coalition 2016–17				3.386	
				(4.358)	
Ruling coalition 2018–20					-4.282
					(3.809)
Constant	17.38**	0.577**	2019.1**	15.70**	20.14**
	(4.677)	(0.0878)	(0.606)	(3.758)	(2.552)
Observations	78	78	52	78	78

Notes: In Column (1), the dependent variable is the total number of existing and proposed mines. In Column (2), the dependent variable is the share of existing mines in the total. In Column (3), the sample is restricted to ACs with any existing mine, and permit year is the average of the years in which the existing mines received their permits. Column (4) shows the correlation between electing an MLA in the 2016–2017 ruling coalition (RJD, JD(U), INC) and the number of sand mine permits received during those two years. Column (5) shows the correlation between electing an MLA in the 2018–2020 ruling coalition (JD(U), BJP, LJP) and the number of sand mine permits received during those three years. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$.

B.2 Flooding



(a) Inundation

(b) Flood

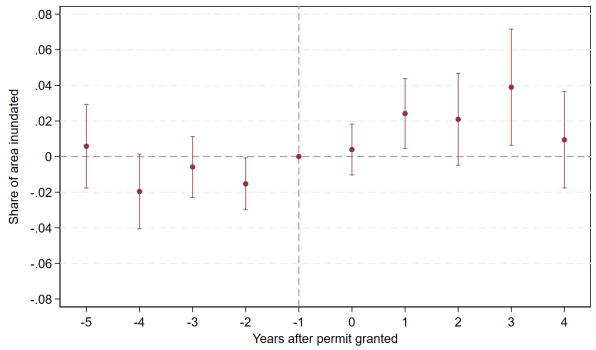
Figure B-1: Mean inundation over time

Notes: This figure plots mean of Inundation (Panel a) and Probability of Flooding (Panel b) for each year grouped by the year of treatment.

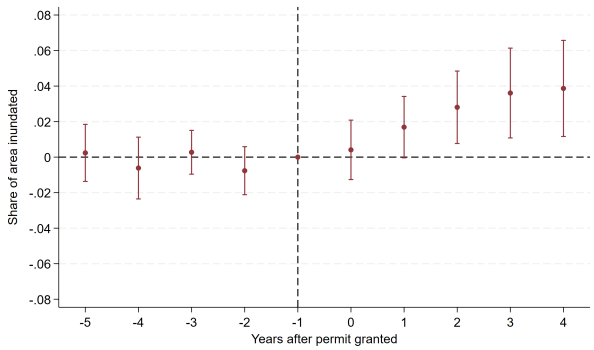
Table B-2: Effect of sand mining on flooding, using all mines listed in the District Survey Reports

	Share of area inundated				Probability of flooding			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated mines	0.025**	0.019**	0.014**	0.011**	0.038***	0.028***	0.026**	0.013
	(0.010)	(0.008)	(0.007)	(0.005)	(0.012)	(0.011)	(0.010)	(0.009)
Observations	13,025	13,663	5,435	5,637	13,025	13,663	5,435	5,637
Mean Dep variable	0.099	0.099	0.099	0.099	0.114	0.114	0.114	0.114
Method	Stacked	Stacked	Sun-Abraham	Sun-Abraham	Stacked	Stacked	Sun-Abraham	Sun-Abraham
Fixed Effect	Dist*River	District	Dist*River	District	Dist*River	District	Dist*River	District

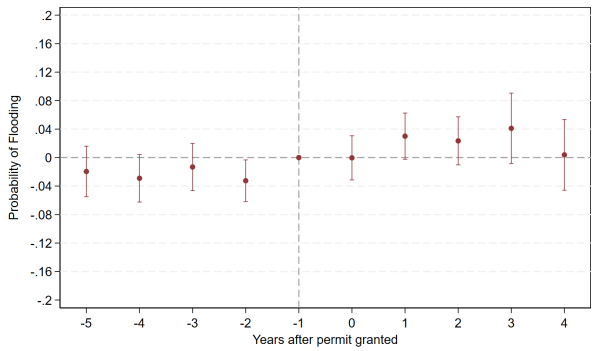
Notes: The sample uses every mine listed in the District Survey Reports, including proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. Estimators, fixed effects, controls, event window and clustering are the same as in Table 2. * p < 0.10, ** p <0.05, *** p<0.01.



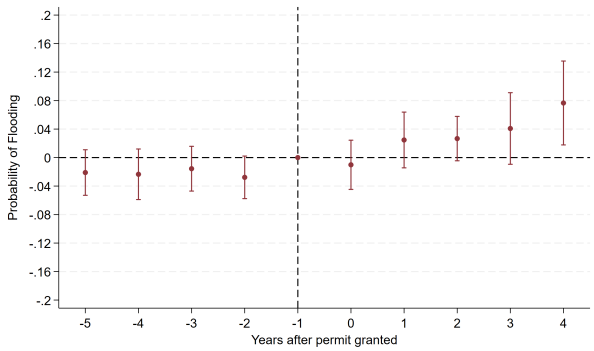
(a) Share of area inundated: stacked difference-in-differences



(b) Share of area inundated: interaction-weighted estimator



(c) Probability of flooding: stacked difference-in-differences



(d) Probability of flooding: interaction-weighted estimator

Figure B-2: Dynamic effects of sand mining on flooding, using all mines listed in the District Survey Reports

Notes: The sample uses every mine listed in the District Survey Reports, including proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. Estimation, fixed effects, controls, event window and clustering are the same as in Figure 5.

B.3 Nightlights

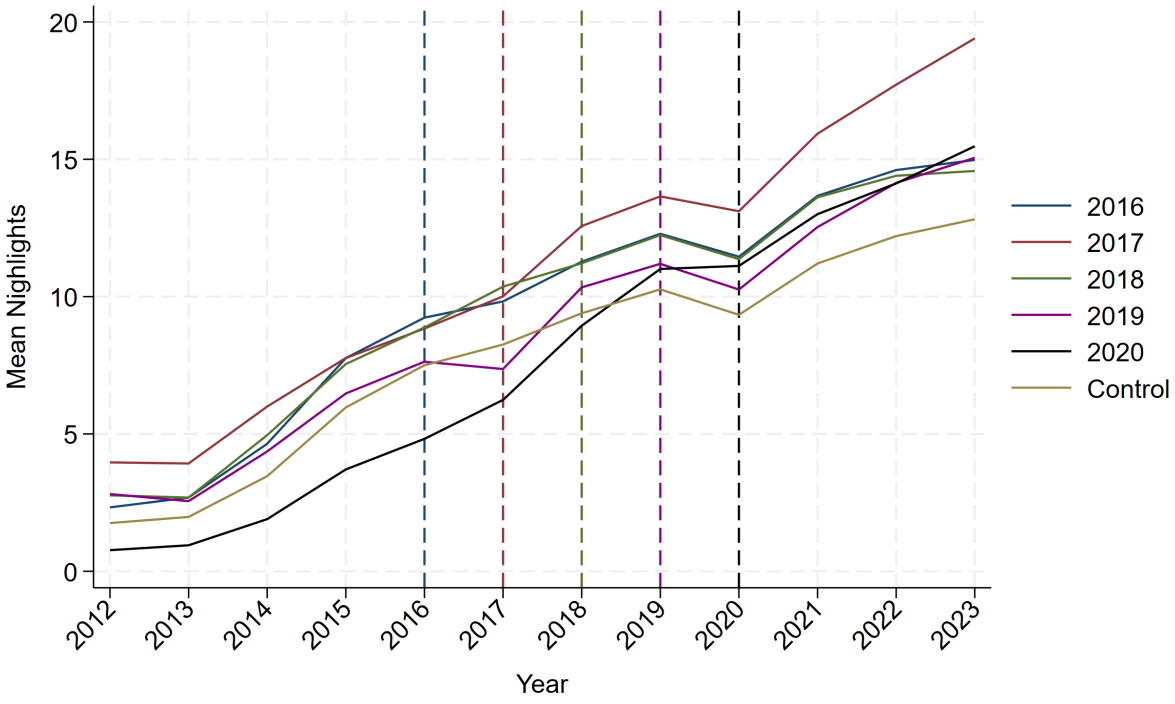


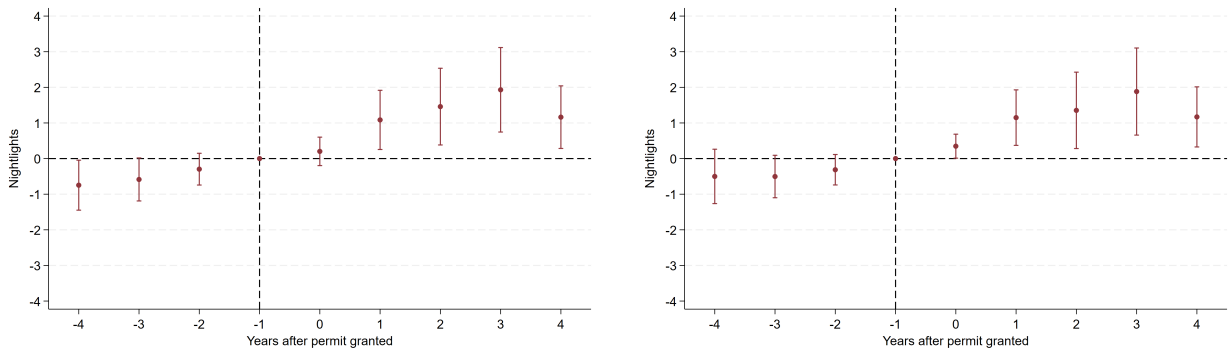
Figure B-3: Mean nightlights over time

Notes: This figure plots mean nightlights for each year, grouped by the year of treatment.

Table B-3: Effects of sand mining on village-level mean nightlights, using all mines listed in the District Survey Reports

	Nightlights			
	(1)	(2)	(3)	(4)
Treated mines	1.573***	1.255***	1.567***	1.470***
	(0.540)	(0.485)	(0.458)	(0.418)
Observations	22,900	24,855	10,229	10,847
Mean Dep variable	9.26	9.26	9.26	9.26
Method	Stacked	Stacked	Sun-Abraham	Sun-Abraham
Fixed Effect	Dist*River	District	Dist*River	District

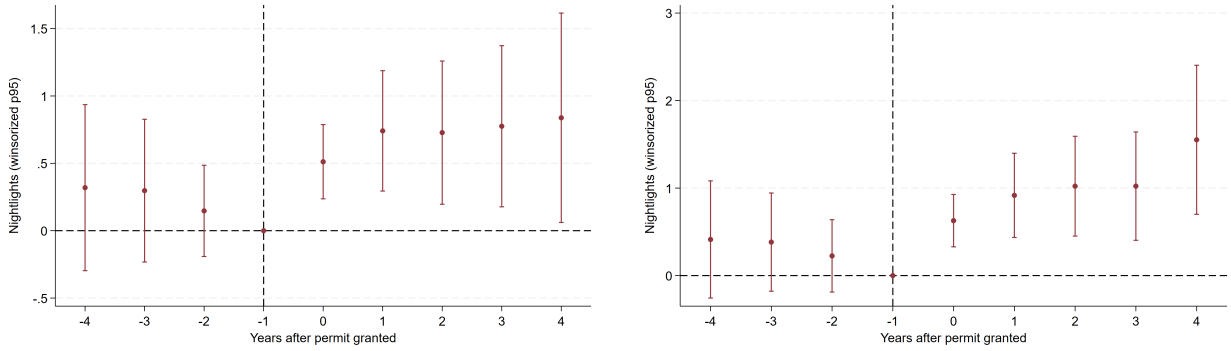
Notes: The sample uses every mine listed in the District Survey Reports, including villages near proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. Estimators, fixed effects, controls, event window and clustering are the same as in Table 3. * p < 0.10, ** p <0.05, *** p<0.01.



(a) Stacked difference-in-differences (b) Interaction-weighted estimator

Figure B-4: Village-level dynamic effects of sand mining on nightlights, using all mines listed in the District Survey Reports

Notes: The sample uses every mine listed in the District Survey Reports, including villages near proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. Estimation, fixed effects, controls, event window and clustering are the same as in Figure 6.



(a) Stacked difference-in-differences (b) Interaction-weighted estimator

Figure B-5: Village-level dynamic effects of sand mining on nightlights, compared with matched villages along the river

Notes: This figure compares villages within 1 km of a permitted mine with control villages from the sampling frame of our household survey. Each treated village is paired with one control village in the same district and on the same river, within 7 km of the treated village. Control villages lie within 5 km of the river and at least 3 km from any permitted mine; pairs whose control village is within 1 km of a permitted mine are dropped. Villages with more than 15,000 residents are excluded. Nightlights are averaged over the village area after removing permitted mines and a 25 m buffer around them, and capped at the 95th percentile of values in the years before mining began. Panel (a) uses stacked difference-in-differences and panel (b) the interaction-weighted estimator of Sun and Abraham (2021), both with the paired control villages as the comparison group. All estimates include village and year-by-pair fixed effects and control for distance to the river, population, and access to electricity, paved roads and mobile phone coverage in 2011, each interacted with year. Treatment status and permit dates use the same mine list as the main results. We show 4 years before and 4 years after a mine started operations. Each dot is an estimated coefficient and vertical lines show 95% confidence intervals; the year before operations began is the omitted period. Standard errors are clustered at the village level.

B.4 Vegetation

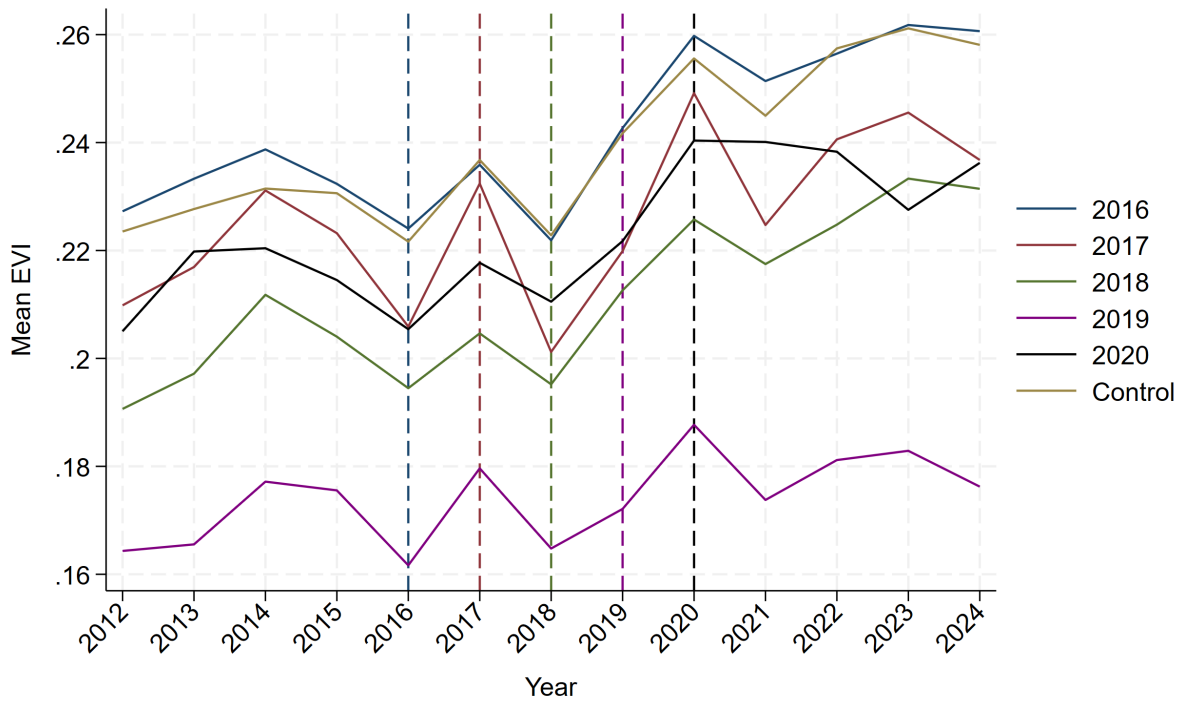


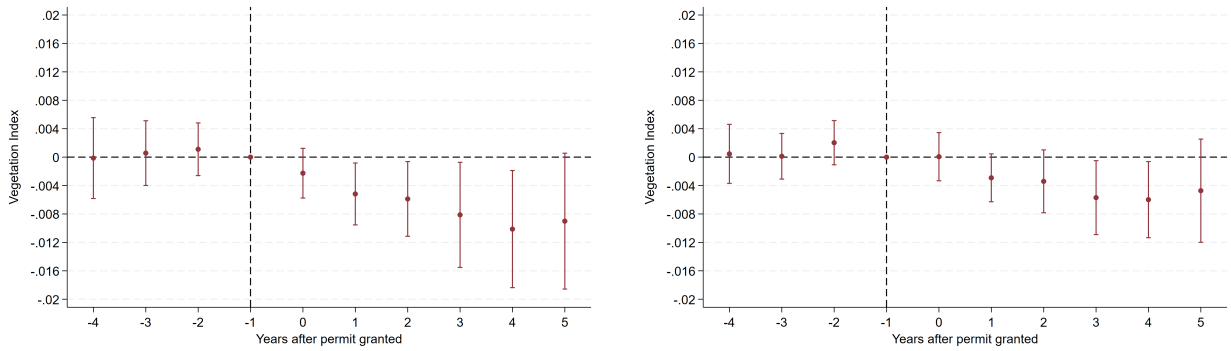
Figure B-6: Mean Enhanced Vegetation Index over time

Notes: This figure plots mean Enhanced Vegetation Index (EVI) for each year, grouped by the year of treatment.

Table B-4: Effects of sand mining on mine-level vegetation, using all mines listed in the District Survey Reports

	Vegetation index			
	(1)	(2)	(3)	(4)
Treated mines	-0.007**	-0.008***	-0.004**	-0.005***
	(0.003)	(0.002)	(0.002)	(0.002)
Observations	19,259	20,580	7,559	7,954
Mean Dep variable	0.245	0.245	0.245	0.245
Method	Stacked	Stacked	Sun-Abraham	Sun-Abraham
Fixed Effect	Dist*River	District	Dist*River	District

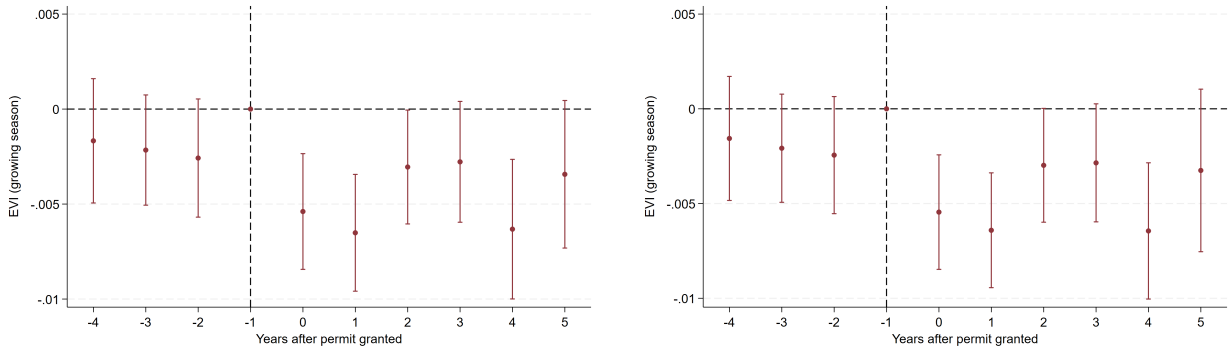
Notes: The sample uses every mine listed in the District Survey Reports, including proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. Estimators, fixed effects, controls, event window and clustering are the same as in Table 4. * p < 0.10, ** p <0.05, *** p<0.01.



(a) Stacked difference-in-differences (b) Interaction-weighted estimator

Figure B-7: Dynamic effects of sand mining on vegetation, using all mines listed in the District Survey Reports

Notes: The sample uses every mine listed in the District Survey Reports, including proposed mines where high-intensity mining covers more than 20% of the mine area prior to the proposed start date. Estimation, fixed effects, controls, event window and clustering are the same as in Figure 7.



(a) Stacked difference-in-differences (b) Interaction-weighted estimator

Figure B-8: Dynamic effects of sand mining on vegetation, compared with matched villages along the river

Notes: This figure compares villages within 1 km of a permitted mine with control villages from the sampling frame of our household survey. Each treated village is paired with one control village in the same district and on the same river, within 7 km of the treated village. Control villages lie within 5 km of the river and at least 3 km from any permitted mine; pairs whose control village is within 1 km of a permitted mine are dropped. The outcome is the vegetation index (EVI) averaged over growing-season observations (January–March and July–October) and over the village area after removing permitted mines and a 25 m buffer around them. Panel (a) uses stacked difference-in-differences and panel (b) the interaction-weighted estimator of Sun and Abraham (2021), both with the paired control villages as the comparison group. All estimates include village and year-by-pair fixed effects and control for the share of agricultural land that is irrigated and irrigated by wells, the share of land sown, access to electricity and population, each interacted with year. Treatment status and permit dates use the same mine list as the main results. We show 4 years before and 5 years after a mine started operations. Each dot is an estimated coefficient and vertical lines show 95% confidence intervals; the year before operations began is the omitted period. Standard errors are clustered at the village level.

B.5 Household assets

Table B-5: Effect of sand mining on household assets: wealth standardised over both rounds

	All (1)	Upper-caste + OBC (2)	SC/ST (3)	All (4)
Post × Treated	0.142*	0.254***	-0.005	-0.035
	(0.078)	(0.098)	(0.114)	(0.115)
Post × Treated × (Upper-caste + OBC)				0.246*
				(0.135)
Observations	9,726	7,059	2,629	9,688
Control mean (pre)	-.075	.065	-.482	-.074
District FE	Yes	Yes	Yes	Yes
River FE	Yes	Yes	Yes	Yes
Caste FE	Yes	No	No	Yes

Notes: The dependent variable is the wealth index score standardised over the pooled sample of NFHS-4 and NFHS-5 households within 5 km of a mine. Columns, sample restrictions, covariates, fixed effects and clustering are defined as in Table 5. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

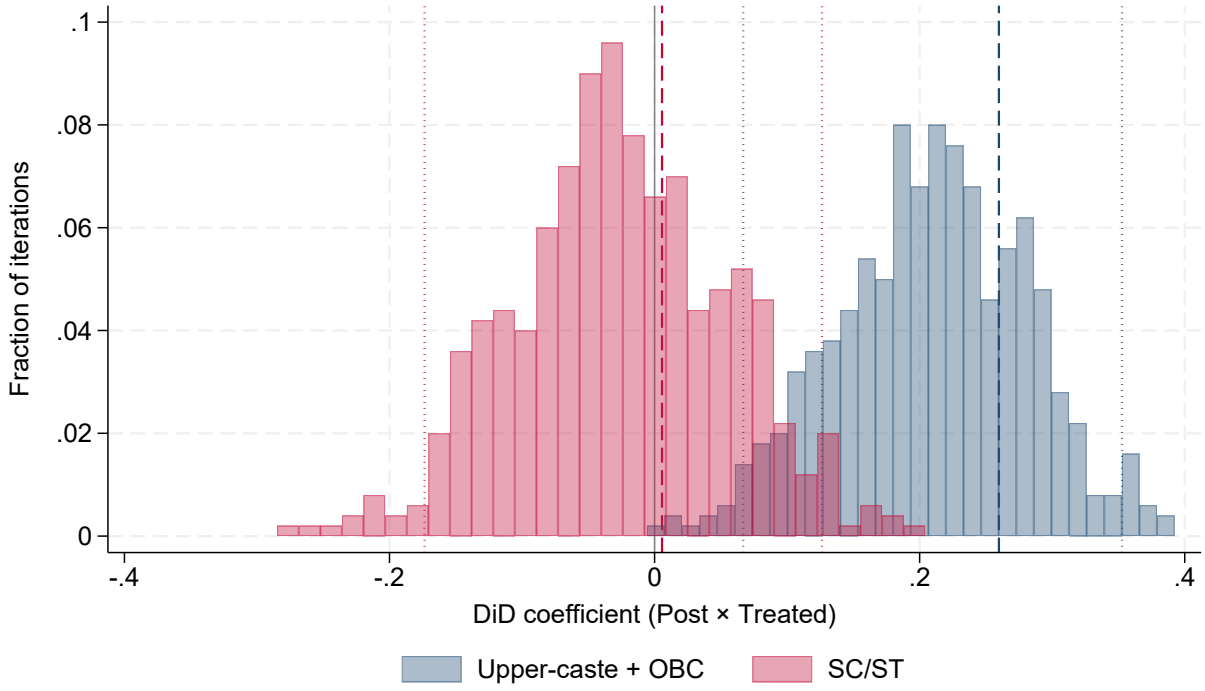


Figure B-9: Effect of sand mining on household assets: random displacement of cluster locations

Notes: The figure shows the distribution of the Post × Treated coefficient for Upper-caste + OBC and SC/ST households (columns (2) and (3) of Table 5) across 500 re-estimations. In each re-estimation, the coordinates of every rural NFHS cluster in both rounds are moved in a random direction by a random distance of up to 2 km, or up to 5 km for a randomly chosen 1% of clusters, and treatment status, distance to the mine, district and river are recomputed from the new locations. Dashed lines mark the estimates at the reported coordinates; dotted lines mark the 2.5th and 97.5th percentiles of each distribution.

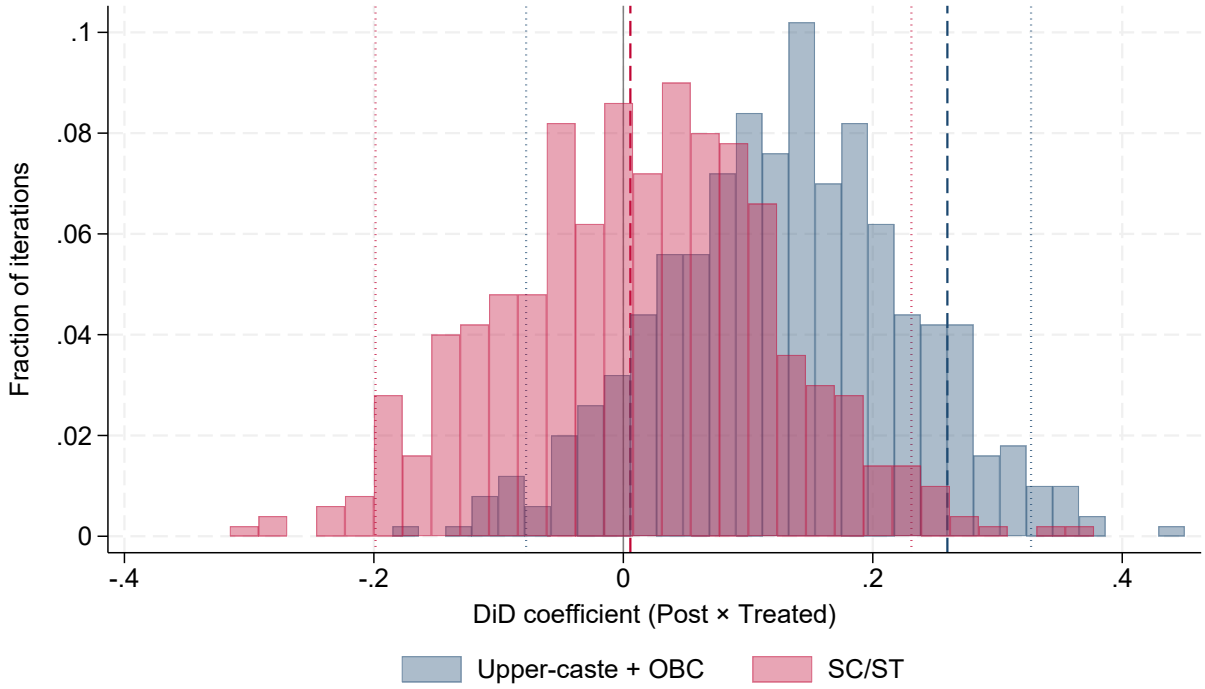


Figure B-10: Effect of sand mining on household assets: random displacement of cluster locations, DHS rural displacement distances

Notes: The figure shows the distribution of the Post × Treated coefficient for Upper-caste + OBC and SC/ST households (columns (2) and (3) of Table 5) across 500 re-estimations. In each re-estimation, the coordinates of every rural NFHS cluster in both rounds are moved in a random direction by a random distance of up to 5 km, or up to 10 km for a randomly chosen 1% of clusters, and treatment status, distance to the mine, district and river are recomputed from the new locations. Dashed lines mark the estimates at the reported coordinates; dotted lines mark the 2.5th and 97.5th percentiles of each distribution.

B.6 Survey of mining villages

This subsection reports additional results for Section 5. Unless stated otherwise, variables, samples and regressions are as described there. Tables B-6–B-8 and Figure B-11 add to Section 5.1 on income from sand; Tables B-10–B-14 to Section 5.2 on costs; Figure B-12 to Section 5.4 on beliefs; Tables B-15–B-17 compare the Sone with other rivers (Sections 5.1, 5.2 and 5.4); Tables B-18–B-20 to Section 5.5 on support for mining; and Table B-21 to Section 5.6 on opposition.

Table B-9 separates Upper-caste, BC, EBC and SC/ST households and gives the crosswalk to the main survey groups and Section 4's broad caste comparison. It reports the same earnings and reported-loss definitions as Section 5, before the combined annual household account used in Section 6.

Measuring land rent. Households receiving land rent were asked the total land rent they received in a year and, depending on how it is paid, the rate per truck, per day, per month or per year. Land rent per year is the largest yearly amount the household reports: the yearly total, the yearly rate, or twelve times the monthly rate. Rates per truck, day or week come without a number of units per year, so for these households the yearly total stands. Of the 138 households receiving land rent in mining villages, this rule raises the amount for 14. 7 recipients report Rs. 1,000 a year or less in every answer; we keep their reported values.

Farming and other costs. Table B-10 reports leasing land in and giving land out by period. Table B-11 compares farming and farm income in 2025 between mining and control villages, and Table B-13 compares the farming outcomes by caste and farmland within mining villages. Table B-12 compares losses by caste and farmland within mining villages, and Table B-14 reports road accidents and drownings at the village level.

Table B-6: Terms of land rent: mining villages

	All (1)	Upper-caste (2)	OBC (3)	SC/ST (4)
A. Households receiving land rent in mining villages				
Paid by: mine owner	31.4	18.5	40.6	36.8
Paid by: contractor	51.8	57.4	48.4	47.4
Paid by: munshi or manager	12.4	16.7	9.4	10.5
Paid by: vehicle owner	0.0	0.0	0.0	0.0
Paid by: local person or middleman	4.4	7.4	1.6	5.3
Basis: per truck or tractor	11.6	5.6	18.5	5.3
Basis: per day, week or month	10.9	9.3	15.4	0.0
Basis: per year	47.1	42.6	44.6	68.4
Basis: lump sum	21.7	27.8	18.5	15.8
Basis: by land area	22.5	24.1	21.5	21.1
Basis: mutual discussion	0.0	0.0	0.0	0.0
Rate set by: landowner and contractor together	84.8	87.0	78.5	100.0
Rate set by: villagers together	15.9	7.4	15.4	42.1
Rate set by: mukhiya or local representative	2.2	1.9	3.1	0.0
Rate set by: mine owner	8.7	5.6	10.8	10.5
Written agreement	73.2	74.1	69.2	84.2
Land rent per year, mean (rupees)	33,490	40,020	33,168	16,032
Households receiving land rent	138			
of which Upper-caste, OBC, SC/ST		54	65	19
B. Village-head respondents in mining villages				
Rate set by: landowner and contractor	56.8			
Rate set by: villagers collectively	1.2			
Rate set by: headman or sarpanch	0.0			
Written agreement (vs oral)	82.9			
Paid by: mine owner	15.1			
Paid by: contractor	40.5			
Paid directly to the landowner	46.8			
Paid through an intermediary	6.8			
All landowners get the same rate	72.2			
Recipients mostly Upper-caste	34.6			
Recipients mostly OBC	41.9			
Recipients mostly SC	14.8			
Recipients mostly the village's dominant caste	47.1			
Dispute over land rent, last 5 years	7.6			
Village-head respondents	602			

Notes: Mining villages only. Panel A reports percentages among land-rent recipients answering each question, overall and by caste, except for the mean yearly rent and household counts. Recipients could name several payment bases and rate-setters. A munshi is a mine manager or accountant. Yearly rent is measured as described above. Panel B reports percentages among village-head respondents answering each question, rather than percentages of villages; several respondents may represent one village. Missing responses are excluded separately for each row.

Table B-7: Sand work, 2011–2025: stacked difference-in-differences

	Control villages (1)	Mining minus control (2)
Household member in sand work (%)	0.6	3.3***
		(0.5)

Notes: Household-by-year panel for 2011, 2015, 2020 and 2025 (Figure B-11). Mining starts in the permit year. Column (1) gives the control mean over all four years. Column (2) gives the stacked difference-in-differences estimate in ppt, with one stack per permit year, that year's mining villages and all controls, and stack-by-household and stack-by-matched-group-by-year fixed effects. Villages mined before 2011 have no observed pre-mining year and do not identify the estimate. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-8: Who receives income from sand: mining villages

	Share of households (%) (1)	Share of all income from sand (%) (2)
Top 1 percent of households	1.0	53.8
Top 5 percent of households	5.0	91.6
Top 10 percent of households	10.0	100.0
Upper-caste	15.7	29.5
OBC	60.9	52.3
SC/ST	23.2	18.2
Owns farmland	63.7	76.0
No farmland	36.3	24.0
Households with any income from sand	9.0	

Notes: Households in mining villages with observed sand income. The first three rows rank households by 2025 sand income and report the share received by the top 1, 5 and 10 percent. Subsequent rows give each caste and farmland group's share of households (column 1) and sand income (column 2). Caste shares use totals that include households without recorded caste. The last row gives the share with positive sand income. Income is defined in Table 6.

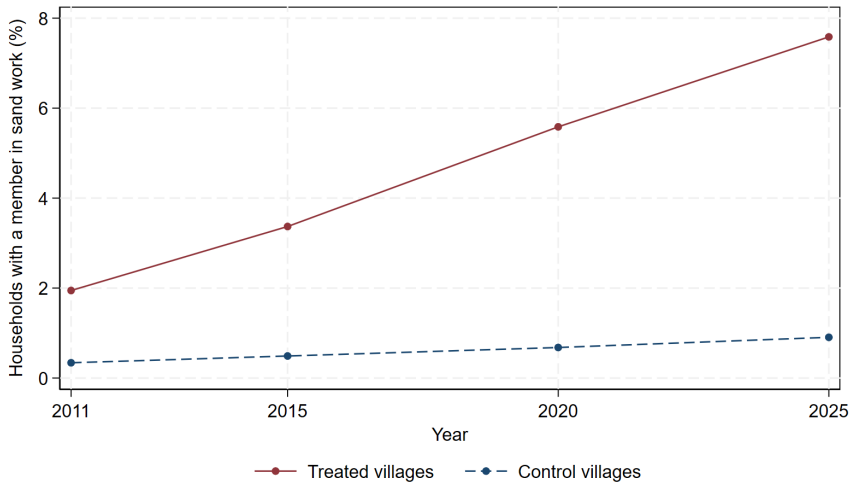


Figure B-11: Households with a member in sand work, 2011–2025

Notes: The figure shows the share of households with a member in sand work in mining and control villages. The 2025 share uses the definition in Table 6; the shares for 2011, 2015 and 2020 come from questions about the roles household members held in sand mining in those years.

Table B-9: Economic positions, mining income and losses across four caste groups

	Upper-caste	BC	EBC	SC/ST
Households	875	1,715	1,663	1,289
Owns farmland (%)	86.3	88.5	44.5	40.3
Member works in sand mining (%)	4.5	5.9	8.8	10.3
Mine labour (%)	1.9	4.1	6.9	8.7
Transport (%)	0.3	0.6	0.4	0.3
Machines or management (%)	0.2	0.3	0.4	0.2
Receives land rent (%)	6.2	2.8	1.1	1.5
Any income from sand (%)	8.4	7.5	9.2	11.2
Income from sand (Rs. a year)	6,777	3,793	2,383	2,836
Income among positive-income recipients (Rs.)	80,673	50,577	25,974	25,403
Land rent among rent recipients (Rs. a year)	40,020	34,051	30,861	16,032
Reported losses: crops, accidents, digging, five years (Rs.)	19,294	14,004	9,444	8,048
Reported flood losses, five years (Rs.)	10,273	10,166	1,810	2,929

Notes: Households in mining villages. Each column reports pooled household means within the indicated caste group. BC comprises Yadav, Koiri/Kushwaha, Kurmi and Sunar households; EBC comprises the other OBC groups in the survey. Combining BC and EBC gives the OBC category used in the main survey tables, alongside Upper-caste and SC/ST. Combining Upper-caste, BC and EBC gives the Upper-caste and OBC side of the broad caste comparison in Section 4; SC/ST is the other category. Roles can overlap. Earnings and annual rent use the definitions in Table 6; missing earnings among recorded workers receive duration-and-role imputation. Conditional earnings and rent means include only households with positive amounts. The non-flood loss total sums losses from crop yields, road accidents and deeper digging for water, with the river-specific groundwater adjustment; losses from road damage and from dust and pollution are not included. Flood losses are reported losses before the attribution adjustment used in Section 6. Loss amounts cover five years; earnings and rent are annual. Missing responses are excluded separately for each row, except where the loss-accounting rules assign zero.

Table B-10: Leasing land in and giving land out, by period

	$\Delta(t_0 - t_{-1})$		$\Delta(t_1 - t_0)$	
	Control villages (1)	Mining minus control (2)	Control villages (3)	Mining minus control (4)
Leases or sharecrops land in (%)	5.0	-0.3	4.7	0.6
		(0.7)		(0.9)
Gives land out (%)	1.4	-0.8	1.1	-0.5
		(0.5)		(0.5)

Notes: Household-by-period panel for 2011–15, 2016–20 and 2021–25, among households farming in 2025. Outcomes indicate leasing or sharecropping land in, or giving land out. Columns (1) and (3) give average changes within control households observed in both periods of the two calendar windows, 2011–15 to 2016–20 and 2016–20 to 2021–25. Columns (2) and (4) give stacked difference-in-differences estimates at mining's start and in the following window, in ppt. Each start-period stack contains its mining villages and all controls, with stack-by-household and stack-by-matched-group-by-period fixed effects. Villages without a surveyed pre-mining period are excluded. Standard errors, clustered by village, are in parentheses. * p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01.

Table B-11: Farming and farm income in 2025: mining and control villages

	Control	Mining minus control villages					
	villages (1)	All (2)	Upper-caste (3)	OBC (4)	SC/ST (5)	Owns farmland (6)	No farmland (7)
Household farmed in 2025 (%)	76.3	-1.7	-2.5	-3.6	6.4**	-0.4	-0.1
		(1.9)	(2.9)	(2.5)	(3.0)	(0.6)	(2.8)
Farm income 2025 (Rs.)	58,286	-6,507*	21,561*	-8,237**	-5,460	-4,866	-10,551
		(3,768)	(12,629)	(3,566)	(3,403)	(3,983)	(8,333)
Log farm income per acre, 2025	10.179	-0.005	-0.025	0.008	-0.027	0.015	-0.060
		(0.028)	(0.070)	(0.035)	(0.059)	(0.027)	(0.081)

Notes: Columns are defined as in Panel A of Table 6. Rows report farming in 2025, farm income among farming households, and log farm income per acre among households with positive farm income and cultivated area. Local units are converted to acres. If one period's unit differs from the others, we retain it or use their common unit, whichever minimizes the ratio of largest to smallest cultivated area across periods. With two observations, the earlier unit is checked. Regressions include matched-group fixed effects. Standard errors, clustered by village, are in parentheses. * p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01.

Table B-12: Who bears the losses: caste and farmland within mining villages

	Caste			Farmland	
	Upper-caste mean (1)	OBC minus Upper-caste (2)	SC/ST minus Upper-caste (3)	Owners mean (4)	Non-owners minus owners (5)
Dust a serious problem (%)	31.6	-4.3**	-4.1**	27.9	-1.2
		(1.7)	(1.9)		(1.5)
Names lower crop yields (%)	45.8	-5.3**	-6.0**	43.9	-9.4***
		(2.4)	(2.9)		(1.6)
Names road accidents (%)	17.5	-0.4	-3.2	13.7	-0.6
		(1.9)	(2.1)		(1.2)
Names deeper digging for water (%)	80.3	-3.6*	-3.7*	76.1	-3.1**
		(1.9)	(2.1)		(1.3)
Names road damage (%)	42.5	-5.5***	-7.3***	38.1	-6.2***
		(1.6)	(2.0)		(1.4)
Names dust and pollution (%)	50.7	-7.4***	-7.1***	43.4	-4.0***
		(2.3)	(2.3)		(1.3)
Names more flooding (%)	3.6	-1.3	-1.2	2.6	0.0
		(0.9)	(0.9)		(0.5)
Loss: lower crop yields (Rs.)	10,912	-4,608***	-6,965***	8,711	-5,976***
		(1,037)	(1,110)		(611)
Loss: road accidents (Rs.)	1,021	-36	-305	901	-335
		(394)	(375)		(220)
Loss: deeper digging for water, mining's share (Rs.)	7,362	-3,300***	-4,563***	5,420	-2,302***
		(685)	(778)		(381)
Loss: total of the three (Rs.)	19,294	-7,944***	-11,832***	15,032	-8,613***
		(1,523)	(1,673)		(908)
Total, % of yearly income	4.0	-0.6	-1.4***	3.8	-1.4***
		(0.4)	(0.4)		(0.2)
Flooded in 2021–25 (%)	10.8	-3.6***	-3.1***	10.6	-0.9
		(1.1)	(1.2)		(0.7)
Flood loss (Rs.)	10,273	-5,609*	-7,144**	8,192	-4,375***
		(3,330)	(3,259)		(1,627)
Repairs after floods (Rs.)	2,750	-2,127**	-2,037**	1,983	-543
		(1,027)	(956)		(562)
Flood loss per flood year (Rs.)	64,136	-16,124	-23,826	63,249	-22,229***
		(16,874)	(18,496)		(6,989)
Flood loss, % of yearly income	1.2	-0.3	-0.7***	1.0	-0.4***
		(0.2)	(0.2)		(0.1)

Notes: Mining villages only. Column (1) reports the mean among Upper-caste households and column (4) the mean among households that own farmland. Columns (2) and (3) report the coefficients on the OBC and SC/ST indicators in Equation 5.2, estimated together with Upper-caste households as the omitted group, and column (5) the coefficient on an indicator for a household without farmland. Damages and losses are defined in Table 8. Flood losses and repair spending cover the past five years. They are zero for households not flooded in 2021–25, and for households whose amount is unknown, including those reporting floods without the years. Loss per flood year divides the five-year loss by the number of years flooded in 2021–25, among flooded households. The last row divides annual flood loss (five-year loss divided by five) by positive 2025 household income; the resulting percentage is capped at its 99th percentile. Regressions include village fixed effects. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-13: Farming: caste and farmland within mining villages

	Caste			Farmland	
	Upper-caste mean (1)	OBC minus Upper-caste (2)	SC/ST minus Upper-caste (3)	Owners mean (4)	Non-owners minus owners (5)
Farm income got worse when mining started (%)	15.8	-2.6	-2.7	14.3	0.6
		(2.1)	(2.4)		(1.6)
Fewer crops per year when mining started (%)	7.3	-2.9	-2.7	6.8	0.6
		(1.8)	(1.7)		(1.0)
Names groundwater, dust or irrigation (%)	57.5	-8.8	-9.3	50.7	-1.3
		(7.1)	(8.3)		(6.8)
Farm income 2025 (Rs.)	104,833	-55,732***	-72,867***	60,432	-30,525***
		(7,938)	(8,379)		(3,909)
Log farm income per acre, 2025	10.126	-0.108**	-0.076	10.209	-0.172***
		(0.054)	(0.065)		(0.044)

Notes: Mining villages only. Column (1) reports the mean among Upper-caste households and column (4) the mean among households that own farmland. Columns (2) and (3) report the coefficients on the OBC and SC/ST indicators in Equation 5.2, estimated together with Upper-caste households as the omitted group, and column (5) the coefficient on an indicator for a household without farmland. The first three rows refer to reported changes in the mining-start window (Table 7); the reasons row includes only households reporting a fall in farm income. The last two rows refer to 2025 (Table B-11). Regressions include village fixed effects. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-14: Road accidents and drownings: village level

	Control villages (1)	Mining minus control villages (2)
Road accident in or around the village, last 2 years (% of households)	30.3	10.0***
		(3.3)
Drowning death in the river, last 5 years (% of households)	7.9	26.9***
		(2.8)

Notes: One observation per village: the percentage of households asked who report a road accident in or around the village in the last two years, or a death by drowning in the river in the last five years; each question was asked of a random half of households. Column (1) reports the mean across control villages and column (2) the difference between mining and control villages, with matched-group fixed effects. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

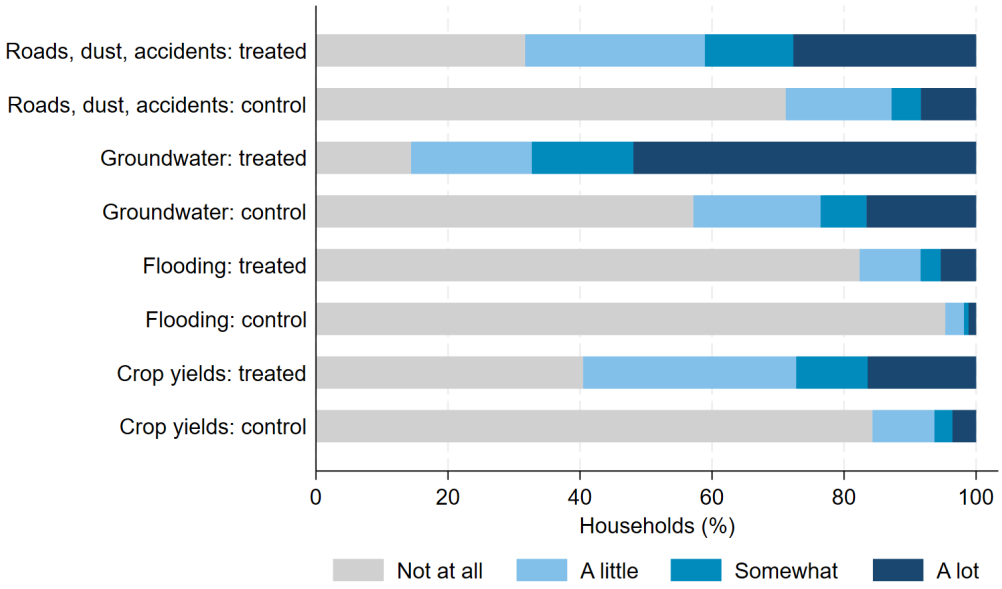


Figure B-12: How much households think sand mining affects the village: all answers

Notes: Bars show answer distributions in mining and control villages. The flooding question asks how much mining increases flood risk; the other questions ask how much it affects crop yields, groundwater, or roads, dust and accidents, without specifying a direction. "Don't know" and refusals are excluded.

Table B-15: Work, land and income from sand on the Sone and on other rivers

	Sone		Other rivers	
	Control villages (1)	Mining minus control (2)	Control villages (3)	Mining minus control (4)
Member works in sand mining (%)	1.4	9.7***	0.3	1.3***
		(1.5)		(0.3)
Mine labour (%)	0.4	8.0***	0.1	1.0***
		(1.4)		(0.2)
Transport (%)	0.4	0.1	0.2	0.1
		(0.2)		(0.1)
Machines or management (%)	0.3	0.2	0.1	-0.1
		(0.1)		(0.1)
Land used for sand work (%)	0.9	4.8***	0.1	1.3***
		(0.7)		(0.3)
Receives land rent (%)	0.7	3.9***	0.0	0.1*
		(0.6)		(0.1)
Any income from sand (%)	1.8	11.9***	0.3	1.4***
		(1.6)		(0.3)
Income from sand (Rs. a year)	1,240	3,779***	151	225**
		(848)		(93)

Notes: Each village is assigned the river of its matched group's mining villages, using river codes from the mine maps. 43 matched groups with 75 mining and 39 control villages are on the Sone, and 38 groups with 62 mining and 38 control villages are on other rivers. Rows are defined as in Table 6, Panel A, and refer to 2025. Columns (1) and (3) give the mean in control villages; columns (2) and (4) give the difference between mining and control villages, with matched-group fixed effects (Equation 5.1), estimated separately for each kind of river. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-16: Damage households attribute to mining on the Sone and on other rivers

	Sone		Other rivers	
	Control villages (1)	Mining minus control (2)	Control villages (3)	Mining minus control (4)
Dust a serious problem (%)	15.2	22.0***	7.4	4.7***
		(2.7)		(1.3)
Names lower crop yields (%)	10.3	45.2***	4.9	12.0***
		(2.4)		(2.0)
Names road accidents (%)	5.7	15.3***	0.4	1.0***
		(2.2)		(0.3)
Names deeper digging for water (%)	34.0	53.0***	20.9	37.0***
		(3.4)		(3.1)
Names road damage (%)	15.8	32.8***	3.7	11.4***
		(2.5)		(1.8)
Names dust and pollution (%)	19.1	45.3***	4.6	9.7***
		(3.3)		(1.8)
Names more flooding (%)	0.7	2.0***	0.7	1.6***
		(0.5)		(0.4)
Loss: lower crop yields (Rs.)	2,524	6,326***	1,257	2,098***
		(644)		(466)
Loss: road accidents (Rs.)	501	772***	0	186**
		(188)		(78)
Loss: deeper digging for water (Rs.)	4,437	7,321***	4,337	5,935***
		(709)		(872)
Loss: total of the three (Rs.)	7,462	14,419***	5,594	8,219***
		(1,090)		(1,229)
Total, % of yearly income	2.6	3.5***	1.5	2.2***
		(0.3)		(0.5)
Flood loss, 2021–25 (Rs.)	2,107	6,312	5,145	1,211
		(4,677)		(2,036)

Notes: Matched groups are assigned to rivers as in Table B-15. Rows are defined as in Table 8, except that the cost of deeper digging for water is counted as households report it, not at mining's share of the fall in the water table. The last row is the household's loss from floods in 2021–25, zero when it was not flooded or the loss is unknown. Columns (1) and (3) give the mean in control villages; columns (2) and (4) give the difference between mining and control villages, with matched-group fixed effects (Equation 5.1), estimated separately for each kind of river. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-17: Farming, groundwater, floods and beliefs on the Sone and on other rivers

	Sone		Other rivers	
	Control villages (1)	Mining minus control (2)	Control villages (3)	Mining minus control (4)
A. Change from t_{-1} to t_0				
Farm income got worse (%)	9.9	4.4***	15.0	1.1
		(1.1)		(1.6)
Fewer crops per year (%)	3.2	1.5*	6.4	5.8***
		(0.8)		(1.2)
Borewell needed deepening (%)	6.4	1.6**	11.4	0.0
		(0.8)		(1.8)
B. Change from t_0 to t_1				
Farm income got worse (%)	27.6	-2.6*	23.1	-1.4
		(1.4)		(1.9)
Fewer crops per year (%)	4.3	0.7	7.1	3.2***
		(0.7)		(1.1)
Borewell needed deepening (%)	18.5	4.8*	17.9	5.1**
		(2.7)		(2.5)
C. Floods and beliefs				
Flooded in 2021–25 (%)	5.5	-0.9	12.3	2.0
		(1.5)		(3.1)
Sees mining affecting flooding (%)	4.8	14.9***	4.5	11.5***
		(1.6)		(1.7)
Sees mining affecting crop yields (%)	20.2	54.8***	9.9	22.5***
		(3.0)		(2.7)
Sees mining affecting groundwater (%)	48.5	47.3***	35.5	35.4***
		(3.6)		(3.2)
D. Other data: village heads (water table) and satellite (vegetation, flooding)				
Fall in the water table, 2020–25 (feet)	7.7	16.6***	18.3	0.4
		(3.0)		(4.6)
Vegetation index (EVI), growing season	0.270	-0.009***	0.326	-0.001
		(0.002)		(0.001)
Probability of flooding (%)	15.5	5.4***	2.0	0.7
		(1.9)		(0.6)

Notes: Matched groups are assigned to rivers as in Table B-15. Panels A and B use variables defined in Table 7, separately for each river's matched groups: columns (1) and (3) give the share in control villages for 2011–15 to 2016–20 (Panel A) and 2016–20 to 2021–25 (Panel B), and columns (2) and (4) the difference between mining and control villages from stacked difference-in-differences. In Panel C, columns (1) and (3) give the mean in control villages and columns (2) and (4) the difference between mining and control villages from Equation 5.1, with matched-group fixed effects. "Flooded" is a flood experienced by the household in 2021–25; "sees mining affecting" is a little, somewhat or a lot rather than not at all, as in Figure 10. The water table is the village-head event study of Figure 8, estimated separately by river: column (1) or (3) gives the fall in control villages' water table from 2020 to 2025 and column (2) or (4) the additional fall in mining villages, with standard errors clustered by matched group. The vegetation index (EVI, growing season) and the probability of flooding, defined as in Section 4, come from satellite data on villages within 1 km of a mine and matched villages near the river, from stacked difference-in-differences with matched-group fixed effects and controls; columns (1) and (3) give the mining villages' mean before mining started. Control villages for the satellite outcomes lie up to about 5 km from the river. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-18: Response to randomly assigned amounts: mining villages

	Share saying yes (%) (1)	Difference from lowest amount (2)
A. Supports mining if paid this amount each year		
1,000 rupees	8.0	
2,500 rupees	13.3	5.5***
		(1.7)
5,000 rupees	16.5	8.6***
		(1.6)
10,000 rupees	21.4	13.3***
		(1.8)
20,000 rupees	27.7	20.0***
		(2.3)
Households		5,537
Villages		136
B. Would contribute this amount to stop or reduce mining		
500 rupees	43.9	
1,000 rupees	36.0	-8.1***
		(2.2)
2,000 rupees	28.9	-15.9***
		(2.0)
5,000 rupees	24.0	-20.4***
		(2.4)
10,000 rupees	19.1	-24.9***
		(2.6)
Households		5,537
Villages		136

Notes: Mining villages only. Panel A: the household would support mining permitted in or near the village if the family received the randomly assigned amount each year. Panel B: the household would contribute the randomly assigned amount to stop or reduce mining in the village. Column (1) reports the share saying yes at each amount; every other answer counts as not yes. Column (2) reports the coefficient on each amount, relative to the lowest, from a regression of saying yes on indicators for the amounts with village fixed effects, in ppt. Standard errors, clustered by village, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B-19: Answers on support for mining: all households

	Mining villages	Control villages
Should there be a sand industry in the village?		
Yes	20.6	14.9
No	76.7	36.3
Mining does not happen here	1.2	47.4
Refused or not answered	1.5	1.5
Minimum compensation per year to support mining		
No compensation needed	21.9	16.0
Up to 2,000 rupees	0.2	0.2
2,001–5,000 rupees	0.7	0.6
5,001–10,000 rupees	2.2	1.9
10,001–20,000 rupees	3.0	2.6
More than 20,000 rupees	12.8	6.7
Would not support at any amount	50.9	18.1
Mining does not affect the village	0.8	44.5
Do not know, refused or not answered	7.4	9.3
Supports mining if paid the offered amount each year		
Yes	17.9	15.2
No	80.2	41.2
Mining does not affect the village	0.7	42.0
Unsure, refused or not answered	1.2	1.7
Would contribute the asked amount to stop or reduce mining		
Yes	30.9	11.8
No	67.2	43.1
Mining does not affect the village	0.4	43.7
Unsure, refused or not answered	1.6	1.4
Households	5,551	2,652

Notes: Percentage of all households giving each answer. The questions are: whether there should be a sand industry in the village; the smallest yearly payment for which the family would support sand mining; whether the household would support mining permitted in or near the village if the family received a randomly assigned amount each year; and whether it would contribute a randomly assigned amount to stop or reduce mining in the village (Section 5.5).

Table B-20: Smallest acceptable payment and the answer to the random offer

	Mining villages		Control villages		
	Households	Accept the offer (%)	Households	Accept the offer (%)	Expected answer
	(1)	(2)	(3)	(4)	(5)
No compensation needed	1,201	19.1	400	20.8	Yes
Minimum at or below the offered amount	116	82.8	41	90.2	Yes
Offered amount inside the minimum's band	11	72.7	3	33.3	Either
Minimum above the offered amount	919	43.3	271	52.0	No
Would not support at any amount	2,797	4.1	402	4.5	No
Answer differs from the expected one (%)	5,033	29.9	1,114	43.1	

Notes: Households that named a smallest yearly payment for which the family would support mining (or said none is needed, or that they would not support mining for any amount) and answered yes or no to the random offer. Payments were asked in ranges; rows compare the stated range with the randomly assigned offer. Column (5) gives the answer to the offer implied by the stated payment: yes if the household needs no payment or the whole range is at or below the offer; no if the whole range is above the offer or the household would not support mining for any amount; either if the offer falls inside the range. The last row reports the percentage of households whose answer differs from the expected one, among households with an expected answer of yes or no.

Table B-21: Opposition to sand mining: supervisors' village histories

	Villages (1)	Percent (2)
Mining villages with a supervisor form	134	
Opposition question answered	111	
Any opposition, protest or dispute ever (% of villages answering)	23	20.7
Form of opposition		
Peaceful protest or dharna	12	52.2
Complaint or petition to the administration	12	52.2
Court or legal case	4	17.4
Blockade of road or ghat	10	43.5
Violent confrontation or clashes	3	13.0
Use of firearms or weapons	5	21.7
Threats or intimidation	10	43.5
Caste groups that led or took part		
Upper-caste	12	52.2
OBC	18	78.3
SC/ST	15	65.2
Stated reasons		
Loss of land, crops or livelihood	14	60.9
Environmental: water table, river, pollution, erosion	16	69.6
Safety: accidents, trucks, road damage	11	47.8
Religious or cultural: ghat, cremation, temple	2	8.7
Control of the resource: who gets to mine	1	4.3
Caste rivalry or factional dispute	0	0.0
Political or party rivalry	0	0.0
Benefits not shared	4	17.4
Supervisor's assessment		
A broad community concern	7	30.4
Mainly a caste or factional struggle over sand	7	30.4
A mix of both	9	39.1
Violence, weapons, injuries, deaths or police/court cases	7	30.4

Notes: Mining villages only. Field supervisors recorded village histories after speaking with villagers. The first percentage uses villages answering the opposition question; subsequent percentages use villages with reported opposition. Villages could have several forms of opposition, participating caste groups and stated reasons. The final rows report supervisors' assessments of the dispute and whether violence, weapons, injuries, deaths or police/court cases occurred.

B.7 Household accounts and political aggregation

This appendix gives the construction and numerical programs behind Section 6. The calculations use one common weighting rule across villages. The main specification distinguishes sixteen groups by farmland ownership, four caste categories and positive mining-profit receipt. Nested specifications pool caste categories within the same economic positions, allowing us to assess what the finer distinctions contribute without changing the household accounts.

B.7.1 Sample and annual household account

The analysis combines the household survey with village mining histories. It covers 126 villages, comprising 74 active and 52 previously operating sites. We exclude 10 villages without a mine and 1 with unknown mining status. Of 5,330 surveyed households in these villages, 5,293 have the information required to construct their gains and losses and determine group membership; 37 are excluded for incomplete information. All villages remain represented. The denominator within village is the number of households with complete information, denoted n_v.

The comparison is the mining regime relative to its absence under a stable-regime account. Recent annual receipts and historical mining-year income are compared with annual-average losses in 2021–25. Including previously operating sites evaluates the mining regime across these histories; it does not assert that every mine is currently operating. The active-only calculation uses the same definitions on the active roster.

For an active site, annual profit is

$$\Pi_{iv} = I_{iv} + R_{iv}, \tag{B.1}$$

where I_{iv} is income from sand work and R_{iv} is annual rent from land used for mining or transport. Households that do not participate in sand work have zero work income. Sand-work income is the household's reported income from sand mining in 2025. For wage roles (mine labour, loading, driving and transport, machine operation, and other roles) we count only the premium over the village farm wage: reported income times $(w^S - w^F)/w^S$, floored at zero, where w^S is the sand daily wage and w^F the village farm daily wage. The sand wage is the household's reported daily wage as a mining labourer or, where that is missing, the village median among households in sand work, the village head's report of the mine daily wage, or the median across households, in that order. The farm wage is the village median of households' reported agricultural daily wage or, where that is missing, the village head's report or the median across households. Daily wages below Rs. 50 are treated as missing. Mine managers and households whose role is providing land keep their reported income in full. The 72 households in sand work that report no amount are assigned the median 2025 amount of households in sand work with the same number of days of sand work and the same role (or the closest of these groups with at least ten households), except that a household whose role is providing land and that receives rent is assigned zero, since that income is the rent. At active sites, the 41 households that worked in sand mining during 2021–25,

the period the cost measures cover, but not in 2025 receive half the median 2025 amount, after the wage premium, for their 2020 role (Rs. 738 on average): leaving at some point during 2021–24 means working, on average, half of the period. Households that did not work in sand mining during 2021–25 receive nothing for it. Rent uses the largest annual amount implied by the reported receipts and rental rates, as described in Appendix B.6. These amounts are treated as profit.

For previously operating sites, sand-work income averages current earnings and an imputed amount for the mining years; reported annual land rent is then added. The pre-closure reference year is 2020 for closures in 2021–25, 2015 for closures in 2016–20, and 2011 for closures in 2011–15. Households reporting involvement in that year are assigned the median 2025 earnings, after the wage premium, of participants in active-mining villages with the corresponding role; nonparticipation gives zero. We use the median because sand earnings are highly concentrated, so a few large amounts would raise a mean well above a typical participant's earnings. Roles distinguish management, machine operation, transport, labour, land provision, and other activities. When several roles are reported, the priority is management, machine operation, transport, labour, land provision, then other activities. An unclassified role, or a role with fewer than ten participants reporting an amount, uses the median across all participants. Where no pre-closure reference year is available, current earnings are retained.

The annual account is

$$C_{iv} = C_{iv}^{N} + \gamma_{r(v)} C_{iv}^{G} + \phi_{r(v)} C_{iv}^{F}, \qquad g_{iv} = \Pi_{iv} - C_{iv}. \tag{B.2}$$

Here C_{iv}^{N} is the annualised reported mining-attributed crop loss, and C_{iv}^{G} is the annualised reported cost of deeper digging for water. Road accidents, road damage, and dust and pollution, which households also report in Section 5.2, are not in the household account: they fall on the village as a whole rather than on particular households. Reported monetary ranges are valued at their midpoints, with Rs. 60,000 assigned to the open upper range above Rs. 50,000 for five-year losses. A damage not reported by the household is assigned zero. So is a reported damage whose amount the household did not know or would not give, and both damages when it did not say which occurred; these 48 households remain in the sample with the losses they did value. Annualised total flood loss, C_{iv}^{F}, is zero for households reporting no flood during 2021–25, and for the 148 households whose 2021–25 flood loss is unknown, mostly because they reported floods without their years. Counting unknown amounts as zero understates these households' losses. The attribution share on river r, $\phi_r = \widehat{\beta}_r/(\widehat{\mu}_r + \widehat{\beta}_r)$, bounded between zero and one, uses the stacked estimate of mining's effect on the probability of flooding and the mining villages' pre-mining flood probability from the comparison with matched villages near the river, estimated separately for the Sone and for other rivers (Appendix Table B-17, Panel D): 25.8% on the Sone and 26.9% on other rivers. That comparison uses the wider of the two matched samples, whose control villages lie up to about 5 km from the river, because the closer one includes almost no villages on the Sone. A common share from the mine-level estimates of Section 4, 24.5% (stacked) or 16.8% (interaction-weighted), serves as a robustness check.

The groundwater share γ_r uses village heads' reports of groundwater depth in 2010, 2015, 2020 and 2025, the data behind Figure 8. We estimate that event study, with village and matched-group-by-period fixed effects, separately for matched groups on the Sone and on other rivers. A group's river is the river of its mining villages' mines in the mine maps, and every village in the group, mining or control, takes that river; the same village–river assignment is used throughout. The household question covers the past five years, so the share uses 2020–25. On the Sone, water tables in mining villages fell 22.4 feet, 16.6 feet more than in matched control villages. On other rivers, mining villages fell 22.4 feet, and the difference from control villages was 0.4 feet. The share is the additional fall divided by the fall in mining villages, bounded between zero and one: 74.0% on the Sone and 1.9% on other rivers. Each household's groundwater cost is scaled by the share for its own village's river. Equation (B.2) precedes additional environmental compensation; land rent is already included.

B.7.2 Group membership and normalization

Households are classified by farmland ownership, caste (Upper-caste, BC, EBC or SC/ST), and receipt of positive mining profit, $a_{iv} = 1\{\Pi_{iv} > 0\}$. Crossing four caste categories with two land and two receipt categories gives sixteen groups, indexed by k. The caste assignment is the same cleaned classification used in Section 5; the accounting sample contains no ST households. Receipt is measured before environmental losses, so recipients can have negative net gains. The original eight-group rule pools Upper-caste with BC and EBC with SC/ST within each ownership-and-receipt position. Pooling Upper-caste, BC and EBC instead reproduces the broad caste contrast observed in Section 4, also yielding eight groups. Complete caste equality leaves four ownership-and-receipt groups. The two-recipient-group and four-land-and-pooled-caste specifications remain additional benchmarks.

For each cell, construct

$$U_{vk} = \frac{1}{n_v} \sum_{i:k_{iv}=k} g_{iv}, \qquad m_{vk} = \frac{1}{n_v} \sum_{i} 1\{k_{iv} = k\}, \qquad \sum_{k} m_{vk} = 1. \tag{B.3}$$

An absent cell contributes zero to both arrays. The model uses raw multipliers $h_k > 0$ common across all villages. The normalized household multiplier and local objective are

$$q_{iv}(h) = \frac{h_{k_{iv}}}{\sum_k m_{vk} h_k}, \qquad V_v(h) = \frac{U_v h}{m_v h}, \qquad V_v(h) + E_v \geq 0. \tag{B.4}$$

Thus $n_v^{-1} \sum_i q_{iv} = 1$. Pressure is linear in signed financial stakes, $f(g) = g$; h is the effective group multiplier. This is not a majority-voting rule. Equal financial stakes receive equal pressure before multiplication by h. All accounts use surveyed-household shares rather than population expansion weights.

B.7.3 Common-rule feasibility and weight bounds

With $E_v = 0$, the common feasible set is $\{h > 0 : U_v h \geq 0 \ \forall v\}$. Homogeneity permits the computational normalization $h_k \geq 1$: any strictly positive feasible vector can be rescaled to satisfy it. The zero vector is excluded. At a highest-to-lowest ratio cap R, imposing $1 \leq h_k \leq R$ is equivalent to allowing positive weights with ratio at most R.

Equal weights set $h = \mathbf{1}$, giving $S_v = \sum_k U_{vk}$. The minimum inequality required to fit every village solves the linear program

$$\min_{h,R} R \quad \text{subject to} \quad U_v h \geq 0 \ \forall v, \qquad 1 \leq h_k \leq R. \tag{B.5}$$

Infeasibility means that no strictly positive common vector fits the full sample; it is not a large estimated ratio. For a nonempty common set, bounds on a contrast h_k/h_1 are obtained by fixing $h_1 = 1$ and minimizing or maximizing h_k over the nonnegative closure of the same feasible set. A zero endpoint can be an unattained limit and an upper endpoint can be infinite. The reference normalization does not assume that group 1 is least influential. The primary full-sample set is empty, so it supplies no finite fitted full-sample vector or projected contrast intervals.

Independent influence evidence could restrict this set through justified orderings or equalities. Reports of who allocates mining jobs and transport work, and nominations of actors influencing mining decisions, describe potential channels of influence. They do not establish numerical political weights for these household groups. The baseline therefore leaves group orderings unrestricted. A feasible weighting rule demonstrates compatibility with the observed accounts.

B.7.4 Maximum sample coverage

For each display cap R, the estimator computes

$$K(R) = \max_{1 \leq h_k \leq R} \sum_v 1\{U_v h \geq 0\}. \tag{B.6}$$

One common vector must satisfy every included village. Introduce $z_v \in \{0, 1\}$ and maximize $\sum_v z_v$ subject to

$$U_v h - M_v(R) z_v \geq -M_v(R), \tag{B.7}$$

$$M_v(R) = \left[-\sum_{k: U_{vk} \geq 0} U_{vk} - R \sum_{k: U_{vk} < 0} U_{vk} \right]_+ . \tag{B.8}$$

The bound follows by minimizing $U_v h$ on $[1, R]^K$; setting $z_v = 0$ therefore releases that restriction. The displayed count is the integer optimizer's selected count. The solver requires zero relative optimality gap and rechecks each selected inequality with tolerance 10^{-6} relative to $\max\{\sum_k |U_{vk}| h_k, 1\}$. Iteration limits and numerical failures stop the run rather than produce a finding of infeasibility. At $R = 1$, an absolute Rs. 10^{-6} sign tolerance is used.

Coverage at a finite cap is not automatically the uncapped maximum $K^* = \sup_{R<\infty} K(R)$. Villages with nonpositive gains in every cell and negative total gains cannot fit any positive vector. Their complement bounds uncapped coverage from above. The estimator also solves the program at a ratio cap of 10,000 and certifies K^* only if that count reaches this independently calculated ceiling. In the primary sixteen-cell model the ceiling is 87 villages, but the program at that cap fits 82, so K^* is not certified; the cap-100 calculation fits 76. Changes in maximum coverage need not preserve the identities of the previously fitted villages.

The caste restrictions reported below are imposed on the full sixteen-cell system. We aggregate the household accounts exactly when imposing equality, preserving both $\sum_k U_{vk}$ and $\sum_k m_{vk}$ in every village. Every restricted rule is reoptimised over all villages for each objective; the calculation does not condition on a village subset selected by the unrestricted rule.

B.7.5 Required outside advantage

Let each outside term satisfy $0 \leq E_v \leq b$. The minimum cap that permits one common local rule to accommodate every village is

$$b^* = \inf_{h>0} \max_v \left[-\frac{U_v h}{m_v h} \right]_+ . \tag{B.9}$$

For a fixed b, feasibility is a linear program with $h_k \geq 1$ and $(U_v + b m_v)h \geq 0$ for every village. The same cap could equivalently be added in every village. Feasibility is monotone in b, permitting bisection from zero to $\max_v [-S_v]_+$, where equal weights work. The reported value is the feasible upper endpoint when the bracket is at most Rs. 1 wide; the infimum can involve limiting weight ratios. Joint optimization in b and h is not itself a linear program.

The primary outside calculation places no upper bound on weight ratios. Separately imposing $h_k \leq 100$ gives the cap-100 threshold of Rs. 2,581. It must not be confused with the primary uncapped threshold. The rule minimizing this outside requirement need not maximize zero-outside coverage. b^* is in normalized annual household monetary-index units; it is not an observed transfer, state revenue or contractor profit, nor an amount each village individually requires.

B.7.6 Additional caste effectiveness conditional on economic position

Let $\mathcal{H}_j(R)$ denote the multipliers satisfying a specified set of caste equalities or orderings and $1 \leq h_k \leq R$. For each restriction j we calculate

$$K_j(R) = \max_{h \in \mathcal{H}_j(R)} \sum_v 1\{U_v h \geq 0\}, \qquad b_j^*(R) = \inf_{h \in \mathcal{H}_j(R)} \max_v \left[-\frac{U_v h}{m_v h} \right]_+ . \tag{B.10}$$

The restrictions enter both the coverage program and every feasibility problem used to find the outside ceiling. These are separate optimisations, so the rule attaining $K_j(R)$ need not attain $b_j^*(R)$. Their comparison uses identical households, profits, costs and village denominators. Nest-

ing requires unrestricted coverage to be weakly higher and its outside ceiling weakly lower than those under any restriction. The code verifies these properties and exact aggregation of the group accounts.

Table B-22 reports the four principal specifications and two partial pooling restrictions. Pooling Upper-caste with BC alone leaves twelve groups; pooling EBC with SC/ST alone also leaves twelve. It additionally reports opposing weak orderings for each of the two binary caste classifications. An ordering applies within every matched land-and-receipt position; it does not impose a hierarchy across the four individual castes. Each row permits one common rule across all 126 villages, and all objectives are reoptimised globally.

Table B-22: Conditional caste restrictions: coverage and outside advantage

	Groups	$K(100)$	$b^*(100)$	b^*
Four separate castes (16 groups)	16	76	2,581	2,445
Upper-caste = BC; EBC = SC/ST (8 groups)	8	75	3,545	3,533
Upper-caste = BC = EBC; SC/ST separate (8 groups)	8	76	4,448	4,337
All castes equal (4 groups)	4	74	5,836	5,797
Upper-caste = BC only (12 groups)	12	76	3,004	2,813
EBC = SC/ST only (12 groups)	12	75	3,158	3,094
Upper-caste/BC at least EBC/SC	8	75	3,710	3,689
Upper-caste/BC at most EBC/SC	8	74	5,836	5,797
Upper-caste and all OBC at least SC/ST	8	75	5,662	5,564
Upper-caste and all OBC at most SC/ST	8	76	4,448	4,337

Notes: Each equality or ordering is imposed within land ownership × positive-profit receipt. $K(100)$ is the maximum number of villages accommodated by one common rule with a highest-to-lowest multiplier ratio of at most 100. $b^*(100)$ is the smallest uniform outside ceiling accommodating all villages under that ratio cap; b^* permits unrestricted positive ratios. Outside ceilings are annual rupees per sampled household in the normalised decision index. The sample comprises all 126 villages. Coverage optimises village selection separately for each row. "At least" and "at most" constrain group multipliers.

Coverage varies little across restrictions, from 74 to 76 villages, while their outside ceilings differ substantially. These comparisons restrict effectiveness within economic positions; they retain caste differences in land ownership, mining receipt, returns and losses. They therefore assess additional conditional caste flexibility, rather than the total importance of caste for the political balance. The following exercise measures how those retained economic differences enter model-implied pressure.

B.7.7 Caste shares of supporting and opposing pressure

We separate positive net stakes, $g_{iv}^{+} = [g_{iv}]_{+}$, from negative stakes, $g_{iv}^{-} = [-g_{iv}]_{+}$. For caste c and political group k, define vectors with elements

$$a_{ck}^{\pm} = \frac{1}{V} \sum_{v} \frac{1}{n_v} \sum_{i: c_i = c,\, k(i) = k} g_{iv}^{\pm}, \qquad a^{\pm} = \sum_{c} a_{c}^{\pm}. \tag{B.11}$$

The caste's share of pooled supporting or opposing pressure is

$$s_c^{\pm}(h) = \frac{a_c^{\pm\prime} h}{a^{\pm\prime} h}. \tag{B.12}$$

All 126 villages contribute, with equal village base weights and equal household weights within villages. These shares pool raw $h_k g_i^{\pm}$ before the village-specific normalisation in Equation B.4. They are neither averages of village percentages nor shares of the normalised village index. The decision rule and outside-advantage calculation remain unchanged. Setting $h = \mathbf{1}$ gives the corresponding reference monetary-stake share.

We bound each share over common rules that accommodate a fixed set of villages, comparing four land-and-receipt groups with equal caste multipliers against the unrestricted sixteen groups. The 39 sign-impossible villages bound coverage at 87. At a ratio cap of 100, neither specification reaches this ceiling: the best economic-position rule accommodates 74 villages and the best sixteen-group rule 76. We fix the set at the 74 villages selected by the economic-position coverage programme. The sixteen-group rule nests the economic-position rule, so both specifications can accommodate this set, and their bounds refer to the same villages. Another selection with the same count could give different bounds. Let $\mathcal{G}_j$ contain the restrictions $U_v h \geq 0$ for these villages and $1 \leq h_k \leq 100$, together with specification j's caste equalities. The incidence calculation retains the other villages even though their local-only inequalities cannot be satisfied.

For each caste and sign, minimise and maximise Equation B.12 over $\mathcal{G}_j$. Both denominators are positive. The transformation $x = th$, $t = 1/(a^{\pm\prime} h)$ yields a linear programme with objective $a_c^{\pm\prime} x$, normalisation $a^{\pm\prime} x = 1$, inequalities $t \leq x_k \leq 100\, t$, $t \geq 0$, and $U_v x \geq 0$ in the constrained villages. Caste equalities also apply to x. The implementation rescales coefficients, reconstructs endpoint rules and verifies the original fractions, ratio cap and village inequalities. It checks that sixteen-group intervals contain the economic-position intervals.

The endpoints are sharp bounds within the maintained model, not sampling confidence limits. Each endpoint can use a different rule; marginal bounds need not be jointly attainable. The rule minimising the outside ceiling is chosen by a different objective and need not belong to this maximum-coverage set. Table 17 reports Upper-caste, OBC and SC/ST households. Its OBC coefficient vector is $a^{\pm}_{\text{OBC}} = a^{\pm}_{\text{BC}} + a^{\pm}_{\text{EBC}}$: we aggregate these stakes before optimising each endpoint, rather than add separately optimised bounds. This reporting aggregation leaves the sixteen political groups unchanged. Table B-23 retains the BC–EBC distinction, and Table B-24 reports the other pooled comparisons. The wide sixteen-group intervals limit claims about a unique caste distribution of pressure; supporting and opposing stakes must both be considered.

B.7.8 Economic positions and the decomposition of caste gaps

Tables B-25 and B-26 connect the political cells to the economic evidence in Section 5. They use the complete annual account, including the existing imputations for missing current income and relevant past participation. Section 5's earnings tables instead describe reported 2025 earnings in

Table B-23: Four caste categories and model-implied political pressure

	Household share	Net-stake share	Pressure-share bounds	
			Economic position	Sixteen groups
A. Supporting pressure				
Upper-caste	16.4	41.1	40.9–44.3	29.4–70.7
BC	31.6	29.2	29.1–31.2	11.3–46.7
EBC	28.3	17.6	14.3–17.8	5.2–31.7
SC/ST	23.8	12.0	10.2–12.1	4.1–19.8
B. Opposing pressure				
Upper-caste	16.4	24.5	11.5–15.2	6.9–35.7
BC	31.6	42.0	29.1–40.1	16.1–66.4
EBC	28.3	19.1	25.5–35.9	9.4–62.8
SC/ST	23.8	14.4	19.6–23.5	7.5–39.8

Notes: Percentages calculated as in Table 17, retaining Upper-caste, BC, EBC and SC/ST separately. All 126 villages contribute to the household, net-stake and pressure shares. Bounds are marginal compatibility ranges, with each endpoint optimised separately over common rules that accommodate the fixed set of 74 villages, with a highest-to-lowest multiplier ratio of at most 100.

Table B-24: Pooled caste classifications and model-implied pressure

	Household share	Net-stake share	Pressure-share bounds	
			Economic position	Sixteen groups
A. Supporting pressure				
Upper-caste/BC	47.9	70.3	70.0–75.5	55.8–89.4
EBC/SC	52.1	29.7	24.5–30.0	10.6–44.2
Upper-caste and all OBC	76.2	88.0	87.9–89.8	80.2–95.9
SC/ST	23.8	12.0	10.2–12.1	4.1–19.8
B. Opposing pressure				
Upper-caste/BC	47.9	66.5	40.6–54.9	25.2–78.4
EBC/SC	52.1	33.5	45.1–59.4	21.6–74.8
Upper-caste and all OBC	76.2	85.6	76.5–80.4	60.2–92.5
SC/ST	23.8	14.4	19.6–23.5	7.5–39.8

Notes: Percentages using Equations B.11–B.12. Economic-position weighting assigns common multipliers across caste within each land-and-receipt position. Rows report two alternative binary caste classifications. All 126 villages contribute to the shares. Bounds are marginal compatibility ranges, with each endpoint optimised separately over common rules that accommodate the fixed set of 74 villages, with a highest-to-lowest multiplier ratio of at most 100.

full, without the wage-premium adjustment. The comparisons here therefore document the inputs to the political exercise rather than reproduce those tables.

Give household i weight $d_{iv} = 1/n_v$, so every village contributes the same total mass. Caste means condition on caste after applying these weights:

$$\overline{y}_c = \frac{\sum_{iv:c_i=c} d_{iv} y_{iv}}{\sum_{iv:c_i=c} d_{iv}}.$$

This differs from an unweighted average of caste-specific village means. Conditional recipient means normalise the same weights over positive-profit recipients. Household counts are unweighted counts; shares of household mass and profits use d_{iv}.

Table B-25: Caste, economic positions and the annual household account

	Upper-caste	BC	EBC	SC/ST
A. Household accounts				
Households	835	1,655	1,589	1,214
Share of household mass (%)	16.4	31.6	28.3	23.8
Owns farmland (%)	88.0	90.3	46.0	42.3
Receives mining profit (%)	6.9	7.5	8.4	10.9
Owns farmland and receives profit (%)	6.7	7.2	4.1	4.3
Annual profit among recipients (Rs.)	66,240	23,804	14,072	9,207
Annual mining profit (Rs.)	4,594	1,788	1,182	1,007
Annual land rent (Rs.)	2,039	851	280	226
Annual environmental costs (Rs.)	3,994	3,449	1,768	1,621
Annual net gain (Rs.)	600	−1,660	−586	−613
Positive net gain (%)	5.6	5.7	5.8	8.5
Share of mining profit (%)	39.8	29.9	17.7	12.7
B. Economic positions: share within caste (%)				
No farmland, no mining profit	11.7	9.4	49.7	51.0
Farmland, no mining profit	81.4	83.1	41.9	38.0
No farmland, mining profit	0.3	0.3	4.3	6.6
Farmland, mining profit	6.7	7.2	4.1	4.3

Notes: The sample comprises households with complete monetary accounts. Monetary entries are annual rupees. Each household receives weight $1/n_v$ before conditioning on caste or recipient status; raw counts are also shown. Land rent is included in mining profit. Costs use river-specific groundwater and flood adjustments. Panel B reports the percentage of each caste in each economic position. A recipient has positive profit before subtracting costs. The accounting sample contains no ST households.

Let s index the four land-ownership-and-receipt positions, p_{cs} the weighted share of caste c in position s, and $\mu_{cs}(y)$ its conditional mean of outcome y. For a comparison of groups A and B, the symmetric identity is

$$\overline{y}_A - \overline{y}_B = \underbrace{\sum_s (p_{As} - p_{Bs}) \frac{\mu_{As}(y) + \mu_{Bs}(y)}{2}}_{\text{composition}}$$

$$+ \underbrace{\sum_{s} \left(\mu_{As}(y) - \mu_{Bs}(y)\right) \frac{p_{As} + p_{Bs}}{2}}_{\text{within-position differences}}. \tag{B.13}$$

The first term captures different position shares evaluated at the average conditional outcomes; the second captures different outcomes within positions evaluated at the average shares. Averaging the two groups symmetrically avoids choosing one as the reference distribution. Every position is populated in each comparison group, and the code checks that the two terms reproduce each observed gap. We report Upper-caste, BC and EBC against SC/ST, and the Section 4-aligned comparison pooling Upper-caste with all OBC households. The latter pool uses the household weights directly, rather than taking an equal average of its three caste means.

Table B-26: Decomposing caste differences in annual profits, costs and gains

Comparison	Outcome	Gap	Composition	Within
Upper-caste minus SC/ST	Profit	3,586	647	2,940
Upper-caste minus SC/ST	Costs	2,373	976	1,397
Upper-caste minus SC/ST	Net gain	1,214	−329	1,543
BC minus SC/ST	Profit	781	−177	958
BC minus SC/ST	Costs	1,828	863	965
BC minus SC/ST	Net gain	−1,047	−1,040	−7
EBC minus SC/ST	Profit	174	−288	462
EBC minus SC/ST	Costs	147	8	139
EBC minus SC/ST	Net gain	27	−296	323
Upper-caste + all OBC minus SC/ST	Profit	1,157	−174	1,331
Upper-caste + all OBC minus SC/ST	Costs	1,320	499	821
Upper-caste + all OBC minus SC/ST	Net gain	−163	−673	510

Notes: Annual rupees using Equation B.13. The gap equals composition plus within-position differences before rounding. Positions are the four combinations of farmland ownership and positive mining-profit receipt. The weights and accounts are those in Table B-25.

The broad group of Upper-caste and all OBC households earns Rs. 1,157 more mining profit than SC/ST households on average. Composition contributes Rs. −174, while within-position differences contribute Rs. 1,331. Higher profits therefore do not arise from more frequent receipt alone: Upper-caste and BC households have lower receipt rates but much larger conditional returns. The same broad group bears Rs. 1,320 more annual costs, leaving a net-gain gap of Rs. −163. These current annual accounts and Section 4's estimates of asset changes measure different objects and periods. Together they motivate examining economic positions, returns and political effectiveness separately. The decomposition does not identify the mechanism producing the asset effects or the causal effect of moving a household between positions.

B.7.9 Reported influence conditional on economic position

The linked community survey asks how much influence households like the respondent's have over mining decisions. Define $Y_{iv} = 1$ for a little, some or a lot of influence, and zero for no influence; uncertain and missing answers are excluded. The primary sample requires the same respondent in the household and community instruments, yielding 2,611 households in 126 villages. These represent 49.3% of the complete accounting sample. Table B-29 reports coverage by caste and the group sizes underlying the comparisons.

We estimate the linear probability model

$$\begin{aligned} Y_{iv} = \alpha_v + \sum_{c \neq \text{SC/ST}} \beta_c 1\{c_i = c\} + \sum_{s \neq 1} \delta_s 1\{s_i = s\} \\ + \sum_{c \neq \text{SC/ST}} \sum_{s \neq 1} \eta_{cs} 1\{c_i = c, s_i = s\} + \varepsilon_{iv}. \end{aligned} \tag{B.14}$$

The first specification omits positions and interactions; the second includes positions but omits interactions; the third includes both. All use village fixed effects, the same household roster within each outcome-and-linkage definition, and standard errors clustered by village. They are unweighted household comparisons, following Section 5, whereas the monetary summaries above use $1/n_v$ weights. Estimates are reported as ppt differences from SC/ST. The first two specifications test the three caste coefficients jointly. The saturated specification tests all caste main effects and caste-by-position interactions jointly; its within-position contrasts are β_c for position 1 and $\beta_c + \eta_{cs}$ for the other positions.

Controlling for economic position, Upper-caste respondents are 11.8 ppt more likely than SC/ST respondents in the same village to report influence (standard error 4.0; $p = 0.004$). The BC and EBC estimates are 3.7 and 0.9 ppt and are individually imprecise. The joint caste test has $p = 0.011$; allowing differences to vary by position gives $p = 0.007$. Pooling all three non-SC/ST categories gives a smaller adjusted difference of 3.8 ppt ($p = 0.169$). The finer comparison therefore reveals differences concealed by the broad grouping, while the data do not establish a uniform caste ordering in every economic position.

These regressions supply evidence about perceived capacity to influence decisions beyond broad economic position. Their coefficients are neither causal effects of caste nor numerical estimates of the model's effectiveness per rupee. In particular, the same reported influence category need not imply the same h_k. We therefore use the evidence to assess the interpretation of the restrictions in Table B-22, rather than translate survey categories into cardinal multipliers or select weights to match the influence regressions.

B.7.10 Linkage, cell support and sensitivity

Table B-29 reports the complete-account and linked samples. All sixteen economic cells have observations, but landless recipients include only 3 Upper-caste households in 3 villages and 7 BC

Table B-27: Reported influence and caste within mining villages

	Caste only	Caste and economic position
A. Four caste categories		
Upper-caste minus SC/ST	11.9***	11.8***
	(3.7)	(4.0)
BC minus SC/ST	4.0	3.7
	(3.1)	(3.3)
EBC minus SC/ST	1.0	0.9
	(2.9)	(2.9)
Joint caste test: p-value	0.003	0.011
Households	2,611	2,611
Villages	126	126
Economic-position controls	No	Yes
B. Section 4-aligned caste contrast		
Upper-caste + all OBC minus SC/ST	4.5*	3.8
	(2.6)	(2.7)
Households	2,611	2,611
Villages	126	126
Economic-position controls	No	Yes

Notes: The outcome is any reported influence versus none. Primary same-respondent sample. All models include village fixed effects, with village-clustered standard errors in parentheses. Position controls distinguish the four land-ownership-and-profit-receipt combinations. Panel B pools Upper-caste, BC and EBC households. Estimates are ppt. * p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01. The joint tests in Panel A concern the three caste coefficients.

households in 6 villages. The influence sample contains three households in each of these cells. A missing cell within a village contributes zero to that village's accounts; it does not require dropping the village or borrowing its caste composition from elsewhere.

For a targeted sensitivity check, we omit in turn each of the 9 villages containing any Upper-caste or BC landless recipient and reoptimise the full and pooled models on the remaining villages. Every omission leaves sixteen-group coverage at 75 or 76 villages and the cap-100 outside ceiling at Rs. 2,581. The corresponding ceilings also remain unchanged for the original eight-group rule, the Section 4-aligned rule and complete caste equality. Their differences from the sixteen-group ceiling therefore survive every single-village omission in this set. This check limits the concern that one of these villages alone drives the reported comparison; it does not resolve sampling uncertainty or establish a precise multiplier for a sparsely populated cell.

B.7.11 Compensation, recognition and robustness

For each village, $D_v = n_v^{-1} \sum_i [-g_{iv}]_+$ and $G_v = n_v^{-1} \sum_i [g_{iv}]_+$ measure compensation required and winners' gains. They satisfy $G_v - D_v = S_v$. The tables report equal-village averages of D_v, G_v, and $[D_v - G_v]_+$; the last quantity preserves local financing constraints. Financial feasibility does not establish observed compensation. Section 5.3 reports the available payment evidence; internal transfers would require both recipient credits and payer debits.

Table B-28: Reported influence: economic positions and alternative definitions

A. Caste contrasts within economic positions, primary sample	No farmland No profit	Farmland No profit	No farmland Profit	Farmland Profit
Upper-caste minus SC/ST	2.4	12.7**	−15.5	24.4**
	(6.7)	(5.2)	(14.2)	(10.8)
BC minus SC/ST	4.8	0.7	23.4	33.5***
	(6.0)	(4.4)	(15.9)	(10.2)
EBC minus SC/ST	0.0	−0.7	15.8	4.9
	(3.7)	(4.6)	(10.5)	(11.6)

B. Outcome and linkage sensitivity, controlling for economic position	Any influence		Some or a lot	
	Same respondent	All linked	Same respondent	All linked
Upper-caste minus SC/ST	11.8***	11.4***	11.0***	10.6***
	(4.0)	(3.9)	(3.6)	(3.6)
BC minus SC/ST	3.7	3.1	5.5**	5.0*
	(3.3)	(3.4)	(2.7)	(2.7)
EBC minus SC/ST	0.9	0.9	3.1	3.3
	(2.9)	(2.9)	(2.7)	(2.7)
Joint caste test: p-value	0.011	0.014	0.014	0.024
Households	2,611	2,624	2,611	2,624
Villages	126	126	126	126

Notes: Entries are ppt differences from SC/ST households. Panel A reports caste contrasts within four groups defined by farmland ownership and receipt of positive mining profit, using caste-by-group interactions and the same-respondent sample. The outcome equals one for a little, some or a lot of reported influence and zero for none. Panel B includes caste and economic-position indicators. Columns (1)–(2) use any influence; columns (3)–(4) use an indicator equal to one for some or a lot of influence and zero for a little or none. "Same respondent" requires the same person to answer the household and community surveys; "all linked" permits different respondents. Missing or uncertain influence responses are excluded. All regressions include village fixed effects. Standard errors, clustered by village, are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

For a common cost discount, replace the household account by $\widetilde{g}_{iv}(\kappa) = \Pi_{iv} - \kappa C_{iv}$. With positive mean cost, equal-weight compatibility requires

$$\kappa \leq \kappa_v^* = \frac{\overline{\Pi}_v}{\overline{C}_v}. \tag{B.15}$$

Zero-cost cases are evaluated directly. The median threshold is 0.16, and counting half the reference costs gives nonnegative surplus in 42 villages. These are valuation sensitivities, not estimates of underrecognition: crop losses already record losses respondents attribute to mining. A common proportional discount also differs from selected households failing to attribute particular harms. Appendix B.7.12 examines that narrower possibility using experience and attribution responses.

Table B-30 repeats the sixteen-group calculation for active sites, a common flood attribution share from Section 4 instead of the river-specific shares (stacked, 24.5%, or interaction-weighted, 16.8%), the addition of annualised flood-repair spending attributable to mining, and reported groundwater costs counted in full rather than at mining's share. Each scenario uses households with the information needed for that account.

The reported calculations condition on the measured sample and valuation choices; they are not sampling confidence regions. Political multipliers are partially identified compatibility pa-

Table B-29: Caste diagnostics: linkage coverage and cell support

A. Household linkage

Caste	Account	Linked	Same respondent valid influence	Coverage (%)
Upper-caste	835	440	433	51.9
BC	1,655	844	824	49.8
EBC	1,589	793	775	48.8
SC/ST	1,214	593	579	47.7

B. Economic cells

Caste	Position	Households	Villages	Primary influence sample
Upper-caste	No farmland, no mining profit	112	58	63
Upper-caste	Farmland, no mining profit	653	87	336
Upper-caste	No farmland, mining profit	3	3	3
Upper-caste	Farmland, mining profit	67	30	31
BC	No farmland, no mining profit	181	66	92
BC	Farmland, no mining profit	1,358	110	671
BC	No farmland, mining profit	7	6	3
BC	Farmland, mining profit	109	49	58
EBC	No farmland, no mining profit	816	106	406
EBC	Farmland, no mining profit	639	110	302
EBC	No farmland, mining profit	69	35	32
EBC	Farmland, mining profit	65	37	35
SC/ST	No farmland, no mining profit	624	114	285
SC/ST	Farmland, no mining profit	448	103	226
SC/ST	No farmland, mining profit	92	43	43
SC/ST	Farmland, mining profit	50	26	25

Notes: Entries are unweighted household and village counts. "Linked" means a community form with voice answers is linked to the household. The primary influence sample requires a valid influence response and the same respondent in the household and community surveys. Coverage is that primary count divided by the complete-account count within caste. In Panel B, "Villages" counts villages with at least one household in the indicated caste–position cell.

Table B-30: Sensitivity of household accounts and the common weighting rule

	Villages	Mean gain	Equal weights	Common $K(100)$	Outside cap b^*
Main: active and closed-mine villages	126	−738	25	76	2,445
Active villages only	74	−22	21	47	2,329
Common flood share, stacked	126	−713	25	76	2,442
Common flood share, interaction-weighted	126	−606	25	76	2,437
Adding repair spending after floods	126	−845	25	76	2,449
Groundwater losses counted in full	126	−2,063	17	69	10,174

Notes: Gain and outside cap are annual rupees per surveyed household. Means weight villages equally. "Equal weights" counts villages with nonnegative mean gain. $K(100)$ is the maximum number of villages accommodated by one common sixteen-cell rule with a highest-to-lowest multiplier ratio of at most 100. The outside column is the smallest uniform outside ceiling accommodating all villages, optimised over common rules with unrestricted positive multiplier ratios.

rameters. Any sampling extension must project simultaneous uncertainty in the group accounts and the shared flood and groundwater calibrations through the common inequalities, rather than treat a selected optimizer as a prespecified estimate of influence.

B.7.12 Environmental experience and attribution

The survey asks separately about environmental experiences and mining's effects. We compare these responses to identify households reporting an experience after mining began who also report no corresponding effect of mining. Table B-31 covers all 5,330 households in the 126 villages, including households outside the monetary analysis.

Table B-31: Environmental experience and absence of attribution to mining

	Reported experience	Experience, no mining effect	Share of all households (%)	Share of domain costs (%)
Flooding	803	558	10.5	64.4
Crops	834	286	5.4	1.3
Groundwater	629	82	1.5	0.0
Any domain / all costs	–	842	15.8	8.3

Notes: The sample comprises all 5,330 households in 126 villages. "Reported experience" counts households reporting the relevant experience after mining began. The next column counts those households that also report no corresponding effect of mining. Its share of all 5,330 households is in the third numerical column. The last column divides their costs in the corresponding domain by total costs in that domain, pooling households with equal weight. The combined row counts each household once; its cost numerator includes only the corresponding domains and its denominator includes all costs. The three domains cover the costs in the household account; road accidents, road damage, and dust and pollution are not in the account. Flood and groundwater costs use the river-specific attributable shares. Missing or uncertain attribution responses are excluded from the no-effect counts.

Across domains, 842 households (15.8%) report an experience without attributing a corresponding effect to mining. Including every household with recorded experience but an unclassified attribution answer raises this number to 858 (16.1%; Table B-33). This alternative changes the treatment of missing attribution answers among households with known experience; it does not resolve missing experience or establish that any household's attribution is mistaken.

Flooding illustrates why the distinction matters. The 558 households reporting a flood after mining began but no mining-related increase in flood risk bear 64.4% of the flood costs assigned using the river-level calibration. Their answers need not be incorrect: an estimated increase in average flood risk does not establish that mining caused a particular household's flood. The monetary measure can therefore assign a mining-related cost to a household that does not itself attribute greater risk to extraction.

To assess the financial scale, we count only costs in the domains where a household reports an experience without attributing an effect to mining, counting each component once. These selected components represent 8.3% of all costs when households are pooled, as in Table B-31.

Table B-34 restricts this comparison to the 5,293 households used in the monetary analysis.

For these households, giving villages equal weight puts the selected costs at 9.1% of all costs. Flooding itself contributes 13.9% of total costs under this latter weighting, so a large share of flood costs need not represent a large share of all environmental losses.

Giving villages equal weight, removing every selected component for these 5,293 households would raise average annual net gain per household by Rs. 238, from Rs. −738 to Rs. −500. This is an extreme sensitivity calculation. For the non-flood losses reported as mining-related, a separate no-effect answer is a disagreement across questions with different framing or recall periods; it does not independently justify discarding the monetary loss. We therefore retain the measured-cost benchmark. Appendix B.7.11 reports a separate sensitivity to a uniform cost discount.

The change in the sample mean also does not determine how many villages would have non-negative surplus or political support. Village surplus depends on where the omitted costs occur; the political balance additionally depends on the multipliers of the households bearing them (Equation B.18). The responses do not quantify actual differences between perceived costs and the monetary benchmark. They qualify the behavioural interpretation of measured stakes but do not by themselves justify revising the baseline village calculations.

Construction. The attribution comparison retains all 5,330 households in the 126 villages and separately reports the 5,293 households in the unchanged monetary-account sample. It uses the same village mining-start dates and experience definitions as Section 5. A missing response, an inapplicable question, or an unresolved date is left unclassified rather than interpreted as absence of experience.

Flood experience is any reported flood affecting the village, house or fields in an observed year at or after mining's start, within the 2011–25 recall history. A household with at least one observed post-start year and no flood in those years is classified as having no reported post-start flood. With no observed post-start years, its history is unclassified. Table B-32 reports the full cross-tabulation. Excluding the start year provides the stricter timing sensitivity in the analysis outputs. Flood experience uses all observed post-start years, whereas the monetary flood-cost component retains the main account's 2021–25 window and river-specific attributable shares.

Table B-32: Post-start flood experience and attribution to mining

Post-mining flood experience	No attributed increase	Some attributed increase	Unclassified	Total
Reported flooding after mining began	558	239	6	803
No reported flooding after mining began	3,709	668	11	4,388
Flood history unavailable	93	40	6	139
Total	4,360	947	23	5,330

Notes: All 5,330 surveyed households in the 126 villages. Attribution refers to whether mining increases flood risk. "Some increase" includes a little, somewhat or a lot; missing and uncertain answers are unclassified. Flood experience requires a reported flood in a year at or after the recorded mining start.

For the other domains, the experience measures refer to 2021–25: worsening farm income relative to 2016–20 among households farming at survey time, and borewell deepening among

borewell users. We retain the same response categories and routing as Section 5.4. The entire window must be at or after mining's recorded start. This holds in all but one village, which began mining in 2022; its households stay in the roster but are timing-unclassified for these experiences because the survey does not locate them within the five-year window. The crop and groundwater measures are proxies for the corresponding environmental harms, rather than independent monetary damage estimates.

The survey asks separately about mining's effect on flooding, crop yields and groundwater, and combines roads, dust and accidents in one attribution response. The household account leaves out road accidents, road damage, and dust and pollution, so the comparison covers the three domains whose costs the account includes.

Let $X_{id} = 1$ indicate recorded post-start experience in domain d, and $A_{id} = 0$ a valid response that mining has no effect in that domain. Define

$$M_{id} = 1\{X_{id} = 1,\ A_{id} = 0\}, \qquad M_i = \max_d M_{id}. \tag{B.16}$$

Unclassified responses do not satisfy this definition. The domain household share is $N^{-1}\sum_i M_{id}$ and the combined share is $N^{-1}\sum_i M_i$, so overlapping domains never double count a household. Among households with recorded experience, allowing every unclassified attribution response to be a zero-effect response gives a further response-completeness bound. It does not resolve missing experience or prove that any response is erroneous.

Table B-33: Coverage of the experience–attribution comparison

	Experience known	Not applicable	Timing unresolved	Other unknown	Attribution unknown	Candidate ceiling
Flooding	5,191	0	0	139	23	564
Crops	3,817	1,347	30	136	61	291
Groundwater	2,733	2,501	30	66	62	91

Notes: All 5,330 households. The four experience-status columns are mutually exclusive and partition the household sample. Farming and borewell questions have domain-specific routing. "Attribution unknown" counts unclassified attribution responses across the entire sample and can overlap any experience status. The candidate ceiling sums households with recorded experience who report no attributed effect and those with recorded experience whose attribution response is unclassified.

The three monetary domains partition the reference account: crop losses, groundwater costs at mining's share, and attributed flood losses. Denote these nonnegative components by C_{id}, with $\sum_d C_{id} = C_i$. The matching cost shares are

$$L_d = \frac{\sum_i M_{id} C_{id}}{\sum_i C_{id}}, \qquad L = \frac{\sum_i \sum_d M_{id} C_{id}}{\sum_i C_i}. \tag{B.17}$$

The combined numerator includes only a household's flagged components. Including all costs borne by households flagged in any one domain would answer a different question and overstate this matching-cost measure. Pooled shares weight households equally. For comparison with the main equal-village account, we first average the numerator and denominator contributions within

each village and then take the ratio of their sums across villages. This is not an average of village-specific percentages.

Table B-34: Experience and attribution in the monetary-account sample

	Experienced harm	No attributed effect	Household share (%)	Matching cost share (%)
Flooding	801	557	10.5	64.4
Crops	829	284	5.4	1.3
Groundwater	623	79	1.5	0.0
Any domain / all costs	–	838	15.8	8.4

Notes: The sample comprises 5,293 households with complete monetary accounts across all 126 villages. "Experienced harm" counts households reporting the relevant environmental experience; "No attributed effect" counts those also reporting no effect of mining in that domain. "Household share" is the latter count as a percentage of this sample. "Matching cost share" is the percentage of the corresponding reference cost borne by these households, pooling households with equal weight. The combined row counts each household once and includes costs only in domains where it reports harm without attributing an effect to mining. Flood and groundwater costs use the river-specific attributable shares used in the household account.

An illustrative account removes every matching component, $g_i^{\text{omit}} = g_i + \sum_d M_{id} C_{id}$, and reports the resulting equal-village mean. This places the largest possible reduction on these recorded components for the flagged households. It does not impute a missing cost or estimate what households actually perceive. In particular, non-flood monetary losses already explicitly attribute damage to mining. A positive matching monetary loss alongside a zero-effect response is a disagreement across questions, whose framing and recall periods differ, rather than independent proof of unrecognised damage. The same interpretation limits the financial shares in both tables.

In the political model, a specified reduction $\Delta C_{iv} \geq 0$ in perceived costs changes the local index by

$$\widetilde{P}_v(h) - P_v(h) = \frac{\sum_i h_{k(i)} \Delta C_{iv}}{\sum_i h_{k(i)}}. \tag{B.18}$$

Thus the political effect depends on both the monetary losses omitted and the group multipliers of the households omitting them. Household prevalence alone cannot determine it. The attribution responses do not identify ΔC_{iv} or a new set of political weights; the descriptive comparison informs the interpretation of the baseline compatibility results.