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Climate change, agricultural production and civil conflict: Evidence from the Philippines

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ABSTRACT

Using unique data on conflict-related incidents in the Philippines, we exploit seasonal variation in the relationship between rainfall and agricultural production to learn about the mechanism through which rainfall affects civil conflict. We find that an increase in dry-season rainfall leads to an increase in agricultural production and dampens conflict intensity. By contrast, an increase in wet-season rainfall is harmful to crops and produces more conflict. Consistent with the hypothesis that rebel groups gain strength after a bad harvest, we find that negative rainfall shocks lead to an increase in conflict incidents initiated by insurgents but not by government forces. These results suggest that the predicted shift towards wetter wet seasons and drier dry seasons will lead to more civil conflict even if annual rainfall totals remain stable. We conclude that policies aimed at mitigating the effect of climate change on agriculture could have the added benefit of reducing civil conflict.

1. Introduction

Climate change poses multiple threats to national security, global stability and human welfare (IPCC, 2014; Department of Defense, 2014; USAID, 2014). One of these threats takes the form of changes in the spatial and temporal distribution of rainfall. In fact, there is strong evidence that climate change is already leading to wetter wet seasons and drier dry seasons (Chou et al., 2013), and this trend is predicted to intensify in the near future (Chou and Lan, 2012). Experts worry that changing rainfall patterns could lead to more civil conflict, defined as intra-country violence between government forces and an organized armed group (Department of Defense, 2014; USAID, 2014). However, despite its importance, the connection between rainfall and civil conflict is not well understood (Nardulli et al., 2015; USAID, 2009, 2014).

Using unique data based on incident reports produced by Philippine military units operating in the field, the current study explores the effect of rainfall by season on agricultural production and civil conflict. Our results provide evidence that rainfall is related to civil conflict, at least in part, through its effect on agriculture as opposed to, for instance, its effect on

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infrastructure. Moreover, they suggest that the predicted shift towards wetter wet seasons and drier dry seasons will lead to an increase in civil conflict.

While there is strong and consistent evidence that hotter temperatures lead to increases in civil conflict (Hsiang et al., 2013), the evidence with regard to rainfall has been mixed. For instance, using data on sub-Saharan African countries, Miguel et al. (2004) and Miguel and Satyanath (2011) found that rainfall spurs economic growth, which in turn reduces the risk of civil conflict. In contrast, Hendrix and Salehyan (2012) found that abnormally wet years are associated with more civil conflict, while Burke et al. (2009) and Buhaug (2010) found no evidence of a relationship between rainfall and civil conflict in sub-Saharan Africa. Of the 60 studies reviewed by Hsiang et al. (2013), 11 considered the effect of rainfall on civil conflict. Four of these studies found that below-average rainfall was associated with increased civil conflict, 6 found a statistically insignificant relationship (at the 5% level), and one found evidence that above-average rainfall was associated with an increase in civil conflict.

Even among researchers who have found an effect of rainfall on conflict, there is disagreement as to the underlying mechanism. Some researchers have argued that rainfall is related to civil conflict through agricultural production (Miguel et al., 2004; Miguel and Satyanath, 2011; Maystadt and Ecker, 2014; Couttenier and Soubeyran, 2014). Alternatively, rainfall could have direct psychological effects on combatants, or be related to civil conflict through its impact on roads, bridges and the availability of surface water (Witsenburg and Adano, 2013; Ciucci et al., 2011; Hiltunen et al., 2012; Sarsons, 2015; Hsiang and Burke, 2014). Disentangling these mechanisms is crucial to informing policy responses to climate change (Burke et al., 2015). Even under the most optimistic scenarios, substantial changes in the spatial and temporal distribution of rainfall appear to be unavoidable (IPCC, 2014, p.189) and designing policies that can increase societal resilience to these changes will become increasingly important (World Bank, 2012; Center for Naval Analyses, 2014; USAID, 2014).

Previous studies document that, in the Philippines, above-average rainfall during the wet season (May through October) has a negative effect on agricultural production, while above-average rainfall during the dry season (November–April) has a positive effect (Lansigan et al., 2000; Gerpacio et al., 2004; Roberts et al., 2009). We hypothesize that, if agricultural production is in fact the mechanism through which rainfall affects civil conflict, then the relationship between rainfall and civil conflict should also exhibit seasonality but in the opposite direction. Using annual data on corn and rice harvests at the province level for the period 2001–2009, we begin our analysis by confirming that the effect of rainfall on agricultural production exhibits the expected seasonality. Next, we turn our attention to estimating the effect of rainfall by season on civil conflict using data based on incident reports produced by Philippine military units. These reports were used to plan operations and are an unusually reliable source of information on the civil conflict in the Philippines (Berman et al., 2011; Crost et al., 2014).

Lending support to the argument that rainfall is related to civil conflict through agricultural production, we show that an increase in wet-season rainfall is associated with more conflict in the following year, while an increase in dry-season rainfall is associated with less conflict in the following year. This pattern of results is not consistent with the argument that heavy rains hinder the movements of troops or supplies. It is especially pronounced in rice-producing provinces; where corn is the primary crop, and in provinces with relatively little land under cultivation, the relationship between lagged rain and conflict does not exhibit as much seasonality.

Because our conflict data are especially rich, we are able to examine the effect of rainfall on which group (the insurgents or government forces) initiated a particular incident. We find that lagged rainfall is related to the number of incidents initiated by insurgents but has essentially no effect on incidents initiated by government forces. We note that more wet-season rainfall the previous year could reduce the opportunity cost of joining an insurgent group and, as a result, build insurgent strength, while more dry-season rainfall could have the opposite effect. Finally, we find that much of the violence attributable to rainfall is directed at civilians, although violence directed at government forces is also affected.

The basic results outlined above have several important implications for policymakers interested in anticipating and bolstering societal resilience to climate change. First, they provide evidence, heretofore lacking, that the predicted shift towards wetter wet seasons and drier dry seasons will lead to more civil conflict even if annual rainfall totals remain stable. Analyses that do not account for changes in the seasonal distribution of rainfall are, therefore, likely to underestimate the true effect of climate change on civil conflict. Second, they suggest that policies aimed at mitigating the effect of climate change on agricultural production could have the added benefit of reducing civil conflict. Finally, our results provide evidence for a link between rainfall and civil conflict using data from the densely populated region of Southeast Asia in a literature that has, thus far, focused almost exclusively on sub-Saharan Africa.[1]

2. Background

2.1. Climate change, rainfall and conflict

Research on the relationship between rainfall and civil conflict has generally focused on Africa (Miguel et al., 2004; Burke et al., 2009; Buhaug, 2010; Miguel and Satyanath, 2011; Hendrix and Salehyan, 2012; O'Loughlin et al., 2012; Theisen, 2012). However, observers have argued that climate change is likely to intensify several on-going conflicts, and lead to new

[1] While a handful of studies have examined the effect of rainfall and temperature on other forms of violence in Asia, such as ethnic riots (Bohlken and Sergenti, 2010; Sarsons, 2015) and historical peasant revolts (Jia, 2014), all four studies reviewed by Hsiang et al. (2013) that found a statistically significant effect of rainfall on civil conflict, defined as intra-country conflict between government forces and an armed organization, analyzed data from sub-Saharan Africa. After the publication of Hsiang et al. (2013), Fetzer (2014) found a negative relationship between monsoon rainfall and civil conflict in India.

conflicts in Southeast Asia (Smith, 2007; Jasparro and Taylor, 2008, 2011; Gerstl and Helmke, 2012).

Indeed, as climate change progresses, many parts of Southeast Asia are likely to receive more precipitation in the rainy season and less precipitation in the dry season (Christensen et al., 2007; Asian Development Bank, 2009; Lyon and Camargo, 2009). Unless new varieties of rice with resistance to heat and water stress are developed (or other technological solutions are adopted), rice yields in Southeast Asia will decline substantially (Lansigan et al., 2000; Fischer et al., 2005; Lansigan, 2005; Asian Development Bank, 2009; Ahmed and Suphachalasai, 2014). It is an open question whether this decline in rice yields will lead to more civil conflict.[2]

Only two previous studies have examined the relationship between rainfall and civil conflict in Asia. Using data from India, Fetzer (2014) found a negative relationship between monsoon rainfall and civil conflict.[3] Using data from 26 Asian countries for the period 1951–2008, Wischnath and Buhaug (2014) found little evidence that civil conflict is sparked by lack of rain, perhaps because Asian economies and/or farmers are less reliant on traditional agricultural practices than their African counterparts. Although Wischnath and Buhaug (2014) concluded that the onset of civil conflict in Asia is unrelated to rainfall and drought, they noted that climate "may shape the severity, duration, and geographic spread of hostilities" (p. 719).

There are several reasons why abnormal rainfall events could affect the duration or intensity of ongoing civil conflicts. While agricultural production is perhaps the most frequently cited mechanism in the literature, other explanations have been suggested. It is, for example, possible that heavy rainfall makes roads and bridges impassable, thereby increasing the cost of carrying out long-distance attacks or impeding state security efforts (Sarsons, 2015; Hsiang and Burke, 2014; Fearon and Laitin, 2003). In addition, above-average rainfall could increase the density of vegetation, allowing combatants to conceal their activities (Witsenburg and Adano, 2013).[4] The mechanism through which rainfall affects civil conflict has important implications for the optimal policy responses to climate change. If agriculture is the mechanism, then policies aimed at reducing the impact of rainfall shocks on crop yields are likely to increase societal resilience to civil conflict in the face of climate change. These policies include investments in irrigation, crop diversification, and breeding programs for increased resistance to water stress. If, on the other hand, infrastructure and/or vegetation density explain the relationship between rainfall and civil conflict, then such policies will have little impact on societal resilience.

Consistent with the argument that agricultural production links rainfall and civil conflict, Harari and La Ferrara (2014) found that weather shocks (such as above-average temperatures or below-average rainfall) during the growing season had a larger impact on conflict-related incidents in Africa than weather shocks outside of the growing season.[5] In an effort to explore the link between rainfall and Hindu-Muslim riots in India, Sarsons (2015) exploited the fact that agricultural production downstream from dams is more likely to depend on irrigation as compared to upstream production. She hypothesized that the effect of rainfall on Hindu-Muslim riots should, therefore, be less pronounced in downstream districts, but found little evidence for this hypothesis. In fact, the relationship was strongest in downstream districts, suggesting that rainfall is related to Hindu-Muslim riots through a mechanism other than agricultural production.

Our empirical strategy is inspired by Harari and La Ferrara (2014) and Sarsons (2015). We hypothesize that if rainfall were related to conflict through infrastructure (by, for instance, increasing the cost of travel), then its effect should be immediate, negative, and more pronounced during the wet, as opposed to the dry, season. While our results provide some evidence of a contemporaneous relationship between wet-season rainfall and conflict, the main effect of rainfall occurs with a one-year lag and follows a seasonal pattern consistent with an agricultural mechanism. Specifically, higher rainfall in the wet season is associated with an increase in civil conflict one year later, while higher rainfall in the dry season is associated with a decrease in civil conflict one year later. This pattern of results is difficult to reconcile with the infrastructure hypothesis, but easily explained by the well-documented seasonality (Lansigan et al., 2000; Gerpacio et al., 2004; Roberts et al., 2009) in the relationship between rainfall and Philippine agricultural production.

2.2. Agriculture and rainfall in the Philippines

Agriculture is an important part of Philippine economy, employing 35 percent of workers and generating 13 percent of GDP in 2009 (World Bank, 2015). The most important crop is rice, which is the main source of income and employment for 11.5 million farming households (Sebastian et al., 2000). Rice supplies 35 percent of caloric intake for the average household, and 60–65 percent of caloric intake for households in the lowest income quartile (David and Balisacan, 1995). In 2002, 42 percent of land under cultivation was planted in rice. The second most important grain crop in the Philippines is corn, which accounted for 25 percent of the land under cultivation. Unlike rice, which is almost exclusively grown as a food crop, corn is mostly used as feed for livestock (Gerpacio et al., 2004).

[2] It should be noted, however, that the effect of climate on agricultural production is difficult to predict and depends upon factors such as groundwater availability, soil types, and the decisions of farmers with regard to what crops they plant and how much water they apply (Ortiz-Bobea, 2012; Oehninger et al., 2017).

[3] Fetzer (2014) was interested in whether the National Rural Employment Guarantee Act (NREGA), passed in 2005, weakened the negative relationship between monsoon rainfall and conflict by providing minimum-wage public employment to rural households in India. He concluded that the introduction of this public employment program has eliminated the link between monsoon shocks and conflict (p. 36).

[4] This effect is likely to be contemporaneous, but could also operate with a lag.

[5] Burke et al. (2009), however, concluded that rainfall during the growing season had a weaker relationship with civil conflict in Africa than simple annual averages of rainfall. Similarly, Bollfrass and Shaver (2015) found that the global relationship between temperature and conflict was as strong in non-agricultural as in agricultural regions and interpreted this pattern of results as evidence of a psychological mechanism.

There are two distinct growing seasons for cereal crops in most of the Philippines – a wet season lasting from May to October, and a dry season lasting from November to April (Lansigan et al., 2000). In the wet season, peak planting months are May through July and peak harvesting months are September through November. In the dry season, peak planting months are December and January and peak harvesting months are March and April.[6] The greatest risk to crops in the wet season is flooding and extreme weather events such as typhoons; as a consequence, above-average rainfall in this season is associated with lower agricultural production (Lansigan et al., 2000; Gerpacio et al., 2004; Roberts et al., 2009). In the dry season, the greatest risk to crops is drought; above-average rainfall in this season is associated with higher agricultural production (Roberts et al., 2009). Below, using annual data on corn and rice harvests at the province level from the Philippine Bureau of Agricultural Statistics, we confirm that the relationship between rainfall and agricultural production exhibits the expected seasonality.

2.3. Civil conflict in the Philippines

The Philippines is involved in two distinct on-going civil conflicts during the period examined by this study, which together have caused more than 120,000 deaths (Schiavo-Campo and Judd, 2005). The most geographically widespread of these conflicts involves the New People's Army (NPA), a Maoist guerrilla group founded in 1969 that seeks to overthrow the Philippine government and replace it with a communist system. In 2005, the mid-point of this study, the NPA was estimated to have 7100 fighters (Felter, 2005). The NPA operates primarily in rural areas and relies on support from the rural poor, who supply most of its labor and logistics.

The second on-going conflict involves the Moro Islamic Liberation Front (MILF), a separatist movement fighting for an independent state in the predominantly Muslim areas of Mindanao Island and the Sulu archipelago. The MILF was formed in 1984, when the group's founders defected from the Moro National Liberation Front (MNLF). After this split, the MILF pursued a strategy of armed conflict against the government, while the MNLF signed a peace agreement in 1996 that created the Autonomous Region of Muslim Mindanao (ARRM). The MILF enjoys broad-based support among Muslims in the Philippines (Kreuzer and Werning, 2007). With an estimated 10,500 fighters, the MILF is larger than the NPA, but has a much narrower geographic reach.

In addition to the NPA and MILF, the Armed Forces of the Philippine (AFP) must also contend with the Abu Sayyaf Group (ASG) and so-called "Lawless Elements". The ASG is a high-profile Philippine terrorist organization with suspected links to al-Qaeda that mostly operates on Basilan Island and in the remote Sulu Archipelago in the far southwest of the country. While ASG receives considerable media attention, it has a far smaller number of fighters than either NPA or MILF and is responsible for only a small fraction of the violence recorded in our dataset. The term "Lawless Elements" refers to small, loosely-allied bands of guerrilla and criminal groups operating across the Philippines. Some of these groups are led by former NPA, MILF or ASG commanders who broke away from the main organization. Many of them employ guerrilla-like tactics but use violence primarily as part of criminal activities such as extortion or kidnapping for ransom, rather than to pursue political objectives.

3. Data

Our analysis is at the province-year level. Province boundaries are from 2001, when the Philippines was divided into seventy-nine provinces, each administered by a separate governor and legislative assembly. Three provinces, all located in the remote Sulu Archipelago (Basilan, Sulu and Tawi-Tawi), were not included in the analysis. The climate of the Sulu Archipelago differs markedly from the rest of the country and does not feature pronounced rainfall seasonality. Another province, Batanes, was excluded from the analysis because of missing information on agricultural production, most likely due to its small size and remote location. Of the remaining 75 provinces, 73 contributed 9 years of data (2001–2009) to the analysis; two provinces (Zamboanga Sibugay and Compostela Valley) contributed 8 years of data because of missing information on agricultural production in 2001.

Data on agricultural production come from the Philippine Bureau of Agricultural Statistics and are publicly available through the CountryStat database.[7] The rainfall measurements for each province were constructed using the Tropical Rainfall Measuring Mission's 3B43 algorithm, which produces estimates of monthly precipitation using a weighted combination of various microwave satellite estimates and rain gauge estimates.[8] The TRMM dataset was selected for its high degree of spatial resolution. Monthly precipitation averages are estimated for a $0.25 \times 0.25°$ latitude and longitude grid, providing a higher spatial resolution than most global precipitation data sets. Each province's precipitation value was constructed by overlaying province boundaries on the $0.25 \times 0.25°$ grid and calculating a weighted mean of precipitation by area.

Our measures of conflict intensity are based on incident reports from Philippine military units operating in the field during the period 2001–2009. These reports were originally collected by Felter (2005) and have been updated through 2009. They were used by Berman et al. (2011) and Crost et al. (2014) to study the determinants of conflict in the Philippines. Because the reports were used by the armed forces to plan operations and were not originally intended for public release, they are an unusually reliable and complete source of information on the civil conflict (Berman et al., 2011; Crost et al.,

[6] Several provinces have three growing seasons. Others have no pronounced dry season and strong rainfall from November to January. In Section 5, we conduct a series of robustness tests excluding these provinces from the analysis.

[7] http://countrystat.bas.gov.ph/. This website was last accessed in February of 2015.

[8] Details are available at http://mirador.gsfc.nasa.gov/collections/TRMM_3B43__007.shtml. Site last accessed February 2015.

2014).[9] They include information on which group (the government or the insurgents) initiated the incident, the number combatants killed, and the number of civilians killed.

We calculated two measures of conflict intensity from these data. The first is equal to the number of casualties by province and year. The second is equal to the number of violent incidents, defined as incidents resulting in at least one casualty. Regressions using this latter measure are less likely to be influenced by outliers because they give less weight to single incidents with above-average casualty counts.

4. Empirical strategy

Our empirical strategy exploits the seasonal pattern of rainfall in the Philippines. Our baseline estimating equation for agricultural production is:

$$Y_{it} = \alpha_0 + \alpha_1 R_{it} + \boldsymbol{X}_{it}\boldsymbol{\beta} + \nu_i + \lambda_i t + \varepsilon_{it}, \tag{1}$$

where Y_{it} denotes the natural logarithm of rice or corn production in province i and year t. R_{it} denotes annual rainfall levels in 10s of centimeters and $\boldsymbol{X}_{it}$ is a vector of controls for average annual temperature and typhoon activity. Specifically, $\boldsymbol{X}_{it}$ includes a set of indicators for 1-degree Celsius bins fully interacted with indicators for the country's four major geographic zones (Luzon, Visayas, Mindanao, and ARMM).[10] The vector $\boldsymbol{X}_{it}$ also includes an indicator for whether the province was hit by a typhoon in year t.[11]

Next, we allow rainfall to have different effects depending on the season by estimating the following equation:

$$Y_{it} = \alpha_0 + \alpha_1 R_{it}^{dry} + \alpha_2 R_{it}^{wet} + \boldsymbol{X}_{it}\boldsymbol{\beta} + \nu_i + \lambda_i t + \varepsilon_{it}, \tag{2}$$

where R_{it}^{dry} and R_{it}^{wet} measure rainfall dry season and wet season rainfall levels in 10s of centimeters, respectively. To estimate the effect of rainfall on conflict, we use a distributed lag model following Burke et al. (2015):

$$C_{it} = \gamma_0 + \gamma_1 R_{it}^{dry} + \gamma_2 R_{it}^{wet} + \gamma_3 R_{it-1}^{dry} + \gamma_4 R_{it-1}^{wet} + \boldsymbol{X}_{it}\boldsymbol{\beta}_{\mathbf{1}} + \boldsymbol{X}_{it-1}\boldsymbol{\beta}_{\mathbf{2}} + \nu_i + \lambda_i t + \varepsilon_{it}, \tag{3}$$

where C_{it} denotes the conflict outcome of interest, which is either the number of casualties or the number of violent incidents (defined as incidents with at least one casualty) in province i and year t. Including lagged rainfall accounts for the possibility that the effect of rainfall is not realized until after the next harvest due to storage and savings (Burke et al., 2015).

As explained in Section 2, we define the wet season as lasting from May through October, while the remaining months comprise the dry season. Following standard practice, rainfall in province i is measured over the course of a season (Deschenes and Greenstone, 2007; Lobell and Burke, 2008; Schlenker and Roberts, 2009; Schlenker and Lobell, 2010). There are two reasons to prefer measuring rainfall over the course of a season as opposed to month-by-month totals. First, precipitation is typically measured with substantial error in global gridded datasets and temporal aggregation reduces attenuation bias by canceling out some portion of the individual errors in the monthly rainfall totals (Lobell, 2013). Second, the effect of low rainfall for three consecutive months in the dry season (e.g., January–March) can be much larger than the sum of the separate effects of experiencing a dry January, February or March. Seasonal aggregation captures this nonlinearity, while including separate monthly rainfall totals does not.[12]

In Appendix Tables A.2 and A.3, we report estimates of equations (2) and (3) using several alternative wet season definitions (e.g., April–September or June–November). These estimates are, in general, smaller and less precise than estimates based on the May–October definition regardless of whether the outcome is agricultural production or civil conflict.

To control for unobservables potentially correlated with rainfall, our estimating equations include province fixed effects (ν_i) and province-specific linear time trends ($\lambda_i t$). Following standard practice in this literature, we do not include year fixed effects in our estimating equation (Miguel et al., 2004; Burke et al., 2009; Schlenker and Lobell, 2010; Hsiang et al., 2011). While year fixed effects would allow us to more flexibly control for time-varying unobservables at the country level, they have two significant disadvantages in this context (Fisher et al., 2012; Aufhammer et al., 2013). First, year fixed effects can severely exacerbate the problem of measurement error in the rainfall variable. Rainfall is always measured with error, especially when it comes from large-scale gridded datasets like the TRMM, and year fixed effects remove a substantial part of the actual variation in rainfall, which can severely increase the ratio of noise to signal and lead to attenuation bias (Fisher et al., 2012). Second, year fixed effects can introduce bias in the presence of spillovers from trade, migration, or movements of insurgents across province boundaries. To avoid these issues, our preferred specification excludes year fixed effects and

[9] For comparison, during the period of observation 2001–2009, our dataset contains information on approximately five times as many violent incidents between government forces and rebel groups as the UCDP Georeferenced Event Database, which is based on newspaper reports of conflict events.

[10] Following Bento et al. (2017) and Oehninger et al. (2017), we experimented with controlling for the 3-year moving averages of seasonal rainfall. The results, which are reported in Appendix Table A.1, are qualitatively similar to those reported in Tables 2 and 3.

[11] To generate this variable, we use data from the EM-DAT database on natural disasters, which contains information on the paths of 71 typhoons that struck the Philippines during the period of observation 2001–2009 (Guha-Sapir et al., 2015). Controlling for which provinces were affected by typhoons has almost no impact on the estimates presented below.

[12] Consequently, exploratory regressions with monthly rainfall totals do not find statistically significant effects of rainfall in any individual month on agricultural production or civil conflict, to a large extent because of the high standard errors associated with the estimates for each month.

Table 1
Summary statistics.

	Mean	Standard deviation
Rainfall in wet season (100 mm)	15.93	4.67
Rainfall in dry season (100 mm)	9.86	6.52
Rice production (1000 metric tonnes)	197.5	223.0
Corn production (1000 metric tonnes)	75.2	140.0
Casualties	14.1	22.7
Government casualties	6.4	10.6
Insurgent casualties	4.3	10.1
Civilian casualties	3.4	7.1
Casualties in government-initiated incidents	6.2	13.3
Casualties in insurgent-initiated incidents	7.8	12.3
Casualties in incidents with the NPA	8.2	12.3
Casualties in incidents with the MILF	2.5	16.4
Casualties in incidents with the ASG	0.3	2.6
Casualties in incidents with LE	2.8	7.8
Violent incidents	6.6	8.2
Incidents with at least one government casualty	3.5	4.8
Incidents with at least one insurgent casualty	2.0	3.0
Incidents with at least one civilian casualty	1.9	2.9
Government-initiated violent incidents	2.5	3.7
Insurgent-initiated violent incidents	4.1	5.5
Violent incidents involving the NPA	4.0	5.7
Violent incidents involving the MILF	0.7	3.7
Violent incidents involving the ASG	0.06	0.44
Violent incidents involving LE	1.5	3.5
No. of provinces	75	75
No. of observations	673	673

The unit of observation is the province-year.

relies on the assumption that variation in rainfall is random across years and therefore uncorrelated with time-varying common shocks that affected the country as a whole. As a robustness test, we report estimates of equations (2) and (3) that include year fixed effects in Table 6. Controlling for year fixed effects produces estimates of the effects of wet-season rainfall that are consistent with those discussed below, while estimates of the effects of dry-season rainfall are less precise and not significant at conventional levels. To account for possible serial correlation of conflict, we cluster the standard errors at the province level.[13]

5. Results

Table 1 provides descriptive statistics for rainfall (by season), agricultural production, conflict-related incidents and casualties. It is apparent from these statistics that rainfall exhibits strong seasonality. During the dry season, the provinces in our sample received an average of 98.6 cm of rainfall; during the wet season, they received an average of 159.3 cm of rainfall, a difference of approximately 60 percent. The optimal seasonal rainfall for rice production in Asia is between 100 and 150 cm (Samui, 1999; IRRI, 2015b), consistent with evidence from the Philippines that above-average rainfall in the dry season increases yields while above-average rainfall in the wet season has the opposite effect (Lansigan et al., 2000; Gerpacio et al., 2004; Roberts et al., 2009).[14]

On average, provinces experienced 6.6 conflict-related incidents per year, resulting in 14.1 casualties. Approximately 45 percent of total casualties were suffered by government forces; 30 percent were suffered by insurgents, with civilians making up the remainder. Sixty-two percent of casualty-producing incidents were initiated by insurgents, and insurgent-initiated incidents accounted for 55 percent of total casualties. Government-initiated incidents accounted for 44 percent of total casualties.

[13] We also estimated the spatial autocorrelation robust standard errors described by Conley (2008) and previously implemented by Hsiang (2010). Appendix Tables A.4 and A.5 show that the Conley standard errors are smaller than clustered standard errors and insensitive to the choice of spatial bandwidth, which suggests that spatial correlation does not lead to a downward bias in our standard error estimates.

[14] We also experimented with using deviations from this optimum level of rainfall. The results are reported in Appendix Table A.6 and are consistent with those reported in Tables 2 and 3.

Table 2
Seasonal rainfall and agricultural production in the Philippines.

	Log of Rice Production		Log of Corn Production	
	(1)	(2)	(3)	(4)
Annual rainfall	−0.0006		−0.0051*	
	(0.0012)		(0.0029)	
Dry season rainfall		0.0032**		0.0022
		(0.0013)		(0.0014)
Wet season rainfall		−0.0054***		−0.0052***
		(0.0015)		(0.0016)
No. of provinces	75	75	75	75
No. of observations	673	673	673	673

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Disaggregation by insurgent group shows that the largest share of incidents (61 percent) involved the New People's Army (NPA). Incidents involving the NPA accounted for 58 percent of total casualties. The Moro Islamic Liberation Front (MILF) was involved in 10 percent of reported violent incidents, although these incidents accounted for 18 percent of casualties. Lawless Elements (LE) were responsible for 22 percent of incidents and 20 percent of total casualties. Finally, the Abu Sayyaf Group (ASG) was involved in less than 1 percent of violent incidents, accounting for less than 2 percent of casualties.[15]

5.1. Rainfall and agricultural production

Table 2 provides estimates of the relationship between rainfall and agricultural production. In column (1), the estimated coefficient of R_{it} is small and statistically insignificant at conventional levels, suggesting that total rainfall received over the course of the year has little effect on rice production. In column (3), the relationship between annual rainfall and corn production is negative and significant: a 10-cm increase in annual rainfall is associated with a decrease in corn production of 0.51 percent.

When R_{it} is replaced by R_{it}^{wet} and R_{it}^{dry}, the expected seasonal pattern emerges, at least with regard to the rice harvest. Specifically, a 10-cm increase in dry-season rainfall is associated with a 0.32 percent increase in rice production.[16] In contrast, a 10-cm increase in wet-season rainfall is associated with a decrease in rice production of 0.54 percent. Both estimates are statistically significant at conventional levels.

A slightly different seasonal pattern emerges for corn. The estimated relationship between dry-season rainfall and corn production is positive, but not statistically significant. A 10-cm increase in wet-season rainfall is associated with a decrease in corn production of approximately 0.52 percent. This latter estimate is significant at the 1 percent level, and the difference between the wet- and dry-season estimates is also significant at the 1 percent level. The results in Table 2 are generally consistent with what we know about the physiology of rice versus corn (Rathore et al., 1997; Zaidi et al., 2004; Nishiuchi et al., 2012). Rice is a wetland plant and, as a consequence, more tolerant to waterlogging. Corn is better adapted to drier conditions, but more susceptible to flooding and submersion in water.

5.2. Rainfall and civil conflict

We report estimates of equation (3) in Table 3. Consistent with the infrastructure hypothesis, wet-season rainfall appears to have a contemporaneous, but relatively modest, impact on conflict intensity. Specifically, a 10-cm increase in wet-season rainfall is associated with 0.12 fewer conflict-related incidents.[17] The estimated relationship between contemporaneous wet-season rainfall and total casualties is also negative, but not significant at the 10 percent level.

Consistent with the hypothesis that rainfall affects conflict intensity, at least in part, through agricultural production, we find that a 10-cm increase in dry-season rainfall is associated with 0.59 fewer casualties and 0.25 fewer conflict-related

[15] These percentages do not add up to 100 because information on which group was involved is missing for approximately 4 percent of the incidents in our data.

[16] Ten centimeters represents 21 percent of a standard deviation in dry-season rainfall (Table 1). Therefore, a one-standard deviation increase in dry-season rainfall is associated with a 1.5 percent increase in rice production, which is similar in magnitude to previous estimates of the relationship between rainfall and rice production. Using farm-level data from 7 tropical and subtropical Asian countries, Welch et al. (2010) found that a one-standard deviation increase in rainfall during the ripening phase was associated with a 1.4 percent increase in rice production. Using farm-level data from India, Bhattacharya and Panda (2013) found that a one-standard deviation increase in rainfall was associated with a 1.9 percent increase in yield. It should also be kept in mind that, because rainfall is measured with error, the estimates in Table 2 can be thought of as lower bounds.

[17] The negative effect of contemporaneous wet-season rainfall on conflict is not consistent with the hypothesis that combatants are concealing their activities in denser vegetation, unless, of course, being better concealed actually allows the combatants to avoid contact.

Table 3
Seasonal rainfall and civil conflict in the Philippines.

	Total Casualties		Violent Incidents	
	(1)	(2)	(3)	(4)
Annual rainfall	−0.059		−0.067	
	(0.199)		(0.055)	
Dry season rainfall		0.207		−0.014
		(0.281)		(0.077)
Wet season rainfall		−0.284		−0.124*
		(0.205)		(0.067)
Lag of annual rainfall	−0.274*		−0.091***	
	(0.151)		(0.034)	
Lag of dry season rainfall		−0.585***		−0.253***
		(0.151)		(0.054)
Lag of wet season rainfall		0.495		0.275***
		(0.363)		(0.083)
No. of provinces	75	75	75	75
No. of observations	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table 4
Rainfall and agricultural production: Excluding provinces with unusual seasons.

	Provinces with 3 seasons excluded		Provinces without dry season excluded	
	Rice	Corn	Rice	Corn
Dry season rainfall	0.0034**	0.0031	0.0038*	0.0070
	(0.0013)	(0.0044)	(0.0021)	(0.0067)
Wet season rainfall	−0.0055***	−0.0160***	−0.0064***	−0.0148***
	(0.0015)	(0.0049)	(0.0014)	(0.0049)
No. of provinces	68	68	61	61
No. of observations	610	610	548	548

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table 5
Effect of rainfall on conflict: Excluding provinces with unusual seasons.

	Provinces with 3 seasons excluded		Provinces without dry season excluded	
	Casualties	Incidents	Casualties	Incidents
Dry season rainfall	0.176	−0.022	0.581	0.016
	(0.279)	(0.078)	(0.602)	(0.144)
Wet season rainfall	−0.248	−0.100	−0.371*	−0.159**
	(0.215)	(0.069)	(0.219)	(0.069)
Lag of dry season rainfall	−0.531***	−0.251***	−0.739***	−0.292***
	(0.147)	(0.055)	(0.207)	(0.070)
Lag of wet season rainfall	0.503	0.257***	0.661	0.319***
	(0.380)	(0.089)	(0.408)	(0.090)
No. of provinces	68	68	61	61
No. of observations	542	542	487	487

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

incidents the following year.[18] A 10-cm increase in wet-season rainfall is associated with 0.28 additional conflict-related incidents the following year. The estimated relationship between lagged wet-season rainfall and casualties, while positive, is

[18] The negative effect of lagged dry-season rainfall on conflict is not consistent with the hypothesis that combatants are concealing their activities in denser vegetation.

Table 6
Seasonal rainfall and civil conflict in the Philippines: Adding year fixed effects.

	Rice (1)	Corn (2)	Casualties (3)	Incidents (4)
Dry season rainfall	0.000	0.002	0.270	0.005
	(0.002)	(0.005)	(0.277)	(0.079)
Wet season rainfall	−0.005***	−0.002	−0.326	−0.050
	(0.002)	(0.005)	(0.240)	(0.088)
Lag of dry season rainfall			−0.309	−0.102
			(0.261)	(0.097)
Lag of wet season rainfall			0.467	0.209**
			(0.346)	(0.102)
No. of provinces	75	75	75	75
No. of observations	673	673	598	598

All regressions include province fixed effects, year fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table 7
Importance of agricultural land area.

	Total Casualties				Violent Incidents			
	Rice Area		Corn Area		Rice Area		Corn Area	
	High	Low	High	Low	High	Low	High	Low
Dry season rainfall	0.379	0.045	0.438	−0.006	0.026	−0.066	−0.114	−0.014
	(0.562)	(0.230)	(0.824)	(0.165)	(0.126)	(0.105)	(0.202)	(0.065)
Wet season rainfall	−0.298	−0.410*	−0.301	−0.404**	−0.160*	−0.126	−0.244*	−0.074
	(0.279)	(0.237)	(0.413)	(0.194)	(0.092)	(0.082)	(0.125)	(0.069)
Lag of dry season rainfall	−0.817***	−0.326	−1.119***	−0.224	−0.332***	−0.147**	−0.423***	−0.135**
	(0.254)	(0.206)	(0.253)	(0.147)	(0.081)	(0.064)	(0.083)	(0.059)
Lag of wet season rainfall	0.626	0.331	0.693	0.370	0.361***	0.149	0.485***	0.132
	(0.584)	(0.348)	(0.744)	(0.268)	(0.121)	(0.124)	(0.170)	(0.081)
No. of provinces	38	37	38	37	38	37	38	37
No. of observations	303	295	302	296	303	295	302	296

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. The variables and denote the mean fraction of the province's land area that is planted to rice and corn during the period of observation, 2001–2009. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

not significant at the 10 percent level.

As noted above, several provinces in the Philippines have three (as opposed to two) growing seasons, while others (located along the country's east coast) lack a pronounced dry season and typically receive heavy rainfall from November through January (IRRI, 2015a; Kintanar, 1984).[19] As a robustness check, we experimented with excluding these provinces from the analysis. The results, reported in Tables 4 and 5, are generally consistent with those reported in Tables 2 and 3. In fact, when provinces without a dry season are excluded, the relationship between rainfall and conflict appears more pronounced.

Table 6 reports results of equations (2) and (3) while flexibly controlling for country-level unobservables with year fixed effects. As discussed in Section 4 above, year fixed effects can lead to two forms of bias in this context: attenuation bias due to measurement error, as well as bias from spillovers due to trade, migration, or movements of insurgents across province boundaries (Fisher et al., 2012; Aufhammer et al., 2013). Nevertheless, the estimates in Table 6 are similar to those from our preferred specifications reported in Tables 2 and 3. Wet-season rainfall has a negative effect on rice production and a positive effect on violent incidents in the following year. The estimated effects of dry-season rainfall in Table 6 are not statistically significant, although their signs are consistent with those from our preferred specifications.

[19] According to IRRI (2015a), the following provinces have three growing seasons: Bukidon, Davao del Sur, Davao Oriental, Ilocos Norte, Iloilo, North Cotabato, South Cotabato. The provinces that lack a pronounced dry season are: Agusan del Norte, Agusan del Sur, Camarines Norte, Catanduanes, Compostela Valley, Davao Oriental, Eastern Samar, Leyte, Northern Samar, Samar, Southern Leyte, Surigao del Norte, Surigao del Sur.

Table 8
Who suffers the casualties?

	Number of Casualties by Group			Number of Violent Incidents by Group		
	Government	Insurgent	Civilian	Government	Insurgent	Civilian
Dry season rainfall	0.137	0.143	−0.073	0.037	0.070	−0.100**
	(0.148)	(0.127)	(0.092)	(0.061)	(0.043)	(0.039)
Wet season rainfall	−0.133	−0.037	−0.114	−0.052	−0.025	−0.057
	(0.115)	(0.085)	(0.077)	(0.039)	(0.028)	(0.037)
Lag of dry season rainfall	−0.294***	0.001	−0.293***	−0.141***	−0.001	−0.155***
	(0.086)	(0.077)	(0.066)	(0.036)	(0.028)	(0.033)
Lag of wet season rainfall	0.039	0.123	0.333**	0.097	0.045	0.174***
	(0.138)	(0.198)	(0.162)	(0.060)	(0.036)	(0.060)
No. of provinces	75	75	75	75	75	75
No. of observations	598	598	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table 9
Who initiates the violence?

	Casualties		Violent incidents	
	Government-initiated	Insurgent-initiated	Government-initiated	Insurgent-initiated
Dry season rainfall	0.309	−0.097	0.103*	−0.112*
	(0.186)	(0.161)	(0.053)	(0.060)
Wet season rainfall	−0.159	−0.124	−0.044	−0.074
	(0.116)	(0.139)	(0.034)	(0.053)
Lag of dry season rainfall	−0.030	−0.542***	−0.009	−0.233***
	(0.102)	(0.104)	(0.039)	(0.044)
Lag of wet season rainfall	0.204	0.277	0.037	0.235***
	(0.239)	(0.186)	(0.051)	(0.076)
No. of provinces	75	75	75	75
No. of observations	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

5.3. *The importance of agricultural area*

Next, we allow the effect of rainfall on conflict to differ according to a measure of land use at the province level, $\frac{HectaresUnderCultivation_i}{TotalHectares_i}$, where the number of hectares under cultivation comes from the CountryStat database (published by the Philippine Bureau of Agricultural Statistics) and the total area of province i comes from the 2000 Census of the Philippines. Specifically, we estimate equation (2) separately for provinces with $\frac{HectaresUnderCultivation_i}{TotalHectares_i}$ greater than the median observed in our data, and for provinces with $\frac{HectaresUnderCultivation_i}{TotalHectares_i}$ less than the median observed in our data. The results of this exercise are reported in Table 7 and suggest an important role for agriculture: the estimated effects of lagged rainfall on conflict intensity are, without exception, much larger in provinces with a greater-than-median proportion of total area devoted to agriculture as compared to provinces with a less-than-median proportion of total area devoted to agriculture.

5.4. *Disaggregation by initiator and victim*

In this section, we investigate the effect of rainfall on conflict intensity by casualty type. The results, which are reported in Table 8, suggest that rainfall shocks can shift the balance of power between insurgents and government forces. The estimated effects of rainfall on insurgent casualties and on incidents resulting in at least one insurgent casualty are generally small and, without exception, statistically insignificant. Rainfall does, however, appear to have an impact on casualties suffered by civilians and government forces. For instance, a 10-cm increase in lagged dry-season rainfall is associated with 0.29 fewer civilian casualties and 0.29 fewer casualties suffered by government forces; a 10-cm increase in lagged wet-

Table 10
Effects by insurgent group.

	Violent Incidents by Rebel Group			
	NPA	LE	MILF	ASG
Dry season rainfall	0.010	−0.063**	0.039	0.006
	(0.063)	(0.030)	(0.035)	(0.006)
Wet season rainfall	−0.100*	−0.066*	0.042*	0.000
	(0.052)	(0.035)	(0.025)	(0.003)
Lag of dry season rainfall	−0.110**	−0.124***	0.004	0.000
	(0.051)	(0.030)	(0.010)	(0.006)
Lag of wet season rainfall	0.114	0.215**	−0.096*	0.023
	(0.072)	(0.084)	(0.054)	(0.020)
No. of provinces	75	75	75	75
No. of observations	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively. The abbreviations NPA, MILF, LE and ASG refer to the four most common insurgent affiliations reported by the AFP: New People's Army (Communist Terrorist Movement), Moro-Islamic Liberation Front, Lawless Elements, and Abu-Sayyaf Group, respectively.

Table 11
Agricultural production and civil conflict: IV estimates.

	Total Casualties		Violent Incidents	
	(1)	(2)	(3)	(4)
Log ag. production (rice + corn)	13.468		0.590	
	(30.581)		(13.196)	
Log ag. production in t-1	−155.859***		−70.200***	
	(57.626)		(25.041)	
Log. of rice production		9.468		−2.610
		(154.921)		(50.379)
Log rice production in t-1		−172.369*		−57.313*
		(88.064)		(32.659)
Log. of corn production		−5.587		4.182
		(40.039)		(12.102)
Log corn production in t-1		−2.012		−5.518
		(47.715)		(16.286)
F-stat of first-stage rice + corn	6.33		6.33	
F-stat of first-stage rice		9.27		9.27
F-stat of first-stage corn		4.92		4.92
No. of provinces	75	75	75	75
No. of observations	598	598	598	598

Estimates are from 2-stage least squares regressions using dry season and wet season rainfall in periods t and t-1 as instruments. All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

season rainfall is associated with 0.33 additional civilian casualties and 0.17 additional incidents resulting in at least one civilian casualty. These results are broadly consistent with those of van den Eynde (2017), who found that low rainfall is associated with an increase in insurgent-on-civilian violence in India.

In Table 9, we report estimates of the effect of rainfall on conflict intensity by who (that is, which group) initiated the violence. The results provide further evidence that rainfall can shift the power balance between insurgents and government forces. Specifically, we find that the estimated effects of lagged rainfall on violent incidents initiated by insurgents are roughly similar in size to those reported in Table 3. In contrast, the estimated effects on government-initiated incidents are closer to zero and not statistically significant.[20] This pattern of results suggests that rainfall shocks that are detrimental to

[20] Table 9 also provides evidence that contemporaneous dry-season rainfall is positively related to incidents initiated by government forces but negatively related to incidents initiated by insurgents. These estimates, however, are only significant at the 10 percent level and should therefore be interpreted cautiously, especially given the fairly large number of hypotheses being tested. It is possible that an increase in dry-season rainfall leads to an increase in the opportunity cost of joining a rebel group. Lacking manpower, rebel groups find it more difficult to launch attacks and government forces take advantage of the situation by going on the offensive.

agricultural production strengthen insurgent groups, enabling them to inflict casualties on government forces and civilians who do not comply with their demands.[21]

5.5. Disaggregation by insurgent group

The Philippine military categorizes incidents based upon which insurgent group was involved. According to the military, the three main active insurgent groups operating in the Philippines are the communist New People's Army (NPA), the Muslim-separatist Moro-Islamic Liberation Front (MILF), and the Islamist Abu Sayyaf Group (ASG). In addition to these armed insurgent groups, the military also reports conflict episodes involving armed criminal groups, or so-called “Lawless Elements”, as recorded in military field reports. Lawless Elements (LE) are composed of apolitical criminal organizations and groups led by renegade former insurgent commanders. Detailed descriptions of these four groups can be found in Section 2. In this section, we estimate the effect of rainfall on conflict intensity stratified by which armed group was involved.

The results of this exercise are reported in Table 10. They provide evidence that lagged dry-season rainfall is negatively related to violent incidents involving the NPA and negatively related to violent incidents involving lawless elements. Lagged wet-season rainfall is positively related to violent incidents involving lawless elements, but negatively related to violent incidents involving the MILF, although this latter estimate is only statistically at the 10 percent level and should be interpreted cautiously given the large number of hypotheses being tested. However, because the Philippine military classifies smaller armed groups led by renegade MILF commanders as LE, it is possible that factional splits caused by poor harvests lead to more violent incidents being attributed to lawless elements and a corresponding reduction in the number of incidents being attributed to the MILF. This explanation is consistent with theoretical and empirical results that suggest that poor economic conditions and low state capacity lead to increased factionalization among rebel groups (Bueno de Mesquita, 2008; Fjelde and Nilsson, 2012).[22] A related explanation is that rainfall shocks affect how military units attribute incidents to the four group categories, even if there is little change in actual insurgent activity. The leadership of NPA and MILF often publicly denounce violence in regions affected by humanitarian crises such as drought or flood. Regardless of their actual affiliation, groups committing violence in these regions may therefore be more likely to be labeled as lawless elements because their actions contradict the public statements of the NPA and MILF leadership.[23]

5.6. Instrumental variables estimates

In Table 11, we report estimates from two-stage least squares (2SLS) regressions that use seasonal rainfall as an instrument to estimate the effect of agricultural production on conflict intensity. This estimation strategy assumes that rainfall only affects conflict through agricultural production and no other route. Since this assumption is likely to be violated (Witsenburg and Adano, 2013; Ciucci et al., 2011; Hiltunen et al., 2012; Hsiang and Burke, 2014; Sarsons, 2015; Christian and Barrett, 2017), the estimates should be interpreted with caution. A further reason for caution is the fact that the first-stage F-statistics are below 10, the standard proposed by Staiger and Stock (1997).

According to the 2SLS estimates reported in Table 11, a 10 percent increase in total agricultural production (rice + corn) is associated with approximately 16 fewer casualties and 7 fewer violent incidents per province-year. When we estimate the effects of rice and corn production separately, we find that a 10 percent increase in rice production is associated with approximately 17 fewer casualties and 6 fewer violent incidents, but there is little evidence of a relationship between corn production and conflict. A possible explanation for this pattern of results is that rice is a subsistence crop while corn is largely grown as a cash crop. It is also possible that this difference is due to a violation of the exclusion restriction if seasonal rainfall patterns affecting corn production are related to violence through other routes.

6. Conclusion

In the Philippines and other parts of Southeast Asia, above-average rainfall can be an unexpected boon for farmers or it can ruin crops, depending on when it occurs (Lansigan et al., 2000; Gerpacio et al., 2004; Roberts et al., 2009). During the dry season, rice (and to a lesser extent corn) is susceptible to drought and above-average rainfall typically leads to an increase in agricultural production. During the wet season, above-average rainfall can lead to flooding and/or waterlogging and, as a consequence, poor harvests.

[21] It has been suggested that an increase in insurgent-on-civilian violence could be the result of decreased insurgent strength, leading to the use of violence to control the population and punish informants (Kalyvas, 2006; Wood, 2010). However, this mechanism is not consistent with the estimates reported in Table 8 showing that lagged dry-season rainfall is negatively related to government casualties but essentially unrelated to insurgent casualties.

[22] Our results are also consistent with evidence that rebel factionalization is often accompanied by increased violence against the state and civilians (Cunningham, 2013).

[23] There is also evidence, albeit tentative, that contemporaneous wet-season rainfall is negatively related to conflict with the NPA and LE, while contemporaneous dry-season rainfall is negatively related to conflict with lawless elements. These estimates are consistent with rainfall having an incapacitating effect, perhaps through an infrastructure mechanism, but should be interpreted cautiously given their lack of precision and the large number of hypotheses being tested. Finally, we find a positive association between contemporaneous wet-season rainfall and conflict with the MILF, which may be due to the fact that regions with and without MILF activity have different climates and rainfall patterns.

Using detailed data on conflict-related incidents collected by the Philippine military for its own internal purposes, we estimate the effect of rainfall by season on agricultural production and civil conflict in the Philippines. Our results suggest that the predicted shift towards wetter wet seasons and drier dry seasons will be harmful to agriculture and lead to an increase in civil conflict. Moreover, they suggest that rainfall is related to civil conflict, at least in part, through its effect on agriculture.

Three pieces of evidence are most salient. First, we find that lagged rainfall is a robust predictor of conflict intensity. Because the effect of rainfall on agricultural production is realized at harvest, we would expect there to be a lag between rainfall and conflict, which we would not expect if rainfall worked exclusively through infrastructure or if rainfall had a direct influence on the psychology of combatants. Second, the relationship between rainfall and conflict-related incidents exhibits seasonality, but in the opposite direction as observed for agricultural production. That is, an increase in dry-season rainfall is good for rice production and dampens conflict intensity. By contrast, an increase in wet-season rainfall is harmful to rice production and leads to more conflict. Third and finally, the effect of rainfall on conflict appears to be more pronounced in provinces with a greater-than-median proportion of total area devoted to the production of rice. Taken together, these results lend strong support to the argument that agricultural production is at least one of the channels through which rainfall impacts civil conflict.

Although climate change is not expected to have a major impact on total rainfall in Philippines or other Southeast Asian countries (Christensen et al., 2007; Asian Development Bank, 2009; Lyon and Camargo, 2009), it is expected to amplify the already pronounced seasonal variation in rainfall. Our findings suggest that this amplification will exacerbate ongoing civil conflict in the Philippines and perhaps spark new conflict in other Southeast Asian countries, especially those heavily dependent on rice for subsistence.

Understanding the mechanisms through which climate change affects civil conflict is crucial to informing policy responses to climate change (Burke et al., 2015). Even under the most optimistic scenarios, substantial climate change appears to be unavoidable (IPCC, 2014, p.189), and designing policies that can increase societal resilience against civil conflict in the face of a changing climate will become increasingly important (World Bank, 2012; Center for Naval Analyses, 2014; USAID, 2014). Our results suggest that policies aimed at mitigating the effect of climate change on agricultural production could have the added benefit of reducing civil conflict.

Acknowledgments

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Appendix

Controlling for 3-year moving averages of lagged seasonal rainfall

Table A.1 shows estimates of equations (2) and (3) that control for the 3-year moving averages of lagged seasonal rainfall. With these added controls, an increase in lagged dry-season rainfall is still associated with fewer violent incidents. It is also associated with fewer casualties, although this estimate is not statistically significant. An increase in lagged wet-season rainfall is still associated with more violent incidents, while the estimated effect of lagged wet-season rainfall on casualties is positive, but not statistically significant.

Table A.1
Seasonal Rainfall, Agricultural Production, and Conflict: Including Moving Avg. of Lagged Rainfall.

	Log Rice Production (1)	Log Corn Production (2)	Violent Incidents (3)	Casualties (4)
Dry season rainfall	0.003*	−0.003	0.003	0.404
	(0.002)	(0.007)	(0.089)	(0.335)
Wet season rainfall	−0.005***	−0.015***	−0.146*	−0.496*
	(0.002)	(0.005)	(0.078)	(0.297)
Lag of dry season rainfall			−0.226***	−0.246
			(0.064)	(0.205)
Lag of wet season rainfall			0.279***	0.535
			(0.086)	(0.381)
No. of provinces	75	75	75	75
No. of observations	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4, as well as lagged 3-year moving averages of dry season rainfall and wet season rainfall. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Robustness to definition of dry/wet season

Tables A.2 and A.3 show results with different definitions of the wet and dry seasons. For both rice production and violent incidents, the effect of seasonal rainfall is largest if the wet season is defined as May–October, as it is defined in all regressions in the main paper. Changing this definition reduces the effect of seasonal rainfall and makes the difference between the seasons less strong, which suggests that the May–October definition best captures the true seasonal variation in rainfall and its effect on agriculture and civil conflict.

Table A.2
Seasonal Rainfall and Rice Yield: Changing Definition of Wet and Dry Season.

	Dependent Variable: Log of Rice Production				
	Definition of Wet Season:				
	Mar–Aug (1)	Apr–Sep (2)	May–Oct (3)	Jun–Nov (4)	Jul–Dec (5)
Dry season rainfall	0.0011	0.0020*	0.0032**	0.0026**	−0.0001
	(0.0013)	(0.0011)	(0.0013)	(0.0013)	(0.0015)
Wet season rainfall	−0.0028	−0.0046***	−0.0054***	−0.0044**	−0.0011
	(0.0018)	(0.0016)	(0.0015)	(0.0017)	(0.0015)
No. of provinces	75	75	75	75	75
No. of observations	673	673	673	673	673

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table A.3
Seasonal Rainfall and Rice Yield: Changing Definition of Wet and Dry Season.

	Dependent Variable: Violent Incidents				
	Definition of Wet Season:				
	Mar–Aug (1)	Apr–Sep (2)	May–Oct (3)	Jun–Nov (4)	Jul–Dec (5)
Dry season rainfall	0.0763	0.1087	−0.0142	−0.0935	−0.1586
	(0.0754)	(0.0692)	(0.0774)	(0.1117)	(0.1035)
Wet season rainfall	−0.2274**	−0.2588***	−0.1238*	−0.0899	0.0125
	(0.1011)	(0.0877)	(0.0667)	(0.0747)	(0.0804)
Lag of dry season rainfall	−0.1188**	−0.1281**	−0.2532***	−0.1867**	−0.1224**
	(0.0540)	(0.0532)	(0.0541)	(0.0762)	(0.0581)
Lag of wet season rainfall	0.0434	0.1530*	0.2754***	0.0573	0.0017
	(0.0625)	(0.0823)	(0.0833)	(0.0942)	(0.0769)
No. of provinces	75	75	75	75	75
No. of observations	598	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Robustness to Conley standard errors

Tables A.4 and A.5 show regressions that use the spatial autocorrelation robust standard errors described by Conley (2008) and previously implemented by Hsiang (2010). The Conley standard errors are smaller than clustered standard errors and insensitive to the choice of spatial bandwidth, which suggests that spatial correlation does not lead to a downward bias in our standard error estimates.

Table A.4
Seasonal Rainfall and Agricultural Production: Conley Standard Errors.

	Log of Rice Production			Log of Corn Production		
Dry season rainfall	0.0033***	0.0033***	0.0033***	0.0029	0.0029	0.0029
	(0.0005)	(0.0005)	(0.0005)	(0.0046)	(0.0047)	(0.0048)
Wet season rainfall	−0.0053***	−0.0053***	−0.0053***	−0.0143***	−0.0143***	−0.0143***
	(0.0017)	(0.0016)	(0.0016)	(0.0011)	(0.0014)	(0.0017)
Spatial Bandwidth (km)	1000	5000	5000	1000	5000	5000
Autocorrelation Cutoff (years)	5	25	25	5	25	25
No. of provinces	75	75	75	75	75	75
No. of observations	673	673	673	673	673	673

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors are robust to spatial and temporal autocorrelation, as described by Conley (2008) and implemented by Hsiang (2010). ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table A.5
Seasonal Rainfall and Civil Conflict: Conley Standard Errors.

	Total Casualties			Violent Incidents		
Dry season rainfall	0.207	0.207	0.207	−0.014	−0.014	−0.014
	(0.307)	(0.308)	(0.311)	(0.067)	(0.090)	(0.089)
Wet season rainfall	−0.284*	−0.284*	−0.284*	−0.124**	−0.124**	−0.124**
	(0.163)	(0.159)	(0.168)	(0.054)	(0.059)	(0.060)
Lag of dry season rainfall	−0.585***	−0.585***	−0.585***	−0.253***	−0.253***	−0.253***
	(0.206)	(0.213)	(0.214)	(0.046)	(0.042)	(0.039)
Lag of wet season rainfall	0.495	0.495	0.495	0.275***	0.275***	0.275***
	(0.420)	(0.449)	(0.455)	(0.087)	(0.103)	(0.102)
Spatial Bandwidth (km)	1000	5000	5000	1000	5000	5000
Autocorrelation Cutoff (years)	5	25	25	5	25	25
No. of provinces	75	75	75	75	75	75
No. of observations	598	598	598	598	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors are robust to spatial and temporal autocorrelation, as described by Conley (2008) and implemented by Hsiang (2010). ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Deviations of seasonal rainfall from 100 mm optimum

Table A.6 shows regressions that use deviations of seasonal rainfall from the 100 mm optimum as the right-hand side variables, which previous studies have reported as the optimal rainfall level in other parts of Asia (Samui, 1999; IRRI, 2015b). The results show evidence that deviations from 100 mm precipitation lead to decreased agricultural production in the wet season. We do not find statistically significant evidence that deviations from 100 mm lead to decreased production in the dry season. The results for the conflict outcomes are consistent with this. We find evidence that deviations from 100 mm precipitation in the wet season lead to an increase in conflict in the following year, but no statistically significant evidence for a corresponding effect of dry season rainfall. These results are consistent with those reported in the main body of the paper: variation in rainfall that is detrimental to agricultural production leads to an increase in conflict in the following year.

Table A.6
Deviations from Optimal Rainfall, Agricultural Production, and Civil Conflict.

	Log Rice Production (1)	Log Corn Production (2)	Violent Incidents (3)	Casualties (4)
Abs. deviation of dry season rainfall from 100 mm	0.0021	−0.0039	−0.0119	−0.1044
	(0.0014)	(0.0049)	(0.0943)	(0.2931)
Abs. deviation of wet season rainfall from 100 mm	−0.0047***	−0.0018	−0.0445	−0.2426
	(0.0018)	(0.0054)	(0.0815)	(0.2450)
Lag of abs. deviation of dry season rainfall from 100 mm			−0.0803	−0.1470
			(0.0763)	(0.2410)
Lag of abs. deviation of wet season rainfall from 100 mm			0.1627*	0.2575
			(0.0945)	(0.3353)
No. of provinces	75	75	75	75
No. of observations	673	673	598	598

All regressions include province fixed effects, province-specific linear time trends and the temperature and typhoon controls described in Section 4. Standard errors, clustered at the province level, are in parenthesis. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

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