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From State to Community: Forest Land Rights and Forest Conservation in India

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ABSTRACT

This paper examines the impact of India's landmark Forest Rights Act (FRA), which granted indigenous forest-dwelling communities legal rights to manage and protect forests, on the incidence of forest fires. Combining high-resolution satellite fire data with a village-level panel, we exploit pre-reform variation in forest cover in a difference-in-differences framework to identify the causal impact of the FRA on the occurrence and intensity of forest fires. We find that, following FRA, villages with greater forest cover experienced significant reductions in the likelihood and severity of fires. District-level data on the actual distribution of forest land titles corroborate these results. We further show that the decline in forest fires is accompanied by broader environmental improvements, including reductions in PM2.5 concentrations and burned area, highlighting the ecological gains from community-based forest governance.

Keywords: Forest land rights, Property rights, Forest Fires, Environment, Common pool resources, Forest governance, Satellite data

JEL Code: Q15, Q23, Q54, O13, H41, K11

From State to Community: Forest Land Rights and Forest Conservation in India

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Abstract

This paper examines the impact of India's landmark Forest Rights Act (FRA), which granted indigenous forest-dwelling communities legal rights to manage and protect forests, on the incidence of forest fires. Combining high-resolution satellite fire data with a village-level panel, we exploit pre-reform variation in forest cover in a difference-in-differences framework to identify the causal impact of the FRA on the occurrence and intensity of forest fires. We find that, following FRA, villages with greater forest cover experienced significant reductions in the likelihood and severity of fires. District-level data on the actual distribution of forest land titles corroborate these results. We further show that the decline in forest fires is accompanied by broader environmental improvements, including reductions in PM2.5 concentrations and burned area, highlighting the ecological gains from community-based forest governance.

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1 Introduction

Well defined property rights are fundamental for economic development as they facilitate improved investment and productivity while insecurity of tenure can result in underinvestment in resource management (Banerjee et al., 2002a; Besley, 1995; Besley and Ghatak, 2010; Field, 2005; Galiani and Schargrodsky, 2010). In the same vein, property rights are essential to how natural resources are managed and conserved, however, property rights over common pool resources are seldom clearly defined with competing claims between central authorities, traditional users and industry. In the absence of clearly defined rights, common-pool resources often suffer from the risk of expropriation and over-exploitation (Hardin, 1968)[1]. In this paper, we study the impact of a landmark forest rights legislation in India, Forest Rights Act (FRA), that vested rights over forest with traditional forest dwellers on the quality of forest cover and extent of forest degradation.

Implemented in 2008, FRA was a unique property rights legislation that transferred a mix of individual and communal property rights over forests to forest dwellers. Individual rights gave forest dwellers the right to own and cultivate forest land and community rights recognised the rights of forest dwelling communities to protect, conserve and manage forest resources using their traditional ecological knowledge. While there have been academic discussions on appropriateness of private versus government ownership and individual versus communal ownership of public goods, (Besley and Ghatak, 2001, 2010), an influential body of work has highlighted that common property resources when managed by local communities can result in sustainable environmental outcomes (Agrawal and Ostrom, 2001; Gibson et al., 2000; Ostrom, 1990, 2009). As the primary users of natural resources, these communities use their understanding of local ecosystems and customary governance in setting up rules for use and protection of these resources. This positions them as critical stewards of effective community management of natural resources (Daurio, 2025). A large scale systematic empirical investigation of this is, however, limited. It is therefore useful to examine whether granting of forest management rights under FRA can

[1]This has been referred to as the 'tragedy of commons'.

impact the occurrence and intensity of forest fires, which are a major risk faced by forests.

We focus on forest fires, rather than standard satellite-derived tree cover measures, as a proxy of quality of forest cover for several reasons. First, tree cover measures capture the quantity of vegetation but not its ecological quality - afforestation drives by the Forest Department, which tribal communities have historically opposed, often involve non-native species that look similar to native forests in satellite imagery but are ecologically distinct and may not be valued by communities in the same way. Fire incidence, by contrast, reflects active community protection of ecologically meaningful forest cover. Second, fire prevention responds to governance changes with a much shorter lag than a tree cover based measure, making it a more sensitive indicator of the behavioral changes induced by FRA. Third, forest fires are a direct cause of forest degradation and globally, a total of 152 Mha of tree cover has been lost to fires between 2001 and 2024 (Global Forest Watch). The ability of forests to resist such events is a key marker of ecological resilience. Forest fires can also limit the ecological and socio-economic benefits that forests offer (Baker and Spracklen, 2019; Smith et al., 2023; Gatti et al., 2021; Waring et al., 2020; Johnson et al., 2013) and so reducing fire incidence has immediate ecological value independent of its use as a proxy (Finlay et al., 2012; Sanderfoot et al., 2022; Singh and Dey, 2021).

The study focuses on the state of Odisha to conduct the empirical analysis. There are three main reasons for this: First, Odisha has a substantial forest dwelling population - as per the population census of 2011, 23% of the total population is constituted by Scheduled Tribes (STs), the major forest dwelling indigenous community of India, much higher than the national average of 8%. Second, Odisha is one of the few states that has been proactive in FRA implementation (see Table A.1 in Appendix). Third, Odisha is the only state that has made district-level data on the distribution of forest rights titles publicly available. This data allows for a more granular and credible analysis of the relationship between community forest governance under the FRA and fire-related outcomes.

We make use of high resolution satellite data on forest fires from the Fire Information for Resource Management System (FIRMS) provided by the National Aeronautics and Space Administration (NASA) to obtain information on fire events in Odisha over the period 2003-2019. We also make use of forest cover data from the Socioeconomic High-resolution Rural-Urban Geographic (SHRUG) database. The use of satellite data allows us to conduct the analysis at a much granular (village) level. We use the baseline cross-sectional variation in forest cover across villages that captures the exposure to FRA [2] along with timing of implementation of FRA to identify the differential impact of the Act on forest fire. In other words, we compare the evolution of forest fires before and after FRA in villages with high and low forest cover in a difference-in-differences framework.

Our results suggest that the implementation of the FRA led to a significant decline in the incidence and intensity of forest fires in Odisha. Post-FRA, a movement from a village with no forest cover to one fully covered by forest is associated with about a 6.5 percentage point decrease in the probability of a fire event and a reduction of 0.55 fire events per km^2 of forest area. These correspond to declines of around 31% and 56% relative to the pre-FRA mean values. FRA also results in a significant decline in the intensity of forest fires, with Fire Radiative Power (FRP) declining by 1.62 units, representing a decline of 29%.

We provide suggestive evidence against differential pre-trends in fire outcomes across villages with varying levels of forest cover. In addition to this, we make use of district-level FRA titles data to capture actual implementation intensity and find that both the potential of the Act and its actual implementation intensity matter in reducing fire outcomes. We find that these results hold across the granting of both community and individual forest rights.

A number of robustness tests are also performed including the inclusion of district-year fixed effects, using an alternative year for capturing baseline forest cover across villages, and restricting our analysis to fire prone months and fire prone villages. We also perform placebo tests to confirm that the observed reductions in fire events stem

[2] Lee and Wolf (2018) find that forest cover is positively and significantly associated with the rate of title distribution under FRA.

from forest fires and not other vegetation fires.

Since forest fires also increase the concentration of PM 2.5 in the air and consequently increase air pollution, we expect the reduction in forest fires post FRA implementation to improve other environmental outcomes. Encouragingly, our results show that both PM2.5 concentrations and the proportion of burned areas decreased as a result of the FRA. This demonstrates that FRA influenced not only the frequency and severity of forest fires but also produced significant environmental co-benefits.

The rest of the paper is organised as follows: Section 2 provides a review of related literature. Section 3 presents the background on the FRA. The data and methodology are presented in Section 4. Section 5 and Section 6 present the results and the robustness tests performed. Section 7 presents results on the environmental consequences of forest fire reduction under FRA, and Section 8 concludes.

2 Literature Review

Our paper contributes to a large literature that evaluates the impact of property rights and tenure security on a range of economic outcomes. The literature suggests that well defined property rights result in improvement in land investments (Besley, 1995; Field, 2005, 2007; Galiani and Schargrodsky, 2010; Subramanian and Kumar, 2024), productivity (Banerjee et al., 2002b), income growth and asset accumulation (Deininger and Nagarajan, 2009) and poverty and inequality reduction (Besley and Burgess, 2000; Besley et al., 2016).

More specifically, our paper contributes to the body of literature that has examined the impact of transferring forest land rights to indigenous communities on environmental outcomes. A majority of these studies focus on Latin America and find mixed impact. Baragwanath and Bayi (2020) and Pacheco and Meyer (2022) find reduction in deforestation under local community management of forest in Brazil. Vergara-Asenjo and Potvin (2014) find that lands which were indigenously claimed in Panama displayed the highest level of forest cover and prevented deforestation most effectively. In Colombia, Romero and Saavedra (2021) and Vélez et al. (2020) document reduced deforestation following communal titling. Blackman et al. (2017) find that the granting of titles to indigenous communities resulted in a reduction in forest clearing in the Peruvian Amazon. Additionally, Ellis and Porter-Bolland (2008) show that community management of forests outperforms protected areas in forest conservation in Mexico. However, Lipscomb and Prabakaran (2020) and BenYishay et al. (2017) find no impact of formalisation of land rights of indigenous communities on deforestation in the Brazilian Amazon.

The work focusing on Asia and Africa has broadly found positive effect of property rights over forest on environmental outcomes. Persha et al. (2011) find that local forest user participation increases tree species diversity and subsistence livelihoods in East Africa and South Asia. In Uganda, Walker et al. (2025) show that insecure tenure systems resulted in increased tree extraction while enhancement of security through land certification reduced this effect. Devolution of forest tenure rights to households in China enhanced labour and capital investments in forest plots (Yi, 2023) and forest vegetation quality and productivity (Zhou et al., 2025). Chankrajang (2019) finds that granting of forest community rights improved environmental outcomes viz. enhancement of forest cover and reduction in the frequency and intensity of fires in Thailand. Rustagi et al. (2010) show that forest user groups with robust local monitoring mechanisms achieved better forest management results. Baland et al. (2010) find that forests managed by local communities in Uttarakhand, India were less lopped in comparison to state protected and open access forests. Somanathan et al. (2009) find that village councils managed forests in Uttarakhand were just as well conserved as those under state management, albeit at a lower cost.

Our work also contributes to a small body of work studying the role of FRA in forest management which mostly constitutes of small sample case studies focusing on a single district. Chand and Behera (2023) find that FRA was associated with improved forest conservation in Bankura district of West Bengal. Somanathan et al. (2013) study the impact of FRA in Udaipur, Rajasthan and find that the Act had negligible impact on deforestation and forests surrounding titled lands witnessed some degradation. While not directly evaluating the impact of FRA, there are existing studies that document that political representation for STs at different levels of government have been instrumental in increasing tree cover and reduced deforestation (Agarwal et al., 2023; Gulzar et al., 2024).

We contribute to these strands of literature by providing causal evidence on how forest rights granted under FRA can impact forest conservation outcomes, using forest fires as a proxy. In doing so, we highlight the way in which statutory land rights can shape forest management practices and enhance ecological resilience.

3 Background

3.1 Forest Rights Act

The colonial Forest Acts of 1865 and 1878 established government control over forest restricting customary access and use by ST and other local communities who had traditionally depended on forests for subsistence. This along with the wildlife protection and forest conservation legislations [3] enacted in the post-independent India that viewed conservation as the responsibility of central and state government forest departments strengthened government control and excluded forest dwelling communities from participating in any decision making related to forest management (Kumar et al., 2005; Kumar and Kerr, 2012).

The National Forest Policy of 1988 that introduced Joint Forest Management (JFM) marks a shift in the approach of the government towards forest management. JFM policy recognized the role that tribal communities play in forest management and conservation. However, the policy lacked clear guidelines for devolving management to the local community and state forest departments continued to dominate decisions regarding forest management. The existing evidence shows that the policy failed to provide any welfare benefits to the participating communities primarily owing to poor implementation (Damodaran and Engel, 2003; Kumar, 2002).

[3] For example: Wildlife Protection Act of 1972 and Forest Conservation Act of 1980

The increasing demand for the recognition of tribal communities rights over forests ultimately led to the enactment of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (also commonly called as Forest Rights Act or FRA). It was a landmark legislation that recognised both individual and community rights of traditional forest dwellers. Implemented in 2008, the Act gives traditional forest dwellers Individual Forest Rights (IFRs) to claim up to 4 hectares of forest land to live in and cultivate. Additionally, FRA allows for Community Rights (CRs) to own, collect, and use minor forest produce (excluding timber) and the right to use grazing lands and water bodies.

The Act also provides for Community Forest Rights (CFRs) wherein, Section 3(1)(i) of the Act explicitly recognises the right of tribal and traditional forest-dwelling communities to protect, regenerate, conserve, or manage community forest resources that they have historically safeguarded and conserved for sustainable use. Once community forest rights are formally recognized, legal ownership and governance authority over these forests shift from the Forest Department to the Gram Sabha (village assembly). The Act provides the Gram Sabha the power to manage and conserve resources within the community's forest resource boundaries using local customs, knowledge systems, and practices. The Act places forest management in the hands of the local communities and thus has the potential to democratise and decentralise forest governance (Kumar, 2002).

The process of rights recognition under the FRA starts with the Gram Sabha which calls for the filing of title claims. The Gram Sabha also appoints the Forests Rights Committee (FRC) which receives these claims and then undertakes their initial verification. The verified claims are then forwarded to the Sub-District Level Committee (SDLC) which cross checks these claims filed and then forwards them to the District Level Committee (DLC) which has the final authority to grant titles.

3.2 Role of Tribal Communities in Preservation of Forest Resources

Tribal communities have historically been involved in sustainable practices surrounding forests. This is rooted in their dependence on forests for livelihood and subsistence, specially in Odisha, (Ota et al., 2020). Beyond this economic significance, forests shape the cultural and religious identity of tribal communities. Odisha in particular has a large number of sacred groves, which are patches of forests dedicated to deities and ancestors, largely concentrated in tribal districts and worshiped by tribal communities. Given this cultural and spiritual significance, these areas have historically been conserved and managed by tribal communities (Ormsby and Bhagwat, 2010; Rath and Ormsby, 2020).

The tribal communities engage in a number of sustainable practices to ensure health of the forest ecosystems. For example, controlled early season prescribed fires are used by tribal communities to avoid dense leaf litter buildup, replenish soil nutrients, and help in regeneration of plant and tree development. These low intensity fires help in reducing the risk of uncontrollable late season fires (Finney, 2001). Tribal communities also engage in shifting cultivation which helps in maintaining soil fertility and vegetation regeneration. These communities leave the land fallow for 10 years or more after cultivation which plays an important role in regenerating forests.

An example of the potential of FRA and its impact on forest conservation comes from the Similipal Tiger Reserve in the Mayurbhanj district of Odisha[4]. Once community forest rights were granted, many villages in the district jointly created a collective organisation which assists Gram Sabhas in establishing and enforcing guidelines for forest conservation. In particular, the practice of *thengapali*, which refers to groups of villagers carrying *thengas* (bamboo lathis) while patrolling forests on a regaular and rotating basis, started being undertaken for the surveillance of forests. Individuals engaged in illegal activities inside the community forest boundaries such as logging or poaching began to be fined and penalised, with higher fines imposed for the cutting

[4] https://fra.org.in/index.php/Welcome/CaseStudies

of valuable tree species. In addition to this, local tribal communities have resisted external interventions that can threaten the ecological balance of their forests. This includes restricting entry of outsiders and not allowing the Forest Department to plant non-native species of plants that can be invasive to the traditional plants. All this has resulted in local forest regeneration and recovery of wildlife habitats. There has also been no reporting of forest fires within the reserve forest as community members play an active role in fire prevention and fire control by responding immediately when fires occur, clearing dry vegetation and dry leaves to create firebreaks, and extinguishing flames manually before Forest Department officials are even notified or arrive.

These community-driven governance methods demonstrate how sustainable forest management can be facilitated by embracing the stewardship role of tribal groups and the recognition of community forest rights under the FRA.

3.3 Odisha and FRA Implementation

Given Odisha's substantial forest cover (37%) and sizeable ST population (23%), the scope for implementation of the Forest Rights Act (FRA) is considerable. [5]. Soon after the notification of the Act, the FRCs and the DLCs were set up in the state by 2008. In several districts, such as Mayurbhanj and Kandhamal, dedicated institutional mechanisms and support systems have been developed to facilitate effective implementation (Ministry of Tribal Affairs, Government of India). These efforts are gradually being extended to other districts and administrative units. In parallel, the Government of Odisha has issued numerous circulars and administrative orders to streamline and strengthen implementation. Taken together, these initiatives underscore the state's proactive approach to the FRA. This is reflected in outcomes: by 2019, Odisha recorded the highest rate of title distribution among Indian states, at approximately 70%, compared to the national average of 47% (see Table A.1 in the Appendix).

[5]The average forest cover in India is 22% and STs constitute 8% of the population

4 Data and Methodology

4.1 Data

We compile multiple datasets for our analysis:

Forest Fires

We obtain information on fire incidents using satellite data from the Fire Information for Resource Management System (FIRMS) developed by the National Aeronautical Space Agency (NASA). It provides global, real-time information on active fires based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. Fire incidents are recorded as pixels where each pixel is one square kilometer (1 km X 1 km) in size [6]. Each of these pixels is geo-referenced with a latitude and longitude identifier, enabling precise spatial identification of fires.

Fire data in FIRMS are available from November 2000 onward. However, consistent and comprehensive coverage is available only from 2003, following the full operation of both the Terra and Aqua satellites.[7] Our analysis thus uses data from 2003 onward to ensure uniform satellite coverage.

For each fire incident, information is reported for the type of fire incident- vegetation fire, active volcano, other static land sources, or offshore (Giglio et al., 2021). For this study, we retain information on only those fire incidents which were vegetation based (in a robustness test, we show that the type of fire events we work with are predominantly forest fires and not other kind of vegetation fires). Further, each fire incident is accompanied by several key attributes, including the date and time of the event, its Fire Radiative Power (FRP) which is a physical measure of fire intensity, and a confidence score (ranging from 0 to 100%) that reflects the likelihood of the event being a true fire. We use FRP to characterize the intensity of fire events in our analysis.

[6] Singh and Dey (2021) have also used this dataset to identify forest fires.

[7] The Aqua satellite became operational in July 2002, while earlier observations were recorded solely by the Terra satellite.

Finally, to link fire incidents to villages, we overlay the fire data on the 2011 village-level Census shapefile, enabling us to assign fire activities to specific villages across Odisha. The number of fire events in a village is computed by counting the number of vegetation fire pixels. To account for differences in forest area across villages, we normalise this count by forest cover area of the village as measured in 2001 census (in km^2).

We compute three measures of forest fire: (i) Whether any fire event occurred in any given village-year, (ii) Count of fire events per km^2 of 2001 forest cover in a village-year, (iii) Average annual FRP of all fire events in a village-year.

Forest Cover

Forest cover data is obtained from the Socioeconomic High-resolution Rural-Urban Geographic (SHRUG) dataset (Asher et al., 2021; Dimiceli et al., 2015). This dataset is obtained from the Vegetation Continuous Fields (VCF) which is also a MODIS product by NASA that assesses tree cover at a 250m resolution. VCF is forecasted using a machine learning algorithm that is based on broad spectrum satellite photos. The SHRUG database provides annual forest cover information for the period 2001-2020 across villages in India. Using this, we obtain the proportion of area across villages in Odisha that is covered with forests for the year 2002[8].

District Level Titles

Odisha is the only state in India for which district level data on the implementation of the FRA is publicly available. We draw on official reports released by the Government of Odisha, which provide detailed information on the progress of FRA implementation across districts. These reports, available from 2009 onward, document the number of individual and community claims filed at the level of the FRC, as well as the number of these claims that have been finally approved by the DLC.

Other Variables

Our analysis also incorporates a range of control variables to account for potential

[8] One year preceding our main study sample period

confounding factors. We use village level night light data provided by the SHRUG database to proxy for economic activity across villages over time (Asher et al., 2021; Henderson et al., 2011).

We also include climatic controls using historical gridded data from the ERA5 reanalysis dataset, which is available at the World Bank's Climate Change Knowledge Portal (CCKP). The ERA5 dataset provides global climate estimates from 1950 onward at a spatial resolution of $0.25 \times 0.25°$. Using this dataset, we compute the average annual mean temperature at the district level over our study period. Similarly, we calculate average annual precipitation using the same ERA5 data source.

Additionally, we use the same dataset to obtain information on wind patterns, which play a crucial role in both the ignition and spread of fires. The dataset provides information on 10 meter U component and V component of wind[9] from 1940 onward at a resolution of $0.25 \times 0.25°$. We use this to obtain their annual average at the district level.

We do not include these control variables at the village level because the ERA5 dataset resolution is too coarse to capture variation across villages[10].

4.2 Summary Statistics

Figure A.4, that reports the total number of fire instances across all villages in Odisha, suggests increasing trend of forest fires over the years. Figure A.5 show that the FRP of fire occurrences remained relatively stable across all villages over years. Table A.2 reports forest fires pre/post FRA with their statistical significance which again suggests increasing trend. The empirical analysis in the paper examines if forest fires incidents are increasing slowly in areas with higher exposure to FRA.

The average proportion of an area covered with forests in a village in Odisha is

[9]These correspond to the zonal (east-west) and meridional (north-south) wind speeds, respectively.

[10]The spatial resolution of $0.25 \times 0.25°$ corresponds to a resolution of around $25km \times 25km$ while the average village size in Odisha is between 3-4 km^2.

around 0.10. This varies with the minimum forest cover reported for a village being 0 while the maximum being around 0.66. We also report information on the total number of claims filed with the Gram Sabha and approved by the DLC in Figure A.6. The number of claims filed steadily increased from about 327,000 in 2009 to over 630,000 by 2019, while approvals also rose from around 105,000 to 453,000 during the same period. Figure A.7 shows that the rate of approval[11] has been improving steadily over time (from around 30% in 2009 to 70% in 2019), signaling improvement in enforcement of the FRA.

4.3 Methodology

Our empirical methodology leverages the substantial variation in forest cover across villages along with the timing of FRA implementation to estimate the effect of the FRA on fire events in a difference-in-differences framework. The key idea is that the exposure to FRA should be stronger in villages with higher forest cover and thus this variation becomes crucial to identify its impact. This assumption is not implausible as it has been documented that larger forest cover has been associated with higher rates of claim distribution (Lee and Wolf, 2018), further supporting the use of forest cover as a proxy for FRA exposure.

We estimate the following regression equation:

$$y_{vdt} = \beta_0 + \beta_1 forest_v \times post_{t \geq 2008} + \beta_2 X'_{vdst} + \delta_v + \delta_t + \epsilon_{vdt} \tag{1}$$

Here, y_{vdt} denotes the forest fires outcomes for a village v in district d at time t. The variable $forest_v$ is the proportion of forest cover in village v in 2002. We use forest coverage data of 2002 to avoid endogeneity concerns as forest cover of later years would be contemporaneously correlated with FRA implementation. $post_t$ is a binary indicator equal to 1 for years following the implementation of the FRA (i.e., from 2008 onward). X_{vdt} is a vector of control variables, including village-level

[11] defined as the share of titles approved by the DLC out of the total claims filed with Gram Sabha

night-lights and district-level climatic variables-annual average precipitation, annual average temperature, and annual average U and V winds. δ_v denote village fixed effects that partial out time invariant village level factors that are likely to influence the susceptibility of a village to forest fires. δ_t represent the year fixed effects which account for time varying factors that influence forest fires that are common to all villages. The error term is denoted by ϵ_{vdt} and we cluster our standard errors at the district level[12]. Our interest lies in estimating the interaction coefficient, β_1.

The above specification measures exposure to FRA using baseline forest cover variation rather than the actual FRA title disbursement due to lack FRA titles data at the village level. We complement our above methodology by leveraging district level data on FRA title claims and disbursal. Specifically, we use district level data on the number of titles filed at the Gram Sabha and the number of titles subsequently distributed by the DLC. We use these to construct the share of the titles that are eventually approved for distribution out of the total claims filed and estimate the following equation-

$$y_{vdt} = \beta_0 + \beta_1 distributed_{dt} + \beta_2 distributed_{dt} \times forest_v + \beta_3 X'_{vdst} + \delta_v + \delta_t + \epsilon_{vdt} \quad (2)$$

In this equation, all the variables are the same as before and $distributed_{dt}$ is the share of claims that get approved for distribution in district d at time t. Note that this variable takes a value 0 for years preceding 2009. We acknowledge that the $distributed_{dt}$ variable is likely to be endogenous as both title distribution and forest fires can be influenced by time varying district and village level factors. While we address some of these concerns in the robustness checks section, we believe presenting these results would be informative to assess if the impact of the FRA is jointly determined by the availability of forest resources and the actual implementation through title distribution.

[12] Even though our treatment is at the village level, the final approval of titles is done by the DLC and therefore we cluster our standard errors at the district level.

5 Results

The results obtained from estimating equation (1) are presented in Table 1. Column (1) shows that post-FRA, a 10% increase in forest cover is associated with a 0.65 percentage point reduction in the probability of experiencing a fire event, which represents a 30% reduction when compared to the pre-FRA baseline probability. Column (2) examines the impact of FRA on the frequency of fire events normalised by 2002 forest cover (in km^2). We find that with a 10% increase in forest cover is associated with a reduction of 0.05 fire events per km^2 of forest area. This is equivalent to a reduction of around 56% compared to the baseline average. Column (3) presents the impact of FRA on fire intensity. The results show that a 10% increase in forest cover is associated with a reduction in FRP of 0.16 units post-FRA, which represents a decrease of around 28% relative to the baseline FRP.

We also estimate the following events study specification to capture the dynamic impact of FRA and to provide suggestive evidence against differential pre-trends in high vs low forest villages before the implementation of FRA:

$$y_{vdt} = \beta_0 + \sum_{k \neq k_0} \beta_k \left(forest_v \times \text{year}_{t=k} \right) + \beta_2 X'_{vdst} + \delta_v + \delta_t + \epsilon_{vdt} \tag{3}$$

Here, all the notations are the same as before except now we have $forest_v$ interacted with $year_{t=k}$, which is a dummy variable equal to 1 if year $t = k$ and 0 otherwise. k_0 is the omitted year which corresponds to 2003 for our analysis.

Figures 1-3, which report the interaction coefficients, show that except one, none of the pre-FRA interaction coefficients are significant for the three outcome variables. Additionally, the magnitude of the pre-2008 coefficients is much smaller as compared to the magnitude of the coefficients post 2008. This provides suggestive evidence in favour of the parallel trends assumption. Also note that beginning from 2008, which is the year of FRA implementation, we find that a movement to villages with higher forest cover is associated with substantial reduction in fire occurrence and severity. Moreover, these reductions increase in magnitude over time. By 2019, a 10% increase in forest cover corresponds to a 1.4 percentage point reduction in the probability of experiencing a fire event and a decline of 0.08 fire events per km^2 of forest area.

5.1 Title Level Data

In this section, we use information on FRA titles distributed at the district level and report regression results from estimating equation 2 in Table 2. Panel A shows that reduction in forest fires is higher in districts where title distribution rate has been high. We find that a 10% increase in forest cover when accompanied by a complete approval of all claims filed leads to around a 0.9 percentage point reduction in the likelihood of a fire event occurring and a reduction of around 0.08 fires per km^2 of forest cover post-FRA. At the same time such a scenario is also accompanied by a reduction in FRP of around 0.2 units.

The disaggregated results for community and individual titles are reported in Panel B and Panel C, respectively. The coefficients on the interaction term are negative and statistically significant in both the panels and the magnitudes of these effects do not differ significantly, implying that community and individual titles contribute similarly to reducing fire events. Taken together, these results highlight that the implementation intensity (in terms of community titles and individual titles distribution) is important in determining how FRA affects forest fires.

6 Robustness

6.1 District-Year Fixed Effects

Our main specification includes village and year fixed effects to control for time-invariant village characteristics and common shocks across years that are same across all villages. As a robustness exercise, we add district-year fixed effects to our main specification. These fixed effects allow us to account for any time varying shock that is common to all villages within the same district that may impact forest fire occurrence and intensity. These shocks can be political or institutional such as a district being more proactive in fire prevention through new campaigns and programs or by the appointment of district level officials who prioritize forest conservation, or they can be environmental such as changes in soil moisture and biomass growth (Hou, Orth, et al., 2020), among others. These fixed effects also address the concern that districts in Odisha experienced broader political and economic changes during this period (e.g., Maoist insurgency in forested districts, changes in forest department staffing) which could confound our estimates. However, the results with inclusion of district-year fixed effects, which are reported in Table A.3, remain statistically significant and consistent with our main findings.

6.2 Alternative Period of Pre-FRA Forest Cover Data

We have used forest cover data from 2002 as the baseline forest cover to capture variation in treatment intensity across villages. As a robustness exercise, we use forest cover data from 2004 to show that the results are not sensitive to the use of a specific year for measuring baseline forest cover. If anything, 2004 lies closer to the implementation of FRA than 2002 and will capture forest cover conditions before the implementation of FRA more accurately. This exercise alleviates concerns that using forest cover data that has larger temporal distance from the introduction of the FRA may not capture its true effect.

The results obtained by undertaking this exercise are presented in Table A.4. We find that the results remain consistent even with this choice of an alternative year for the baseline forest cover.

6.3 Forest Fire Prone Months

Forest fires are seasonal in nature, with forests being more susceptible to fires during drier months when vegetation moisture is low and leaf litter accumulates. In this subsection, we restrict our analysis to only those months that are the most fire-prone in Odisha. By doing so, the analysis focuses on periods when forest fires are ecologically likely and when community fire management efforts are likely to matter the most.

Including months outside the fire season may capture fires that are unrelated to forest management practices and more likely to be driven by other factors, such as agricultural burning.

According to official reports, forest fire risk is highest during the first half of the year (Odisha Forest Department) in Odisha. Accordingly, we focus on the first six months of each year and aggregate fire events over this six month period for all villages. From Table A.5 we see that while the magnitude of the estimated effects slightly reduce in this specification, they remain statistically significant.

6.4 Restriction to Fire Prone Villages

As an additional robustness check, we restrict the sample to villages that experience at least one fire event during the study period. Estimating these conditional treatment effects help us to see how the FRA affects fire occurrence and intensity in villages that are susceptible to fire events to begin with.

From Table A.6 we see that, in the post-FRA period, among villages that experienced at least one fire between 2003 and 2019, a 10% increase in forest cover is associated with around 3% point point reduction in the likelihood of observing a fire event and a reduction of around 0.3 fire events per km^2 of forest area. In terms of intensity of fire events, such a similar move is associated with a decline of about 0.6 in FRP in the post-FRA period. We observe that restricting the analysis to villages that experienced at least one fire event yields larger estimated impacts compared to the main results, indicating that the FRA's effects are concentrated in villages where forest fires is a real risk.

6.5 Tobit Estimation: Impact of FRA on Fire Events

We observe fire events across 3% of our village-year observations. Since we do not observe any fire events for a large number of village-years, this then leaves us with fire incidence and occurrence variables that have a substantial number of zeros with the remaining observations being positive values. In such a situation, relying on methodology that assumes a continuous outcome variable is not appropriate and therefore we account for the excess zeros in the outcome variable by using a corner solution model, namely, the censored Tobit regression model (Wooldridge, 2010). This model is based on a latent continuous outcome variable where our forest fires outcome is a non-linear function of the latent variable. Since Tobit is a non-linear model, we do not include village fixed effects in our specifications to avoid incidental parameter problem that can lead to our estimates being inconsistent (Lancaster, 2000). Instead, we add district fixed effects in this estimation.

The marginal effects obtained from the Tobit estimation are reported in Table A.7. These results are consistent with our main results and show that with there is a reduction in the occurrence and intensity of forest fires post-FRA, even when the the censoring at zero is accounted for.

6.6 Bootstrapping to Address Small Cluster Count Issue

In our main analysis, we cluster our standard errors at the level of the district to allow for correlation of errors across villages in the same district. The total number of districts in the state of Odisha is 30 and so with this limited number of clusters, the estimated conventional cluster robust standard errors which are based on large sample assumptions may lead to unreliable inference (Cameron et al., 2008). To account for this concern, we use wild bootstrapped standard errors proposed by Roodman et al. (2019). We use wild bootstrapping using 9999 replications with resampling at the district level using Rademacher weights. Figure A.10 shows that estimated effects of the interaction terms continue to remain statistically significant at the 5 percent level across all measures of forest fire incidence and intensity.

6.7 Placebo Test: Lowest Forest Decile

The FIRMS data provides information on vegetation fires based on satellite images that detects thermal anomalies. However, the data does not distinguish between fires occurring in forest areas and those taking place in agricultural land or other types of vegetation cover. One concern is that we may be capturing agricultural fires rather than forest fires. To rule out this concern, we run our main analysis only using villages falling in the lowest decile of forest cover. This acts as a placebo test to assess whether the estimated reductions in fire outcomes reflect changes in forest fires rather than agricultural burning or other non-forest fire activity.

The results obtained from this robustness exercise are presented in Table A.8. We find that the coefficients corresponding to the interaction between FRA implementation and baseline forest cover are statistically insignificant across all measures of fire occurrence and intensity and infact the sign of the three of four coefficients are positive. This exercise reinforces our claim that the observed impact of FRA is not driven by reduction in agricultural fires.

6.8 Heterogeneous Treatment by Forest Cover Decile

As an additional robustness check, we replace the continuous measure of baseline forest cover with multiple discrete variables capturing forest cover deciles. We interact these decile indicators with the post-FRA variable. This approach provides multiple benefits as it not only captures the non-linear effect of forest cover on forest fires but also acts as a test of validity of using forest cover as a measure of the potential intensity of FRA as we should not observe any large reductions in forest fires post-FRA in areas that had low levels of baseline forest cover.

Table A.9 shows that the impact of the FRA on reducing fire incidence and intensity becomes increasingly more pronounced and statistically significant in higher forest cover deciles, particularly from the 5th decile onward. The fact that the impact of the FRA is not just concentrated in the top most forest cover decile rules out any outlier driven effects. Also, as expected, we find no significant effects in the lower forest cover deciles in case of most of the measures (2nd to 4th in case of fire event and FRP).

6.9 Heterogeneity by Elevation and Terrain

Tribal communities have historically resided in mountainous and higher elevation zones which tend to be more remote and less accessible (Ministry of Tribal Affairs, 2013). We therefore expect to see a larger impact in areas with more rugged terrain and higher elevation, where ST population shares are likely to be larger and FRA is likely to have a significant role.

We make use of elevation and terrain data from the SHRUG database to conduct this heterogeneity analysis. Specifically, we re-estimate our main specification separately for villages located above (below) median elevation and above (below) median ruggedness of terrain, allowing us to examine heterogeneity in the impact of the FRA across different topographic contexts. From Table A.10, we find that post-FRA there is a significant reduction in forest fire occurrences and intensity in villages with larger forest cover which are characterised by higher elevation and more rugged terrain. For villages with low elevation and non-rugged terrain, we find no significant impact. The differences in coefficients across these two groups are statistically significant for all outcomes except for the scaled fire event variable indicating that the reduction in fire events and intensity is significantly larger in areas with above median elevation and above median rugged terrain.

7 Environmental Consequences of Forest Fire Reduction

There is extensive evidence that forest fires contribute significantly to air pollution (Burke et al., 2023; Haikerwal et al., 2015; Khadgi et al., 2024; Sastry, 2002; Xie et al., 2020) and to burned area (Boer et al., 2020; Grillakis et al., 2022). Since FRA led to a reduction in the incidence and intensity of forest fires, we also expect to see the positive impact of the Act on other environmental outcomes. In this section, we present evidence of the implementation of FRA on two broad environmental outcomes, PM 2.5 concentration and burned area, both of which are likely to be mediated by frequency and severity of forest fires. This exercise also serves as a check of consistency, as if emissions and burned area remain unchanged, this can raise questions about the main impact we observe on fire events and intensity.

7.1 Particulate Matter 2.5

We quantify the impact of FRA on air pollution by focusing on PM 2.5. We use data on ground level fine particulate matter (PM 2.5) available at the village level from the SHRUG database (Asher et al., 2021; Van Donkelaar et al., 2021). This data is estimated by combining Aerosol Optical Depth (AOD) retrievals that make use of observations from various NASA based satellite instruments. We re-estimate equation (1) and (3) using the annual mean PM 2.5 concentration as the dependent variable. We only focus on those villages that reported fire events during the sample period. Table 3 presents the results where columns (1) and (2) present the aggregate and dynamic effect respectively with the inclusion of village fixed effects[13] and columns (3) and (4) present the aggregate and dynamic impact respectively when only the district fixed effects are included.

Across both specifications, the interaction term is statistically significant in columns (1) and (3), suggesting that areas with greater forest cover experienced reduction in PM 2.5 concentrations post-FRA. The disaggregated year on year estimates are presented in columns (2) and (4) which show that villages with greater forest cover reported lesser mean concentration of PM 2.5 post FRA where this impact sets in from around 2010-11. Assuringly, we do not find any statistically significant interaction coefficients in the pre-FRA period.

7.2 Burned Area

We also quantify the impact of FRA on burned area as its reduction can yield substantial benefits, including preservation of environmental quality, biodiversity and

[13] In this case those villages which report a single fire event over the entire sample period get dropped from the analysis.

avoidance of economic losses associated with fire damage. We use monthly burned area data which is available at a resolution of $0.5° \times 0.5°$ from the Earth System Science Data (Guo et al., 2025). We aggregate this to obtain annual burned area at the district level[14].

As in the previous analysis, we present results restricted to villages that reported fire events. These results are presented in Table 4 where the first two columns display estimates that include village fixed effects, while the final two columns incorporate district fixed effects. The coefficient on the aggregate post-treatment interaction term is negative across both the specifications (but statistically significant in column (3)), indicating that FRA implementation is associated with a (modest) reduction in burned area. The dynamic effects represented in columns (2) and (4) reveal that the reductions in burned area are concentrated in years following FRA implementation in 2008.

8 Conclusion

This paper examines the impact of a landmark forest land rights legislation, FRA, that granted community forest management rights to tribal communities on the incidence and intensity of forest fires. The Act marked a turning point in Indian forest policy by transferring control over protection, conservation, and use of forest resources from state forest departments to local Gram Sabhas, thereby, laying the the foundation for community based forest management. This reform is particularly significant because tribal communities constitute the majority of forest dwellers in India. These communities have historically maintained a symbiotic relationship with forests by depending on them for food and livelihood while also protecting them through traditional knowledge and customary practices.

The analysis focuses on the state of Odisha, which presents an especially appropriate

[14]We aggregate the data to the district level because there are significant missing observations when combining the satellite data with the village level shapefiles owing to the coarse resolution of the dataset.

context due to its substantial forest cover, high proportion of ST population, and strong dependence on forest resources. Using a difference-in-differences methodology and exploiting pre-FRA variation in forest cover across villages in Odisha to capture the potential of the Act, we find that the FRA led to a substantial reduction in both the occurrences and severity of forest fires. The findings from district level FRA titles data also re-enforce the results obtained. Furthermore, we find that post FRA there was a reduction in PM 2.5 concentrations and proportion of burned areas in high-forest regions suggesting that changes in fire activity have translated into meaningful environmental co-benefits.

This paper contributes to ongoing academic and policy debates on whether devolving forest property rights to local communities, as opposed to retaining centralised state control, leads to more sustainable resource use. Our findings highlight that the formal recognition of community rights to manage and protect forests creates strong incentives for sustainable management of forests which translates into improved environmental outcomes. However, we acknowledge that since Odisha is among the best-performing states on FRA implementation, our estimates likely represent an upper bound on the impact of FRA in contexts where implementation remains weak. Our findings thus underscore the importance of combining legal recognition of forest rights with the actual transfer of governance authority to local institutions as powerful mechanisms for improving ecological outcomes. This would ensure that forest conservation is aligned with the knowledge systems and long-term interests of those who depend most closely on these ecosystems. This provides important policy lessons for states in India that are yet to actively distribute claims filed under FRA and countries which have not involved local communities in forest management.

9 Tables

Table 1: **Impact of FRA on Fire Events**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	-0.065***	-0.546***	-1.624**
	(0.019)	(0.102)	(0.600)
Annual Mean Precipitation	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Annual Mean Temperature	0.024***	0.128**	0.665***
	(0.008)	(0.062)	(0.190)
Night Light	0.000	0.001	0.004
	(0.000)	(0.004)	(0.006)
U Wind	0.023	0.241*	0.276
	(0.019)	(0.136)	(0.317)
V Wind	0.012	0.103	0.194
	(0.014)	(0.105)	(0.301)
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.225	0.185	0.161
Baseline (pre-2008) Mean	0.021	0.097	0.568

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

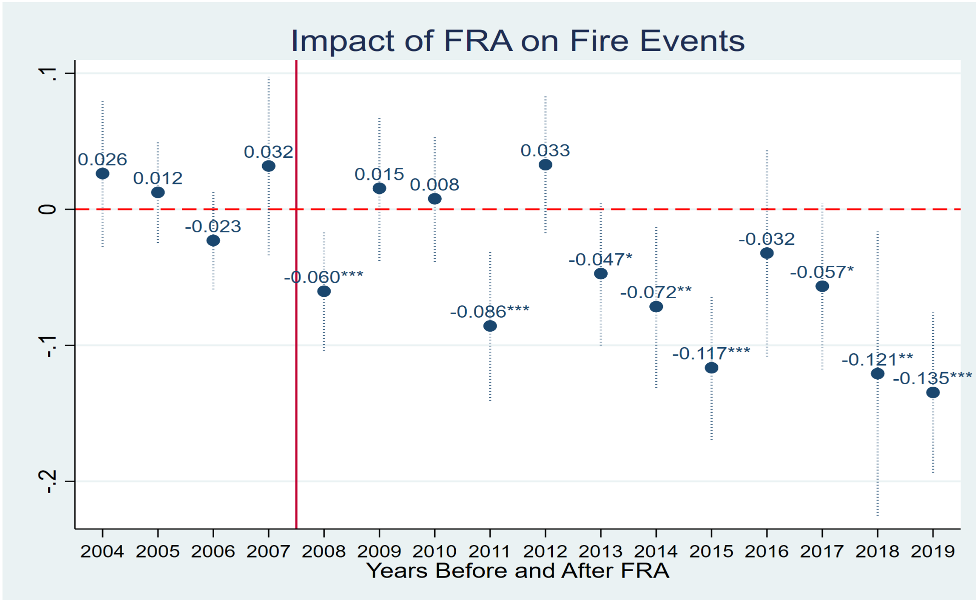

Figure 1: Dynamic Effects: Impact of FRA on Fire Events

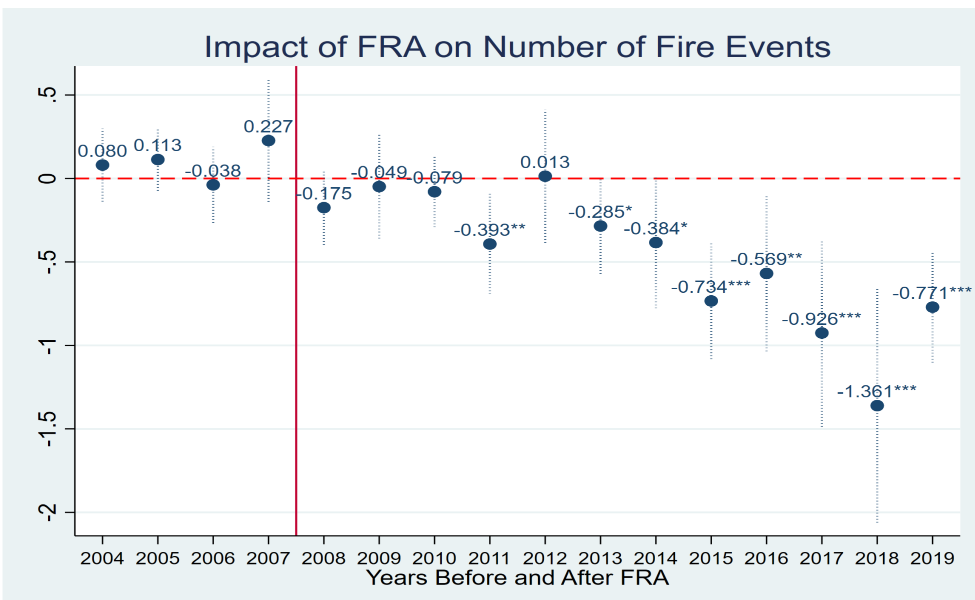

Figure 2: Dynamic Effects: Impact of FRA on Number of Fire Events

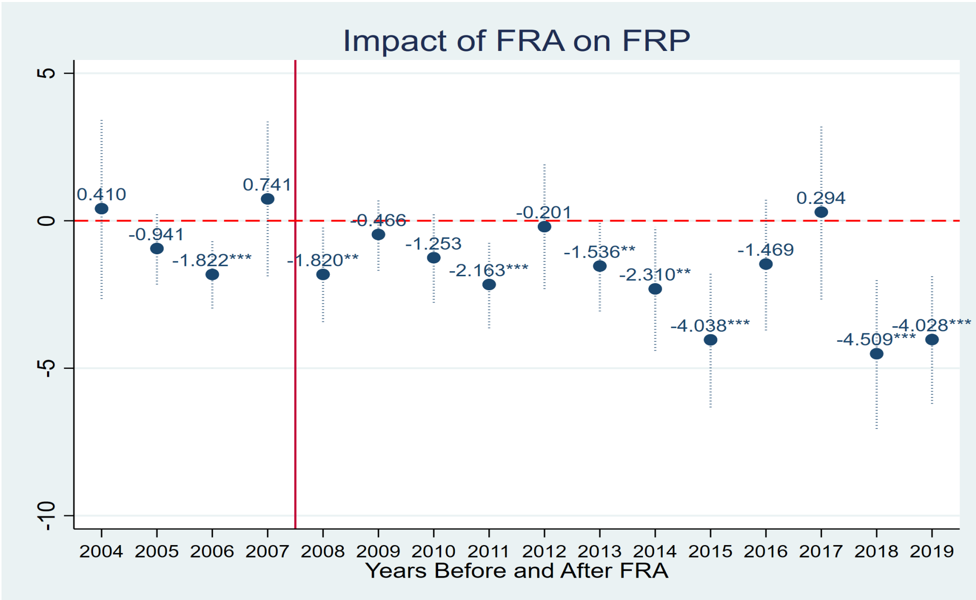

Figure 3: Dynamic Effects: Impact of FRA on FRP

Table 2: **Impact of FRA on Forest Fires (Using District Level FRA Titles Data)**

	(1)	(2)	(4)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Panel A: Community + Individual Titles			
Total Distributed	-0.004	0.026	0.009
	(0.007)	(0.063)	(0.137)
Forest Cover × Total Distributeds	-0.088***	-0.794***	-2.064**
	(0.027)	(0.225)	(0.828)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.225	0.185	0.161
Panel B: Community Titles			
Community Distributed	0.010*	0.070+	0.174+
	(0.005)	(0.043)	(0.114)
Forest Cover × Community Distributed	-0.072*	-0.582***	-1.497*
	(0.035)	(0.210)	(0.749)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.225	0.185	0.161
Panel C: Individual Titles			
Individual Distributed	-0.003	0.029	0.007
	(0.007)	(0.064)	(0.136)
Forest Cover × Individual Distributed	-0.082***	-0.794***	-2.042**
	(0.026)	(0.223)	(0.819)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.225	0.185	0.161
Baseline (pre-2008) Mean	0.021	0.097	0.568

+,*, ** and *** represent significance at .15, .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Total Distributed* represents the share of titles filed with the FRC that got approved by the DLC. *Community Distributed* and *Individual Distributed* represent the share of community and individual titles filed with the FRC that got approved by the DLC respectively. Title distribution rate in the post-FRA period was 0.48 for individual titles and 0.26 for community titles. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

Table 3: **Impact of FRA on PM 2.5**

	(1)	(2)	(3)	(4)
	Aggregate	Dis-aggregate	Aggregate	Dis-aggregate
Forest Cover × Post	-3.368*		-5.262***	
	(1.791)		(1.723)	
Forest Cover × 2004		-1.510		-4.160
		(1.504)		(2.817)
Forest Cover × 2005		0.788		1.994
		(0.922)		(2.442)
Forest Cover × 2006		0.289		-2.017
		(1.938)		(2.746)
Forest Cover × 2007		-2.461		-3.527
		(1.762)		(4.018)
Forest Cover × 2008		-3.693		-3.049
		(2.623)		(3.792)
Forest Cover × 2009		-3.109		-5.015
		(2.458)		(3.427)
Forest Cover × 2010		-2.816		-6.232**
		(2.109)		(2.917)
Forest Cover × 2011		-4.462*		-4.777
		(2.378)		(3.163)
Forest Cover × 2012		-0.028		-4.256
		(2.318)		(3.601)
Forest Cover × 2013		-7.997**		-10.758***
		(3.040)		(3.536)
Forest Cover × 2014		-4.661		-5.134
		(4.188)		(4.002)
Forest Cover × 2015		-3.908		-6.461*
		(2.917)		(3.778)
Forest Cover × 2016		-6.199*		-8.360**
		(3.407)		(3.889)
Forest Cover × 2017		-4.725		-8.953*
		(3.139)		(4.414)
Forest Cover × 2018		-4.726*		-8.839**
		(2.659)		(3.714)
Forest Cover × 2019		-3.147		-8.015*
		(3.430)		(4.230)
Village Fixed Effects	Yes	Yes	No	No
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,591	15,591	21,007	21,007
R-squared	0.984	0.985	0.836	0.836
Baseline (pre-2008) Mean	34.736	34.736	34.736	34.736

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Forest Cover* is the proportion of area covered by forests in a village.

Table 4: **Impact of FRA on Burned Area**

	(1)	(2)	(3)	(4)
	Aggregate	Dis-aggregate	Aggregate	Dis-aggregate
Forest Cover × Post	-0.002		-0.002*	
	(0.001)		(0.001)	
Forest Cover × 2004		-0.006		-0.005
		(0.003)		(0.003)
Forest Cover × 2005		0.001		-0.001
		(0.005)		(0.005)
Forest Cover × 2006		-0.003		-0.002
		(0.007)		(0.007)
Forest Cover × 2007		-0.001		-0.000
		(0.001)		(0.001)
Forest Cover × 2008		-0.004***		-0.005***
		(0.001)		(0.001)
Forest Cover × 2009		0.003		0.002
		(0.002)		(0.002)
Forest Cover × 2010		-0.000		-0.002
		(0.004)		(0.004)
Forest Cover × 2011		-0.006**		-0.005**
		(0.002)		(0.002)
Forest Cover × 2012		-0.001		-0.002
		(0.003)		(0.003)
Forest Cover × 2013		-0.001		-0.002
		(0.005)		(0.005)
Forest Cover × 2014		-0.009***		-0.010***
		(0.003)		(0.003)
Forest Cover × 2015		-0.011*		-0.012**
		(0.005)		(0.005)
Forest Cover × 2016		-0.004		-0.003**
		(0.002)		(0.002)
Forest Cover × 2017		-0.005		-0.005
		(0.003)		(0.003)
Forest Cover × 2018		-0.003*		-0.003***
		(0.001)		(0.001)
Forest Cover × 2019		-0.010		-0.011*
		(0.006)		(0.006)
Village Fixed Effects	Yes	Yes	No	No
District Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,143	15,143	20,284	20,284
R-squared	0.896	0.900	0.875	0.880
Baseline (pre-2008) Mean	0.005	0.005	0.005	0.005

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Forest Cover* is the proportion of area covered by forests in a village.

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10 Appendix

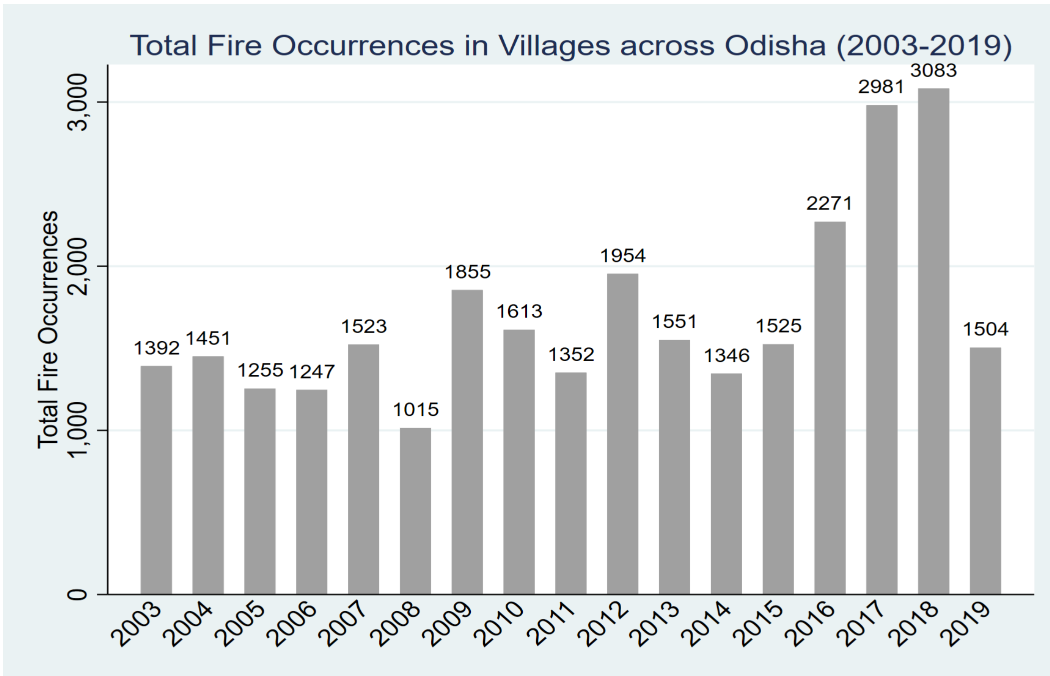

Figure A.4: Total Fire Occurrences

Authors' construction based on NASA FIRMS (MODIS) data for Odisha villages (2003-2019). Figure reports the number of fire events reported across Odisha in a given year.

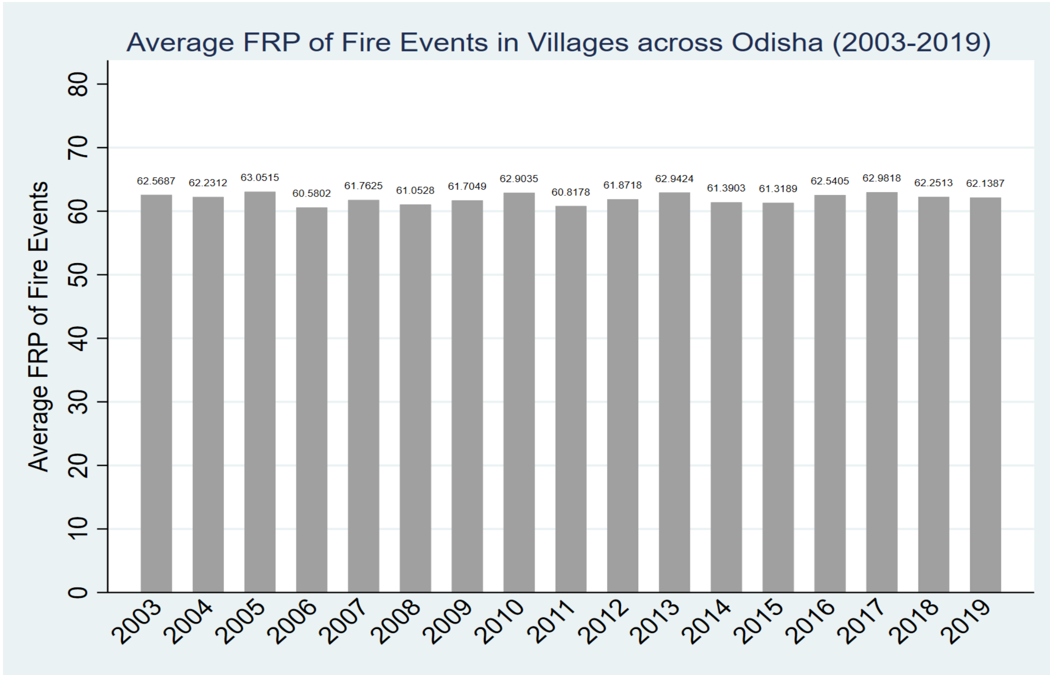

Figure A.5: Average FRP of Fire Events

Authors' construction based on NASA FIRMS (MODIS) data for Odisha villages (2003-2019). Figure reports the average FRP of all fire events reported across Odisha in a given year.

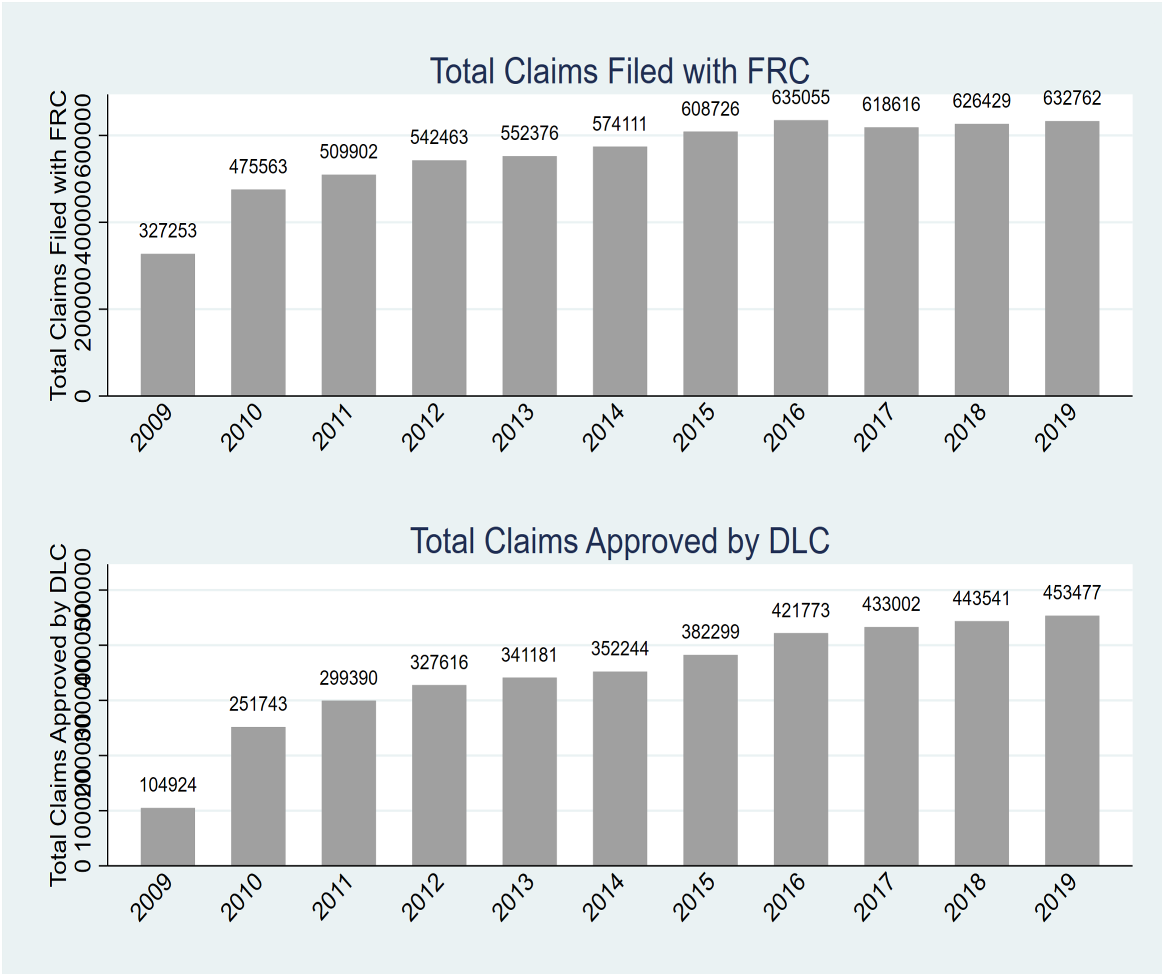

Figure A.6: FRA Titles Filed for And Approved in Odisha

Source: the Ministry of Tribal Affairs, Government of India (www.fra.org.in).

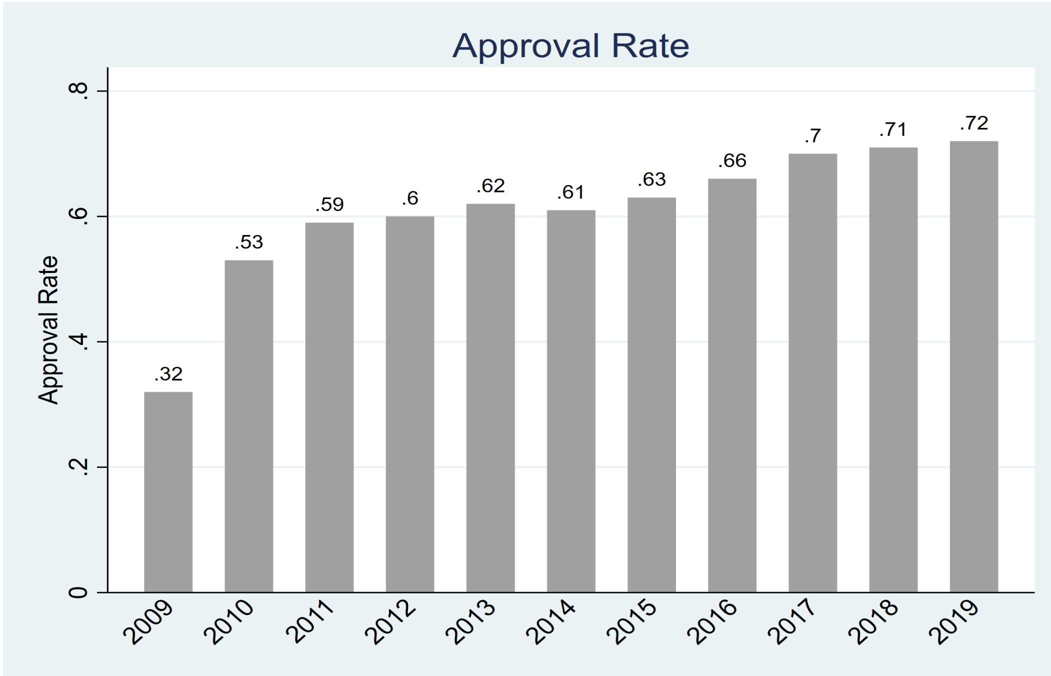

Figure A.7: Approval Rate of FRA Titles in Odisha

Source: the Ministry of Tribal Affairs, Government of India (www.fra.org.in). This figure shows the share of titles filed that were approved for distribution in Odisha over 2009-2019.

Table A.1: **State Level FRA Claims and Titles Distributed (as on 31st Dec., 2019)**

State	**Claims Filed**			**Titles Distributed**			**Titles Distributed/ Claims Filed (%)**
	Individual	**Community**	**Total**	**Individual**	**Community**	**Total**	
Andhra Pradesh	1,77,446	4,062	1,81,508	96,675	1,374	98,049	54.02%
Assam	1,48,965	6,046	1,55,011	57,325	1,477	58,802	37.93%
Bihar	8,022	-	8,022	121	-	121	1.51%
Chhattisgarh	8,58,682	31,558	8,90,240	4,01,251	21,967	4,23,218	47.54%
Goa	9,758	378	10,136	17	8	25	0.25%
Gujarat	1,82,869	7,187	1,90,056	88,226	3,516	91,742	48.27%
Himachal Pradesh	2,466	234	2,700	129	35	164	6.07%
Jharkhand	1,07,032	3,724	1,10,756	59,866	2,104	61,970	55.95%
Karnataka	2,75,446	5,903	2,81,349	14,667	1,406	16,073	5.71%
Kerala	43,237	1,012	44,249	26,105	0	26,105	59.39%
Madhya Pradesh	5,85,239	42,182	6,27,421	2,29,027	27,970	2,56,997	40.96%
Maharashtra	3,62,679	12,037	3,74,716	1,65,032	7,084	1,72,116	45.93%
Odisha	6,18,771	13,991	6,32,762	4,36,421	6,576	4,42,997	70.01%
Rajasthan	74,414	1,441	75,855	38,007	103	38,110	50.24%
Tamil Nadu	32,983	1,005	33,988	6,111	276	6,387	18.79%
Telangana	1,83,252	3,427	1,86,679	93,639	721	94,360	50.55%
Tripura	2,00,358	277	2,00,635	1,27,931	55	1,27,986	63.79%
Uttar Pradesh	92,520	1,124	93,644	17,712	843	18,555	19.81%
Uttarakhand	3,574	3,091	6,665	144	1	145	2.18%
West Bengal	1,31,962	10,119	1,42,081	44,444	686	45,130	31.76%
Total	4,09,09,675	1,48,798	4,28,43,473	1,90,82,850	76,202	1,97,90,52	46.58%

Source: Ministry of Tribal Affairs, Government of India

Table A.2: **Summary Statistics: Differences in Fire Occurrences and Intensity Before and After FRA**

	(1) Pre-FRA	(2) Post-FRA	(3) Overall	(4) Difference (2)-(1)	(5) t-value
Fire Event	0.02	0.03	0.03	0.01***	18.36
Fire Event (No.)	0.10	0.17	0.15	0.08***	11.26
Average FRP	0.57	0.64	0.62	0.07***	4.05

Fire Event is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *Average FRP* is the average FRP of all fire events reported in a given village-year.

Table A.3: **Impact of FRA on Fire Events (Including District-Year Fixed Effects)**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	-0.032**	-0.443***	-0.987**
	(0.012)	(0.142)	(0.463)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.233	0.187	0.163
Baseline (pre-2008) Mean	0.021	0.097	0.568

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

Table A.4: **Impact of FRA on Fire Events (Alternative Baseline Forest Cover)**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	-0.066***	-0.555***	-1.489**
	(0.019)	(0.106)	(0.639)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.225	0.185	0.161
Baseline (pre-2008) Mean	0.021	0.097	0.568

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

Table A.5: **Impact of FRA on Fire Events (Restricted to Fire Prone Months)**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	-0.060***	-0.443***	-1.576**
	(0.019)	(0.089)	(0.600)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.219	0.140	0.159
Baseline (pre-2008) Mean	0.020	0.085	0.557

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

Table A.6: **Impact of FRA on Fire Events (Restricted to Fire Prone Villages)**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	-0.297***	-2.775***	-5.982***
	(0.041)	(0.418)	(1.243)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	165,835	165,835	165,835
R-squared	0.153	0.179	0.138
Baseline (pre-2008) Mean	0.102	0.476	2.776

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

Table A.7: **Impact of FRA on Fire Events (Marginal Effects After Tobit Estimation)**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	-0.066***	-0.688***	-1.935***
	(0.011)	(0.128)	(0.309)
Controls	Yes	Yes	Yes
District Dummies	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes
Observations	810,509	810,509	810,509
Baseline (pre-2008) Mean	0.021	0.097	0.568

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

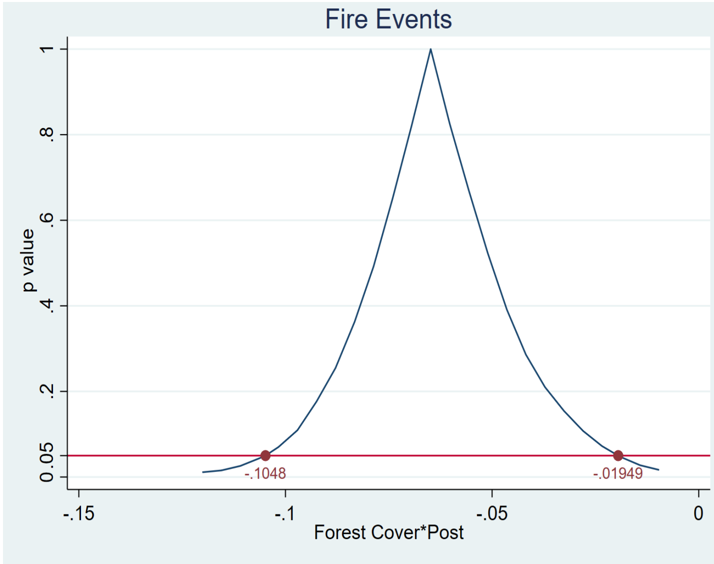

Figure A.8: Wild Cluster Bootstrap Confidence Interval for the Estimated Effect of FRA on Fire Events

This figure reports the estimated effect of FRA on fire events using wild bootstrap standard errors. The x-axis reports the values of the coefficient of interest obtained with wild bootstrapping and the y-axis shows the corresponding p-value. The horizontal red line represents the 5% significance level. The bootstrap 95% confidence interval (-0.105, -0.019) is entirely negative and contains the original point estimate of -0.065 which indicates that the negative effect remains statistically significant and robust to the wild-cluster bootstrap method.

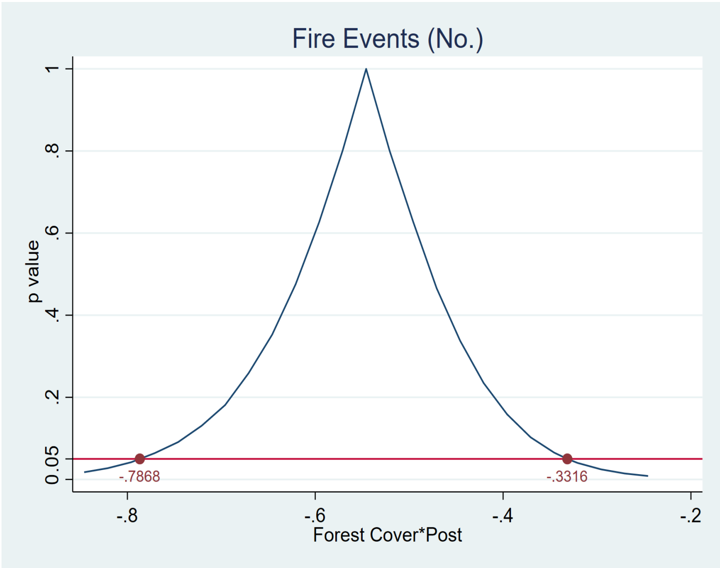

Figure A.9: Wild Cluster Bootstrap Confidence Interval for the Estimated Effect of FRA on Fire Events (No.)

This figure reports the estimated effect of FRA on fire events using wild bootstrap standard errors. The x-axis reports the values of the coefficient of interest obtained with wild bootstrapping and the y-axis shows the corresponding p-value. The horizontal red line represents the 5% significance level. The bootstrap 95% confidence interval (-0.787, -0.332) is entirely negative and contains the original point estimate of -0.546 which indicates that the negative effect remains statistically significant and robust to the wild-cluster bootstrap method.

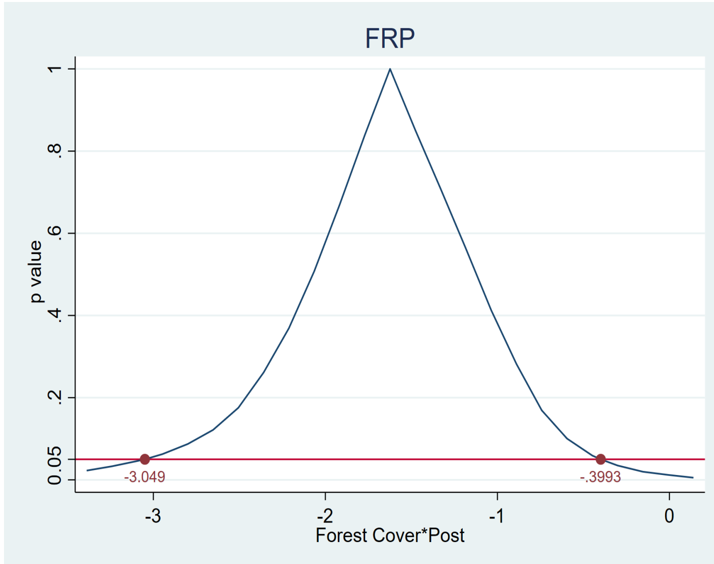

Figure A.10: Wild Cluster Bootstrap Confidence Interval for the Estimated Effect of FRA on FRP

This figure reports the estimated effect of FRA on fire events using wild bootstrap standard errors. The x-axis reports the values of the coefficient of interest obtained with wild bootstrapping and the y-axis shows the corresponding p-value. The horizontal red line represents the 5% significance level. The bootstrap 95% confidence interval (-3.049, -0.399) is entirely negative and contains the original point estimate of -1.624 indicating that the negative effect remains statistically significant and robust to the wild-cluster bootstrap method.

Table A.8: **Placebo Test: Impact of FRA on Fire Events for Lowest Forest Cover Decile**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Forest Cover × Post	0.099	-34.800	1.705
	(0.324)	(21.797)	(5.469)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	81,056	81,056	81,056
R-squared	0.159	0.108	0.152
Baseline (pre-2008) Mean	0.004	0.046	0.046

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.

Table A.9: **Heterogeneous Impact of FRA on Fire Events across Forest Cover Deciles**

	(1)	(2)	(3)
	Incidence		Intensity
	Fire Event	Fire Event (No.)	FRP
2nd Forest Cover Decile × Post	0.000	-0.051	0.023
	(0.002)	(0.041)	(0.036)
3rd Forest Cover Decile × Post	-0.003	-0.124**	-0.018
	(0.002)	(0.050)	(0.039)
4th Forest Cover Decile × Post	-0.003	-0.146***	-0.051
	(0.002)	(0.051)	(0.042)
5th Forest Cover Decile × Post	-0.006**	-0.149***	-0.092**
	(0.003)	(0.044)	(0.041)
6th Forest Cover Decile × Post	-0.006*	-0.168***	-0.150**
	(0.003)	(0.053)	(0.071)
7th Forest Cover Decile × Post	-0.007**	-0.228***	-0.160**
	(0.003)	(0.060)	(0.069)
8th Forest Cover Decile × Post	-0.008**	-0.213***	-0.114
	(0.004)	(0.058)	(0.079)
9th Forest Cover Decile × Post	-0.020***	-0.272***	-0.359**
	(0.007)	(0.058)	(0.155)
10th Forest Cover Decile × Post	-0.023***	-0.247***	-0.601***
	(0.006)	(0.055)	(0.212)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	810,509	810,509	810,509
R-squared	0.225	0.185	0.161
Baseline (pre-2008) Mean	0.021	0.097	0.568

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year.

Table A.10: **Heterogeneous Impact of FRA on Fire Events by Terrain and Elevation**

	(1)	(2)	(3)
	Incidence		**Intensity**
	Fire Event	**Fire Event (No.)**	**FRP**
Panel A: Above Median Terrain and Above Median Elevation			
Forest Cover × Post	-0.070***	-0.464***	-1.731***
	(0.017)	(0.110)	(0.613)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	326,434	326,434	326,434
R-squared	0.229	0.185	0.156
Baseline (pre-2008) Mean	0.044	0.173	1.282
Panel B: Below Median Terrain and Below Median Elevation			
Forest Cover × Post	-0.006	-0.350	0.034
	(0.023)	(0.209)	(0.456)
Controls	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	326,434	326,434	326,434
R-squared	0.185	0.299	0.181
Baseline (pre-2008) Mean	0.004	0.040	0.067
Difference (Above–Below)	−0.064**	−0.114	−1.765**

*, ** and *** represent significance at .10, .05 and .01 level respectively. Robust standard errors are reported in parentheses and are clustered at the district level. *Fire Event* is a dummy variable which takes the value 1 if any fire event occurs in a given village-year. *Fire Event (No.)* is the count of fire events reported in a given village-year which is scaled by 2001 forest cover (in km^2). *FRP* is the average FRP of all fire events reported in a given village-year. *Forest Cover* is the proportion of area covered by forests in a village.