Impact of Weather Shocks on Trust in Agrarian Communities: Evidence from Rural India*

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October 24, 2025

Abstract

Climate change is likely to increase risk in the agricultural sector in developing countries by affecting resources like water. It is unclear how social institutions like trust and cooperation respond to resource scarcity created through weather shocks. This paper examines how drought affects collective action in rural India. Using the two-wave India Human Development Survey panel (2005 and 2012) and district-level drought measures (SPEI), I compare households in districts within the same state that experienced different numbers of dry seasons. Wet-season (Kharif) drought is not associated with reported community cooperation on water problems, while dry-season (Rabi) drought increases cooperation by about three percentage points, which does not differ significantly by baseline irrigation access.

Keywords: Weather shocks; trust; cooperation; conflict; historical institutions
JEL Classification: O13; Q15; Q54; D74

*This paper is based on my Master's thesis at the Paris School of Economics (Master's in Analysis and Policy in Economics). I am grateful to my advisor, Karen Macours, for her continuous support and advice, to Liam Wren-Lewis and Jérémie Gignoux and the seminar participants at PSE for helpful comments, and to my peers at PSE for their feedback. All errors are my own.

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1 Introduction

Trust and cooperation play a crucial role in economic development, particularly in agrarian communities of developing countries where formal institutions are generally weak. In such a setting, communities rely on trust between farmers to enforce resource sharing agreements (water, informal credit etc.). Agriculture is an important sector in rural India, with 60% of the labour force dependant on agriculture (PLFS, 2018-19). This project aims to look at short-term resource scarcity (water) created through weather shocks on trust in agricultural communities. It is not clear how resource scarcity affects trust (or cooperation) in agricultural communities, whether people compete for scarce resources or cooperate more to ensure efficient management. On the one hand, people compete for scarce resources and over-extract them to maximise personal welfare (Haseeb, 2020). On the other hand, when people are altruistic about their community or when the community puts social sanctions on deviations, then resource scarcity may increase people's willingness to cooperate (Nie et al., 2020, Wade, 1989).

In this study, I look at the effect of short-term water scarcity created through weather shocks on trust in agricultural communities in rural India. In particular, I am looking at the effect of weather shocks on the probability of collectively solving water problems. The measure of trust I use (water cooperation) is a self-reported measure of the probability of a community collectively solving all its water problems. I assume water problems in a community can be classified broadly based on their use into agricultural water problems (irrigation) and household/domestic water problems. I am interested in the effect of weather shocks on water cooperation through the agricultural channel. Agriculture is one of the most vulnerable sectors of climate change (Parry, 2007), and it is important to understand how social institutions like trust and cooperation play an important role in adapting to these climate changes.

This paper shows that short-term water scarcity created through weather shocks are unlikely to change cooperation through the agricultural channel. I find Rabi shocks increase cooperation; it could be through the domestic channel or represent an increase in general collective action within the community. I use variation in the total number of dry shocks and the number of consecutive dry shocks between baseline and endline in each cropping season (Kharif and Rabi) to identify the effect of weather shocks on water cooperation. To calculate dry shocks, I use the deviation of SPEI (a drought index) from its historical mean in each cropping season in a given district. Through this and controlling for state fixed effects, I exploit only random variation in weather shocks. I find weather shocks in Kharif, the main growing season, doesn't affect water cooperation. Weather shocks in Rabi, (the dry season) slightly increase the probability to cooperate in solving water problems by 4.1%. The effect of Kharif shocks is similar to the full estimate (not different from zero) for the subsample of farmers, and Rabi shocks effect is slightly lower in magnitude. I look at heterogeneity in the effect of weather shocks due to irrigation. The effect of weather shocks on water cooperation through the agricultural channel is relevant only

for households with irrigation. But I don't find heterogeneity due to irrigation. Further, I look at heterogeneity due to irrigation technologies, as surface water resources require more cooperation from communities. Again I don't find any heterogeneity due to irrigation technologies. Water cooperation in agriculture has to go through irrigation sources, and no heterogeneous effect due to irrigation strengthens my interpretation that weather shocks are not affecting water cooperation related to agriculture.

To understand mechanisms better, I look at other outcome variables like conflict and no. of loans between baseline and endline. I find conflict reduces if people experience Kharif shocks, and conflict increases when people experience Rabi shocks. I find these effects are driven by conflict between communities/caste groups. One way to interpret these results along with water cooperation results could be when shocks are moderate, people cooperate more within their communities but reduce cooperation between communities/caste groups. But when shocks are more intense, they could induce cooperation even between groups. When resource scarcity is higher, value of collective action increases and people with potentially conflicting interests may reduce their conflicts. Next, I look at the effect of weather shocks on no. of loans taken between baseline and endline (a majority of loans in my sample are taken from informal sources like friends, family, etc., which are given based on trust). I found there is a decrease in the number of loans for households that experience Rabi shocks; an additional Rabi shock leads to an 8.5% decrease in the number of loans. These results are driven by households that experience early shocks (shocks between 2006-2008). The effect of early Rabi shocks is almost twice of what I found for the total number of Rabi shocks. It could be possible that households that experience early shocks may not repay their loans and get lesser loans (repayment channel). When shocks are more intense (consecutive shocks or Kharif shocks), effects are not statistically significant from zero. When shocks are more damaging, in addition to the repayment channel, there could be an insurance channel where informal networks (friends, family etc.) act as insurance and provide more loans.

To understand factors explaining cooperation (or non-cooperation) due to weather shocks better, I study the role of historical institutions created during British colonial times. I follow the work of Banerjee and Iyer, 2005 for this analysis, where they showed differences in historical land tenure systems led to sustained economic differences. My results are in line with the findings of Banerjee and Iyer, 2005, the areas where historical land rights were given to landlords; there would be less water cooperation when they experience weather shocks. These effects are larger for farmers sub-sample. The landlord areas are marked by high inequality in wealth and land distribution. Even after the abolition of this land tenure system post-independence, there are no major land reforms to reduce this inequality (except in West Bengal and Kerala). Rich landlords may appropriate more resources when there is scarcity, and poor farmers may try to resist that. This conflicting environment would create less scope for collective action.

I provide robustness checks to my results using an alternative linear specification where I allow for shock in each year to have different effects. The effect of Rabi shocks and Kharif shocks on the probability to cooperate lies in the range of main specifications, but estimates are noisy and not significantly different from zero. As a second robustness check, I used rainfall shocks (defined in the same way as SPEI shocks). I found the effect of rainfall shocks are very noisy as state fixed effects take up a lot of variation in rainfall shocks. When I use specification without state fixed effects, results are largely in line with SPEI results. Finally, I showed my results are robust to sample selection issues and an alternative definition of farmers.

This work falls in the interface of three strands of literature, first on how contextual shocks change social preferences and social norms. Studies in this literature looked at the effect of how long-term exposure to water scarcity on within community cooperation (Nie et al., 2020), effects of short-term water scarcity created through weather shocks on inter-village water theft incidents in irrigation canals (Haseeb, 2020). A few studies focus on long-term changes in access to groundwater access on farm income, agricultural adoption (Blakeslee et al., 2020) and disputes over irrigation (Sekhri, 2014). My work contributes to this literature by analysing short-term resource scarcity created through weather shocks on both intra-community and inter-community (between caste groups) in the same context. Richness in IHDS data allowed me to look at the heterogeneous effect of different irrigation technologies (surface water and groundwater), whereas studies in the literature focused either on the role of surface water or groundwater irrigation. Related literature explored effects of more extreme events like Tsunami (Hill and Viceisza, 2012) on prosocial behaviour, risk aversion and the effect earthquake and relief followed that on trust on Europeans and Americans (Andrabi and Das, 2017).

Second, this study contributes to a recently grown literature on the effect of weather shocks reviewed in detail in Dell et al., 2014. More recent literature looked at the effect of seasonal weather shocks on the conflict at a more disaggregated level (Harari and Ferrara, 2013), the role of irrigation projects on mitigating conflict due to weather shocks (Sarsons, 2015, Gatti et al., 2020). Another related literature looks at agricultural adoption to long term environmental changes (Burke and Emerick, 2016, Taraz, 2017). I contribute to this literature by looking at the effect of aggregated shocks instead of individual shocks on different outcomes: water cooperation, lack of conflict and no.of loans. I also look at the effects of weather shocks with varying intensity (consecutive vs total number of shocks) on trust and cooperation. Although I am looking at short-term weather shocks, studying effects on social norms like trust and cooperation helps us understand the dynamics of adaptation to long-run environmental changes. This understanding of adaption is crucial in developing country setting and agricultural sector, as both are vulnerable to climate change(Parry, 2007).

The third strand of literature is related to the role of historical institutions in contemporary outcomes like agricultural productivity Banerjee and Iyer, 2005, and human capital and health outcomes (Lehne, 2019). Both works are in the context of historical institutions in India set up by the British during colonial times. My work is also closely related to the work on the long-term persistence of social trust and social capital. The few existing studies on the topic have examined specific historical shocks that induced or destroyed cooperation and that had persistent effects on cooperative attitudes, such as the slave trade (Nunn and Wantchekon, 2011), economic risk (Durante and Buggle, 2017). Previous studies looked at the level of trust or cooperation due to historical institutions. I contribute to this literature by looking at changes in trust level due to contemporary weather shocks in areas which had different historical land tenure systems.

This paper is organised as follows; in the next section, I discuss data sources. In section 3, I describe my empirical strategy. In section 4, I describe results and discuss possible mechanisms and, in section 5, limitations and scope for future work. In the final section, I provide discussion of the findings in the paper and concluding remarks.

2 Data

I use Indian Human Development Survey (IHDS) for measures of trust, conflict and loans. IHDS is a nationally representative panel survey of 40018 households surveyed in 2005 and 2012, covering 373 districts (1503 rural areas and 971 urban neighbourhoods). For this paper, I will focus on rural sample, as agricultural communities are mostly located in rural India. The Rural IHDS sample has 28205 households spanning across 285 districts. I rely on this survey data to measure trust, and it is captured through cooperation in solving water problems. Here I am adapting the interdependence perspective of trust, which is key for cooperation in situations involving social interdependence and some degree of conflict (Balliet and Lange, 2012). In particular, I am using the question, "In some villages or neighbourhoods, when there is a community problem such as water supply problem, people bond together to solve the problem. In other communities, people take care of their own families individually. What is your community like?" and my trust measure "water cooperation" takes"1" if community solves water problems together, otherwise "0". I assume water problems in a community can be categorised based on their use into water problems related to agriculture (irrigation resources) and water problems related to domestic use. We have to be careful in how we interpret this measure of trust, and people could feel good about their community if they respond that their community solves problems together (social desirability bias); this could lead to an upward bias in our measurement of trust. But this doesn't bias my estimates as I don't expect social desirability bias to be correlated with weather shocks.

Weather data: I use 2001 census boundaries at the district level to extract (as IHDS data is identifiable at district level) to extract rainfall and temperature data using ERA5 data (0.25 degrees

resolution) using Google Earth Engine. I use the SPEI index[1] to calculate weather shocks, which takes into account the effects of rainfall, potential evapotranspiration, following Harari and Ferrara, 2013. India has two main growing seasons, one Kharif from July - October and another Rabi from November to March. The SPEI index for Kharif is calculated on a time scale of 4 months, and for Rabi, it's calculated on five months. I calculated the historical mean for each district in each cropping season using SPEI data from 1980-2003 (the period before the baseline). SPEI dry shocks for each season in a district are measured as a dummy variable that takes one if SPEI deviation (SPEI-historical mean) is less than -1*SD otherwise zero. For each cropping season SPEI dry shock is given by

$$\text{SPEI dry shocks} = \begin{cases} 1, & \text{if } \frac{SPEI - mean(SPEI)}{SD} < -1 \\ 0, & \text{otherwise} \end{cases}$$

Mean SPEI, SD is estimated as the sample mean and sd of SPEI data from 1980-2003, respectively, using the period before baseline. SPEI shock is my preferred measure for weather shocks as it accounts for the water demand of the soil at different temperatures. I aggregated SPEI dry shocks between baseline and endline in two ways: the total number of dry shocks in each cropping season and the second number of consecutive dry shocks in each cropping season. These aggregated shocks are explanatory variables in our main specification.

I also use rainfall shocks to check for the robustness of my results, and I measure them in the same way as SPEI shocks. First, I calculated rainfall Z scores for each cropping season in each district. For example, a given district Kharif rainfall Z score for a year is measured as (total Kharif rainfall - mean (Kharif rainfall in the district))/ sd of rainfall. Mean, and sd are estimated as the sample mean and sd for each district using rainfall data from 1980-2003. Rabi shocks are defined in the same way. Then I defined rainfall shocks as a dummy variable that takes one if the Z score is less than -1, otherwise 0. I aggregated them in the same way as SPEI dry shocks, the total number of rainfall shocks and the number of consecutive shocks between baseline and endline.

I used IHDS data for irrigation and irrigation technology. If the main source of irrigation is reported as tube well (private or government), variable"groundwater" takes one otherwise, 0, if their main source of irrigation is reported as the river, canal, pond, tank or others variable "surface water" takes one otherwise 0. Latitude for each district is the latitude of the centroid of the district, and it is extracted using 2001 census boundaries from the google earth engine. For data on conflict, I combined IHDS questions "Do people in your village get along or have some or lot of conflict" and "In your village, how much conflict would you say there is between communities/jatis that live here?" and created variable lack of conflict which take five if there is no conflict at all, one if there is a lot of conflict. Loan data also comes from IHDS survey; I used the question No. of

[1]The Standardized Precipitation Evapotranspiration Index, SPEI is designed to take into account both precipitation and potential evapotranspiration (PET) in determining drought developed by Vicente-Serrano et al., 2010

loans taken in the past 5-6 years, as this better captures loan data between baseline and endline compared to questions on the largest loan (which on average was taken 1.9 years ago)

Historical Data For data on historical institutions, I relied on the work of Banerjee and Iyer, 2005. They have data at the district level, and my main variable of interest, "pnland", measures the proportion of the area under the non-landlord tenure system in the district. Their data set has other geographical controls like latitude, altitude, soil type, if the district is a coastal district, length of time under British control. I use fuzzy matching to match names of the districts in the IHDS data set (according to the 2001 census) and dataset from Banerjee and Iyer, 2005 (1991 census). Data set from Banerjee and Iyer, 2005 has 271 districts spanning over 16 states and IHDS has 385 districts. There are 192 districts common in both data sets and missing districts may not be sampled in IHDS data set and there is redistricting (1991 census has 466 districts and 2001 census has 593 districts). I show summary statistics of missing households in Table 13 and they are almost similar to summary statistics (Mean, sd, min and max) for the full sample reported in Table 12. I use this data to analyse how weather shocks affect trust differently in areas with different land tenure systems.

3 Empirical Strategy

I estimate the effect of weather shocks on trust in agrarian communities using the following regression model :

$$y_{1_{id}} = \alpha + \beta_1 * y_{0_{id}} + \beta_2 * Kharifagg_d + \beta_3 * Rabiagg_d + \alpha_s + lat_d + \epsilon_{id} \tag{1}$$

I have trust data at the household level and weather shocks at the district level. The dependent variable is trust and is measured through cooperation in solving water problems at the endline (in 2012 for most households). I aggregate weather shocks (explanatory variables Kharifagg and Rabiagg in the model) in two ways, total no of SPEI dry shocks between baseline and endline and the number of consecutive SPEI dry shocks. I control for baseline trust measure, latitude and state fixed effects(α_s). We can interpret the estimates as the effect of weather shocks on the trust level between districts within a state, as we exploit only within state variation of weather shocks. For example, β_2 is a change in probability of cooperation in issues related to water between districts within a state if there an additional SPEI shocks between baseline and endline. I have clustered standard errors at the district level.

To provide robustness to the my results, I estimated the effect of weather shocks using the following model

$$y_{1_{id}} = \alpha + \beta_0 * y_{0_{id}} + \sum_{t=1}^{t=6} \beta_t * Kharif_{dt} + \sum_{t=1}^{t=6} \gamma_t * Rabi_{dt} + \alpha_s + lat_d + \epsilon_{id} \tag{2}$$

In this model, I use a linear specification of SPEI shocks in Kharif and Rabi season in the same way as above using a dummy variable which takes 1 if Z score ((SPEI-Mean(SPEI))/SD) is less than -1 otherwise zero. Mean and sd are calculated in the same way as above using the sample from 1980 to 2003. Similar to the above specification, I controlled for baseline trust, latitude and used state fixed effects. Through this specification, I can estimate the effect of individual weather shocks.

To estimate heterogeneous effects of irrigation and Irrigation technology using the regression model below in the equation 3.3. It is the same as the main specification, equation 3.1, except that I interact weather shocks with baseline irrigation at the household level. $\beta_4(\beta_5)$ estimates the difference in the effect of Kharif shocks (Rabi shocks) between households that have access to irrigation and that don't have access to irrigation (within a state).

$$y_{1_{id}} = \alpha + \beta_1 * y_{0_{id}} + \beta_2 * Kharifagg_d + \beta_3 * Rabiagg_d + \beta_4 * Kharifagg_d * Irrigation2005_{id} + \beta_5 * Rabiagg_d * Irrigation2005_{id} + \beta_6 * Irrigation2005_{id} + lat + \alpha_s + \epsilon_{id} \quad (3)$$

I use the following model to estimate the heterogeneous effect of weather shocks on different land tenure systems. Following the model used in Banerjee and Iyer, 2005, I interact weather shocks with "pnland", a measure of the proportion of district area under the non-landlord tenure system. I control for the same variables used in the benchmark specification of Banerjee and Iyer, 2005 i.e., geographic variables like latitude, altitude, type of soils, whether a district is coastal or not, and also for the length of British rule. I use state fixed effects in this model consistent with my other models[2].

$$y_{1_{id}} = \alpha + \beta_1 * y_{0_{id}} + \beta_2 * Kharifagg_d + \beta_3 * Rabiagg_d + \beta_4 * Kharifagg_d * pnland_d + \beta_5 * Rabiagg_d * pnland_d + \beta_6 * pnland_d + \gamma_1 * X_d * Kharifaggd + \gamma_2 * X_d * Rabiagg_d + \gamma_3 * X_d + \alpha_s + \epsilon_{id} \quad (4)$$

Identification I define weather shocks as SPEI deviations from their historical mean, controlling for any time-invariant SPEI characteristics of a district. Therefore I exploit random variation in weather over cropping seasons within each district to identify the effects on trust in agricultural communities in India.

Even though weather shocks are random by nature, there could be a possible correlation of shocks across time within a given district and this temporal persistence of weather conditions could be arising from shifts in climate patterns. If these shifts are associated with certain geographical conditions or other unobservable characteristics correlated with trust, they could bias our estimates. For example, If characteristics of India's summer monsoon is changing due to

[2]Banerjee and Iyer, 2005 didn't use state fixed effects in their model as there is no within state variation for states like Bihar, Gujarat, Karnataka, Rajasthan, and West Bengal. I show that my results are robust even if I don't use state fixed effects

climate change[3] over time, it can affect states (or larger geographic regions) differentially based on their location wrt to the monsoon direction, and location of state is possibly correlated with water cooperation[4].

I address these identification concerns in two ways. First, to understand the spatial distribution of weather shocks, I plotted consecutive SPEI shocks between 2006 and 2012 (both Kharif and Rabi) Figure 1 and future SPEI shocks Figure 2. These maps indicate consecutive SPEI shocks are spatially correlated, which we would expect in a monsoon climate. I decided to use state-fixed effects to control for any possible monsoon trends that might be affecting deferentially across states. Hence I am exploiting variation in weather shocks across districts in a given state.

Second, I do a placebo test using future weather shocks defined over six years (2014-2019)[5] and test if they have any effect on the trust. I expect these future shocks have no effect on trust levels between 2005 and 2012.Table 1 reports effects of future shocks (2014-2019) on water cooperation. I used the same specification as in equation 3.1. Column 1 and 3 report estimates for the full sample using total dry shocks and the number of consecutive dry shocks as explanatory variables. The effect of both Kharif and Rabi future shocks on water cooperation is not statistically different from zero. Column 2 and 4 reports estimates for a sample of farmers who report positive agricultural income using the exact specification. Results of this sub-sample are in line with what I expected; both Kharif and Rabi don't impact water cooperation. These results provide more confidence in my identification strategy.

4 Results

Impact of weather shocks on Income: I use the equation 4.1 to estimate the effect of weather shocks on self reported agricultural income. Kharif and Rabi shocks are defined as dummy variables which takes one if SPEI deviation (SPEI-mean(SPEI))/SD (or if rainfall deviation) is less -1, otherwise 0. I used SPEI (or rainfall) measures in the year before the survey (2003 for IHDS-I and 2010 for IHDS-II). I controlled for district fixed effects and year fixed effects.

$$y_{idt} = \alpha + \beta_1 * Kaharif_{dt} + \beta_2 * Rabi_{dt} + \nu_d + \theta_t + \epsilon_{idt} \tag{5}$$

In the Table 2, I report the effect of weather shocks on agricultural income. In column 1, I report the effect of Kharif and Rabi rainfall shocks and in column 2, I report the effects of SPEI shocks.

[3]India has two major monsoons, South-west monsoons(or summer monsoon) sets in early June and spread over the country slowly, second north-east monsoon (or winter monsoon), which sets at the end of October or early November. Based on the location of the state wrt to the direction of the monsoon, it receives varied rainfall

[4]For example more precisely, if summer monsoons at the onset got weaker due to shifts in climate pattern, Kerala might receive lower rainfall than its historical average due to this shift. Water cooperation in Kerala would be different from other states due to its geographical location or unobserved factors

[5]I took a 6-year window after the endline, period same as between baseline and endline. I left 2013, as few households were surveyed in early 2013

Table 1: Future SPEI Shocks (2014-2019) - Placebo Test

	water cooperation 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
water cooperation 2005	0.012	0.020	0.012	0.021
	(0.012)	(0.015)	(0.012)	(0.015)
Kharif total shocks	−0.010	−0.020		
	(0.010)	(0.012)		
Rabi total Shocks	−0.014	−0.011		
	(0.016)	(0.018)		
Kharif cons shocks			−0.007	−0.009
			(0.011)	(0.013)
Rabi cons shocks			−0.010	−0.010
			(0.011)	(0.013)
latitude	0.016*	0.012	0.016*	0.014
	(0.009)	(0.011)	(0.009)	(0.011)
Constant	0.282	0.464	0.236	0.348
	(0.317)	(0.373)	(0.330)	(0.386)
water cooperation 2012 mean	0.743	0.738	0.743	0.738
STATE Fixed effects	YES	YES	YES	YES
Observations	27,153	14,050	27,153	14,050

Notes: This table reports effect of future SPEI shocks on water cooperation from (2014-2019). Column 1 reports the effect of the total no of dry shocks in Kharif and Rabi seasons, and column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present effects for no. of consecutive dry shocks on full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 2: First Stage Results

	Income	
	Rainfall shocks	SPEI shocks
	(1)	(2)
Kharif Rainfall	774.33**	
	(259.25)	
Rabi Rainfall	−65.02	
	(417.22)	
Kharif SPEI		606.15
		(501.01)
Rabi SPEI		121.78
		(587.21)
Year FE	YES	YES
DIST FE	YES	YES
Income mean	4881	4881
N	20364	20364

Notes: This table reports effect of weather shocks on reported agricultural income. Column 1 reports effect of rainfall shocks and column 2 reports effects of SPEI shocks. std errors are clustered at district level. *p<0.1; **p<0.05; ***p<0.01

Results indicate farmers in districts which had Kharif rainfall shocks (dry shocks) have 15.85% higher income compared to farmers in districts which didn't have Kharif rainfall shocks. Effects of Kharif SPEI shocks and Rabi season (for both rainfall and SPEI shocks) are not different from zero. These results indicate that dry weather shocks don't affect agricultural income (It increase income in the case of Kharif rainfall shocks). Signs of the estimates are opposite of what I expect, dry rainfall shocks/SPEI shocks is showing positive effects. These results should be taken with caution, agricultural incomes are self-reported, and estimates are very noisy.

Impact of aggregate weather shocks on trust Table 3 shows the effect of aggregate SPEI shocks on water cooperation estimated using equation 3.1. Column 1 reports the effect of the total number of dry shocks in the Kharif and Rabi season. Kharif shocks don't change water cooperation, whereas an additional dry shock in the Rabi season increases the probability of water cooperation by 4.1%. In column 3, I report the effect of the number of consecutive dry shocks in the Kharif and Rabi season. The effect of consecutive Kharif shocks is statistically not significant from zero, but an additional consecutive shock in Rabi season increases water cooperation by 3.9%. In columns 2 and 4, I report the effects of weather shocks for a subsample of farmers defined as households who report positive agricultural income. If these effects go through water cooperation in agriculture, I expect effects to be larger for this subsample as they experience direct effects of water scarcity relevant for agriculture. Effects are statistically not different from zero for both Kharif and Rabi

season and effects for Rabi season are smaller in magnitude compared to the full sample estimates.

Kharif season receives 77% of the annual rainfall[6] in India. Water demanding crops like rice, corn, sugarcane, groundnuts, soya beans, pearl millets are predominantly grown in Kharif season[7]. Kharif season rainfall at the end of the season is essential even for Rabi crops through moisture retained in the soil(Prasanna, 2014). If the effect of weather shocks on water cooperation goes through the agricultural channel, then I expect dry shocks in the Kharif season to have more effect. But the results indicate that it is unlikely to weather shocks change how people collaborate in solving water issues related to agriculture. Increasing cooperation due to Rabi shocks could be arising from more cooperation in solving water problems related to domestic use. Another possible interpretation of the above results could be, Rabi shocks lead to more community cohesion when they experience weather shocks. The way the water cooperation question is posed asks about community collaboration taking water problems as an example. It may capture more general collaboration in solving problems. I don't have separate measures for water cooperation related to agriculture or domestic usage to provide direct evidence. I can't eliminate the possibility of Rabi shocks not affecting cooperation through the agricultural channel. As Rabi crops are grown with irrigation, weather shocks in the Rabi season have may relative importance for agriculture as they can potentially increase dependence on irrigation. I discuss these possibilities further when looking at irrigation heterogeneity.

I used two types of aggregation in weather shocks, the total number of weather shocks and the number of consecutive weather shocks. There are two reasons for using the number of consecutive weather shocks. First, it gives some signal on how shocks are distributed between baseline and endline [8]. I expect the marginal effect for consecutive shocks to be higher than the marginal effect of total no of shock, and this goes through the higher intensity of resource shocks (water) created when people experience consecutive weather shocks. I am not exactly using the number of consecutive shocks in the earlier specifications, but consecutive weather shocks in a given season. Kharif season is the most important season for agriculture in India and gets 77% of the total annual rainfall. So I assume consecutive Kharif shocks is almost equivalent to experiencing consecutive dry shocks in agriculture. Consecutive Kharif shocks can potentially intensify water scarcity for agriculture, and I expect them to have a stronger effect. I observe that the effect of total Kharif shocks and consecutive Kharif shocks is not statistically different from each other (and not different from zero for Kharif shocks). These results further suggest weather

[6]I have calculated share of Kharif rainfall in each district from 1980-2019, and then calculated the mean Kharif rainfall for all districts in India. Rabi accounts for 12%, and summer rainfall accounts for 11%. Ideally, I should take the weighted average over the area of the district. These estimates match with data reported in the literature, e.g., Monsoon seasons receive 80% of annual rainfall (Prasanna, 2014), southwest monsoon season accounts for 75-90% of annual rainfall (Preethi et al., 2011)

[7]These six crops constitute 70% of the total area cultivated in Kharif, whereas rice alone accounts for 40% of the total area grown in the Kharif Emerick, 2018

[8]I am not using complete information on the distribution of shocks, for example, I don't differentiate between three consecutive in early years vs three consecutive shocks in recent years wrt to endline

shocks doesn't affect water cooperation through the agricultural channel.

Table 3: Effect of SPEI Dry Shocks on Water Cooperation

	Water cooperation 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
Water cooperation 2005	0.012	0.021	0.011	0.022
	(0.011)	(0.014)	(0.011)	(0.014)
Kharif total shocks	−0.007	−0.015		
	(0.012)	(0.015)		
Rabi total shocks	0.031**	0.023		
	(0.013)	(0.014)		
Kharif cons shocks			0.011	0.007
			(0.013)	(0.016)
Rabi cons shocks			0.029**	0.024
			(0.014)	(0.015)
Latitude	0.013	0.010	0.017*	0.013
	(0.010)	(0.012)	(0.010)	(0.011)
Constant	0.176	0.351	0.047	0.207
	(0.337)	(0.388)	(0.326)	(0.384)
Water cooperation 2012 mean	0.743	0.738	0.743	0.738
STATE Fixed effects	YES	YES	YES	YES
Observations	27,153	14,050	27,153	14,050

Notes: This table reports the effect of weather shocks (SPEI shocks) on water cooperation. Column 1 reports the effect of the total no of dry shocks in Kharif and Rabi seasons, and column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present effects for no. of consecutive dry shocks on full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

I look at the heterogeneous effect of the total no of dry shocks between the households which have irrigation and which doesn't have irrigation in the Table 4. Irrigation resources are a prime example of a common pool resource in agriculture [9] that requires trust and cooperation to maintain sharing agreements in a developing country context where formal institutions are generally weak Ostrom, 1990. If changes in water cooperation due to weather shocks are through the agricultural channel, there should be some heterogeneity in the effect of weather shocks due to irrigation. In households without irrigation, water cooperation related to agriculture is not relevant, and any changes in water cooperation have to be through the domestic channel. Effects in water cooperation through domestic channel would be the same for households with and without irrigation.

[9]Communities play different roles for maintaining common polled resources, for example, they pool efforts and resources in constructing and maintaining field channels at the local outlet level. They regulate water allocation to communities, and they monitor violations Bardhan, 2000

Column 1 presents results for a sample of households who reported irrigation. Questions about irrigation access in IHDS were posed only to the household that either owns agricultural land or cultivates it. Column 2 shows results for a sub-sample of farmers who reported positive income. Results suggest that there is no heterogeneity due to irrigation. The magnitude of effects in the total number of shocks in Kharif and Rabi season (although statistically not significant from zero for Rabi season) are similar to what we found in the main specification Table 3. To provide more robustness to the results, I reported results with the number of consecutive shocks in Kharif and Rabi as explanatory variables reported in the Table 14. Both consecutive shocks and the total number of shocks have similar effects.

Table 4: Irrigation Heterogeneity - Total Dry Shocks

	Water cooperation 2012	
	full sample	farmers
	(1)	(2)
Water cooperation 2005	0.017	0.021
	(0.013)	(0.014)
Kharif total shocks	−0.011	−0.009
	(0.015)	(0.016)
Rabi total shocks	0.021	0.017
	(0.013)	(0.015)
Irrigation 2005	−0.036	−0.060
	(0.041)	(0.046)
Latitude	0.009	0.010
	(0.011)	(0.011)
Kharif total shocks*Irrigation 2005	−0.011	−0.011
	(0.011)	(0.014)
Rabi total shocks*Irrigation 2005	0.004	0.010
	(0.012)	(0.014)
Water cooperation 2012 mean	0.739	0.738
STATE Fixed effects	YES	YES
Observations	16,164	14,012

Notes: This table reports effect of total SPEI shocks interacted with baseline irrigation (heterogeneity due to irrigation). Column 1 presents the total no of dry shocks that are interacted with baseline irrigation on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. All specifications have state fixed effects, and std errors are clustered at the district level $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 5 reports heterogeneity in effects between households that use surface water, groundwater and no irrigation for a sample who reported irrigation. There can be different channels through which heterogeneity in different irrigation technologies can propagate. Surface water is publicly managed, whereas groundwater is privately managed. It creates a possibility of free-

riding/ deviations from agreements in surface water irrigation. Also, government authorities maintain surface water, and there can be bureaucratic inefficiencies, more likely in a developing country setting (Bardhan, 2000), which could lead to the inefficient allocation of water to canals and tanks (misallocation of resources). The third one is, surface water itself could be affected by rainfall shocks. For example, when water is sourced from rain-fed rivers (e.g., non-perennial rivers in south India), they can't provide enough water to canals and tanks. These results indicate there is no heterogeneous effect of different irrigation technologies on water cooperation. These results further strengthen the above arguments on weather shocks not affecting trust in agricultural communities in issues related to water. I reported results using the number of consecutive shocks in Kharif and Rabi seasons as explanatory variables Table 15 and they are similar to the results reported in Table 5. These results also indicate no heterogeneity due to irrigation is not due to opposite effects from different technologies. To show some suggestive evidence that my results are not driven by a lack of within-state variation in irrigation (or irrigation technologies). I provide summary statistics, i.e., sd and within state-sd Table 12 for the irrigation variables, and they indicate state fixed effects doesn't take up a lot of variation in the variables, i.e., sd and within state sd are qualitatively similar.

Mechanisms Our benchmark estimates indicate that its unlikely water cooperation changes through the agricultural channel. In this section, I explore other outcomes through which weather shocks can affect trust in agricultural communities.

Lack of conflict and Loans In this section, I look at the effect of weather shocks on lack of conflict and No.of loans people got in the last five years.

As explained in the data section, I combined two different measures of conflict to reduce measurement error. Here I measure the perception of conflict within the village instead of actual incidents of violent conflict like deaths or severe injuries etc. I report results for the effect of weather shocks (SPEI) on lack of conflict in the Table 6. I find that Kharif shocks, both total shocks (column 1) and consecutive shocks (column 3), decrease conflict and the effect is stronger for consecutive shocks. The effect of Rabi shocks is not statistically different from zero for total shocks, the magnitude of the effect is the same as Kharif shocks, but the sign is opposite (increases conflict). Consecutive Rabi shocks increases conflict (significant at 10%). For the sample of farmers, the effect of Kharif and Rabi total shocks (column 2) is not significantly different from zero, and effects are smaller in magnitude compared to full sample estimates.

Opposite signs in estimates for Kharif and Rabi in the Table 6 are not driven by lack of variation. I have estimated the effects of each season separately and reported estimates in Table 17. Kharif and Rabi shocks have maintained their signs and the magnitude of the effects are comparable to Table 6. To further understand which kind of conflict is driving the results, I look

Table 5: Irrigation Technology Heterogeneity - Total Dry Shocks

	Water cooperation 2012	
	full sample	farmers
	(1)	(2)
Water cooperation 2005	0.015	0.020
	(0.013)	(0.014)
Kharif total shocks	−0.010	−0.008
	(0.015)	(0.016)
Rabi total shocks	0.021	0.017
	(0.013)	(0.014)
Surface water 2005	−0.049	−0.084
	(0.057)	(0.061)
Ground water 2005	−0.036	−0.056
	(0.043)	(0.048)
Latitude	0.009	0.010
	(0.011)	(0.011)
Kharif total shocks*Surface water 2005	0.002	0.003
	(0.012)	(0.014)
Kharif total shocks*Ground water 2005	−0.016	−0.015
	(0.013)	(0.015)
Rabi total shocks*Surface water 2005	−0.007	0.002
	(0.017)	(0.017)
Rabi cons shocks*Ground water 2005	0.009	0.013
	(0.013)	(0.015)
Water cooperation 2012 mean	0.739	0.738
STATE Fixed effects	YES	YES
Observations	16,164	14,012

Note: This table reports the effect of total SPEI shocks interacted with baseline irrigation technologies, that is, surface water and groundwater irrigation. Column 1 presents the total no of dry shocks that are interacted with baseline irrigation technologies on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. All specifications have state fixed effects, and std errors are clustered at the district level *p<0.1; **p<0.05; ***p<0.01

at the effect of weather shocks on two conflict variables separately (general conflict and conflict between communities/caste groups). I report the results in the Table 18. It looks like almost all the effect on lack of conflict variable goes through lack of conflict between communities/castes. An increase in water cooperation and increased conflicts due to Rabi shocks could be explained by parochial altruism behaviour, i.e., people are kind towards members of their group but hostile towards outsiders (e.g. Abbink et al., 2012). Water cooperation focuses on collaboration within the community, and conflict question captures the conflict between communities. I observe Kharif shocks reduce conflicts even between communities/caste groups. As Kharif shocks are intense (potential damage due to Kharif shocks in high) compared to Rabi shocks, it could be possible that more intense shocks may decrease conflict between groups. People with potentially conflicting interest compete less when resource scarcity is high, and hence conflict reduces. Potential damage due to Rabi shocks is moderate, and maybe moderate shocks don't induce cooperation between different communities or caste groups. There is some evidence of a curvilinear relationship in the literature between water scarcity and collective action (Bardhan, 2000). These results provide some suggestive evidence that intragroup trust and intergroup trust changes differently to shocks with varying intensity.

After conflict outcomes, Now I look at the effect of weather shocks on the number of loans people got over the last five years. I report results in Table 7. They indicate that additional Rabi shock would lead to an 8.5% decrease in the number of loans they have got in the past five years. The effect of Kharif shocks is not different from zero. The effect of total Rabi shocks for a sub-sample of farmers is slightly higher (a decrease of 8.9% in the number of loans). Consecutive Rabi shocks also lead to a decrease in the number of loans (effect size is slightly lesser than the total number of shocks), but it is not significantly different from zero. One possible interpretation of the results could be that more weather shocks might have affected the repayment, and hence those households are less likely to get more loans. I don't have data on the source for all the loans taken, but 52% of the households took their largest loan from an informal source (friends, relatives and local money lender). It would be more likely for smaller loans to be taken from informal sources. We can interpret this decrease in the number of loans due to weather shocks could be due to a decrease in trust, as loans from informal sources are given based on trust[10]. I provide some suggestive evidence on this repayment mechanism below.

To study how weather shocks affect trust in financial transactions better, I should examine how shocks in earlier years would affect the number of loans people got from their informal networks (friends, relatives) in the later years between baseline and endline. I don't have data on loan source and timing for all loans and repayment data (to check for the first stage if weather shocks affect repayment). I expect people who have taken loans from informal networks in the earlier

[10]I don't claim the effect I observe here can be attributed completely to trust mechanism, there can be other channels through which weather shocks affect the number of loans people get. For example, if weather shocks lead to income loss, farmers may invest less in agriculture and take fewer loans

Table 6: Lack of Conflict - SPEI Dry Shocks

	Lack of conflict 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
Lack of conflict 2005	−0.003	0.010	−0.001	0.011
	(0.023)	(0.027)	(0.023)	(0.027)
Kharif total shocks	0.075*	0.044		
	(0.042)	(0.050)		
Rabi total shocks	−0.075	−0.044		
	(0.049)	(0.054)		
Kharif cons shocks			0.102**	0.094*
			(0.046)	(0.055)
Rabi cons shocks			−0.083*	−0.072
			(0.050)	(0.051)
Latitude	0.061**	0.037	0.063**	0.048
	(0.031)	(0.034)	(0.030)	(0.034)
Constant	2.545**	3.153***	2.418**	2.770**
	(1.012)	(1.132)	(1.004)	(1.127)
Lack of conflict mean 2012	3.92	3.90	3.92	3.90
STATE Fixed effects	YES	YES	YES	YES
Observations	27,072	14,014	27,072	14,014

Notes: This table reports the effect of weather shocks (SPEI shocks) on lack of conflict. Column 1 reports the effect of the total no of dry shocks in Kharif and Rabi seasons, and column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present effects for no. of consecutive dry shocks on full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

years and affected by weather shocks would be less likely to repay them. It would affect the trustworthiness of households, and they would be less likely to get loans from informal networks (repayment channel). Another possibility could be that informal networks act as insurance to these households when affected by weather shocks and provide them with more loans (insurance channel). To provide some suggestive evidence, I look at the effect of the total number of early and late weather shocks on the number of loans people took over the last five years[11]. I classified weather shocks as early and late shocks, the total number of Kharif shocks between 2006-2008 is early Kharif shocks, and the total number of Kharif shocks between 2009-2011 is classified as late Kharif shocks. I used the same classification for Rabi shocks. I reported results in the Table 19, and it shows that almost all the effect is due to early Rabi shocks. The effect due to early Rabi shocks is almost twice what I found for total shocks in the Table 7; the magnitude of the effect is a 15.38% decrease in the number of loans for the full sample and 17.52% for the sub-sample of farmers. Although I can't show the first stage, the effect of a decrease in loans for households that experienced weather shocks only in the early years suggests in a context where the share of informal loans is high suggests changes in trust levels in financial transactions due to weather shocks.

Aggregated Shocks In this analysis, I aggregate shocks irrespective of the season, the total number of dry shocks between baseline and endline and the number of consecutive dry shocks. I report results in the Table 8 and effects are stronger for column 3 (consecutive shocks) when compared to column 1 (total shocks). The effect of the total number of shocks on water cooperation is statistically not different from zero (for both full sample and farmers). I found an additional consecutive shock increases the probability of cooperating in water issues by 2.9% for the full sample. For a sub-sample of farmers, the effect of the number of consecutive shocks is positive and of similar magnitude as the full sample (but it is not statistically different from zero).

One might argue that season-specific shocks don't change trust levels in agriculture, but higher resource scarcity created through consecutive shocks may go through agricultural channels. Then, I expect the effects of consecutive shocks to be stronger for a sub-sample of farmers if it goes through agricultural trust. The effect of consecutive shocks for farmers subsample is not significantly different from zero, and even the magnitude of the effect is smaller than the full sample estimate. Unless the effect of weather shocks on cooperation in water issues related to agriculture and domestic use goes in the opposite direction, I wouldn't expect a lesser effect for a sub-sample of farmers. It's unlikely that the same people (people in the same community) react completely different to the same weather shocks affecting the same resource (water) based on its use. I also look at the heterogeneous effect of consecutive shocks due to irrigation and irrigation technology. I reported these results in columns 3 and 4 of Table 16. I don't find any heterogeneity

[11] Ideally, I should be checking the effect of early shocks on informal loans taken in the later years, but I don't have data in timing and source of each loan taken

Table 7: Effect on No of Loans Over Past 5 Years

	N Loans 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
N Loans 2005	0.050***	0.050***	0.050***	0.050***
	(0.013)	(0.016)	(0.013)	(0.016)
Kharif total shocks	0.030	0.056		
	(0.074)	(0.079)		
Rabi total shocks	−0.158*	−0.180*		
	(0.085)	(0.095)		
Kharif cons shocks			0.002	0.069
			(0.078)	(0.091)
Rabi cons shocks			−0.133	−0.159
			(0.085)	(0.098)
Latitude	−0.106**	−0.073	−0.116**	−0.077
	(0.052)	(0.062)	(0.054)	(0.065)
Constant	5.927***	4.789**	6.092***	4.669**
	(1.893)	(2.302)	(1.960)	(2.355)
N Loans 2012 mean	1.852	2.020	1.852	2.020
STATE Fixed effects	YES	YES	YES	YES
Observations	27,237	14,083	27,237	14,083

Notes: This table reports the effect of weather shocks (SPEI shocks) on No.of loans people got between baseline and endline. Column 1 reports the effect of the total no of dry shocks in Kharif and Rabi seasons, and column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present effects for no. of consecutive dry shocks on full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

due to irrigation or irrigation technology due to consecutive weather shocks. My results are broadly consistent with my interpretation that the effect of weather shocks are unlikely to go through the agricultural channel.

I also look at the effect of consecutive shocks on other outcome variables (lack of conflict and loans). I report these results in column 1 and column 2 of Table 16, and I find consecutive shocks (irrespective of seasons) doesn't affect either loans or conflicts. Conflict results are consistent with my earlier findings. Intense shocks and moderate shocks can have effects in opposite directions for conflict between communities/caste groups. When I consider them together, they could nullify each other. Effect on loans is also consistent with the above findings in Table 7, where I find effects due to the total number of shocks rather than consecutive shocks. It could be possible when shocks are more intense (through consecutive shocks) insurance channel. [12] also comes into play along with repayment channel (less likely to repay due to shocks and hence gets lesser loans). These results show some evidence that the effect on trust and cooperation varies with the intensity of resource scarcity created through weather shocks.

Table 8: Aggregate SPEI Shocks - Total Shocks

	Water cooperation 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
Water cooperation 2005	0.013	0.023	0.013	0.024*
	(0.011)	(0.014)	(0.011)	(0.014)
Total shocks	0.011	0.004		
	(0.008)	(0.009)		
Consecutive shocks			0.022**	0.015
			(0.011)	(0.012)
Latitude	0.019**	0.016	0.021**	0.018*
	(0.009)	(0.011)	(0.009)	(0.011)
Constant	−0.004	0.174	−0.096	0.079
	(0.315)	(0.371)	(0.300)	(0.360)
Water cooperation 2012 mean	0.743	0.738	0.743	0.738
STATE Fixed effects	YES	YES	YES	YES
Observations	27,153	14,050	27,153	14,050

Notes: This table reports the effect of aggregated weather shocks (SPEI shocks) on water cooperation. Column 1 reports the effect of the total no of dry shocks (in all seasons), and column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present effects for no. of consecutive dry shocks (in all seasons) on full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

[12] Informal networks (family and friends) provide loans more loans in distress to support people within their network, i.e., higher within-group cooperation

Historic Institutions: I base my analysis in this section on the work of Banerjee and Iyer, 2005. India during the time of British colonisation has largely three land tenure systems: A landlord-based system (zamindari system), an individual cultivator based system (raiyatwari system) and a village-based system (mahalwari system). In the landlord areas, the landlord was free to set land revenue terms for the peasants under his jurisdiction and dispossess any peasant who did not pay the landlord what they owed him. In an effective sense, these landlords hold property rights on the land. In the raiyatwari system, cultivators pay the British directly, and they hold land rights, and in the mahalwari system, village bodies pay taxes to the British. Banerjee and Iyer, 2005 argue that these historical institutions were placed differently in different regions due to reasons exogenous to their outcome variables (Eg: Preference of administrators). They compared areas with landlord system with areas which don't have landlord system. These different land-tenure systems led to differences in the distribution of wealth, political environments. Banerjee and Iyer, 2005 found in their work that even though these land tenure systems were abolished after independence, areas with landlord systems have significantly lower agricultural investments and productivity, lower investments in public goods like health and education.

Due to the very high inequality created by these land tenure systems, elites and masses rarely shared the trust required for collective action in the landlord areas. I hypothesise that when landlord areas experience weather shocks (droughts), households in these areas would be less likely to act collectively to solve problems. It could be possible that the rich would appropriate more resources when there is scarcity, leading to less cooperation. I used the model specified in equation 3.4, a similar model to my main specification. Through this model, I estimate how aggregate shocks affect the level of water cooperation differently in landlord and non-landlord areas. I control for all factors used in the benchmark specification used in Banerjee and Iyer, 2005[13].

Table 9 reports the heterogeneous effect of the total number of shocks between baseline and endline on areas with the landlord and non-landlord systems. Column 1 reports effects for the full sample, and column 2 reports effects for the sub-sample of farmers. The difference in cooperation level between non-landlord areas and landlord areas due to the total number of shocks is positive in magnitude for both Kharif and Rabi seasons (but the difference is not statistically different from zero). An increase in total Kharif shocks increases the probability to cooperate increases by 15.19% (statistically significant at 5%) in non-landlord areas for farmers sub-sample. In column 3, I report the effects of weather shocks on water cooperation on this sub-sample (without interaction with historical institutions). Rabi shocks positively affect water cooperation, which is consistent with my main results (in fact, Rabi effects are stronger in this subsample). I report the effect of consecutive shocks in Table 20. These results are also largely consistent with the above findings. Non-land areas show more cooperation when they experience weather shocks (except for Rabi consecutive shocks for the full sample, all the effects are not significantly different from

[13] I controlled for altitude, latitude, type of soil, length of British rule.

zero). I also find water cooperation is lower in areas with non-landlord tenure systems compared to landlord areas (within a state) when they do not receive any weather shocks. This is consistent in both Table 9 and Table 20 (negative sign in coefficient of prop non landlord). I do not have a clear explain on what is driving this effect. In above specifications, I used State Fixed effects, in compliance with other specifications I used in this paper. In Banerjee and Iyer, 2005, they haven't used State Fixed effects as there is no within state variation for states like Bihar, Gujarat, Karnataka, Rajasthan, and West Bengal. I also reported results without state fixed effects in Table 21. These results are also largely similar to what I found in the specification with state fixed effects. Results are largely in line with what I expected and what Banerjee and Iyer, 2005 found. The sign and magnitude of the effects are consistent in all estimates. They indicate despite formal abolition of land revenue system, social inequalities and conflicting environment created by it reduces possibilities for collective action.

Table 9: Heterogeneous Effect of Total shocks on Land Tenure Systems

	Water cooperation 2012		
	full sample	farmers	No-interaction
	(1)	(2)	(3)
Water cooperation 2005	0.044***	0.046**	0.018
	(0.015)	(0.018)	(0.017)
Kharif total shocks	0.960	1.115	−0.035**
	(1.274)	(1.255)	(0.014)
Rabi total shocks	−0.724	−0.941	0.054**
	(1.789)	(1.825)	(0.023)
Prop non-landlord	−0.287**	−0.267*	
	(0.139)	(0.153)	
Kharif total shocks*Prop non-landlord	0.071	0.107**	
	(0.048)	(0.050)	
Rabi total shocks*Prop non-landlord	0.050	0.031	
	(0.032)	(0.032)	
Controls	YES	YES	NO
Water cooperation mean	0.71	0.70	0.71
STATE Fixed effects	YES	YES	YES
Observations	10,422	5,649	10,422

Notes: This table reports effect of total SPEI shocks interacted with the prop of the non-landlord system in a district (heterogeneity due to land tenure system). Column 1 presents the total no of dry shocks that are interacted with the prop of the non-landlord system on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. Column 3 represents the effect of total SPEI shocks in each season on water cooperation for this subsample with land tenure data. Both column 1 and 2 have latitude, altitude, type of soil, coastal district, length of British rule as controls. All specifications have state fixed effects, and std errors are clustered at the district level *p<0.1; **p<0.05; ***p<0.01

Robustness checks

Alternative specification: To provide robustness to my results, I use linear specification of weather shocks in each cropping season in each year between baseline and endline. Table 10 reports effects for this specification (given by equation 3.2). I defined weather shocks for each year in the same way as the main specification[14]. Through this specification, I allow shocks of each year to have different effects on the level of trust. Column 1 shows the effects for the full sample. For most years effect of Kharif shocks (2006,2010, 2011) is close to zero. Effect of Rabi shocks on probability to cooperate lies in the range of 0-8.48% in the years between baseline and endline. But these estimates are not statistically different from zero for all years except for Kharif 2007. Rabi shock effects for sub-sample (Column 2) of farmers lie in the same range as in the full sample, whereas the for Kharif shocks sample estimates are noisy around zero.

By looking at the magnitudes of the Rabi shocks, it looks like individual shocks (each year shocks) and aggregated shocks (total shocks or number of consecutive shocks in Table 3) have a similar effect. I expected aggregated shocks to have the cumulative effect of individual shocks through the increased resource scarcity channel. It looks like the effect of the aggregate shocks is not additive of each year shocks but an average effect of the shocks. It might be possible that there is a discrete effect of the shocks on water cooperation, and when I consider multiple years, there is less measurement error on the weather shocks (additional shocks increasing signal on the shock variable), and I get more precision in estimating that discrete effect.

Kharif shocks of the year 2007 seem to be an anomaly, and effects are strongly negative. They indicate that Khairf shocks of 2007 decrease probability of cooperating on water issues by 14.4% for the full sample and 21.4% for farmers'. I used multiple specifications like only using 2007 year shocks, removing fixed effects, etc., but the effects are still robust. I also checked if the number of districts having dry shocks in Kharif 2007 too high or too low, but it doesn't seem like the case[15]. I am unsure about the interpretation of this particular shock.
'

Rainfall Shocks: Now I turn my analysis to the most used weather shocks in the literature, rainfall shocks, to check for robustness of my results. I present them in the table Table 11. Column 1 and 3 report the effects of the total number of dry shocks and consecutive shocks, which are negative in both Kharif and Rabi season and stronger in farmers subsample. These estimates are very noisy, and they are not significantly different from zero. When I use state fixed effects, they take up a lot of variation in the rainfall shocks and makes these estimates noisy. I reported estimates without state fixed effects in Table 22; these estimates are still not statistically different

[14] A dummy variable which takes one if SPEI deviation (SPEI-mean(SPEI))/SD is less -1, otherwise 0
[15] 25% of districts in our sample have dry shocks in 2007

Table 10: Effect of Weather Shocks on Water cooperation - Linear Specification

	Water cooperation 2012	
	(full sample)	(farmers)
	(1)	(2)
Water cooperation 2005	0.017	0.024*
	(0.011)	(0.014)
Kharif SPEI 2006	0.007	−0.020
	(0.039)	(0.046)
Rabi SPEI 2006	0.001	−0.033
	(0.039)	(0.043)
Kharif SPEI 2007	−0.107***	−0.158***
	(0.034)	(0.040)
Rabi SPEI 2007	0.028	0.043
	(0.028)	(0.031)
Kharif SPEI 2008	0.065	0.089*
	(0.050)	(0.051)
Rabi SPEI 2008	0.044	0.062
	(0.042)	(0.042)
Kharif SPEI 2009	−0.022	−0.010
	(0.032)	(0.038)
Rabi SPEI 2009	0.063	0.038
	(0.040)	(0.050)
Kharif SPEI 2010	−0.0005	−0.005
	(0.033)	(0.035)
Rabi SPEI 2010	0.056	0.020
	(0.074)	(0.090)
Kharif SPEI 2011	0.006	0.019
	(0.039)	(0.050)
Rabi SPEI 2011	0.040	0.026
	(0.034)	(0.035)
Latitude	0.019*	0.016
	(0.010)	(0.011)
Constant	−0.055	0.148
	(0.327)	(0.355)
Water cooperation 2012 mean	0.743	0.738
STATE Fixed effects	YES	YES
Observations	27,153	14,050

Note: This table reports the effect of the Kharif and Rabi SPEI shocks each year on water cooperation. Column 1 presents the effect of individual shocks on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

from zero. But results are largely in line with what we found for SPEI weather shocks, and Rabi rainfall shocks positively affect water cooperation.

Table 11: Rainfall shocks - Robustness check

	Water cooperation 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
Water cooperation 2005	0.013	0.025*	0.014	0.026*
	(0.012)	(0.014)	(0.011)	(0.014)
Kharif total shocks	−0.013	−0.026		
	(0.022)	(0.026)		
Rabi total shocks	−0.013	−0.017		
	(0.014)	(0.017)		
Kharif Cons shocks			−0.016	−0.030
			(0.024)	(0.027)
Rabi Cons shocks			−0.011	−0.015
			(0.021)	(0.025)
Latitude	0.022**	0.021*	0.021**	0.020*
	(0.010)	(0.012)	(0.010)	(0.012)
Constant	0.038	0.118	0.036	0.114
	(0.327)	(0.388)	(0.336)	(0.398)
Water cooperation 2012 mean	0.743	0.738	0.743	0.738
STATE Fixed effects	YES	YES	YES	YES
Observations	27,153	14,050	27,153	14,050

This table reports the effect of rainfall shocks on water cooperation. Column 1 reports the effect of the total no of dry rainfall shocks in the Kharif and Rabi seasons. Column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present the effects of the no. of consecutive rainfall shocks on the full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Sample Selection issues There is a big difference between sample sizes of Table 3 and Table 14 in the full sample columns. This difference arises as irrigation related questions are asked only to the people who own agricultural land or cultivate some land. I address two concerns by restricting my sample to people who don't have missing information on irrigation and using the model in equation 3.1 (main specification). First, irrigation heterogeneity results may not be generalised to the full sample (main specification). Second, I used people who have reported positive agricultural income at baseline as farmers; this sample is based on another definition of farmers: people who own or cultivate some land. It could be possible that there could be farmers who report zero agricultural income as they may not sell their agricultural produce (subsistence farming), or their

crops might get complete damage etc. [16]. I reported results for this sub-sample in the Table 23. Column 1 and 3 reports a sample of households who report irrigation for total shocks and consecutive shocks, respectively. Column 2 and 4 report effects for the subsample of household with positive agricultural income at baseline. The effect of Kharif shocks (both the total number of shocks and the number of consecutive shocks) is not statistically different from zero. The effects of Rabi season are positive and significant at 10%, and each additional Rabi shock between baseline and endline increases the probability of cooperating in issues related to water by 3.2%. These results indicate that sample selection issues do not drive our results. The effect of weather shocks on this subsample is almost identical to the farmers' subsample in the main specification.

5 Limitations and Future Work

The first limitation of this work arises from the interpretation of the variable water cooperation, as it measures if people solve water problems collectively or not. It could be possible that during a dry shock, some people deviate from resource sharing agreements (for example, water thefts), and if the members of the community do not observe them, then my trust variable does not capture these water theft issues. I expect these deviations to be correlated with weather shocks (It could be possible that the more the weather shocks, the more will be the deviations), leading to biased estimates. Haseeb, 2020 in his recent work has found that an increase in negative rainfall shocks during the cropping season increases demand for water sources, and people who are upstream of a surface water irrigation channel over-extract the water. I use the reported measure of water cooperation, and these reported measures are prone to measurement error due to unobservable factors. Access to administrative data on water discharge and usage would help me to identify theft incidents and reduce these measurement issues. I am looking at water cooperation within the community. Water theft incidents within a community are more likely to be observable compared to inter-village theft incidents as in the work of Haseeb, 2020. Hence, bias in our measurements from these theft incidents may not be a big concern.

Another limitation of this work is I use weather shocks at the district level with state fixed effects. I am looking at the effect of weather shocks on intra-community/village water cooperation. It would be more appropriate to look using weather shocks at the village level to capture water scarcity in the village in a given cropping season. Two reasons restrict me from analyzing at the district level. First, IHDS data is identifiable at the district level [17]. Second, I haven't come across

[16] This sub-sample also involves people who own agricultural land but doesn't cultivate it. Hence I choose the farmers sub-sample who reported only positive income for a majority of the analysis. Also, sample size differences in full sample and farmers subsample in Table 23 is low compared to main results, which indicates both samples have almost the same households. Anyways I show the main results, irrigation heterogeneity results and irrigation technology for this sample of farmers, and results are almost identical to the sample of farmers with positive income

[17] According to the documentation in IHDS, geographical identification is possible at the district level, but using variable "TEHSIL" in the village dataset of IHDS-I, I could identify them at the sub-district level. Due to computational limitation in obtaining sub-district boundaries of India, I choose to work at the district level

any data set with enough resolution to identify weather shocks at the village level. The data set I use for weather shocks, ERA5, has a resolution of 0.25 degrees (approx 30 km), size of the pixel is slightly bigger than the average size of a sub-district in India. Figure 1 indicate high spatial correlation in weather shocks; even if I analyse with village-level shocks, I expect no large deviations in my results.

There is some evidence in the literature on the curvilinear relationship between scarcity and cooperation in irrigation systems (Bardhan, 2000, Araral, 2009). These results may not hold when scarcity of resources is higher (e.g., SPEI deviation is less than two sd). I provide some evidence on cooperation changes with varying intensity of weather shocks in Table 8, but I need to look at a wider range of resource scarcity to understand relation between resource scarcity and cooperation better. Other than that, I can extend my analysis by looking at distributional features of weather shocks. When looking at shocks between baseline and endline, early shocks and late shocks could differential impact on cooperation level. I find the number of loans people got is affected only by early shocks. Finally, I could improve inference by correcting s.e's for spatial correlation. Figure 1 and Figure 2 shows weather shocks are correlated in space, although I clustered my s.e's at the district level but weather shocks are correlated in larger geographic regions.

6 Discussion and Conclusion

Discussion In the absence of formal resource sharing agreements, farmers depend on trust within the community to enforce those agreements. In this paper I found short term water scarcity created through weather shocks show a slight increase in within community cooperation. It is unlikely that this increase in cooperation to go through agricultural channel. When I was looking at inter-community conflicts, I found conflict increases between communities/caste groups due to Rabi shocks. Inter community conflict results are in line with the work of Haseeb, 2020, where he found short-term water scarcity created through weather shocks increases water-theft incidents by upstream farmers Haseeb, 2020 is looking at inter-village cooperation. In fact he is looking at weekly shocks in number of rainfall days, which can be considered as shocks that creates less-moderate scarcity similar to my Rabi shocks (shocks during low rainfall season). It could be possible that people would act differently when interacting/sharing resources with people from their community (intra-community) compared to sharing resources with people outside their community (inter-community) when shocks are moderate. People may exhibit parochial altruism behaviour, i.e., people are kind towards members of their group but hostile towards outsiders (e.g. Abbink et al., 2012). Another evidence in line with these findings is, the existence of threats from out-groups can increase intra-group social capital accumulation (Jennings and Sanchez-Pages, 2017).

I find some evidence on people with potentially conflicting interests (different caste groups) reduce conflict to maintain high cooperation during kharif shocks (potentially more damaging) in

contrast with Rabi shocks (moderately damaging) where conflict increases. When water becomes scarcer, the value of collective action increases and farmers have incentives to work more closely as discussed in Carpenter and Seki, 2005 and Gneezy et al., 2015). It could be possible that different caste groups are reducing their conflict and competing less to foster a collaborative culture when shocks are more intense, i.e., when cost of non-cooperation is high. It could be possible when scarcity is moderate, incentives for cooperation may be enough to put aside their differences and collaborate.

I did not find any heterogeneous effect of weather shocks due to irrigation or different irrigation technologies. Results in this study indicate that within cooperation does not change due to weather shocks through the agricultural channel. These results are not inline with the work of Nie et al., 2020, where they found that greater water scarcity increases within group cooperation among individuals in an irrigation system. They are looking at long-term water scarcity created through a historic irrigation quota system in a sample of 26 villages in western China where as I am looking at short-term water scarcity created through weather shocks. It could be possible that people tend to adapt and cooperate more in the long-term. Haseeb, 2020 found long-term scarcity created through groundwater pollution resulted in more cooperation even across communities.

One possible explanation for no change in irrigation cooperation could be, farmers in India have been sharing their irrigation water resources for a along time and it could be possible that they may have solved their collective action problem. 74.3% households in my sample reported that solve community water problems together. Trust between farmers is already high as they have been interacting with each other for a long time, and they expect to repeat interactions in the future (Alesina and La Ferrara, 2002).

Conclusion Resources like water are becoming increasingly vulnerable to changing climate, and if the current trend persists, problems like water scarcity will be challenging, particularly in developing countries. It is important to understand how people's sharing norms and preferences change when they experience scarcity in a setting where formal institutions are generally weaker. In this study, I look at the effect of water scarcity created through weather shocks on the cooperative behaviour of households in rural India. I use deviations in the SPEI index to define my weather shocks, which considers joint effects of rainfall, temperature and potential evaporation. I rely on randomness in weather shocks for identification, and I show that my results are not biased due to any time trends in weather shocks associated with geographical conditions using a placebo of future weather shocks. I find weather shocks do not affect water cooperation through the agricultural channel, but water cooperation slightly increases (4.1% increase in probability to cooperate) for domestic use. There is no heterogeneity in water cooperation due to irrigation or irrigation technologies, consistent with no change in water cooperation through the agricultural channel.

I show some evidence that varying intensity of weather shocks can have different implications for water cooperation, that is consecutive shocks have stronger effect than total shocks. I also find complementary effects like decreased conflicts between different caste groups within a community when they experience more intense weather shocks but more likely to increase conflict when they experience moderate shocks. Also, weather shocks affect trust in financial transactions, and I find households in the districts which experience early weather shocks get a 15.38% lower number of loans during five years between baseline and end-line. These results are robust to alternative specifications, alternative weather shocks like rainfall and sample selection issues.

Overall this study highlights the importance of social institutions like trust and cooperation in adapting to weather fluctuations in agricultural communities. These results should be taken with caution; my measure of water cooperation doesn't capture all deviations from resource sharing agreements. It is a self reported measure which captures if people solve water problems collectively or not. Also, we don't have much evidence what explains differences in inter-group cooperation and intra-group cooperation when they face shocks, how trust and cooperation varies with varying intensity of weather shocks and how long term climate changes affect trust and cooperation. I hope this study can provide some insights in further exploring these research questions.

References

Abbink, K., Brandts, J., Herrmann, B., & Orzen, H. (2012). Parochial altruism in inter-group conflicts. *Economics Letters*, *117*(1), 45–48. https://doi.org/https://doi.org/10.1016/j.econlet.2012.04.083

Alesina, A., & La Ferrara, E. (2002). Who trusts others? *Journal of Public Economics*, *85*(2), 207–234. https://doi.org/10.1016/S0047-2727(01)00084-6

Andrabi, T., & Das, J. (2017). In Aid We Trust: Hearts and Minds and the Pakistan Earthquake of 2005. *The Review of Economics and Statistics*, *99*(3), 371–386. https://ideas.repec.org/a/tpr/restat/v99y2017i3p371-386.html

Araral, E. (2009). What explains collective action in the commons? theory and evidence from the philippines. *World Development*, *37*(3), 687–697. https://doi.org/https://doi.org/10.1016/j.worlddev.2008.08.002

Balliet, D., & Lange, P. (2012). Trust, conflict, and cooperation: A meta-analysis. *Psychological bulletin*, *139*. https://doi.org/10.1037/a0030939

Banerjee, A., & Iyer, L. (2005). History, institutions, and economic performance: The legacy of colonial land tenure systems in india. *American Economic Review*, *95*(4), 1190–1213. https://doi.org/10.1257/0002828054825574

Bardhan, P. (2000). Irrigation and cooperation: An empirical analysis of 48 irrigation communities in south india. *Economic Development and Cultural Change*, *48*, 847–65. https://doi.org/10.1086/452480

Blakeslee, D., Fishman, R., & Srinivasan, V. (2020). Way down in the hole: Adaptation to long-term water loss in rural india. *American Economic Review*, *110*(1), 200–224. https://doi.org/10.1257/aer.20180976

Burke, M., & Emerick, K. (2016). Adaptation to climate change: Evidence from US agriculture. *American Economic Journal: Economic Policy*, *8*(3), 106–140. https://doi.org/10.1257/pol.20130025

Carpenter, J., & Seki, E. (2005). Do social preferences increase productivity? field experimental evidence from fisherman in toyama bay. *Economic Inquiry*, *49*, 612–630. https://doi.org/10.1111/j.1465-7295.2009.00268.x

Dell, M., Jones, B. F., & Olken, B. A. (2014). What do we learn from the weather? the new climate-economy literature. *Journal of Economic Literature*, *52*(3), 740–98. https://doi.org/10.1257/jel.52.3.740

Durante, R., & Buggle, J. (2017). Climate Risk, Cooperation, and the Co-Evolution of Culture and Institutions. *12380*. https://ssrn.com/abstract=3057294

Emerick, K. (2018). Agricultural productivity and the sectoral reallocation of labor in rural india. *Journal of Development Economics*, *135*, 488–503. https://doi.org/https://doi.org/10.1016/j.jdeveco.2018.08.013

Gatti, N., Baylis, K., & Crost, B. (2020). Can Irrigation Infrastructure Mitigate the Effect of Rainfall Shocks on Conflict? Evidence from Indonesia. *American Journal of Agricultural Economics*, *00*(2014), 1–21. https://doi.org/10.1002/ajae.12092

Gneezy, U., Leibbrandt, A., & List, J. A. (2015). Ode to the Sea: Workplace Organizations and Norms of Cooperation. *The Economic Journal*, *126*(595), 1856–1883. https://doi.org/10.1111/ecoj.12209

Harari, M., & Ferrara, E. (2013). Conflict, climate and cells: A disaggregated analysis. *The Review of Economics and Statistics*, *100*. https://doi.org/10.1162/REST_a_00730

Haseeb, M. (2020). Resource scarcity and cooperation [Unpublished, Job Market Paper].

Hill, R. V., & Viceisza, A. (2012). A field experiment on the impact of weather shocks and insurance on risky investment. *Experimental Economics*, *15*(2), 341–371. https://doi.org/10.1007/s10683-011-9303-7

Jennings, C., & Sanchez-Pages, S. (2017). Social capital, conflict and welfare. *Journal of Development Economics*, *124*, 157–167. https://doi.org/https://doi.org/10.1016/j.jdeveco.2016.09.005

Lehne, J. (2019). Irrigation vs education: The long-run effects of opium cultivation in british india [Unpublished, Job Market Paper].

Nie, Z., Yang, X., & Tu, Q. (2020). Resource scarcity and cooperation: Evidence from a gravity irrigation system in china. *World Development*, *135*, 105035. https://doi.org/https://doi.org/10.1016/j.worlddev.2020.105035

Nunn, N., & Wantchekon, L. (2011). The slave trade and the origins of mistrust in africa. *American Economic Review*, *101*(7), 3221–52. https://doi.org/10.1257/aer.101.7.3221

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.

Parry, M. (2007). *Climate change 2007: Impacts, adaptation and vulnerability : Contribution of working group ii to the fourth assessment report of the intergovernmental panel on climate change*.

Prasanna, V. (2014). Impact of monsoon rainfall on the total foodgrain yield over India. *Journal of Earth System Science*, *123*(5), 1129–1145.

Preethi, B., Revadekar, J., & Kripalani, R. (2011). Anomalous behaviour of the indian summer monsoon 2009. *Journal of Earth System Science*, *120*, 783–794.

Sarsons, H. (2015). Rainfall and conflict: A cautionary tale. *Journal of Development Economics*, *115*, 62–72. https://doi.org/10.1016/j.jdeveco.2014.12.007

Sekhri, S. (2014). Wells, water, and welfare: The impact of access to groundwater on rural poverty and conflict. *American Economic Journal: Applied Economics*, *6*(3), 76–102. https://doi.org/10.1257/app.6.3.76

Taraz, V. (2017). Adaptation to climate change: Historical evidence from the indian monsoon. *Environment and Development Economics*, *22*(5), 517–545. https://doi.org/10.1017/S1355770X17000195

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. *Journal of Climate*, *23*(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Wade, R. (1989). Village republics. *Cambridge University Press.*

A Appendix

Table 12: Summary Statistics

	Measurement	max	mean	min	sd	within state-sd
1	Irrigation 2005	1	0.559	0	0.497	0.410
2	Kharif cons shocks	6	1.755	0	1.314	0.690
3	kharif total shocks	6	2.214	0	1.605	0.805
4	Lackofconflict 2005	5	4.004	1	1.052	0.995
5	Lackofconflict 2012	5	3.920	1	1.228	1.137
6	Nloans 2005	50	1.530	0	2.783	2.305
7	Nloans 2012	53	1.853	0	2.961	2.574
8	Rabi Cons Shocks	6	2.573	0	1.196	0.751
9	Rabi total Shocks	6	3.144	0	1.351	0.815
10	Watercooperation 2005	1	0.594	0	0.491	0.470
11	Watercooperation 2012	1	0.743	0	0.437	0.423
12	Groundwater 2005	1	0.459	0	0.498	0.396
13	Surfacewater 2005	1	0.099	0	0.299	0.271

Table 13: Summary Statistics for missing households in Land revenue data

	Measurement	max	mean	min	sd
1	Irrigation 2005	1	0.530	0	0.499
2	Kharif cons shocks	6	1.823	0	1.369
3	Kharif total shocks	6	2.197	0	1.600
4	Lackofconflict 2005	5	4.006	1	1.063
5	Lackofconflict 2012	5	3.919	1	1.244
6	Nloans 2005	50	1.454	0	2.656
7	Nloans 2012	50	1.794	0	2.887
8	Rabi cons shocks	6	2.628	0	1.255
9	Rabi total shocks	6	3.212	0	1.362
10	Watercooperation 2005	1	0.604	0	0.489
11	Watercooperation 2012	1	0.766	0	0.423
12	Groundwater 2005	1	0.424	0	0.494
13	Surfacewater 2005	1	0.105	0	0.307

Table 14: Irrigation Heterogeneity Consecutive Dry Shocks

	Water cooperation 2012	
	full sample	farmers
	(1)	(2)
Water cooperation 2005	0.017	0.021
	(0.013)	(0.014)
Kharif cons shocks	0.006	0.010
	(0.016)	(0.018)
Rabi cons shocks	0.021	0.017
	(0.014)	(0.016)
Irrigation 2005	−0.052	−0.075
	(0.040)	(0.046)
Latitude	0.012	0.013
	(0.011)	(0.011)
Kharif cons shocks*Irrigation 2005	−0.003	−0.006
	(0.013)	(0.016)
Rabi cons shocks*Irrigation 2005	0.005	0.013
	(0.013)	(0.015)
Water cooperation 2012 mean	0.739	0.738
STATE Fixed effects	YES	YES
Observations	16,164	14,012

Notes: This table reports the heterogeneous effect of consecutive SPEI shocks interacted with baseline irrigation. Column 1 presents the number of consecutive dry shocks that are interacted with baseline irrigation on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. All specifications have state fixed effects, and std errors are clustered at the district level *p<0.1; **p<0.05; ***p<0.01

Table 15: Irrigation Technology Heterogeneity- Consecutive Shocks

	Water cooperation 2012	
	full sample	farmers
	(1)	(2)
Water cooperation 2005	0.016	0.020
	(0.013)	(0.014)
Kharif cons shocks	0.007	0.011
	(0.016)	(0.018)
Rabi cons shocks	0.021	0.016
	(0.014)	(0.016)
Surfacewater 2005	−0.052	−0.084
	(0.054)	(0.057)
Ground water 2005	−0.052	−0.073
	(0.042)	(0.048)
Latitude	0.012	0.013
	(0.011)	(0.011)
Kharif cons shocks*Surface water 2005	0.008	0.004
	(0.013)	(0.018)
Kharif cons shocks*Ground water 2005	−0.008	−0.009
	(0.015)	(0.018)
Rabi cons shocks*Surface water 2005	−0.011	0.002
	(0.018)	(0.017)
Rabi cons shocks*Ground water 2005	0.011	0.017
	(0.013)	(0.015)
Water cooperation 2012 mean	0.739	0.738
STATE Fixed effects	YES	YES
Observations	16,164	14,012

Note: This table reports effect of consecutive SPEI shocks interacted with baseline irrigation technologies, that is, surface water and groundwater irrigation. Column 1 presents the total no of dry shocks that are interacted with baseline irrigation technologies on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 16: SPEI Consecutive Shocks - Other Outcome Variables

	Dependent variable:			
	Lack of conflict 2012	N Loans 2012	Water cooperation 2012	
	(1)	(2)	(3)	(4)
Lack of conflict 2005	0.003			
	(0.023)			
N Loans 2005		0.048***		
		(0.013)		
Water cooperation 2005			0.020	0.019
			(0.013)	(0.013)
Consecutive shocks	−0.029	−0.015	0.016	0.016
	(0.038)	(0.068)	(0.012)	(0.012)
Irrigation 2005			−0.025	
			(0.035)	
Surfacewater 2005				−0.060
				(0.047)
Groundwater 2005				−0.018
				(0.036)
Total cons shocks*Irrigation 2005			−0.006	
			(0.011)	
Total cons shocks*Groundwater 2005				−0.002
				(0.013)
Total_consds*Groundwater 2005				−0.006
				(0.011)
Latitude	0.032	−0.137***	0.017*	0.017*
	(0.027)	(0.052)	(0.010)	(0.010)
Outcome mean	3.92	1.852	0.739	0.739
STATE Fixed effects	YES	YES	YES	YES
Observations	27,072	27,237	16,164	16,164

Notes: This table reports the effect of aggregated consecutive weather shocks (SPEI shocks) on different outcomes. Column 1 reports the effect of the no of consecutive dry shocks (in all seasons) on conflict, and column 2 reports the same effect on the number of loans between baseline and endline. Column 3 and 4 present heterogeneous effects of the no. of consecutive dry shocks (in all seasons) due to irrigation and irrigation technology. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 17: Lack of conflict - Season Specific Shocks

	Lack of conflict 2012			
	full sample	full sample	full sample	full sample
	(1)	(2)	(3)	(4)
Lack of conflict 2005	−0.001	0.003	−0.001	0.003
	(0.023)	(0.023)	(0.023)	(0.024)
Kharif total shocks	0.054			
	(0.038)			
Rabi total shocks		−0.051		
		(0.045)		
Kharif cons shocks			0.078*	
			(0.043)	
Rabi cons shocks				−0.053
				(0.047)
Latitude	0.045	0.043	0.047*	0.043
	(0.028)	(0.028)	(0.028)	(0.028)
Constant	2.781***	3.219***	2.713***	3.173***
	(0.984)	(0.922)	(0.981)	(0.927)
Lack of conflict 2012 mean	3.92	3.92	3.92	3.92
STATE Fixed effects	YES	YES	YES	YES
Observations	27,072	27,072	27,072	27,072

Notes: This table reports the effect of weather shocks (SPEI shocks) in each season on conflict. Column 1 reports the effect of the total no of dry Kharif shocks, and column 2 reports the effect of the total no of dry Rabi shocks. Column 3 and 4 present effects for no. of consecutive dry shocks in Kharif and Rabi seasons. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 18: Effect on Caste Conflict and General Conflict

	Lack of conflict variables			
	Caste	Caste	General	General
	(1)	(2)	(3)	(4)
Lack of caste conflict 2005	0.007	0.008		
	(0.017)	(0.017)		
Lack of general conflict 2005			−0.003	−0.002
			(0.018)	(0.018)
Kharif total shocks	0.046**		0.029	
	(0.022)		(0.022)	
Rabi total Shocks	−0.047*		−0.027	
	(0.026)		(0.026)	
Kharif cons shocks		0.063***		0.038
		(0.024)		(0.024)
Rabi cons shocks		−0.052**		−0.030
		(0.026)		(0.026)
Latitude	0.043***	0.045***	0.018	0.018
	(0.016)	(0.015)	(0.016)	(0.016)
Constant	1.448***	1.359***	2.073***	2.033***
	(0.500)	(0.496)	(0.559)	(0.557)
Outcome mean	2.48	2.48	2.44	2.44
STATE Fixed effects	YES	YES	YES	YES
Observations	27,131	27,131	27,127	27,127

Notes: This table reports the effect of weather shocks (SPEI shocks) on different types of conflict. Column 1 reports the effect of the total no of dry shocks on the conflict between communities/caste groups, and column 2 reports the effect of no. of consecutive shocks on the same variable. Column 3 and 4 present the effects of the total number of dry shocks and no. of consecutive dry shocks on the general conflict level in the village. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 19: Effect on No of Loans Over Past 5 Years - Early vs Late Shocks

	N Loans 2012	
	full sample	farmers
	(1)	(2)
N Loans 2005	0.053***	0.054***
	(0.013)	(0.017)
Early Kharif shocks	−0.030	−0.059
	(0.089)	(0.115)
Late Kharif shocks	0.055	0.112
	(0.105)	(0.111)
Early Rabi shocks	−0.285**	−0.354**
	(0.128)	(0.146)
Late Rabi shocks	0.031	0.087
	(0.127)	(0.147)
latitude	−0.091*	−0.039
	(0.052)	(0.063)
Constant	5.118***	3.199
	(1.928)	(2.380)
N Loans 2012 mean	1.852	2.020
STATE Fixed effects	YES	YES
Observations	27,237	14,083

Note: This table reports the effect of weather shocks (SPEI shocks) on No.of loans people got between baseline and endline. For this analysis, I divided the total number of shocks as early shocks (between 2006-2008) and late shocks (2009-2011). Column 1 presents the effect of early shocks and late shocks (in both seasons) on the full sample, and column 2 shows the same effects for the subsample of farmers who reported positive income at the baseline. *p<0.1; **p<0.05; ***p<0.01

Table 20: Heterogeneous Effect of Consecutive Shocks on Land Tenure Systems

	Water cooperation 2012		
	full sample	farmers	No-interaction
	(1)	(2)	(3)
Water cooperation 2005	0.046***	0.050***	0.020
	(0.015)	(0.019)	(0.013)
Kharif cons shocks	0.843	1.260	−0.013
	(1.145)	(1.378)	(0.015)
Rabi cons shocks	−1.892	−2.591	0.054***
	(1.785)	(2.090)	(0.017)
Prop non-landlord	−0.323**	−0.281	
	(0.162)	(0.182)	
Kharif cons shocks*Prop non-landlord	0.093	0.090	
	(0.075)	(0.085)	
Rabi cons shocks*Prop non-landlord	0.080*	0.060	
	(0.046)	(0.049)	
Controls	YES	YES	NO
Water cooperation 2012 mean	0.71	0.70	0.71
STATE Fixed effects	YES	YES	YES
Observations	10,422	5,649	10,422

Notes: This table reports effect of no. of consecutive SPEI shocks interacted with the prop of the non-landlord system in a district (heterogeneity due to land tenure system). Column 1 presents the effect of no of consecutive dry shocks that are interacted with the prop of the non-landlord system on the full sample, and column 2 presents the same estimates on the subsample of farmers who reported positive baseline income. Column 3 represents the effect of consecutive SPEI shocks in each season on water cooperation for this subsample with land tenure data. Both column 1 and 2 have latitude, altitude, type of soil, coastal district, length of British rule as controls. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 21: Heterogeneous Effect on Land Tenure Systems- Without State Fixed Effects

	Water cooperation 2012	
	full sample	fullsample
	(1)	(2)
Water cooperation 2005	0.040**	0.029*
	(0.017)	(0.016)
Kharif cons shocks	−1.585	
Rabi cons shocks	0.348	
Kharif total shocks		−0.746
Rabi total shocks		0.551
Prop non landlord	−0.347***	−0.295*
	(0.134)	(0.157)
Kharif cons shocks*Prop non landlord	0.009	
Rabi cons shocks*Prop non landlord	0.098***	
Kharif total shocks*Prop non landlord		0.035
Rabi total shocks*Prop non landlord		0.053
Controls	YES	YES
Water cooperation 2012 mean	0.71	0.71
STATE Fixed effects	NO	NO
Observations	10,422	10,422

Notes: This table reports the effect of SPEI shocks interacted with the prop of the non-landlord system in a district (heterogeneity due to land tenure system). This specification doesn't contain state fixed effects. Column 1 presents the effect of total number of dry shocks that are interacted with the prop of the non-landlord system on the full sample, and column 2 presents the effect of no. of consecutive SPEI shocks on the full sample. Both column 1 and 2 have latitude, altitude, type of soil, coastal district, length of British rule as controls. Std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

Table 22: Aggregate Rainfall shocks - without state fixed effects

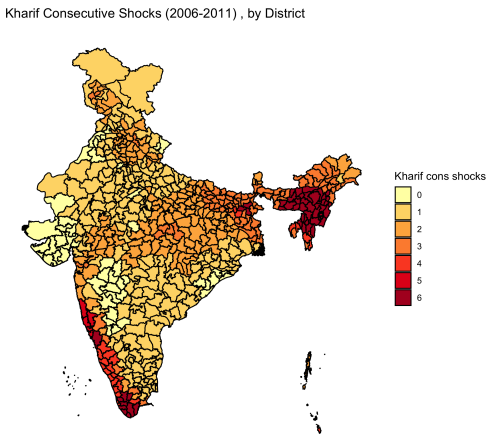
	Water cooperation 2012	
	full sample	full sample
	(1)	(2)
Water cooperation 2005	0.039**	0.037**
	(0.015)	(0.015)
Kharif total shocks	−0.024	
	(0.022)	
Rabi total shocks	0.012	
	(0.010)	
Kharif Cons shocks		−0.033
		(0.025)
Rabi Cons shocks		0.019
		(0.013)
Latitude	0.714***	0.713***
	(0.022)	(0.022)
Water cooperation 2012 mean	0.743	0.738
STATE Fixed effects	NO	NO
Observations	27,153	27,153

This table reports the effect of rainfall shocks on water cooperation using a specification without state fixed effects. Column 1 reports the effect of the total no of dry rainfall shocks in the Kharif and Rabi seasons. Column 2 reports effects for no. of consecutive dry shocks on the full sample. These estimates don't contain state fixed effects. Std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

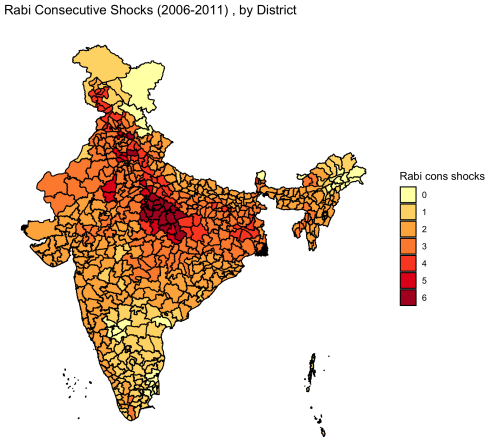
Table 23: Aggregate SPEI Shocks - Sample Who Reports Irrigation

	Water cooperation 2012			
	full sample	farmers	full sample	farmers
	(1)	(2)	(3)	(4)
Water cooperation 2005	0.017	0.022	0.017	0.022
	(0.013)	(0.014)	(0.013)	(0.014)
Kharif total shocks	−0.016	−0.015		
	(0.014)	(0.015)		
Rabi total shocks	0.024*	0.023*		
	(0.013)	(0.014)		
Kharif cons shocks			0.005	0.007
			(0.015)	(0.016)
Rabi cons shocks			0.024*	0.025*
			(0.014)	(0.015)
Latitude	0.009	0.010	0.013	0.013
	(0.011)	(0.012)	(0.011)	(0.011)
Constant	0.361	0.347	0.205	0.203
	(0.370)	(0.389)	(0.364)	(0.384)
Water cooperation 2012 mean	0.739	0.738	0.739	0.738
STATE Fixed effects	YES	YES	YES	YES
Observations	16,164	14,012	16,164	14,012

Notes: This table reports the effect of weather shocks (SPEI shocks) on water cooperation for subsample of households who reported irrigation data. Column 1 reports the effect of the total no of dry shocks in Kharif and Rabi seasons, and column 2 reports the same effect but for a sub-sample of farmers whose baseline income is positive. Column 3 and 4 present effects for no. of consecutive dry shocks on full sample and sub-sample of farmers. All specifications have state fixed effects, and std errors are clustered at the district level. *p<0.1; **p<0.05; ***p<0.01

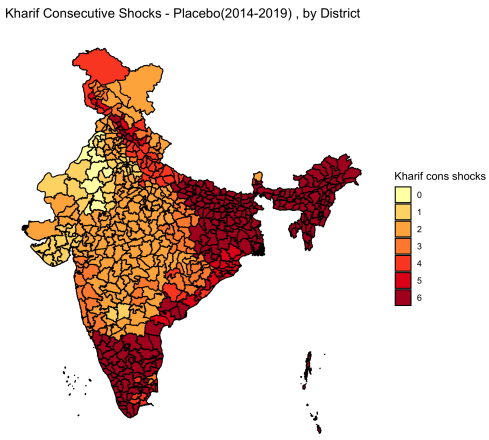


(a) Kharif Consecutive shocks (2006-2011)

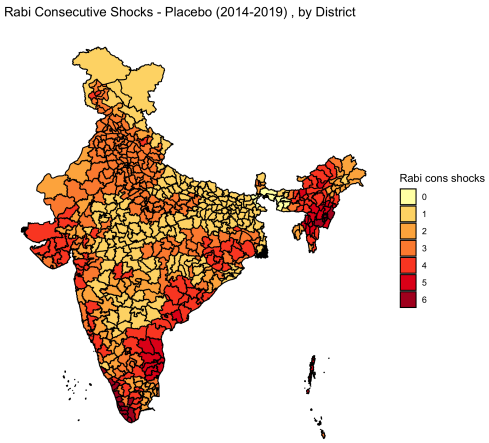


(b) Rabi Consecutive Shocks (2006-2011)

Figure 1: Weather shocks between 2006-2011



(a) Kharif Consecutive shocks - Placebo



(b) Rabi Consecutive Shocks - Placebo

Figure 2: Placebo Shocks - 2014 -2019