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ORIGINAL ARTICLE

Effects of Drought and Flood on Farmer Suicides in Indian States: An Empirical Analysis

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Abstract The study examines the effects of drought and flood on farmer suicides using state-level panel data from 17 Indian states for the period 1995–2011. The empirical estimates based on unconditional fixed effect Negative Binomial model show that while drought significantly increases farmer suicides, flood has no direct impact on the same. The results also show that incidence of farmer suicides is higher in cotton producing states of India because these states experience frequent drought conditions. Furthermore, our findings reveal that states with high levels of rural poverty experience a higher number of farmer suicides as a result of frequent occurrence of droughts and moderate floods. To obtain robust results, fixed effect Poisson model has been used in the study. Overall, the findings are consistent with unconditional fixed effect Negative Binomial model. Hence, in light of the results obtained by this study, it is important for the government to devise suitable policies such as loan waiver for poor farmers, compulsory crop insurance scheme, improving farm income through revamping of agricultural marketing policies, creating public awareness among farmers and providing micro-irrigation

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facilities as well as introducing alternative cropping pattern in the drought prone areas in order to reduce the occurrence of farmer suicides.

Keywords Farmer suicides · Natural disaster · Rural poverty · Count model · Indian states

JEL Classification Q10 · C39 · I32

Introduction

Natural disasters are a recurrent phenomenon in India. Every year different states of India experience several forms of natural disasters due to the geo-climatic conditions. Around 12% of land in India is vulnerable to flood, 68% of cultivable land is vulnerable to drought, 60% of the land mass is prone to earthquakes and 8% of the total area is prone to cyclones (National Disaster Management Authority). Higher disaster-prone areas as well as a higher degree of socioeconomic vulnerability due to poverty, low per capita income and rapid urbanization are responsible for increasing disaster impact in terms of damage to physical and human capital as well as increasing fiscal pressure on the federal governments in India.[1] India has experienced 192 floods, 69 droughts[2] and 113 cyclones during 1970–2009 (Centre for Research on the Epidemiology of Disasters). In global ranking, India's rank is 14th in terms of Global Climate Risk Index (Kreft 2017).

Natural disaster impact depends on the frequency, magnitude and severity of the disasters. India lost around 0.46% of Gross Domestic Product (GDP) annually, crop losses were estimated at around 0.18% of GDP and around 6% rural population were affected each year due to floods during the period 1980–2011 (Parida 2017). In contrast, moderate and low flood events significantly increase agricultural productivity, agricultural wages and economic growth through enhancing fertility of agricultural land (Brammer 1990; Banerjee 2007, 2010; Loayza et al. 2012; Parida 2017).

Natural disaster is indirectly responsible for farmer suicides through increasing crop failure. Around 17% of farmers committed suicides due to crop failure in 2013 (Ministry of Home Affairs 2014a). Udmale et al. (2015) showed that frequent droughts in rural Maharashtra adversely affected the poor farming community. In addition, other studies have also shown that drought is one of the important factors causing farmer suicides because of the resultant income loss due to crop failures over the years (Sarma 2004; Sridhar 2006; Vaidyanathan 2006; Mishra 2006; Dongre and Deshmukh 2012; Khairnar et al. 2015).

Despite globalization and liberalization of the Indian economy, agriculture and allied sectors remain a major source of livelihood for the rural population. The contribution of agriculture to Gross Domestic Product (GDP) has declined relative to other sectors over the years. The agriculture and allied sectors contributed close to 22.5% to GDP in 2000–01, which declined to around 13% in 2015–16. Moreover, with an increased emphasis on industrial and service sectors, the share of agriculture in GDP is expected to decline further. Consequently,

[1] India lost around 12% of federal revenue due to natural disasters during the period 1996–2000 (Financing Rapid Onset Natural Disaster Losses in India: A Risk Management Approach, The World Bank, August 2003, Page 8).

[2] Author's calculation from (http://farmer.gov.in/Drought/Droughtreport.aspx), between 2000 and 2011, 17 states experienced 69 droughts. Out of this, Tamil Nadu experienced 9 times, while Andhra Pradesh, Karnataka faced 8 times each. However, Madhya Pradesh and Maharashtra faced 7 times each. Gujarat, Himachal Pradesh, Odisha and Utter Pradesh faced 4 times each, while West Bengal and Kerala faced 2 times each and rest of states faced less than 2 times.

there is a sharp decline of rural workforce participation[3] in the agriculture and allied sectors from 81.1% in 1983 to 64.1% in 2011. Nonetheless, agriculture and allied sectors provide more employment than any other sector in rural India. As per the government of India's estimate, the farming population declined by 7% during the period 2001–2011 because of shrinking economic prospects of agriculture (Census 2011, GoI).[4] The various reasons attributable for this phenomenon are low agricultural income, lack of incentives in agriculture and allied sectors, crop loss due to frequent occurrence of natural disasters, inadequate agricultural infrastructure and government's poor agriculture related marketing policies. Among the many uncertainties facing agriculture and allied sectors, one of the most unpredictable factors is the irregular occurrence of natural disaster events, mostly the rainfall volatility. Climate change in last two decades has impacted the Indian agriculture and allied sectors severely. The failure of rainfall leads to drought and excess rainfall causes flood which adversely affects the agricultural output and rural employment, thus creating a downward pressure on agricultural income and agricultural wages. The frequent occurrence of floods and droughts affect the socioeconomic conditions of rural households and enhances rural poverty. A set of studies have found increasing evidence of the linkage between farmer suicides and climate change across various economies (Judd et al. 2006; Mohanakumar and Sharma 2006; Sridhar 2006; Berry et al. 2011; Guiney 2012).

Apart from drought and flood impacts, over the last few decades, increasing debt burden, especially among the medium and small-scale farmers, has also been found to be a major reason behind the rising incidence of farmer suicides across the country (Asadi 2000; Shah 2012; Sadanandan 2014). The heavy indebtedness among the farmers also stems from various external factors such as crop failure, prevalence of irregular monsoons, rising costs of cultivation and declining access to institutional credit. Additionally, subsequent studies done in Indian context have indicated various reasons such as excessive economic liberalization, low import tariffs, growing disparities between agriculture and non-agriculture sectors, withdrawal of state support system, government's poor extension services and dumping of agricultural goods in global markets as the main determinants of increasing farmer suicides in the recent years. (Mishra 2006; Sridhar 2006; Vaidyanathan 2006; Jeromi 2007).

Apart from the aforesaid factors, in the recent years, the phenomenon of Bt Cotton cultivation has also resulted in rising number of farmer suicides mainly in western and southern states of India (Rao and Suri 2006; Herring 2008; Smale et al. 2009; Gruere and Sengupta 2011). The continued adoption of Bt cotton crop leads to the abandonment of the entire soil in the long-run for further agricultural usage. Thus, the introduction of Bt cotton in some parts of India coupled with drought conditions and excessive dryness of soil has reduced the agricultural yield below the normal level. Such agricultural losses have led to an increasing number of farmer suicides in southern and western parts of India. To put the numbers in perspective, in 2014, the number of farmer suicides rose to a staggering high of 5650. This implies a suicide rate of 1.5 on an average for every 0.1 million population in India (Ministry of Home Affairs 2014b). As per the National Crime Records Bureau (NCRB) report, nearly 296,417 farmers committed suicide over the period 1995 to 2013, with an average of 15,000 farmers committing suicide per year.

In view of the increasing incidence of farmer suicides, the present study empirically examines the effect of drought and flood, and cropping pattern in states and incidence of rural

[3] Employment and Unemployment reports (National Sample Survey, 38th and 68th rounds)
[4] www.thehindu.com/opinion/columns/sainath/over-2000-fewer-farmers-every-day/article4674190.ece

poverty on farmer suicides using a state-level panel data from 17 Indian states over the period 1995 to 2011. The study has the following objectives. First, we examine if the states with higher drought or flood prone areas have experienced a higher incidence of farmer suicides. Second, we analyze the impact of drought on farmer suicides by classifying the states based on wheat and cotton cultivation. Finally, the study examines if the states with higher incidence of rural poverty experience a higher number of farmer suicides as a result of frequent droughts and floods. We have employed unconditional fixed effect Negative Binomial model because our outcome variable, “number of farmer suicides in Indian states” is a count variable. For robust analysis, the study has used fixed effect Poisson model and Ordinary Least Squares (OLS). This empirical study not only contributes towards development literature, but also provides suitable policy suggestions to minimize the occurrence of farmer suicides in Indian states.

The rest of the paper is structured as follows. Second section presents the overview of farmer suicides in various Indian states. Third section explains the linkage between farmer suicides and vulnerability of a region towards disaster. Fourth section discusses the data sources and econometric identification. Empirical results are provided in section five. Finally, conclusion and discussion of the results are presented in sixth section.

Overview of Farmer Suicides in Indian States

A Farmer suicide is one of the greatest economic adversities that the Indian agriculture sector has ever faced in the twenty-first century. As noted by Basu et al. (2016), more than 0.3 million farmers have committed suicides across various states of India. In this section, we analyze the trend of farmer suicides in India for the period 1995 to 2011. We have used state-wise farmer suicide data available from NCRB. The focus is primarily on the 17 major states of India, where the problem of farmer suicides is more acute. Figure 1 shows the gender-wise and total farmer suicides occurring per million rural population in India for the period 1995–2011. As Fig. 1 shows, the total number of farmer suicides per million rural population is on a decelerating trend over the years. Moreover, the incidence of female farmer suicides is considerably lower than that of male farmer suicide. Consequently, the trend seen in male suicides mirrors the trend of total farmer suicides in India, while female suicides have remained more-or-less stable over the recent years. However, female suicides trend in certain states like Andhra Pradesh, Maharashtra and Karnataka has been rising continuously during this period. Considering state-wise data on farmer suicides as shown in Fig. 2, the average number of farmer suicides per million of rural population during the period 1995–2011 is the highest in the southern and western states of Karnataka, followed by Maharashtra and Kerala.

Nagthan et al. (2011) examine farmer suicide trends in Karnataka and explain that socioeconomic factors like humiliation from private money lenders, indebtedness, family pressures and crop failures accounted for nearly 58% of the farmer suicides cases across the state. A report submitted by the Tata Institute to the Mumbai High Court in 2005, cited government’s lack of interest, the absence of a safety net for farmers and lack of access to information related to agriculture as the main causes for the poor condition of farmers in the state of Maharashtra. A report by the Kerala State Farmers’ Debt Relief Commission (2007) finds that the evidence of rising debt burden is the main driving factor behind increasing farmer suicide rates in the state. In contrast, the northern states have seen relatively lower

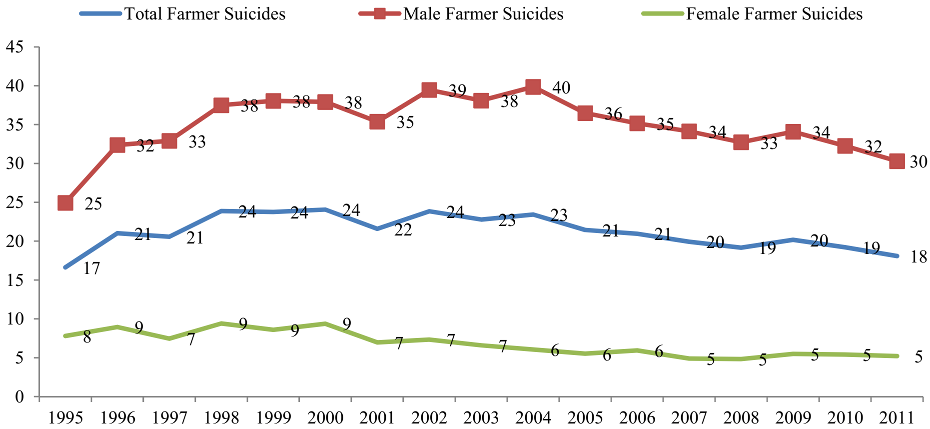

Fig. 1 Farmer suicides per million rural population during 1995–2011. Note: Author calculation. Total farmer suicides (male + female) per million rural populations in 17 major states in India. Female farmer suicides per million rural female population. Male farmer suicides per million rural male population

incidences of farmer suicide, which is a result of a good network of irrigation facilities present in those states.

Exploring the Linkage between Farmer Suicides and Vulnerability of a Region towards Natural Disasters

In this section, the study identifies the linkages between state-wise farmer suicides and vulnerability of a particular region to drought and flood. We have collected information regarding disaster-prone areas such as state-wise drought and flood prone areas from various sources, described in the footnote of Table 1. Later, the disaster prone areas are normalized using state-wise geographical areas. Further, we have estimated state-wise average number of farmer suicides per million rural population[5] for the period 1995–2011. Table 1 reveals that Karnataka state has experienced the highest incidence of farmer suicides in India. Karnataka has the largest proportion of drought prone area, and a relatively smaller flood prone area compared to the other states. Although, according to Rural Head Count Ratio (RHCR), Karnataka is relatively a less poor state than other states of India. Maharashtra state, which ranks next to Karnataka in terms of average number of farmer suicides, has the highest percentage of drought prone area and a relatively low flood prone area.

Therefore, it is observed that the top 5 states (Karnataka, Maharashtra, Kerala, Andhra Pradesh and Madhya Pradesh) which have seen the highest incidence of farmer suicides also feature among the top five states with the highest percentage of drought prone area. However, as can be seen from Table 1, that none of these five states features among the top five states which contain the highest percentage of area liable to flood and the states with the highest RHCR (with the exceptions of Andhra Pradesh and Madhya Pradesh).

[5] Here we have calculated farmer suicides per million of rural population for the period 1995 to 2011 in 17 states. The state-wise and year-wise agrarian population data is not available in India. Therefore, we have normalized farmer suicide by rural population because 64% of rural workforce depends on rural agriculture and allied sectors (68th round NSS, 2011).

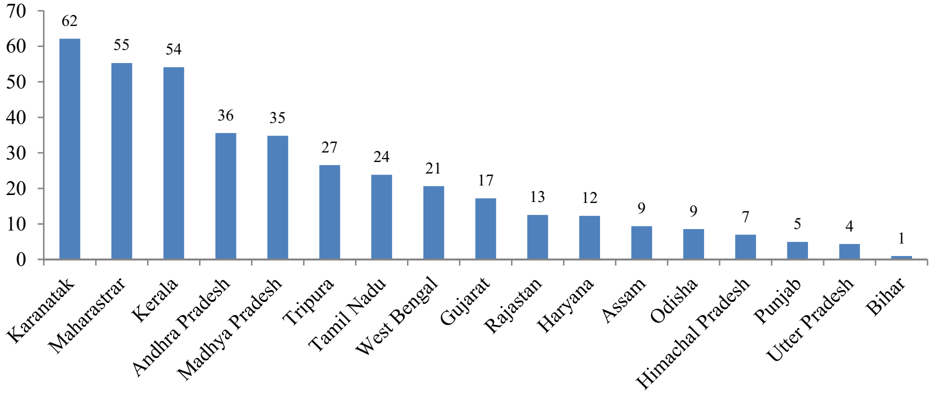

Fig. 2 State-wise average farmer suicides per million rural population during 1995–2011. Note: Author's calculation. Average number of farmer suicides per million state-wise rural population in 17 major Indian states

This has two important implications: (i) the states which have experienced a relatively larger number of farmer suicides contain a higher percentage of drought prone area and a lesser percentage of flood prone area and (ii) the less poor states have witnessed a higher number of farmer suicides. For instance, Karnataka records the highest number of farmer suicides as shown in Fig. 1. However, the state is less poor than other Indian states according to the RHCR, as can be seen in Table 1. The northern states such as Himachal Pradesh, Punjab and Uttar Pradesh are relatively well irrigated states, which consist of a relatively lower percentage of drought prone area and a concomitant lower number of farmer suicides.

Farmer Suicides and State-Wise Indebtedness

As mentioned earlier, one of the reasons often discussed in literature for the rising incidence of farmer suicides is the high level of indebtedness of the farmers in different states of India. Dongre and Deshmukh (2012) found that farmers in the Vidarbha region of Maharashtra ranked debt as the most important reason for farmer suicides.

In Table 2, we examine the crucial linkage between farmer suicides and level of indebtedness of farmer. The data shows that the states with higher number of farmer suicides are the ones which record the largest difference in percentage of indebted farmers over the period 2003 and 2013. However, there are a few exceptions, the most notable being states like Odisha and Bihar which have experienced a large difference in percentage of indebted farmers during this time period, but have witnessed a lower incidence of farmer suicides from 1995 to 2011. In contrast, states like Madhya Pradesh have experienced a higher number of farmer suicides, but the percentage of indebted farmers has been on a decline.

Data Sources and Econometric Identification

This section explains data sources, definition of variables and empirical identification employed in this study. The state-wise total farmer suicide data is obtained from the various issues of annual report titled "Accidental Deaths and Suicides in India", NCRB, Ministry of Home Affairs, Government of India (GoI). NCRB introduced state-wise farmer suicide data (self-employed in agriculture and farming sectors) from the year 1995. The state-wise area

Table 1 Impact of drought prone area and flood prone area on farmer suicides in Indian states

States	Average farmer suicides per million rural population from 1995 to 2011	Rank	Drought prone area over State geographical area (%)	Rank	Liable to flood prone area over State geographical area (%)	Rank	Rural HCR, 2011 (%)	Rank
Karnataka	62	1	44.0	2	0.1	17	19.8	13
Maharashtra	55	2	63.2	1	0.7	15	22.5	10
Kerala	54	3	25.2	5	22.4	8	7.3	17
Andhra Pradesh	36	4	36.1	3	5.1	12	39.3	5
Madhya Pradesh	35	5	28.9	4	0.6	16	45.2	2
Tripura	27	6	3.0	16	31.4	4	22.5	11
Tamil Nadu	24	7	22.6	6	3.5	14	24.3	9
West Bengal	21	8	13.1	11	29.8	5	30.1	8
Gujarat	17	9	22.4	7	7.1	11	31.4	7
Rajasthan	13	10	9.3	13	9.5	9	21.4	12
Haryana	12	11	18.9	8	53.2	2	11	15
Assam	9	12	6.1	14	40.2	3	42	3
Odisha	9	13	16.8	9	9.0	10	47.8	1
Himachal Pradesh	7	14	6.0	15	4.1	13	11.1	14
Punjab	5	15	0.0	17	73.4	1	7.4	16
Utter Pradesh	4	16	14.8	10	24.9	6	38.1	6
Bihar	1	17	10.1	12	24.5	7	40.1	4

State-wise liable to flood prone area estimated by *Rashtriya Barh Ayog* (National Flood Commission), Report of Working Group on Flood Management and Region-Specific Issues for XII Plan, 2011, Planning Commission, Government of India. The state and year wise data on drought affected area is available from Department of Land Resources, Ministry of Rural development, Government of India. For few states such as Haryana, data on drought prone is available from Agriculture Research Data Book, 2002. For Assam, the data for drought prone area is available from Agriculture and Irrigation in Assam, Government of Assam. For Tripura, drought prone area is available from National Disaster Risk Reduction Portal, Tripura. For Kerala, drought prone area is available from K. K. Nathan (2000) "Characteristics of Drought in Kerala, India" Water Technology Centre, Indian Agricultural Research Institute, New Delhi 110,012. The rural poverty Head Count Ratio (HCR) data for each state is taken from the estimations conducted by Prof. Tendulkar, and available in Planning Commission (2014) "Report of the Expert Group to Review the Methodology for Measurement of Poverty", Government of India

affected by flood data is compiled from Central Water Commission (CWC), GoI. Furthermore, the country-wise flood data is collected from Dartmouth Flood Observatory (DFO; http://floodobservatory.colorado.edu). The state-wise drought data is taken from Department of Land Resources, Ministry of Rural Development, GoI (http://farmer.gov.in/drought/droughtreport.aspx).

In addition, we have compiled state-wise drought and flood related information from EM-DAT database. The state government expenditure on flood control and drainage, expenditure on agriculture and allied activities, and total expenditure is obtained from various volumes of State Finance Reports published by Reserve Bank of India. The state-wise agriculture Gross State Domestic Product (GSDP) at constant prices is taken from the National Account Survey (NAS), available in Ministry of Statistics and Program Implementation, GoI. The state-wise data on rural male, rural female, rural total population and literate population are available

Table 2 State-wise average farmer suicides per million rural population and indebtedness in Indian states

State	Average farmer suicides per million rural population from 1995 to 2011	Indebted farmer households in 2003 (%)	Indebted farmer households in 2013 (%)	Difference in percentage between 2003 and 2013
Karnataka	62	61.6	77.3	15.7
Maharashtra	55	54.8	57.3	2.5
Kerala	54	64.4	77.7	13.3
Andhra Pradesh	36	82.0	92.9	10.9
Madhya Pradesh	35	50.8	45.7	−5.1
Tripura	27	49.2	22.9	−26.3
Tamil Nadu	24	74.5	82.5	8.0
West Bengal	21	50.1	51.5	1.4
Gujarat	17	51.9	42.6	−9.3
Rajasthan	13	52.4	61.8	9.4
Haryana	12	53.1	42.3	−10.8
Assam	9	18.1	17.5	−0.6
Odisha	9	47.8	57.7	9.9
Himachal Pradesh	7	33.4	27.9	−5.5
Punjab	5	65.4	53.2	−12.2
Utter Pradesh	4	40.3	43.8	3.5
Bihar	1	33.0	42.5	9.5

Percentage of indebted farmer households = (Indebted farmer households / All farmer households)*100. Data on percentage of indebted farmer households in the year 2003 is obtained from Situation Assessment Survey of Farmers, Indebtedness of Farmer Households, 59th round of National Sample Survey (NSS), 2003. Furthermore, data on the percentage of indebted farmer households in year 2013 is obtained from Income, Expenditure, Productive Assets and Indebtedness of Agricultural Households in India, 70th round NSS

from the Census of India. In India, the population census is conducted with an every ten-year interval (for examples 1991, 2001 and 2011). Thus, we have applied linear interpolation method to generate population figures for the intervening years.

The state-wise monthly data on rural agricultural wages for male workers is compiled from the various volumes of Agriculture Wages in India. Real agricultural wage is constructed by deflating nominal agricultural wages for male workers by state-wise consumer price index for agricultural laborers (base year 1986–87 = 100). The state-wise consumer price index for agricultural laborers (base year 1986–87 = 100) is obtained from Labour Bureau, GoI. The state-wise gross irrigated area is extracted from the various volumes of Land Use Statistics. Similarly, state-wise cotton and wheat production information is obtained from the state-wise area production and yield statistics, Directorate of Economics and Statistics, Ministry of Agriculture and Farmer Welfare, GoI. The data on RHCR was compiled from the "Report of the Expert Group to Review the Methodology for Measurement of Poverty", Planning Commission, GoI.

In this empirical analysis, we could not use 'state-wise total area affected by flood' as one of the explanatory variables because it combines low, moderate and even high flood magnitudes based on total area affected. Moreover, it does not provide a clear information regarding impact of area affected by flood on farmer suicides. Our objective is to examine the relative impact of flood magnitudes on farmer suicides in Indian states. To account for that, we have categorized the state-wise flood affected area in three categories for 17 states for the period 1995 to 2011. First, high flood magnitude dummy equals 1, if state-wise area affected by flood lie above 75 percentile, otherwise it is zero. Second, moderate flood magnitude dummy equals

1, if state-wise area affected by flood lie between 50 and 74 percentile, otherwise it is zero. Finally, low flood magnitude dummy equals 1, if state-wise area affected by flood is less than equal to 49 percentile, otherwise it is zero. As the information regarding state-wise area affected by drought was not available, we have created state-wise dummy variables for drought affected years. For state-wise cotton production and wheat production, we have created dummies for ten cotton producing states and for nine wheat producing states respectively. Further, we have normalized all other variables for empirical purpose. The details of summary statistics are shown in Table 12.

The study examines the effect of drought and flood on farmer suicides in major 17 Indian states[6] using state-level panel data from 1995 to 2011. The study also examines whether the states with a higher incidence of rural poverty experience a greater number of farmer suicides as a result of drought and flood. The following equations have been formulated for examining the various determinants of farmer suicides in Indian states.

$$SFS_{it} = \beta_0 + \beta_1 DD_{it} + \beta_2 HFMD_{it} + \beta_3 MFMD_{it} + \beta_4 LEFI_{it} + \beta_5 Z_{it} + \theta_r + \gamma_t + \mu_{1it} \quad (1)$$

$$SFS_{it} = \alpha_1 + \alpha_2 CPSD_{it} + \alpha_3 (CPSD{*}DD)_{it} + \alpha_4 (WPSD{*}DD)_{it} + \alpha_5 Z_{it} + \theta_r + \gamma_t + \mu_{2it} \quad (2)$$

$$SFS_{it} = \vartheta_1 + \vartheta_2 RHCR_{it} + \vartheta_3 (RHCR{*}DD)_{it} + \vartheta_4 (RHCR{*}HFMD)_{it} + \vartheta_5 Z_{it} + \theta_r + \gamma_t + \mu_{3it} \quad (3)$$

Where SFS_{it} is the state-wise number of farmer suicides, DD_{it} is the state-wise drought dummy variable, $HFMD_{it}$ is the high flood magnitude dummy variable, $MFMD_{it}$ is the moderate flood magnitude dummy variable, $LEFI_{it}$ is the natural logarithm of government expenditure on flood control and drainage, $CPSD_{it}$ is the cotton producing states dummy, $CPSD * DD$ is the interaction term between cotton producing states dummy and drought dummy, $WPSD * DD$ is the interaction term between wheat producing states dummy and drought dummy, $RHCR_{it}$ is the rural head count ratio, $RHCR * DD$ is the interaction term between rural head count ratio dummy and drought dummy, $RHCR * HFMD$ is the interaction term between rural head count ratio dummy and high flood magnitude dummy, Z_{it} denote the control variables, θ_r controls for the unobserved region effects, γ_t indicate year specific effects and μ_{it} is the error term.

In Eqs. (1) to (3), the dependent variable is the number of farmer suicides. This is a non-negative count variable. The variance of the dependent variable exceeds the mean implying that the 'number of farmer suicides' variable is over-dispersed as shown in Table 12. The summary statistics clearly show that the outcome variable has violated the assumptions of normal distribution. In this case, Ordinary Least Squares (OLS) estimation produces biased, inefficient and inconsistent results. It is appropriate to apply Negative Binomial or Poisson model to estimate Eqs. 1 to 3. Kahn (2005) estimates Zero-Inflated Negative Binomial model and controls for unobserved continent fixed effects using a cross country disaster data set. In our study, we could not use the Zero-Inflated Negative Binomial model because the share of observations indicating zero farmer suicides is not extremely large. However, Kellenberg and Mobarak (2008) have estimated conditional Fixed Effect (FE) Negative Binomial model

[6] At present, India has 29 states (including Telangana). Telangana state is recently formed from Andhra Pradesh in 2014. Total farmer suicides stand at 94% in the major 17 states and the remaining 6% of farmer suicides occur in rest of the states.

because it controls for unobserved country effects in a cross-country disaster data set. But this models 'is not a true fixed-effects model' (Hilbe 2012: 474) as it does not control for all time invariant covariates efficiently (Allison and Waterman 2002). Only the conditional FE Negative Binomial model controls for time invariant unobserved effects under a very specific set of assumptions (Guimarães 2008). Therefore, we use an unconditional FE Negative Binomial model to analyze the effects of flood and drought on farmer suicides. This model provides consistent parameter estimates and controls for the unobserved time invariant effects efficiently when the cross-sectional units are less than 20 (Hilbe 2012: 473). In our study, we have controlled for the unobserved time invariant region effects as the cross-section units (number of states) are equal to 17. There are a few empirical studies which have used unconditional FE Negative Binomial model and controlled for the unobserved region (or continent) fixed effects using disaster fatality dataset (Anbarci et al. 2005; Kahn 2005; Escaleras et al. 2007; Parida 2016). The unconditional FE Negative Binomial produces inconsistent estimates due to the incidental parameter problem in case of short panel data (Cameron and Trivedi 1998:282). Therefore, to obtain robust results, we use fixed effect Poisson model. Unlike the unconditional FE Negative Binomial model, the FE Poisson model does not suffer from the incidental parameter problem and it completely controls for the unobserved time invariant effects (Wooldridge 2002: 674–676).

Empirical Results; Effects of Drought and Flood on Farmer Suicides

The FE Negative Binomial estimates of Eq. (1) are shown in Table 3. In Model-1, the coefficient of drought dummy is positive and statistically significant, implying that the frequent occurrence of drought significantly increases farmer suicide in Indian states due to crop failure.

Agricultural crop failure due to natural disasters leads to lower agricultural income. As a result, farmers are unable to repay their loans, which eventually lead to higher incidence of farmer suicides. In Model-4, the coefficient of drought dummy is positive and statistically significant after adding all control variables. Our estimates are robust throughout the models.

Further, the coefficient of dummy variables indicating high and moderate flood magnitudes are statistically insignificant from Model-2 to Model-4. The results show that occurrence of flood does not significantly affect the incidence of farmer suicides in Indian states. There are a few reasons which help to explain the fact that flood has no direct impact on farmer suicides. First, frequent occurrence of flood in different states helps in groundwater recharging and increases the storage capacities of dams. This in turn significantly helps in irrigation. Second, although flood affects *kharif* crops, but it also increases the productivity of the forthcoming *rabi* crops by increasing soil quality through increasing moisture in the agricultural land (Brammer 1990; Banerjee 2010; Singh et al. 2011). Finally, flood not only increases agricultural productivity, but also increases rural agricultural wages and economic growth (Banerjee 2007; Loayza et al. 2012; Parida 2017). However, drought not only has an adverse impact on rice yields in India, but also results in farmer suicides due to the resultant income loss from crop failures over the years (Sarma 2004; Sridhar 2006; Vaidyanathan 2006; Mishra 2006; Dongre and Deshmukh 2012; Khairnar et al. 2015; Birthal et al. 2015).

In Model-3 and Model-4, we have introduced a new variable, namely real agricultural wages for male workers. The coefficient of this variable is negative and statistically significant in both models which imply that the states with higher agriculture wages for male workers

Table 3 Impact of drought and flood on farmer suicides: FE Negative Binomial model

Variables	Model-1	Model-2	Model-3	Model-4
Drought dummy	0.658*** (0.124)	0.654*** (0.124)	0.560*** (0.127)	0.299** (0.127)
High flood magnitude dummy		−0.004 (0.116)	−0.014 (0.114)	0.082 (0.106)
Moderate flood magnitude dummy		0.065 (0.128)	0.068 (0.127)	0.076 (0.108)
Ln(Real agricultural wages for male workers)			−0.514*** (0.123)	−0.269** (0.121)
Ln(Expenditure of flood control and drainage /Revenue development expenditure)				−0.041 (0.040)
Ln(Expenditure of flood control and drainage /Revenue development expenditure)(−1)				−0.067* (0.040)
Ln(Expenditure of agriculture and allied activities/Total expenditure)				−0.142 (0.124)
Ln(Expenditure of agriculture and allied activities/Total expenditure)(−1)				−0.277** (0.138)
Region FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
$\chi2$ (d.f.)	576.14 (22)	579.95 (24)	620.72 (25)	1202.17 (28)
Log-likelihood	−2120	−2120	−2116	−1961
No. of states	17	17	17	17
Observations	289	289	289	272

Robust standard errors are reported in parentheses. Dependent variable is the total number of farmer suicides. Low flood magnitude is the base category dummy variable

*p < 0.1 denote 1%, 5% and 10% levels of significance respectively

**p < 0.05

***p < 0.01

witness lower incidence of farmer suicides. Agricultural wages act like insurance for the rural farmers, which reduces their stress levels and causes a decline in the number of farmer suicides. In Model-4, the coefficients of public expenditure on flood control and drainage, and public expenditure agriculture and allied activities are negative and statistically significant, which shows that there exists a negative correlation between government interventions and farmer suicides. This result appears logical as government plays an important role in minimizing the occurrence of farmer suicides through increasing expenditures on agriculture and allied sectors and flood control measures. To control for endogeneity issue, we have introduced one year lag of the variables indicating public expenditure on flood control and drainage and public expenditure on agriculture and allied activities in Model-4.We also estimate Eq. (1) using OLS model and the estimates are shown in Table 9. In Model-3, the coefficient of drought dummy is positive and significant, which shows that drought has significantly increased the occurrence of farmer suicides by 32%.[7] The OLS estimates are consistent with the estimates of unconditional FE Negative Binomial model.

The results of FE Poisson model for Eq. (1) are shown in Table 6. The coefficient of drought dummy is positive and significant through all the models, which implies that our

[7] We estimate log linear OLS model using Eq. (1) with drought dummy. The estimates are shown in Model-3 in Table 9. The impact of drought on farmer suicides is calculated in percentage terms. The coefficient of drought dummy is 0.278 (shown in Model 3 of Table 9) and we take [exp (0.278)-1]*100 = 32.04%.

estimate is robust and consistent. This finding is also in line with our earlier findings (results obtained using unconditional FE Negative Binomial model, as shown in Table 3). Moreover, the coefficients of agricultural wages for male workers and government expenditure on flood control and drainage are negatively correlated with the incidence of farmer suicides (see Table 6). This finding is also consistent with our earlier results as shown in Table 3. Another interesting finding is that the coefficient of moderate flood magnitude dummy is positive and significant in Model-3 and Model-4 which implies that the states with frequent occurrence of moderate flood witness higher occurrence of farmer suicides. However, this result is not consistent with our earlier findings which showed that the coefficient of moderate flood magnitude dummy is not statistically significant (see Table 3).

Effects of Cotton and Wheat Production on Farmer Suicides

The above analysis shows that while drought has a direct impact on farmer suicides, floods have no direct impact on the same. In this section, we examine the effects of cotton and wheat production in various states on the incidence of farmer suicides using Eq. (2) over the period 1995–2011. The FE Negative Binomial model is applied to estimate Eq. (2) and the estimates are presented in Table 4. In our empirical analysis, we consider total ten cotton producing states and nine wheat producing states.[8] Since cotton is a cash crop; farmers invest heavily in its cultivation, which forces them to borrow money from various formal and informal sources. In the event of a failure of the standing cotton crop because of natural disasters like droughts, floods, farmers are unable to repay loans which increase the occurrence of farmer suicides in cotton producing states. This argument is supported by our empirical results. In Model-1, the coefficient of cotton producing state dummy is positive and significant, which implies that the cotton producing states experience a higher number of farmer suicides than other states producing different crops. In Model-4, the coefficient of cotton producing state dummy remains positive and significant after adding other control variables. This shows that our estimates are robust throughout the models.

Further, in Model-2 to Model-5, the interaction variable (Cotton producing state dummy*drought dummy) is positive and significant, which implies that the probability of farmer suicide is higher in cotton producing states because those states experience frequent occurrence of droughts.[9] A host of factors are responsible for the rise in farmer suicides in cotton producing states. First, the study by Gruere and Sengupta (2011) show that ‘Bt cotton production has indirectly contributed to farmer indebtedness, leading to suicides, but its failure is mainly the result of the environment in which it was planted’. In the southern state of Andhra Pradesh, suicides among the cotton growing farmers are prevalent due to adverse rainfall, low yields, unremunerative prices and increase in cost of cultivation (Parthasarathy and Shameem 1998).

[8] In this analysis, we have used dummy variables to indicate states producing wheat and cotton because 10 out of 17 states use 99.9% land for cotton production and 9 out of 17 states use 99.23% land for wheat production. For example, the percentage of cotton area estimated = cotton cultivated area for 10 states over total cotton cultivated area for 17 states in the year 2011 (Land Use Statistics at a Glance, 2014). Therefore, we have used the dummy variables for cotton and wheat production states instead of the area of production. The percentage figure shows that some states produce wheat and not cotton. Similarly, other states produce cotton and not wheat.

[9] In year 2011, 83% of total cotton in India was produced by five major states namely Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra and Gujarat. The drought prone area combining all these five states stands at 75%, while farmer suicide stands at 67% in the period 1995–2011 in these states.

Table 4 Farmer suicides in cotton and wheat production states: FE Negative Binomial model

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
Cotton producing state dummy	0.602*** (0.131)	0.353*** (0.131)	0.377*** (0.090)	0.403*** (0.091)	0.446*** (0.098)
Cotton producing state dummy*drought dummy		0.722*** (0.126)	0.633*** (0.110)	0.493*** (0.139)	0.524*** (0.138)
Wheat producing state dummy			1.332*** (0.144)	1.286*** (0.145)	1.355*** (0.182)
Wheat producing state dummy*drought dummy				0.240 (0.170)	0.236 (0.167)
Ln(Gross irrigated area in million hectares)					−0.024 (0.054)
Literacy rate					−0.015* (0.007)
Region FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
$\chi 2$ (d.f.)	487.09 (22)	594.27 (23)	1059.03 (24)	1122.66 (25)	1075.96 (27)
Log-likelihood	−2123	−2113	−2088	−2087	−2085
No. of states	17	17	17	17	17
Observations	289	289	289	289	289

Robust standard errors are reported in the parentheses. Dependent variable is the total number of farmer suicides.

*$p < 0.1$denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

Furthermore, introduction of new Bt cotton seeds, increasing usage of insecticides and pesticides have led to the declining yield of cotton cultivation, thus adversely affecting profitability conditions of farmers (Shetty 2004; Stone 2011; Thomas and De Tavernier 2017). The agricultural output losses have put cotton farmers under huge debt trap due to the increasing dependence on non-institutional credit sources (Behere and Behere 2008; Chhikara and Kodan 2013; Manoranjitham et al. 2010; Merriott 2016; Dandekar and Bhattacharya 2017). The average percentage of indebtedness among the rural communities is quite high in the cotton producing southern and peninsular states with Andhra Pradesh topping the list (Rajeev et al. 2011). Nevertheless, cotton producing states constitute nearly 88% of total farmer suicides in India, accounting for 11,026 suicides out of total 12,602 suicides in 2015 (The Hindu Business Line, 5th January, 2017).

Furthermore, farmer suicides are higher in wheat producing states as shown in Model-3 to Model-5 of Table 4. In Model-4 and Model-5, the interaction term (Wheat producing state dummy*drought dummy) is positive but not statistically significant. This implies that higher frequency of droughts do not increase the incidence of farmer suicides in wheat producing states. Other factors can help explain the rising farmer suicides in wheat producing states. Wheat is a *rabi* crop which depends more on irrigation than adequate rainfall. In Model-4, we see that the coefficient of gross irrigated area is negative and statistically insignificant, which implies that the provision of irrigation facilities is not sufficient enough to minimize the occurrence of farmer suicides. Finally, the coefficient of literacy rate is found to be negative and significant, which shows that higher literacy among farmers reduces the incidence of suicides. We estimate Eq. (2) using OLS model and results are shown in Table 10. The OLS estimates are consistent with the results obtained from using unconditional FE Negative Binomial model (see Table 4). To obtain robust results, we have estimated Eq. (2) using FE

Poisson model, the estimates of which are shown in Table 7. We find that the estimates are robust throughout the models and consistent with our earlier findings as shown in Table 4.

Effects of Rural Poverty and Drought on Farmer Suicides

As discussed in the earlier sections, there are many reasons responsible for the higher incidence of farmer suicides in Indian states, and rural poverty is one of the main determinants. In this section, we analyze the effects of rural poverty on farmer suicides in 17 Indian states using Eq. (3) for the time period 1995–2011. Around 26% of rural population live below the poverty line and 64% of rural workforce is dependent directly and indirectly on agriculture and allied sectors for their livelihood in the year 2011 (NSS 68th round, 2011). Any extreme climate event such as drought and flood not only affect agricultural output, but also affects the households' economic condition through damage to crops, damage to house and private properties, and deterioration of human health. The study uses RHCR[10] estimated by Lakdawala[11] and Tendulkar[12] using four rounds of household consumer expenditure[13] data. We estimate Eq. (3) using four rounds of RHCR[14] for years 1999, 2004, 2009 and 2011 along with drought dummy matched for these respective years. The unconditional FE Negative Binomial estimates are shown in Table 5. The coefficient of RHCR is positive but not statistically significant in Model-1 to Model-3, implying that rural poverty is not the sole cause for the occurrence of farmer suicides in Indian states.

Furthermore, the coefficients of the interaction terms (RHCR*drought dummy) and (RHCR*moderate flood magnitude dummy) are positive and significant from Model-2 to Model-3 of Table 5. This result implies that relatively poor states witness higher incidence of farmer suicides coupled with the negative impacts of frequent occurrence of droughts and moderate floods. Moreover, in Model-3 the coefficient of Mahatma Gandhi National Rural Employment Guarantee (MGNREGS)[15] dummy is insignificant, implying that MGNREGS is not an effective social protection measure for the farmers. In Model-4, the coefficient of agricultural productivity is not significant, which shows that a small increase in agricultural productivity is not sufficient enough to minimize the incidence of farmer suicides. For robustness analysis, we estimate Eq. (3) using FE Poisson model, the estimates of which are presented in Table 8. The coefficients of interaction terms (RHCR*drought dummy) and (RHCR*moderate flood magnitude dummy) are positive and significant from Model-2 to Model-3. Our estimates are robust and these are consistent with our earlier findings shown in Table 5. Next, we estimate Eq. (3) using OLS model and estimates are shown in Table 11. The coefficients of (RHCR*drought dummy) and (RHCR*moderate flood magnitude dummy) are

[10] See Planning Commission (2014) "Report of the Expert Group to Review the Methodology for Measurement of Poverty", Government of India.

[11] We have used Rural Head Count Ratio for the year 1999–2000 estimated by Lakdawala.

[12] We have used Rural Head Count Ratio for three years such as 2004–05, 2009–10 and 2011–12 estimated by Tendulkar.

[13] Thick rounds of Household Consumer Expenditure surveys are conducted by National Sample Survey Office (NSSO), Ministry of Statistics and Programme Implementation, GoI, within five years intervals, such as 1999, 2004, 2009 and 2011.

[14] We have used only four rounds of Rural Head Count Ratio (RHCR) data along with drought data compiled for those years only. The data rounds used are as follows: 55th round (1999–2000) of RHCR estimated by Lakdawala and rest of the three rounds of RHCR (61st round, 2004–05; 66th round, 2009–10; 68th round, 2011–12) are estimated by Tendulkar. Total number of observations are (17 States × 4 years = 68 observations). We have matched the drought data with RHCR data available for these four years.

[15] MGNREGS is the largest public funded program in India.

Table 5 Impact of poverty and drought on farmer suicides: FE Negative Binomial model

Variables	Model-1	Model-2	Model-3
Rural Head Count Ratio (RHCR)	0.010 (0.019)	0.007 (0.017)	0.024 (0.021)
Rural HCR *drought dummy	0.012 (0.008)	0.016* (0.008)	0.017** (0.007)
Rural HCR *high flood magnitude dummy		0.003 (0.009)	0.007 (0.007)
Rural HCR *moderate flood magnitude dummy		0.024** (0.010)	0.020** (0.010)
MGNREGS dummy			0.549 (0.402)
Ln(Agricultural productivity per hectare gross irrigated land)			−0.168 (0.234)
Coastal state dummy			2.677*** (0.523)
Region FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
χ2 (d.f.)	130.72 (10)	145.95 (12)	272.13 (14)
Log-likelihood	−500	−498	−488
No. of states	17	17	17
Observations	68	68	68

Robust standard errors are reported in the parentheses. Dependent variable is the total number of farmer suicides. Low flood magnitude is the base category dummy variable

*$p < 0.1$denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

positive and significant in Model-3 implying that one unit change in rural poverty increase farmer suicides by 2.89% and 3.52% respectively as a result of frequent occurrence of droughts and moderate floods respectively. The OLS estimates are consistent with the results of unconditional FE Negative Binomial model (see Table 5).

Conclusion and Discussion

The study examines the effect of extreme weather events (mainly floods and droughts) on farmer suicides in Indian states over the period 1995 to 2011. The estimates based on unconditional FE Negative Binomial model reveal that drought has significantly increased the incidence of farmer suicides across Indian states. However, flood has almost no direct impact on the occurrence of farmer suicides. The estimates further show that public expenditure on flood control and irrigation related activities significantly reduces the occurrence of farmer suicides. The study also shows that agricultural wage earnings of male workers significantly reduce farmer suicides due to increasing income securities of rural households. The result also shows that the incidence of farmer suicides is higher in cotton producing states because these states experience frequent drought conditions. Further, our findings reveal that states with high level of rural poverty experience a higher number of farmer suicides as a result of frequent occurrence of droughts and floods. Another interesting finding of the study is that higher literacy rate has significantly reduced farmer suicides. For robustness analysis, we have employed FE Poisson model and OLS model, which confirms that drought causes a higher incidence of farmer suicides.

Further, our empirical findings also suggest that the negative impact of natural disasters and other factors of economic deprivation also influence the incidence of farmer suicides to a significant extent. To end such humanitarian crisis, both central and state governments should initiate strict monitoring and expedite the following agricultural policies. First, state governments should initiate compulsory crop insurance schemes and insure all farmers including sharecroppers and landless farmers. Second, our results show that drought creates major adverse impacts on the agriculture and allied sectors. Therefore, it is important to reduce the dependence of Indian agriculture on the vagaries of monsoon by improving minor and major irrigation facilities and introducing alternative cropping pattern in various states. This should be coupled with increasing agrarian investment in the areas of controlling flood, irrigation management and agricultural research and development. Finally, our results show that higher agricultural wage income of male workers and availability of alternative employment opportunities in agriculture and allied sectors can potentially arrest the rising incidence of farmer suicides.

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Appendix

Table 6 Impact of drought and flood on farmer suicides: FE Poisson model

Variables	Model-1	Model-2	Model-3	Model-4
Drought dummy	0.541*** (0.104)	0.559*** (0.103)	0.434*** (0.105)	0.396*** (0.101)
High flood magnitude dummy		0.141 (0.103)	0.119 (0.095)	0.142 (0.093)
Moderate flood magnitude dummy		0.157 (0.104)	0.176* (0.103)	0.191* (0.099)
Ln (Real agricultural wages for male workers)			−0.572*** (0.120)	−0.406*** (0.119)
Ln(Expenditure of flood control and drainage/Revenue development expenditure)				−0.029 (0.028)
Ln(Expenditure of flood control and drainage/Revenue development expenditure) (−1)				−0.048* (0.029)
Region FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
$\chi2$ (d.f.)	608.31 (22)	625.87 (24)	749.45 (25)	1020.66 (26)
Log-likelihood	−53,109	−52,520	−48,686	−39,526
No. of states	17	17	17	17
Observations	289	289	289	272

Robust standard errors are reported in parentheses. Dependent variable is the total number of farmer suicides. Low flood magnitude is the base category dummy variable

*$p < 0.1$denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

Table 7 Farmer suicides in cotton and wheat production states: FE Poisson model

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
Cotton producing state dummy	0.404*** (0.077)	0.186** (0.093)	0.368*** (0.089)	0.385*** (0.087)	0.478*** (0.094)
Cotton producing state dummy*drought dummy		0.565*** (0.117)	0.545*** (0.114)	0.477*** (0.116)	0.511*** (0.117)
Wheat producing state dummy			1.372*** (0.173)	1.334*** (0.175)	1.553*** (0.197)
Wheat producing state dummy*drought dummy				0.147 (0.144)	0.089 (0.150)
Ln(Gross irrigated area in million hectare)					−0.070 (0.044)
Literacy rate					−0.018*** (0.005)
Region FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
χ2 (d.f.)	495.90 (22)	671.67 (23)	970.32 (24)	1021.58 (25)	948.71 (27)
Log-likelihood	−55,160	−50,531	−45,474	−45,290	−43,543
No. of states	17	17	17	17	17
Observations	289	289	289	289	289

Robust standard errors are reported in parentheses. Dependent variable is the total number of farmer suicides

*$p < 0.1$ denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

Table 8 Impact of poverty and drought on farmer suicides: FE Poisson Model

Variables	Model-1	Model-2	Model-3
Rural Head Count Ratio (RHCR)	0.018 (0.017)	0.010 (0.014)	0.011 (0.014)
Rural HCR *drought dummy	0.014** (0.005)	0.020*** (0.005)	0.026*** (0.004)
Rural HCR *high flood magnitude Dummy		0.005 (0.007)	0.013*** (0.003)
Rural HCR *moderate flood magnitude dummy		0.023*** (0.006)	0.023*** (0.006)
MGNREGS dummy			0.425 (0.307)
Ln (Agricultural productivity per hectare gross irrigated land)			−0.080 (0.109)
Coastal state dummy			2.911*** (0.628)
Region FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
χ2 (d.f.)	140.57 (10)	196.40 (12)	279.39 (14)
Log-likelihood	−10,724	−9393	−6946
No. of states	17	17	17
Observations	68	68	68

Robust standard errors are reported in parentheses. Dependent variable is the total number of farmer suicides. Low flood magnitude is the base category dummy variable

*$p < 0.1$ denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

Table 9 Impact of drought and flood on farmer suicides: OLS model

Variables	Model-1	Model-2	Model-3
Drought dummy	0.6204*** (0.171)	0.5028*** (0.181)	0.2781* (0.162)
High flood magnitude dummy		−0.1328 (0.189)	0.0053 (0.154)
Moderate flood magnitude dummy		0.0837 (0.179)	0.1718 (0.152)
Ln (Real agricultural wages for male workers)		−0.6665** (0.259)	−0.5845** (0.244)
Ln(Expenditure of flood control and drainage/ Revenue development expenditure)			−0.0454 (0.037)
Ln(Expenditure of flood control and drainage/ Revenue development expenditure) (−1)			−0.0628* (0.036)
Ln(Expenditure of agriculture and allied activities/Total expenditure)			−0.0888 (0.175)
Ln(Expenditure of agriculture and allied activities/Total expenditure) (−1)			−0.2894 (0.179)
Constant	3.7411*** (0.731)	5.8491*** (1.260)	4.2616*** (1.022)
Observations	289	289	272
R-squared	0.499	0.514	0.662

Robust standard errors are reported in parentheses. Dependent variable is Ln (total number of farmer suicides+0.1). All regressions include region and year fixed effects.. Low flood magnitude is the base category dummy variable

*$p < 0.1$ denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

Table 10 Farmer suicides in cotton and wheat production states: OLS model

Variables	Model-1	Model-2	Model-3
Cotton producing state dummy	0.6612*** (0.136)	0.4128*** (0.149)	0.3072** (0.155)
Cotton producing state dummy*drought dummy		0.7019*** (0.224)	0.7327*** (0.222)
Wheat producing state dummy		0.8505*** (0.198)	0.7431*** (0.279)
Wheat producing state dummy*drought dummy		0.1338 (0.279)	0.1446 (0.274)
Ln(Gross irrigated area in million hectares)			0.0852 (0.088)
Literacy rate			−0.0246** (0.010)
Constant	3.2388*** (0.707)	2.7817*** (0.670)	3.5562*** (0.840)
Observations	289	289	289
R-squared	0.506	0.549	0.557

Robust standard errors are reported in parentheses. Dependent variable is Ln (total number of farmer suicides+0.1). All regressions include region and year fixed effects

*$p < 0.1$ denote 1%, 5% and 10% levels of significance respectively

**$p < 0.05$

***$p < 0.01$

Table 11 Impact of poverty and drought on farmer suicides: OLS model

Variables	Model-1	Model-2	Model-3
Rural Head Count Ratio (RHCR)	−0.0090 (0.016)	−0.0142 (0.015)	−0.0101 (0.012)
Rural HCR *drought dummy	0.0269* (0.015)	0.0303** (0.014)	0.0289*** (0.010)
Rural HCR *high flood magnitude dummy		−0.0176 (0.018)	−0.0093 (0.014)
Rural HCR *moderate flood magnitude dummy		0.0402*** (0.015)	0.0352* (0.020)
MGNREGS dummy			−0.3561 (0.328)
Ln(Agriculture productivity per hectare gross irrigated land)			−0.2586 (0.166)
Coastal state dummy			1.7518*** (0.252)
Constant	6.3616*** (0.547)	5.9090*** (0.488)	8.9444*** (2.313)
Observations	68	68	68
R-squared	0.068	0.161	0.537

Robust standard errors are reported in parentheses. Dependent variable is Ln (total number of farmer suicides+0.1). All regressions include year fixed effects. Low flood magnitude is the base category dummy variable

*p < 0.1 denote 1%, 5% and 10% levels of significance respectively

**p < 0.05

***p < 0.01

Table 12 Summary statistics of variables

Variables	Definition of variables	Obs	Mean	Std. Dev.	Min	Max
Dependent variable						
Total number of farmer suicides	Number of farmer suicides in 17 Indian states in respective years	289	871.4	936.4	0	4453
Explanatory variables						
Disaster variables						
Drought dummy	Drought dummy equals to 1 if the state suffered drought situation in respective years, otherwise 0.	289	0.2	0.4	0	1
Low flood magnitude dummy	Low flood magnitude dummy is equal to 1, if state wise area affected by flood lies less than equal to 49 percentile, otherwise 0.	289	0.5	0.5	0	1
Moderate flood magnitude dummy	Moderate flood magnitude dummy is equal to 1, if state wise area affected by flood lie between 50 and 74 percentile, otherwise 0.	289	0.2	0.4	0	1
High flood magnitude dummy	High flood magnitude dummy is equal to 1, if state wise area affected by flood lie above 75 percentile, otherwise 0.	289	0.3	0.5	0	1
Major crop production dummy variables						
Major cotton producing state dummy	Major 10 cotton producing states dummy is equal to 1, otherwise 0.	289	0.6	0.5	0	1
Major wheat producing state dummy	Major 9 wheat producing states dummy is equal to 1, otherwise 0.	289	0.5	0.5	0	1
Interaction variables						
		289	0.2	0.4	0	1

Table 12 (continued)

Variables	Definition of variables	Obs	Mean	Std. Dev.	Min	Max
Major cotton producing state dummy*drought dummy	Major 10 cotton producing states dummy interacted with drought dummy of particular states in specific years.					
Major wheat producing state dummy*drought dummy	Major 9 wheat producing states dummy interacted with drought dummy of particular states in specific years.	289	0.1	0.3	0	1
Rural Head Count Ratio (RHCR)*drought dummy	Percentage of rural population living below the poverty line interacted with drought dummy for a particular state in different years.	68	10.4	17.4	0	55.7
Rural Head Count Ratio (RHCR)*high flood magnitude dummy	Percentage of rural population living below the poverty line interacted with high flood dummy for a particular state in different years.	68	6.2	13.6	0	55.7
Rural Head Count Ratio (RHCR)*moderate flood magnitude dummy	Percentage of rural population living below the poverty line interacted with moderate flood dummy for a particular state in different years.	68	3.4	9.4	0	37.1
Income, government expenditure and other variables						
Ln(Real agriculture wages for male workers)	Nominal agricultural wages for male workers deflated by state-wise consumer price index of agricultural laborer (1987 = 100).	289	3.0	0.4	2.2	4.3
MGNREGS dummy	Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) takes the value 1 for the years 2005 and above, and otherwise 0.	289	0.4	0.5	0	1
Coastal state dummy	Coastal state dummy takes the value 1 if the particular state has coastal area, otherwise 0.	289	0.5	0.5	0	1
Rural Head Count Ratio (RHCR)	Percentage of rural population living below the poverty line for each state.	68	27.8	13.6	6.4	60.8
Literacy rate (%)	State-wise literate population over adult population, excluding child population.	289	59.4	10.8	22.7	94
Ln(Expenditure of flood control and drainage/Rev. development expenditure)	State government expenditure on flood control and drainage over revenue development expenditure	289	−8.6	4.8	−19.7	−3.9
Ln(Expenditure of agriculture and allied activities/Total expenditure)	State government expenditure on agriculture and allied activities over total government expenditure	289	−3.7	0.9	−5.8	−2.2
Ln(Gross irrigated area in million hectares)	State-wise gross irrigated area in million hectares.	289	7.8	1.5	3.9	9.9
Ln (Agriculture productivity per gross irrigated land in hectare)	State-wise agriculture Gross State Domestic Product (GSDP) to Gross irrigated area in hectare.	289	13.6	0.8	12.6	16.0

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