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Distributional Impact Analysis of Past Climate Variability in Rural Indonesia

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Abstract

In rural Indonesia, around 60 percent of workers engage in agriculture and face regular climatic shocks that may threaten their crop production, household income, and human capital investments. Little is known about households' ability to maintain consumption in response to these shocks. This paper uses both longitudinal and repeated cross-sectional data to examine the extent to which farm profits and household consumption are reduced by delayed monsoon onset, an important determinant of rice production in Indonesia. It also investigates whether poor households are more vulnerable to delayed onset. Overall, delayed onset has minor effects on rural households' profit and consumption. For poor households, defined as those with average per capita consumption in the lowest quintile, delayed onset the previous year is associated with a 13 percent decline in per capita consumption. Most of this decline is due to an increase in household size, however, and delayed onset two years ago is positively correlated with consumption. The findings suggest that poor households experience greater volatility but no lasting reduction in consumption following delayed monsoon onset.

This paper—a product of the Poverty Reduction and Economic Management Division, East Asian and Pacific Region—is part of a larger effort in the region to understand the effects of climate shocks on households in developing countries. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at dnewhouse@worldbank.org or mduarte@worldbank.org.

Distributional Impact Analysis of Past Climate Variability in Rural Indonesia

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Key Words: climate variability, agriculture productivity, household consumption, farm profits

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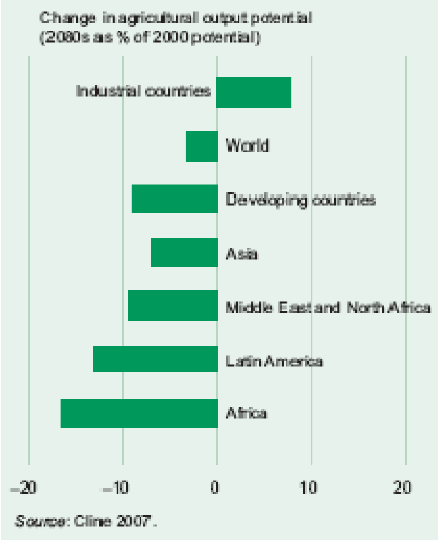
I. Introduction

How does variation in monsoon onset affect rural households' economic welfare? Over 60 percent of the world's poor reside in rural areas and a significant share of their income derives from agriculture, either directly or indirectly. Projected increases in climate variability and extreme weather events underscore the importance of understanding how climatic shocks affect households. The expected changes in climate patterns represent a serious threat to agricultural productivity in developing countries (Figure 1). Increased temperatures reduce yields, and have resulted in an estimated combined loss for wheat, maize, and barley of roughly $5 billion per year between 1981 and 2002 (Lobell and Field, 2007). A temperature rise of 2.0 C and an 8 percent increase in precipitation, in the absence of carbon fertilization, could lead to a 12 percent reduction in agricultural revenue in Brazil and a 20 percent reduction in India (Sanghi and Mendelsohn, 2008).[1]

Figure 1. Change in agricultural output potential (2080 as a % of 2000 potential).



Empirical estimates of the effect of rainfall shocks on household consumption vary considerably across countries. In Ethiopia and Burkina Faso, for example, household consumption appears to be sensitive to rainfall shocks.[2] In contrast, Thai and Indian households are largely able to smooth consumption in response to rainfall shocks, partly by increasing the number of hours worked.[3]

It is difficult to know whether poor households are particularly vulnerable to climatic shocks. Poor households may be especially vulnerable to delayed onset, if they can't afford formal or informal insurance from climatic shocks. Wealthier households, conversely, might have greater access to informal insurance networks through relatives or other sources, or irrigated farmland that offers partial protection from drought. However, poor households may

[1] These estimates measure the effects of changes in seasonal temperature and precipitation but do not take into account other possible changes such as inter annual variation or diurnal temperature variation. In addition, the estimates do not reflect productivity gains that might accrue from changes in technology and therefore in crop choices, land use and prices.
[2] Dercon (2004), Kazianga and Udry (2006).
[3] Kochar (1997), Jacoby and Skoufias (1998), and Townsend (1994), and Paxson (1992).

also be less vulnerable to climatic shocks, to the extent that they protect themselves by adopting low risk and low return strategies that perpetuate their poverty (Rosenzweig and Binswanger 1993).

Households' response to shocks can have important effects on both their short and long-term prospects. Well-developed financial and insurance markets, where they exist, help insulate household consumption from shocks. In developing countries, however, formal financial and insurance markets tend to be limited. As a result, most *ex-ante* and *ex-post* strategies for coping with rainfall shocks in poor rural areas are costly, and may lead to lasting reductions in consumption or asset holdings.[4] Rainfall shocks and crop loss can also have pernicious long-term impacts by disrupting human capital investments. [5]

Past climate shocks have reduced Indonesian households' human capital investments and income. For example, early-life drought between 1953 and 1974 adversely affected health, educational attainment, and adult socioeconomic status (Maccini and Yang, 2009). Self-reported crops loss was associated with reduced education expenditure (Cameron and Worswick, 2001). Finally, low rainfall in specific quarters has, in the past, been correlated with substantial and lasting reductions in farmers' income (Newhouse, 2005).

We know of no study that has examined the effects of delayed monsoon onset on the welfare of different types of households. Previous studies have instead focused on estimating the impact of climate variability on aggregate Indonesian rice production**.** This paper fills this gap by investigating the effect of delayed monsoon onset in prior years on farm profits and per capita consumption of rural Indonesian households, separately for poor and rich farm and non-farm households. The timing of the monsoon is an important factor in determining the amount of rice and other crops that can be planted. A key innovation in this study is the use of a large longitudinal household survey, which allows us to separately estimate the effect of delayed onset on groups of households defined on the basis of time-invariant household characteristics, such as initial farm status and average per capita consumption of the household.

Our primary finding is that on average, households are well protected against delayed onset, but that poor households are vulnerable to temporary falls in consumption. A one-standard deviation or 24 day delay in monsoon onset the previous year is associated with a 1 percent reduction in household per capita expenditure for all rural households, but a 13 percent reduction for the poorest households. This reduction largely occurs through an increase in household size. However, a one standard-deviation delay in monsoon onset is associated with an 11 percent increase in household per capita expenditure for all rural households, measured two years later, and a 23 percent increase for poor households. These increases are largely due to an increase in total household expenditure. We conclude that delayed onset reduces per capita consumption for poor households, largely through increased household size, but that poor households recover within two years.

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[4] For example, in response to the 1998 financial crisis in Indonesia, households sold non-productive assets such as jewelry (Frankenberg, *et al*, 2003).
[5] See Jacoby and Skoufias for India, 1997, Jenson in Cote d'Ivoire, 2000, and Beegle, et al, in Tanzania, 2008, among others.

II. Context

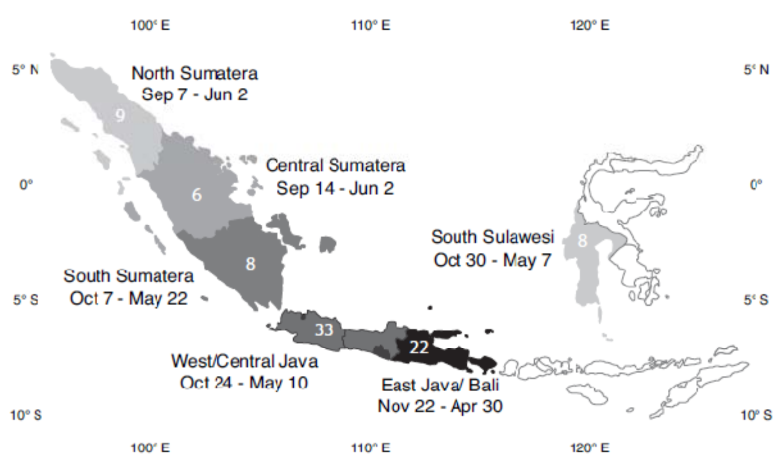
Climate variability and agricultural productivity in Indonesia

Rainfall patterns are the most important dimension of weather variation in Indonesia and they vary greatly across years and regions. The interaction of variation in monsoon trajectories and local topography causes unpredictable variation in the timing and level of precipitation. Rainfall patterns exhibit substantial variability within year across districts as well as within districts over time. In the 20 years before 2004, a 30-day delay monsoon onset occurred nearly 18 percent of the time in West/Central Java and 10 percent in East Java/Bali (Naylor, *et al*, 2007).

Agriculture, despite its declining contribution to GDP (from 47 percent in 1969 to around 13 percent in 2006) employs most rural Indonesians. Agriculture currently accounts for 60 percent of rural employment, only slightly declining from 70 percent in 1990. Two thirds of the households in the bottom two consumption quintiles work in agriculture (Kishore *et al*: 2000; World Bank: 2008).

Crop planting can only occur after the onset of the monsoon. During the 3-4 months grow-out period from planting to harvest, rice requires 600-1200 mm of water depending on the agro-ecosystem and the timing of the rainfall or irrigation. The timing of the onset of the monsoon is affected by the El Nino Southern Oscillation (ENSO), which causes anomalies in the sea surface temperature and sea-level pressure. In neutral ENSO years, most rice is planted at the beginning of the rainy season between October and December (see Figure 2 for regional variations), when there is enough moisture to prepare the land for cultivation and to facilitate the early rooting. The main planting period occurs before the peak of the monsoon, because excessive water hampers rooting. A smaller, dry season planting takes then place in April and May after the wet season crop is harvested (De Datta: 1981 in Naylor *et al*: 2001).

Figure 2. Regional monsoon onset and termination dates in Indonesia and regional percentage of total Indonesia rice production in 2004.



Note: Onset date is the date past August 1 when accumulated rainfall equals 20 cm, averaged over reporting rainfall stations in the region for the years 1979–2004; termination date is the date on which 90% of that year's rainfall has accumulated.
Source: Naylor *et al*, (2007).

El Nino events can delay rice planting by up to two months, reducing the area cultivated and delaying the plantings of next year's dry-season crop. [6] Monsoon timing affects the total amount of land planted for many crops (Table 1), but is especially important for rice. From 1983-2004 a 30-day delay in monsoon onset caused rice output to fall, on average, by 580.000 metric tons in East Java/Bali and 540.000 metric tons in West/Central Java during the main rice harvest season between January and April[7] (Naylor, *et a*l, 2007). Also studies on rice farming in India have found that variability in area cultivated is higher than yield variability (Walker and Ryan, 1990).

Table 1. ENSO-Sensitivity[1] by Crop in Indonesia 1963-1998.

Crop	Production (t)	Area Harvested (ha)	Yield
Maize	0.61*	0.61**	**0.2**
Sweet Potato	0.48*	0.46**	**0.05**
Soybean	0.41*	0.43**	**-0.02**
Groundnut	0.34*	0.52**	**-0.25**
Rice	0.23	0.50**	**-0.17**
Cassava	0.16	0.05	**0.16**

Correlation between percentage deviations from 5 year moving average and SOI monthly average (June-September).
Significance: **P<0.01, *P<0.05
Source: Irawan (2002).

Most of the climate-induced variation in rice production is a consequence of changes in the area harvested rather than in the per hectare yield. Falcon *et al* (2004) estimated each degree Celsius increase in the SSTAs (using the August Niño 3.4 sea surface temperature anomaly) results in a national area affected of -261 thousand hectares, a production effect of -1,318mt[8] and a $21/metric ton change in the world price for lower quality rice (Table 2). El Niño events cause delays in the main rice harvest and often also drive up prices in domestic and international markets. Decreases in rice stocks and increases in prices have a disproportionate impact on poor net consumers of rice (Naylor *et al:* 2007; Falcon *et al:* 2004). During the 1997-1998 El Niño, for example, Indonesia had to import over five million tons of rice to ensure food availability (Kishore *et al.* 2000).

III. Data and Methodology

Our prior hypothesis is that late onset reduces both farm profits and household expenditure in rural areas. This is based on previous research which indicates that delayed monsoon onset decreases the amount of rice area harvested in the following rice calendar year (Falcon *et al*, 2004). Early onset, on the other hand, is expected to have a neutral or positive effect on consumption. There is, however, no direct empirical evidence on the magnitude of the negative effects and the types of rural households are most vulnerable.

[6] During El Nino events, the warmer ocean water shifts eastward away from Indonesia causing rain to fall over the central Pacific Ocean.
[7] The average production in this season was 9 million metric tons – mmt - in West/Central Java and 5 mmt in East Java/Bali.
[8] For the September-December trimester changes are 142 thousand hectares in area harvested and production by 556tmt. For the January-April trimester the production change is of 938 mmt. For the May-August trimester the slope coefficients are positive rather than negative.

Table 2. Estimated effects of a one degree Celsius increase in August SSTA on rice production, by province.

Province	Crop-Year Production Effect (Sep-Aug) (tmt)	Percentage of National Effect	Significance of Production Effect (t-statistic)	Ratio of Production Effect to Average Yearly Production 1997/98 – 2001/02
West Java	-380	28.83	-3.01	**-0.037**
Central Java	-238	18.06	-3.67	**-0.026**
East Java	-232	17.60	-4.06	**-0.026**
South Sulawesi	-102	7.74	-2.02	**-0.033**
North Sumatra	-54	4.10	-1.57	**-0.016**
West Sumatra	-46	3.49	-2.18	**-0.026**
East Kalimantan	-41	3.11	-2.60	**-0.118**
North Sulawesi	-38	2.88	-3.31	**-0.104**
West Nusa Tenggara	-30	2.28	-2.63	**-0.021**
Riau	-17	1.29	-2.14	**-0.041**
Southeast Sulawesi	-10	0.76	-1.68	**-0.033**
Bali	-3	0.23	-2.82	**-0.003**
Subtotal	**-1.191**	**90.36**		
Coefficient for all Indonesia	**-1.318**	**100.00**		

Source: Falcon *et al*. (2004).

To obtain empirical evidence on this question, we utilize the first three rounds of the Indonesian Family Life Survey. [9] The IFLS is a longitudinal household survey that began with roughly 7,200 households taken from 320 communities in 13 out of Indonesia's 33 provinces. The 13 provinces encompass 83 percent of the population and the survey covers virtually all of the provinces highlighted in figure 2, which account for roughly 85 percent of national rice production. Subsequent rounds of the survey, conducted in 1997 and 2000 attempted to re-contact all households interviewed in 1993, and household attrition rates were generally below 5 percent. Split-off households, which were tracked as long as they remained in the 13 provinces, are included in the sample but treated as new households. The exclusion of urban areas limits the total sample to 11,400 observations on 4,000 households, taken from 181 communities in 1993.[10] The consumption module consists of 37 food and 19 non-food items, and self-consumption is reported separately. Household per capita expenditure is equal to the sum of all expenditures reported by the spouse in the past month, deflated by a local price index, divided by the number of persons in the household. [11]

The national socioeconomic survey is as an important and complementary source of data on household consumption. Each year, in late February or early March, a new set of roughly 190,000 households are interviewed as part of the core of the national socio-economic census (SUSENAS). The dataset includes results from a small consumption module, consisting of 15 food items and 8 non-food items, that combines purchased and self-consumption. To utilize these data, we randomly drew a 5 percent sample of all rural households from 1993 to 2004, stratified by district and per capita

[9] A fourth round of the survey was conducted in 2007, but this was not used in study, due to our inability to obtain rainfall data beyond 2004.

[10] Additional information about the survey is provided in Strauss *et al* (2000), Frankenberg and Thomas (1997), and Frankenberg and Karoly (1993).

[11] For IFLS1, per capita consumption is taken from the expend2.dta file provided in the re-release of IFLS, which imputes non-food expenditures for households that were not asked to report them. In addition, because no price index is provided for the 1993 data, the national price index for the local provincial capital is used to deflate expenditures from 1993 to 1997.

consumption quintile. These 12 datasets were then combined into a single dataset consisting of 118,500 households.

Both datasets were matched to local daily rainfall data. Rainfall data is taken from the NOAA (National Oceanic and Atmospheric Administration) Global Summary of the Day combined with additional data obtained from the Indonesian Meteorological Agency (*Badan Meteorologi dan Geofisika, BMG*). Imputed values for the missing values in the Global Summary of the Day data were provided by CEREGE, *Centre Europeen de Recherche et d'Enseignement des Geosciences de l'Environnement*.
Rainfall data contains daily rainfall data for 52 stations, of which 36 stations match with the IFLS data and 49 stations match with the SUSENAS data. In the IFLS data households were matched with the closest weather station at the community level whereas in the SUSENAS they were matched at the kabupaten (district) level.

The definition of monsoon onset is based on daily rainfall data. The start of the monsoon is defined as the number of days past August 1 that cumulative rainfall exceeds 200 mm, following Naylor *et al.* (2007). For each station, we calculated the start date of monsoon defined as the number of days past August 1 when cumulative rainfall exceeds 200 mm. Onset was then standardized using each station's "leave-out" mean and standard deviation across years. In other words, data from the onset year was excluded when calculating the mean and standard deviation used to standardize each year's onset.

Monsoon onset is sufficiently variable across Indonesia to allow for detailed analysis. Annex 2 displays district-level maps of Indonesia that indicate the timing of monsoon onset from 1990 to 1999. These maps show that the 36 rain stations used to match the IFLS data generate meaningful variation in monsoon onset.

To estimate the effect of late monsoon onset on household expenditure, we estimate the following simple model.

(1) $$\ln C_{it} = \alpha + \sum_{p=1}^{4} \beta_p O^p + \alpha_i + D_t + \varepsilon_{it}$$

Where C_{it} represents the per capita expenditure of household ***i*** in year ***t***, and α_i is a household-specific fixed effect that captures all time-invariant characteristics of the household, including all household characteristics determined prior to 1993. D_t represents a vector of dummy variables for each year.

$O_{i,t-1}$ represents standardized monsoon onset, at the nearest weather station in the previous year. A value of $O_{i,t-1}$ equal to zero would indicate that the nearest station's monsoon onset last year was equal to its historical average, while a value equal to one would indicate that last year's monsoon arrived one standard deviation late. The standard deviation of monsoon onset across the entire sample is 24 days.

The key estimated parameters are β_1 and β_2, β_3 and β_4, which define a quartic function that approximates the effect of monsoon onset on per capita consumption the following year.

ε_{it} is a stochastic error term, which is robust to heteroscedasticity and clustered on weather station in order to allow correlation between households that have been allocated the same rain station.

Our preferred specification includes two lags of onset. During the years and regions covered in the survey, rainfall exhibits negative serial correlation. As a result, late onset in a particular year is associated with a reduced probability that the monsoon will be delayed the following year.[12] If late onset is detrimental to household consumption and this effect persists for two years, then the estimated effect of late rainfall in equation (1) will underestimate the true negative effect of delayed onset. This is because the effect of late onset, estimated in equation (1), will also capture the diminished probability of late onset the previous year. Less intuitively, if late onset two years ago is associated with an increase in per capita consumption, perhaps because households experiencing late onset adapt in ways that improve their income-generating capacity, then the estimated effect from equation (1) will be overestimated. Regardless, to capture the potential effects of prior years' onset, our preferred specification includes an additional lag of monsoon onset:

$$(2)\ \ln C_{it} = \alpha + \sum_{p=1}^{4} \beta_p O_{i,t-1}{}^{p} + \sum_{p=1}^{4} \beta_{p+4} O_{i,t-2}{}^{p} + \alpha_i + D_t + \varepsilon_{it}$$

In addition, we also estimated the effect of another specification that included the second lag without the first lag. The results change little, and therefore for the sake of brevity we only present results from equation (2).[13]

The model is re-estimated for poor and rich farm and non-farm households. Households are classified as rich or poor on the basis of their average real per capita consumption, over the course of the panel. Poor households are those whose average consumption falls in the bottom quintile, while rich households are those whose average consumption falls in the top quintile. Households are classified as farm households if at least one member reported working on a farm business on household-owned land in 1993. Across all three years of the survey, 58 percent of rural households are farm households. Both owning a farm and being rich or poor do not vary for households over the course of the panel, and are therefore collinear with α_i in equations (1)-(2). As a result, these variables are uncorrelated with the error term, and restricting the sample does not introduce bias into the estimates.

1. Results from IFLS

All rural households

To facilitate interpretation, we focus on the implied effects of monsoons that arrive one standard deviation early or late, relative to the average date. We report the estimated effect of early onset, defined as the effect on per capita consumption when onset is set to negative one:

$$(3)\ EO = -\beta_1 + \beta_2 - \beta_3 + \beta_4 .$$

This is equal to the average effect on consumption of experiencing monsoon onset one standard deviation early, relative to the average date of onset. The estimate effect of late onset is calculated analogously, as:

$$(4)\ LO = \beta_1 + \beta_2 + \beta_3 + \beta_4 .$$

[12] The correlation between rainfall and lagged rainfall in the data is -0.33.

[13] We also estimated versions of the model with three lags, with qualitatively similar results.

Late onset therefore represents the average effect of moving from a mean onset year to a year in which onset is one standard deviation late. In general, we focus on these estimated effects of early and late onset estimated from equation (2), since they conveniently summarize the regression results. Tables 1 through 10 in Annex 1 provide these results for early and late onset for a variety of subsamples.

Estimates of the impact of monsoon onset on household per capita expenditure, for all rural Indonesian households, are displayed in Table 1 in Annex 1. The table, which gives the estimation results from equations (1) and (2), is divided in two parts. The top part displays the estimated coefficients on the timing of onset on consumption, while the bottom portion presents the estimated effect of early and late onset.

Early onset in the previous year, as expected, has a positive effect on expenditure. The first row of the estimated effects shows that early onset increases household per capita consumption by approximately 7 percent. Both farm and non-farm households benefit from the early onset, which most likely boost the agricultural output (see for example Naylor *et al*. 2004).

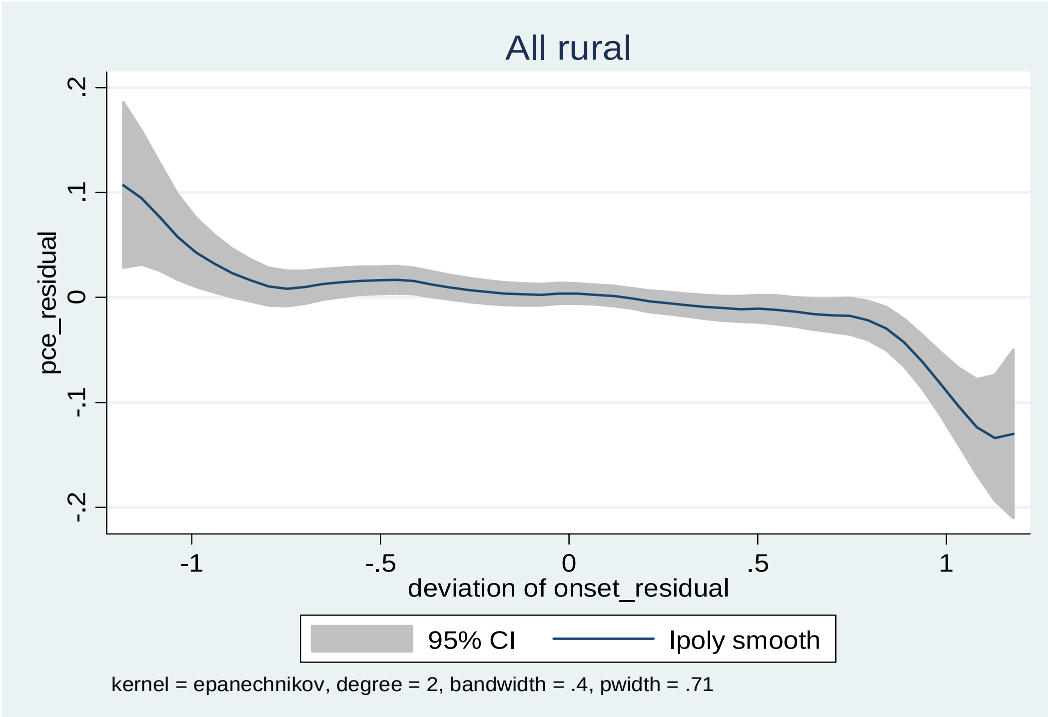
Late onset in the previous year does not have a significant effect on per capita consumption for all rural households. The bottom rows of Table 1 give the estimated effect of late onset on household per capita expenditure (PCE). Late onset is associated with a reduction in consumption of 1.4 percent. The estimated effect is larger – 6.5 percent – when only one lag is included, but this estimate is not statistically significant. These findings suggest the rural households as a whole are relatively well insured against late start of the rainy season.

These results are robust to non-parametric estimation. Figure 3 shows non-parametric estimates of the relationship between onset and per capita consumption non-parametrically, after controlling for household and year fixed effects. The results are similar to the parametric estimates presented above. When monsoon onset is one standard deviation early, household consumption rises by approximately 6 percent. Meanwhile, household consumption begins to fall when onset exceeds 0.75 standard deviations. When onset is one standard deviation late, per capita consumption falls by approximately 9 percent, and this fall is statistically significant. The similarity with the regressions results reported above indicates that the quartic specification described in equation (1) and (2) is sufficiently flexible to capture the highly non-linear relationship between onset and consumption.

Late onset two years ago is positively associated with per capita consumption. The bottom part of the second column of Table 1 in Annex 1 shows the effect of early and delayed onset coefficients from equations (2). Early onset two years ago has negative but insignificant effect on consumption. Late onset two years ago, however, is associated with a roughly 11 percent increase in per capita consumption, and the estimate is marginally statistically significant. This result essentially rules out the possibility that households experience a substantial reduction in consumption two years following delayed onset.

Most of the positive association with delayed onset two years ago results from an increase in total consumption rather than household size. The third column of Table 2 in Annex 1 shows that late onset two years ago decreases household size by a negligible amount. Therefore, late onset two years ago is associated with an 11 percent increase in total household consumption, despite having virtually no effect on household size. *El Niño* is usually followed by *La Niña*, abnormally high rainfall, implying that if our one-lagged early onset is not fully capturing the positive effects of La Niña, this could at least partially explain the positive effect of twice-lagged late onset.

Figure 3. Local polynomial smooth for all rural households, IFLS.



Local polynomial smooth, conditional on household and year fixed effects.

Farm households, non-farm households, poor households, and rich households

Farm households and non-farm households face similar risk to all rural households. Farm households are defined as those that reported owning a farm in 1993. These households may be more susceptible to crop loss due to delayed onset, due to their reliance on agricultural profits. On the other hand, however, the negative effect of delayed planting may be at least partially offset by higher prices for crops in late onset years. To assess the effect of delayed onset on farm and non-farm households, we re-estimate equations (1) and (2) on rural farmers and non-farmers. Tables 3 and 4 in Annex 1 show the results, which are broadly similar to those for all rural households. For farmers, Table 3 shows that late onset reduces consumption by approximately 4 percent, but this is not statistically different from zero. Meanwhile, early onset has a moderate positive effect of 7 percent on farm households' per capita consumption, and the effect is statistically significant at 10 percent level. Finally, the effect of late onset two years ago is positive, marginally statistically significant, and approximately the same as for all households. Table 4 shows similar results for non-farm households. These households also benefit from early onset, which increases their per capita consumption by 8.2 percent. For non-farmers, late onset in the previous year has a positive effect on households' expenditure, but the effect is not statistically different from zero. The positive association between per capita consumption and delayed onset two years ago is 5 percent and not statistically significant for non-farmers. In general, however, the estimated effect of onset timing is similar for farm and non-farm rural households.

Late onset reduces total farm profits by a small and statistically insignificant amount. Table 5 in Annex 1 shows the results from regressions of delayed onset on monthly farm profits, with two lags of rainfall. The dependent variable is not logged, in order to include observations in which reported farm profit was negative. The results do not support our prior hypothesis that delayed onset decreases farm profits. Late onset one year ago has a negative effect on farm profits, but the coefficient is not statistically significant. The estimated effect is mild- roughly five thousand rupiah per month, or six percent of mean reported profits. Farm profits, however, are likely to be poorly measured in the IFLS survey, as respondents may not know their revenues (including production for own consumption) and costs for the past 12 months, and there is no disaggregated information on revenues and costs.

Delayed onset one year ago has substantial adverse effects on the expenditure of poor households. We re-estimated equations (1) and (2) for the subsample of poor households. Poor households are defined as those whose average per capita consumption, over the three rounds of the survey, falls in the bottom quintile. The results are given in Table 6 (Annex 1). In contrast to all rural households, poor households suffer from delayed onset. The estimated reduction in consumption due to late onset in the previous year is approximately 13 percent and statistically significant. Poor household also benefit slightly less from early onset than all households, as early onset only raises consumption by 2.7 percent. The findings suggest that poor households are not well-insured against delayed onset, at least in the short run.

Delayed onset two years ago is strongly and positively associated with per capita consumption for poor households. Delayed onset two years ago is associated with a 23 percent rise in per capita consumption, which is larger than the 1 percent increase for all households. At this point, we cannot explain the large estimated positive effect of delayed onset two years ago on per capita consumption. A more detailed analysis on the effect of delayed onset on rural wages and rice prices is needed to shed further light on this result. For now, we conclude that poor households are able to recover within two years, and that delayed onset has no lasting negative effects on poor household's consumption.

Most of the negative effect of late onset one year ago on per capita consumption is due to an increase in household size. The timing of the monsoon arrival can affect per capita consumption either through the numerator, total consumption, or the denominator of household size. The effect of climatic shocks on household size is ambiguous, in theory. Climatic shocks may increase household size by encouraging households to combine and discouraging the formation of new households. Shocks, however, may also decrease household size by encouraging out-migration from large households (Henry *et al*. 2004). To better understand the effect of delayed onset on per capita consumption, we decomposed the effect of delayed onset into its effect on household size and its effect on total household consumption, by re-estimating equation (2) with log household size and log total consumption as dependent variables. Table 7 in Annex 1 shows the results for the poor households. The bottom portion of the second and third column indicates that delayed onset in the prior year decreases household consumption by roughly 4.3 percent while increasing household size by roughly 6.8 percent. Therefore, in this specification, over 60 percent of the total effect of delayed onset on per capita consumption comes through an increase in household size.

For rich rural households, variation in monsoon onset is not an important determinant of per capita expenditure or farm profits. Table 8 in Annex 1 gives the estimated effects of late onset for rich households – those whose average per capita consumption fall in the top quintile. Rich households neither benefit from early onset, nor suffer from delayed onset one or two years ago. While early onset two years ago reduces consumption by 12 percent for the richest households, the estimate is only marginally statistically significant. If rice prices falls with early onset, following a peak in rice production, net producers would be negatively affected. However, it is not possible to study further whether the households in the top quintile are mostly net producers or consumers of rice.

In general, delayed onset reduces consumption only for poor rural households. Across all rural households, consumption decreases by 1.5 percent the year following delayed onset, but these changes are not statistically different from zero. The most disadvantaged households – those in the bottom quintile of per capita expenditure - face substantially larger effects, both positive and negative. Delayed onset reduces per capita expenditure of the poor by 13 percent but poor people benefits from late onset two years ago approximately by 23 percent. Table 3 below summarizes the key results.

Table 3. Impact of delayed monsoon onset on rural household's consumption and farm profit, IFLS.

		Dependent variable	**One year ago**		**Two years ago**	
IFLS			Coef	S.E.	Coef	S.E.
All	All	Log PCE	-0.014	0.088	0.108	0.060*
	Farm	Log PCE	-0.41	0.080	0.143	0.071*
		Profit pc ('00 rp)	3,815	7,121	4,524	5,45
	Non-farm	Log PCE	0.098	0.065	0.05	0.049
Rich	All	Log PCE	-0.034	0.114	0.100	0.114
	Farm	Log PCE	-0.052	0.180	0.200	0.166
		Profit pc ('00 rp)	-48,943	32,211	10,971	13,001
	Non-farm	Log PCE	-0.243	0.399	-0.018	0.081
Poor	All	Log PCE	-0.136	0.062**	0.229	0.066***
	Farm	Log PCE	-0.093	0.058	0.228	0.072***
		Profit pc ('00 rp)	2,572	4,251	8,454	5,715
	Non-farm	Log PCE	-0.018	.130	0.140	0.110
Susenas						
All	All	Log PCE	0.001	0.007	-0.003	0.006
	IFLS equivalent	Log PCE	-0.082	0.038**	-0.011	0.032

2. Results from SUSENAS

This section considers the estimated impacts of monsoon onset on consumption using repeated cross-sections from the SUSENAS core survey. The SUSENAS core data has both advantages and disadvantages as a data source, compared with the IFLS. The main advantage is that annual data are available from 1993 through 2004, rather than only 1993, 1997, and 2000. In addition, since the SUSENAS covers the entire country, 49 weather stations covering 22 provinces can be matched per year.[14] The IFLS, in contrast, only covers 13 provinces and 36 matched weather stations. However, the SUSENAS has two important drawbacks. First, its consumption module in the SUSENAS core surveys covers relatively few goods and may not be sufficiently detailed to accurately detect variation in household consumption. Second, it does not re-interview the same households in successive years. As a result, the effect of rainfall on consumption is estimated with less precision, for a fixed number of households. In addition, it is not possible to separately estimate the effect on onset on different types of households using the SUSENAS, without introducing spurious correlation between household type and the error term.

[14] Provinces were omitted from the analysis if they did not contain a rain station.

To assess the effect of delayed onset on consumption using the SUSENAS core data, we estimated the following equation:

$$(5)\ \ln C_{it} = \alpha + \sum_{p=1}^{4} \beta_p O_{i,t-1}{}^{p} + \beta_5 Z_{it} + D_P + D_t + \varepsilon_{it}$$

Where, as before, C_{it} represents the per capita expenditure of household *i* in year *t* and O represents monsoon onset measured in standard deviations. Z contains a vector of household characteristics that are assumed to be unaffected by rainfall shocks (gender, age, and education of the household head). D_P is a set of province dummy variables, and D_t is a set of year dummies. As with the IFLS estimates, we also estimated versions of equation (5) that included two lags of monsoon onset. The results are shown in Tables 13, 14 and 16 in Annex 1.

Variation in onset has little effect on household per capita consumption. Table 15 (Annex 1) shows that delayed onset the previous year has virtually no effect on per capita expenditure when estimated for all years and provinces in the sample. Neither does early onset affect per capita expenditure. The estimates are sufficiently precise to rule out negative effects larger than 1.3 percent with 95 percent confidence. The decomposition of the effect of monsoon onset on total household consumption and household size are presented in Table 16. As we would expect from earlier results, monsoon onset has little effect either on total household consumption or household size.

Delayed onset two years ago has virtually no effect on consumption when using the SUSENAS. The positive association between delayed onset two years ago and per capita consumption found in the IFLS analysis is not robust to the use of SUSENAS. In the full rural sample, delayed onset two years ago is associated with a less than a one half percent reduction in log per capita consumption, and can rule out effects larger than 1.5 percent.

Late onset has a larger negative effect when the sample is limited to IFLS years and provinces. IFLS data covers only a subset of the provinces and years covered by the SUSENAS. To test the importance of this limited coverage, we re-estimated the effect on variation in monsoon onset using the SUSENAS, but limited the sample to only the provinces and years covered by the IFLS. Table 17 shows that there is a substantially larger negative effect of delayed onset on per capita consumption, equal to 8.2 percent, when the SUSENAS sample is limited to IFLS years and provinces.

The negative correlation between delayed onset and consumption in the cross-section appears to be especially strong in IFLS years. When the sample is extended to all provinces but limited to IFLS years, delayed onset reduces consumption by 6.6 percent. On the contrary, the negative effect of delayed onset disappears when the sample is extended to all years but only IFLS-provinces are included. This evidence suggests that the negative effect of delayed onset on household expenditure is not consistent across years.

IFLS years contain disproportionately few cases of late monsoon onset. In 1993 approximately 4.6 percent of households experienced onset that was at least 0.5 standard deviations late; in 1997, none of the households did and in 2000, 10 percent of the households did. For all years, the corresponding proportion is 26.5 percent.

The nature of the IFLS survey, which disproportionately represents older heads, may also overstate the impact of delayed onset. The IFLS makes no effort to re-contact persons born after 1968 that exited households after 1993, unless they were the two children of the head in 1993 that were selected as "main respondents”. In addition, not all new split-off households are successfully re-contacted and re-interviewed. As a result, successive rounds of the IFLS increasingly over-represent households with older heads. If households with older head are more likely to accept new members in response to delayed onset, this may also lead the IFLS results to overstate the negative effect of delayed onset on per capita consumption.

The SUSENAS surveys’ limited information on household consumption, in contrast, may not accurately capture the effect of delayed onset on consumption. The IFLS consumption measure is likely to be more accurate, for three reasons. First, The IFLS consumption questionnaire is far more detailed than the SUSENAS core. It asks households to report expenditures on 37 food items and 19 non-food items, whereas the SUSENAS core questionnaire only asks about 15 food items and 8 non-food items. Second, the IFLS questionnaire asks separately about purchased food, and food that was given or self-produced. In contrast, the SUSENAS asks households to estimate the total amount that is purchased, self-produced, or given. Third, the IFLS likely uses more accurate deflators. In 1997 and 2000, price deflators were calculated for each specific IFLS village. For the first IFLS round, as well as all SUSENAS rounds, consumption was deflated using price data published by the Central Bureau of Statistics (BPS). Unfortunately, price data is only published for major cities, meaning that the SUSENAS data is deflated by the capital city in the provinces, and may not accurately reflect changes in rural prices as a result of delayed onset.

In sum, analysis of the SUSENAS core provides additional evidence that the effect of delayed onset on all rural households is small. In the SUSENAS, delayed onset in the previous year has virtually no correlation with per capita consumption, and delayed onset two years ago is associated with one-half percent lower per capita consumption. Furthermore, rural households in IFLS provinces appear to be more vulnerable to delayed onset than rural households in provinces not covered by the IFLS. Unfortunately, it is impossible using the SUSENAS data to test the hypothesis that poor households are more vulnerable to late onset.

IV. Summary and Conclusions

To our knowledge, no study has focused on how climatic variability has affected household welfare in rural Indonesia. The topic is important for at least two main reasons. First, climate variability appears to be an important determinant of agricultural productivity, particularly rice production. In addition, the agricultural sector contributes the second largest share of GDP, employs more than 60 percent of the poor nationwide, and accounts for 60 percent of all rural workers (Kishore *et al*: 2000; World Bank: 2008). We fill this gap by estimating the effect of delayed monsoon onset on household per capita consumption.

…delayed monsoon onset one year ago for all rural households…

Estimates consistently show small effects on all rural households. To assess the effect of delayed onset, we consider the average effect of experiencing a one standard deviation delay, rather than an average date of monsoon onset, on per capita farm profits and per capita consumption. Delayed onset the previous year reduces per capita farm profits by a small amount -- nearly 4,000 rupiah, or roughly 40 cents per month. This is equal to six percent of average monthly profits and two percent of a standard deviation. This estimate is sufficiently precise to rule out a loss greater than 20,000 rupiah. Turning to household capita consumption, delayed onset the previous year is associated with a 1.4 percent reduction in per capita consumption. The SUSENAS cross-sectional data, however, include many more years and provide more precise estimates. In these data, the estimated effect of late onset the previous year is negligible, and the results are sufficiently precise to rule out negative effects greater than 1.5 percent. Since the estimated negative effects of delayed onset rise to 6 percent when limited to IFLS provinces, and 8 percent when limited to IFLS provinces and IFLS years, the IFLS results may overstate the negative effect of delayed onset for all Indonesian households.

…delayed monsoon onset two years ago for all rural households…

In the IFLS, delayed onset two years ago is associated with an 11 percentage point increase in per capita expenditure for all rural households and this result is statistically significant at the ten percent level. Most of this positive association is due to an increase in total consumption rather than household size. This may partly be explained by a *La Niña* effect, which normally follows *El Niño* episodes and is associated with abnormally high rainfall levels and higher agriculture outputs (to the extent that the *La Niña* is not captured by controlling for lagged onset). However, the positive effect of delayed onset two years ago does not extend to the SUSENAS data, which shows a tiny negative effect of around three tenths of a percent. Overall, the results rule out the possibility that delayed onset has a substantial negative effect on rural households two years later.

...distributional impact of delayed monsoon onset...

Delayed monsoon onset has substantially larger short-term effects the following year on poor households. The effect of delayed onset on poor households can only be estimated cleanly using the IFLS data. Delayed monsoon onset the previous year likely reduced household per capita expenditure for the poor, by approximately 13 percent, but the majority of this effect occurs through an increase in household size. Specifically, delayed onset in the previous year decreases household consumption by roughly 4.3 percent while increasing household size by roughly 6.8 percent. Climatic shocks may increase household size through several mechanisms. Households may respond to negative shocks by combining households. This could occur, for example, if higher food prices push more urban Indonesians to migrate back to their families in rural areas. Households with older heads, who are over-represented in the IFLS as the panel ages, may be particularly likely to receive additional household members. A final possibility is that delayed onset increases household size by reducing the number and size of roving bands of crop harvesters, which are common in Indonesia.

Poor households show the largest positive effects of delayed onset two years later. Delayed onset two years ago is associated with a 23 percent rise in per capita consumption, which is larger than the 11 percent for all households. This suggests that the positive association between per capita consumption and delayed onset two years ago might be due to the positive effects of *La Niña* or the ability of farm households to “catch up” following delays in planting two years ago.[15]

Caveats

An important limitation is the amount and quality of the rainfall data. Only 36 rain stations can be matched to each wave of the IFLS, which reduces the variation in our main independent variable. Unfortunately the years prior to the IFLS interviews do not show wide variation in monsoon onset, and none of the years captured by the IFLS follow a strong *El Niño* year. Finally, the measure of late onset is based on daily rainfall data, which is undoubtedly measured with error. Since measurement error in rainfall is independent of local household consumption, the true effect of delayed onset, both positive and negative, is likely greater than the estimates presented here.

[15] The beneficial effects of La Niña could occur even controlling for the timing of onset the previous year, due to the imprecise nature of the quadratic approximation used in the econometric possibility. Another possibility is that the beneficial effects of La Nina are felt through other factors such as rainfall amount that are not included as control variables.

Future Research

An extensive agenda remains for future research on Indonesian households' response to climate shocks. Future studies could identify the mechanisms by which different types of households are able or unable to maintain their consumption in the face of delayed onset. The results presented above suggest that poor households are more vulnerable to climatic shock than wealthier households. They say very little, however, about how some households protect their consumption and why others do not. For example, more research could probe migration decisions in response to rainfall shocks.

Additional research could also probe the role of household income, labor supply decisions, and community infrastructure in mitigating climatic shocks. Several existing studies examine the extent to which households are insured against income losses due to rainfall shocks in other countries. Additional work could use income data to examine this question in Indonesia, and could examine how rice prices and agricultural wages are affected by variation in the monsoon onset. From a policy perspective, it is important to understand how community characteristics such as the availability of irrigation and credit might play an important role in households' ability to cope with climatic shocks. Finally, additional analysis could examine heterogeneity in households' ability to maintain human capital investments, such as children's school attendance, in response to rainfall shocks.

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Annex 1. Econometric Result

Sample Descriptive statistics

	IFLS		SUSENAS	
Variable	Mean	s.d.[a]	Mean	s.d.[a]
Log per capita monthly expenditure[b]	12.022	0.683	12.353	0.438
Log total household monthly expenditure[b]	13.538	0.701	13.867	0.492
Log household size	1.520	0.449	1.514	0.413
Monthly farm profits per capita[b]	34577.97	64928.56	NA	NA
Monsoon onset previous year	-0.553	0.644	-0.003	1.087
Monsoon onset 2 years ago	-0.281	1.150	0.092	1.113
Head female	NA	NA	0.079	0.269
Head age 15-24 years	NA	NA	0.021	0.143
Head age 25-34 years	NA	NA	0.197	0.400
Head age 35-49 years	NA	NA	0.450	0.497
Head age 50-64 years	NA	NA	0.251	0.433
Head age 65+ years	NA	NA	0.081	0.273
Head no schooling	NA	NA	0.134	0.340
Head primary education	NA	NA	0.650	0.477
Head junior high school	NA	NA	0.113	0.316

	IFLS		SUSENAS	
Variable	Mean	s.d.[a]	Mean	s.d.[a]
Aceh	NA	NA	0.033	0.180
North Sumatra	NA	NA	0.069	0.254
West Sumatra	NA	NA	0.031	0.173
Riau	NA	NA	0.033	0.179
Jambi	NA	NA	0.017	0.130
South Sumatra	NA	NA	0.061	0.240
Bengkulu	NA	NA	0.017	0.128
Lampung	NA	NA	0.068	0.252
Belitung	NA	NA	0.012	0.111
Riau Islands	NA	NA	0.004	0.064
West Java	NA	NA	0.146	0.353
Central Java	NA	NA	0.123	0.328
Yogyakarta	NA	NA	0.008	0.091
East Java	NA	NA	0.146	0.353
Banten	NA	NA	0.033	0.179
Bali	NA	NA	0.011	0.106
West Nusa Tenggara	NA	NA	0.023	0.149
East Nusa Tenggara	NA	NA	0.028	0.166
West Kalimantan	NA	NA	0.032	0.176
Central Kalimantan	NA	NA	0.021	0.144
South Kalimantan	NA	NA	0.017	0.130
East Kalimantan	NA	NA	0.016	0.125

Head senior high school	NA	NA	0.086	0.281
Head university	NA	NA	0.017	0.130
South Sulawesi	NA	NA	0.041	0.198
West Sulawesi	NA	NA	0.008	0.087
Sample size	11399		97928	

NA signifies not applicable.

[a]Denotes for standard deviation

[b]Household expenditure and farm profits are expressed in December 2000 Jakarta prices in the IFLS data and 2007 prices in the SUSENAS data.

Table 1: All rural households, IFLS

Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-0.161	0.085***	-.120	.084*
Onset squared	-.015	.070***	.01	.065*
Onset cubic	.086	.079***	.077	.083*
Onset quartic	.025	.043***	.019	043*
Two years ago				
Monsoon Onset			.092	.043
Onset squared			.043	.055
Onset cubic			-.021	.014
Onset quartic			-.006	.013
Observations	11,399			
Households	4,014			
R^2 (within)	0.131		0.133	
Estimated Effects				
Early onset				
Prior year	.085	.035**	.072	.035**
Two years ago			-.034	.045
Late onset				
Prior year	-.065	.094	-.014	.088
Two years ago			.108	.06*

Table 2. Decomposition of the effect of monsoon onset on real per capita expenditure by real total expenditure and household size, IFLS

	Log total household expenditure		Log household size		Difference	Effect from table 1
Coefficients	Coef	SE	Coef	SE		
Prior year						
Onset	-.063	.089	.058	.021*		
Onset squared	.040	.064	.028	.019*		
Onset cubic	.066	.096	-.016	.023*		
Onset quartic	.012	.046	-.009	.0102*		
Two years ago						
Onset	.080	.046**	-.016	.014		
Onset squared	.057	.055**	.009	.015		
Onset cubic	-.019	.014**	.003	.005		
Onset quartic	-.005	.012**	.002	.004		
Observations	11,399			11,399		
Households	4014			4014		
R^2 (within)	0.135			0.0046		
Estimated Effects						
Early onset						
Prior year	.050	.033	-.023	.015	0.073	0.072
Two years ago	-.009	.045	.023	.013	-0.032	-0.034
Late onset						
Prior year	.055	.104	.061	.037	-0.006	-0.014
Two years ago	.114	.064*	-.002	.017	0.116	0.108

Monsoon onset is measured in standardized deviations from historical means. The estimated effect of early onset refers to the estimated effect on per capita consumption when onset is adjusted from zero to -1. It is calculated as the sum of the coefficient on onset squared and onset to the fourth power, minus the coefficients on onset and onset cubed. The estimated effect of late onset refers to the effect on consumption when onset is adjusted from 0 to 1. The reported effect of late onset is the sum of the four onset coefficients. Onset is defined the number of days past August 1 when cumulative rainfall exceeds 200 mm, and is constructed using data from 36 rain stations. Additional controls include survey year effects and household-level fixed effects, and split-offs are treated as new households. Standard errors are clustered on rain stations, and are robust to heteroscedasticity. Households are weighted by the product of their sample weight and their average size. *, **, and *** denote statistical significance at 10, 5, and 1 percent respectively.

Table 3: Rural farm households, IFLS

Dependent variable: Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.139	.100**	-.112	.01
Onset squared	-.019	.0811**	.002	.068
Onset cubic	.058	.082**	.057	.083
Onset quartic	.014	.045**	.012	.044
Two years ago				
Monsoon Onset			.123	.053***
Onset squared			.043	.062***
Onset cubic			-.019	.018***
Onset quartic			-.004	.014***
Observations	7,086		7,086	
Households	2,463		2,463	
R^2 (within)	0.145		0.154	
Estimated Effects				
Early onset				
Prior year	.077	.039*	.070	.037*
Two years ago			-.065	.051
Late onset				
Prior year	-.086	.106	-.041	.080
Two years ago			.143	.071*

See notes to table 1.

Table 4. Rural non-farm households, IFLS.

Dependent variable: Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.194	.075***	-.145	.075*
Onset squared	.019	.060***	.044	.059*
Onset cubic	.155	.084***	.152	.081*
Onset quartic	.048	.045***	.046	.044*
Two years ago				
Monsoon Onset			.048	.038***
Onset squared			.021	.045***
Onset cubic			-.018	.014***
Onset quartic			-.002	.012***
Observations	4296		4296	
Households	1544		1544	
R^2 (within)	0.117		0.124	
Estimated Effects				
Early onset				
Prior year	.106	.042**	.082	.036**
Two years ago			-.011	.038
Late onset				
Prior year	.029	.065	.098	.065
Two years ago			.050	.049

See notes to table 1.

Table 5: Rural farm profits per capita, IFLS

Dependent variable: Farm profits per capita	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior Year				
Monsoon Onset	-10082	5921	-9094	5657
Onset squared	-5494	3632	-3627	4312
Onset cubic	7642	4654	5817	4165
Onset quartic	4390	2202	3089	1995
Two years ago				
Monsoon Onset			1338	4706**
Onset squared			5384	3593**
Onset cubic			-666	1499**
Onset quartic			-1532	954**
Observations	6880		6880	
Households	2463		2463	
R^2 (within)	0.017		0.02	
Estimated Effects				
Early onset				
Prior year	1336	3156	2740	2987
Two years ago			3180	3206
Late onset				
Prior year	-3544	5888	-3815	7121
Two years ago			4524	5450

See notes to table 1.

Table 6: All rural households, bottom quintile, IFLS

Dependent variable: Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior Year				
Monsoon Onset	-.093	.087***	-.016	.096**
Onset squared	-.083	.078***	-.017	.079**
Onset cubic	-.032	.063***	-.065	.074**
Onset quartic	-.015	.045***	-.038	.049**
Two years ago				
Monsoon Onset			.140	.050***
Onset squared			.155	.061***
Onset cubic			-.036	.018***
Onset quartic			-.030	.015***
Observations	2,287		2,287	
Households	795		795	
R^2 (within)	0.166		0.184	
Estimated Effects				
Early onset				
Prior year	.028	.042	.027	.045
Two years ago			.021	.049
Late onset				
Prior year	-.223	.072***	-.136	.062**
Two years ago			.229	.066***

See notes to table 1.

Table 7. Decomposition of the effect of monsoon onset on real per capita expenditure for poor households, by real total expenditure and household size, IFLS.

	Log household total expenditure		Log household size		Difference	Effects (from Table 1)
Coefficients	Coef	SE	Coef	SE		
Prior year						
MonsoonOnset	.036	.133	.036	.046		
Onset squared	.021	.078	.030	.020		
Onset cubic	-.060	.108	.004	.046		
Onset quartic	-.039	.057	-.002	.021		
Two years ago						
MonsoonOnset	.140	.064**	-.017	.022***		
Onset squared	.188	.072**	.008	.029		
Onset cubic	-.042	.022**	.001	.008		
Onset quartic	-.029	.017**	.005	.007		
Observations	2,287					
Households	795					
R^2 (within hh)	0.181					
Estimated Effects						
Early onset						
Prior year	.006	.059	-.012	.021	0.018	0.027
Two years ago	.060	.067	.030	.021	0.03	0.021
Late onset						
Prior year	-.043	.071	.068	.037*	-0.111	-0.134
Two years ago	.258	.081***	-.003	.034	0.255	0.229

See notes to table 1.

Table 8: All rural households, top quintile, IFLS

Dependent Variable: Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.065	.161	-.013	.161
Onset squared	.027	.128	.020	.113
Onset cubic	-.019	.174	-.017	.162
Onset quartic	-.034	.092	-.024	.080
Two years ago				
Monsoon Onset			.111	.086**
Onset squared			-.032	.097**
Onset cubic			-.000	.034**
Onset quartic			.022	.025**
Observations	2,276		2,276	
Households	822		822	
R^2 (within)	0.104		0.114	
Estimated Effects				
Early onset				
Prior year	.076	.103	.025	.095
Two years ago			-.121	.068*
Late onset				
Prior year	-.091	.143	-.034	.114
Two years ago			.100	.114

See notes to table 1

Table 9: Rural farm households, bottom quintile, IFLS

Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	.020	.077***	.083	.107***
Onset squared	-.072	.050***	-.003	.066***
Onset cubic	-.092	.047***	-.119	.073***
Onset quartic	-.032	.024***	-.054	.042***
Two years ago				
Monsoon Onset			.125	.056*
Onset squared			.160	.062*
Onset cubic			-.026	.025*
Onset quartic			-.030	.014*
Observations	1558		1558	
Households	542		542	
R^2	0.142		0.246	
Estimated Effects				
Early onset				
Prior year	0.007	0.016	-.021	.038
Two years ago			.032	.052
Late onset				
Prior year	-0.124	0.060**	-.093	.058
Two years ago			.228	.072***

See notes to table 1.

Table 10: Rural farm households, top quintile, IFLS

Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.089	.201	-.021	.191
Onset squared	.022	.169	.026	.138
Onset cubic	.021	.227	-.029	.212
Onset quartic	-.007	.110	-.027	.098
Two years ago				
Monsoon Onset			.215	.127**
Onset squared			.014	.127**
Onset cubic			-.033	.052**
Onset quartic			.003	.034**
Observations	1303		1303	
Households	453		453	
R^2	0.086		0.100	
Estimated Effects				
Early onset				
Prior year	.082	.141	.050	.138
Two years ago			-.165	.074**
Late onset				
Prior year	-.052	.262	-.052	.180
Two years ago			.200	.166

See notes to table 1.

Table 11: Rural non-farm households, bottom quintile, IFLS

Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.275	.189**	-.205	.201
Onset squared	-.048	.107**	-.001	.107
Onset cubic	.166	.220**	.1452	.238
Onset quartic	.056	.126**	.043	.134
Two years ago				
Monsoon Onset			.119	.082**
Onset squared			.076	.092**
Onset cubic			-.038	.030**
Onset quartic			-.017	.024**
Observations	729		729	
Households	253		253	
R^2	0.093		0.103	
Estimated Effects				
Early onset				
Prior year	.117	.069	.101	.070
Two years ago			-.021	.065
Late onset				
Prior year	-.102	.118	-.018	.130
Two years ago			.140	.111

See notes to table 1

Table 12: Rural non-farm households, the top quintile, IFLS

Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.002	.151***	.0113	.152***
Onset squared	-.001	.178***	-.042	.199***
Onset cubic	-.209	.163***	-.130	.176***
Onset quartic	-.139	.085***	-.082	.080***
Two years ago				
Monsoon Onset			-.001	.061***
Onset squared			-.108	.081***
Onset cubic			.042	.021***
Onset quartic			.050	.018***
Observations	973		973	
Households	369		369	
R^2	0.142		0.159	
Estimated Effects				
Early onset				
Prior year	.071	.084	-.006	.059
Two years ago			-.099	.078
Late onset				
Prior year	-.351	.315	-.243	.399
Two years ago			-.018	.081

See notes to table 1

Table 13: Farm profits per capita, farm households, bottom quintile, IFLS

Real farm profits	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-5881	5830	913	5842
Onset squared	-3491	4756	3103	5652
Onset cubic	3956	4509	-485	4365
Onset quartic	2277	3049	-959	3097
Two years ago				
Monsoon Onset			2101	3844
Onset squared			11559	7293*
Onset cubic			-1140	1529
Onset quartic			-2145	1956
Observations	1511		1511	
Households	542		542	
R^2	0.017		0.04	
Estimated Effects				
Early onset				
Prior year	712	2726	1716	2841
Two years ago			8454	5715
Late onset				
Prior year	-3139	3283	2572	4251
Two years ago			10374	6294

See notes to table 1

Table 14: Farm profits per capita, rural farm households, top quintile, IFLS

Real farm profits	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	7586	17270	2331	16245
Onset squared	-6625	14578	-7142	16530
Onset cubic	-24633	19493	-30102	16864
Onset quartic	-10520	7734	-14030	7155
Two years ago				
Monsoon Onset			3812.1	11147***
Onset squared			12387.5	11215***
Onset cubic			-598.8	4836***
Onset quartic			-4630.1	3390***
Observations	1278		1278	
Households	453		453	
R^2	0.014		0.026	
Estimated Effects				
Early onset				
Prior year	-97.7	11678.2	6598.9	11855.4
Two years ago			4544.1	9008.8
Late onset				
Prior year	-34193.1	32622.5	-48942.6	32211.4
Two years ago			10970.6	13004.5

See notes to table 1

Table 15 : All rural households, SUSENAS

Dependent variable: Log PCE	One lag		Two lags	
Coefficients	Coef	SE	Coef	SE
Monsoon Onset	-.003	.007	-.003	.008
Onset squared	.003	0.003	.003	.006
Onset cubic	.001	.002	.002	.002
Onset quartic	-.000	.001	-.001	.001
Monsoon Onset			.005	.007
Onset squared			-.006	.006
Onset cubic			-.002	.002
Onset quartic			.001	.001
Monsoon Onset				
Onset squared				
Observations	97,928		97,928	
Years	12		12	
R^2	0.18		0.18	
Estimated Effects				
Early onset				
Prior year	.004	.009	.004	.009
Two years ago			-.008	.01
Late onset				
Prior year	.001	.007	.001	.007
Two years ago	00		-.003	.006

Table 16. Decomposition of the effect of monsoon onset on real per capita expenditure by real total expenditure and household size, SUSENAS data.

	SUSENAS, log hh total expenditure		SUSENAS, log household size		Difference	Effect (table 6)
Coefficients	Coef	SE	Coef	SE		
Prior year						
Onset	.003	.011	.006	.006*		
Onset squared	.007	.006	.004	.003*		
Onset cubic	.000	.002	-.001	.001*		
Onset quartic	-.000	.001	.000	.000*		
Two years ago						
Onset	.004	.008	-.000	.005**		
Onset squared	-.005	.007	.001	.003**		
Onset cubic	-.002	.002	.000	.002**		
Onset quartic	.001	.001	.000	.000**		
Observations	97,928		97.928			
Years	12		12			
R^2	0.24		0.19			
Estimated Effects						
Early onset						
Prior year	.003	.012	-.000	.006	0.003	0.004
Two years ago	-.006	.011	.002	.004	-0.008	-0.008
Late onset						
Prior year	.01	.009	.009	.005*	0.001	0.001
Two years ago	-.002	.007	.001	.004	-0.003	-0.003

Onset is measured in standard deviations from historical mean. Data on onset are taken from 46 rain stations. Additional controls include survey year effects and province-level fixed effects and time-invariant household controls, including gender, age and education of the head. Standard errors are clustered on rain stations, and are robust to heteroscedasticity. Households are weighted by the product of their sample weight and their size.

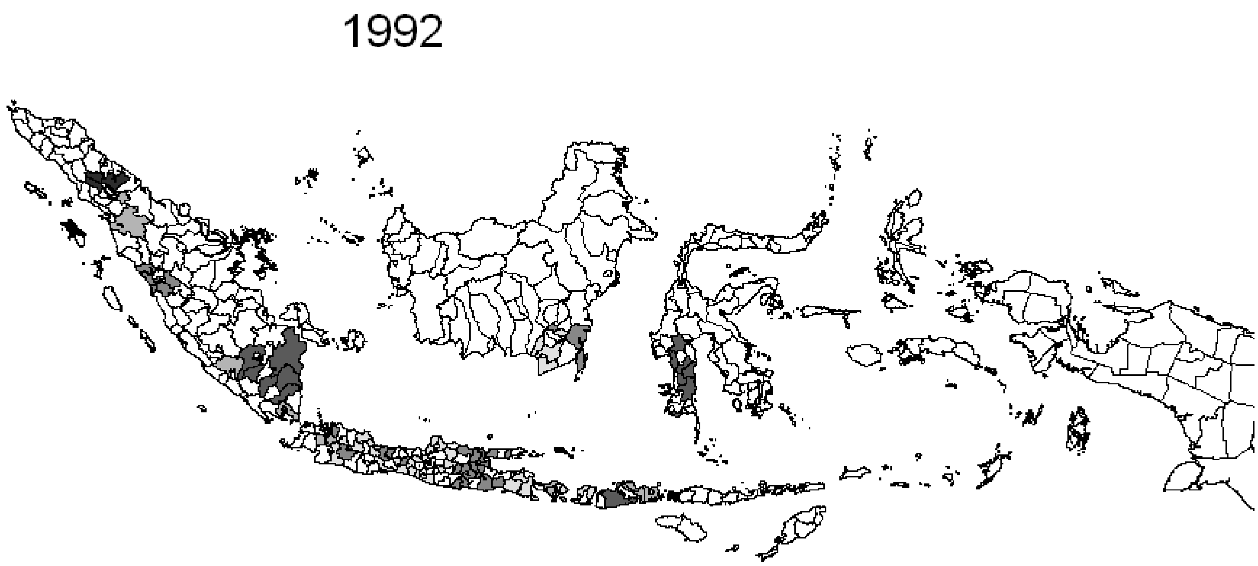
Table 17: All rural: Comp. of full SUSENAS vs. SUSENAS in IFLS years and provinces

Dependent variable: Log PCE	Complete SUSENAS		SUSENAS: Limited to IFLS years and provinces	
Coefficients	Coef	SE	Coef	SE
Prior year				
Monsoon Onset	-.003	.007	.048	.043**
Onset squared	.003	0.003	-.036	.031**
Onset cubic	.001	.002	-.073	.038**
Onset quartic	-.000	.001	-.020	.021**
Two years ago				
Monsoon Onset	.005	.007	-.008	.028
Onset squared	-.006	.006	-.016	.025
Onset cubic	-.002	.002	.008	.01
Onset quartic	.001	.001	.004	.007
Observations	97,928		17230	
Number of Years	12		3	
Number of Provinces	22		13	
R^2	0.18		0.21	
Estimated Effects				
Early onset				
Prior year	0.004	0.009	-.032	.026
Two years ago	-0.008	0.01	-.012	.029
Late onset				
Prior year	0.001	0.007	-.082	.038**
Two years ago	-0.003	0.006	-.011	.032

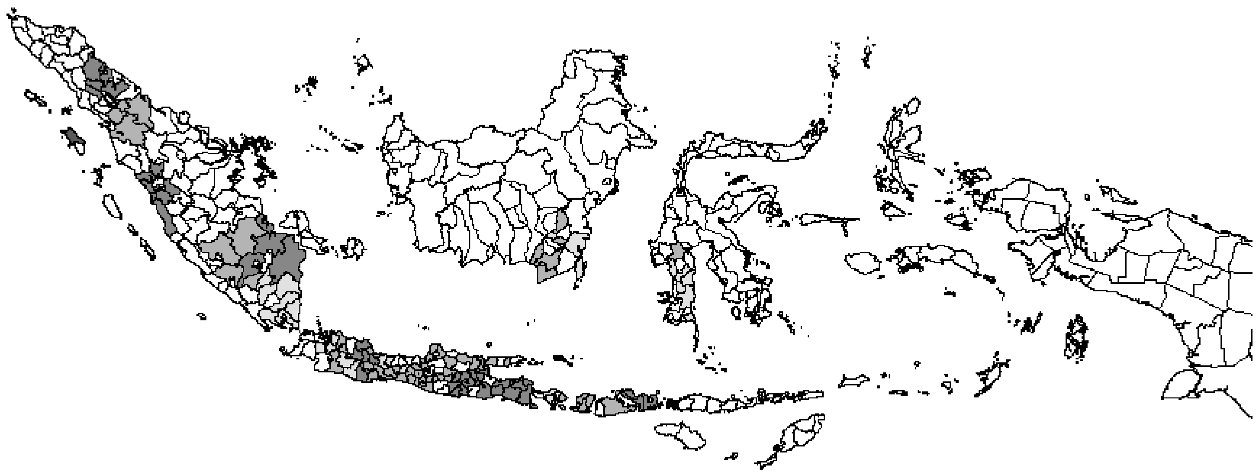
Annex 2: IFLS Rainfall Maps

These maps indicate the timing of monsoon onset, by district and year in the IFLS data survey. White districts excluded from the survey, which only covers 13 provinces, most which are on Sumatra and Java. Darker shades indicate later monsoon onsets, corresponding to the following five categories: earlier than one standard deviation (lightest), -1 to -0.5 standard deviation, from -0.5 to 0 standard deviations, from 0 to 0.5 standard deviations, from 0.5 to 1 standard deviations, and later than one standard deviation (darkest).

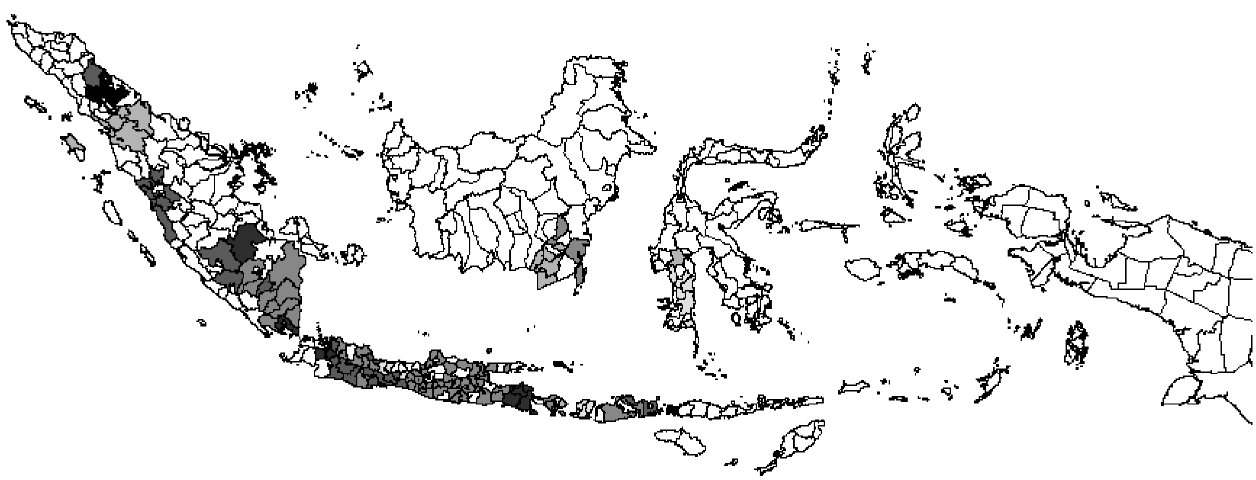
One-year lags



1996

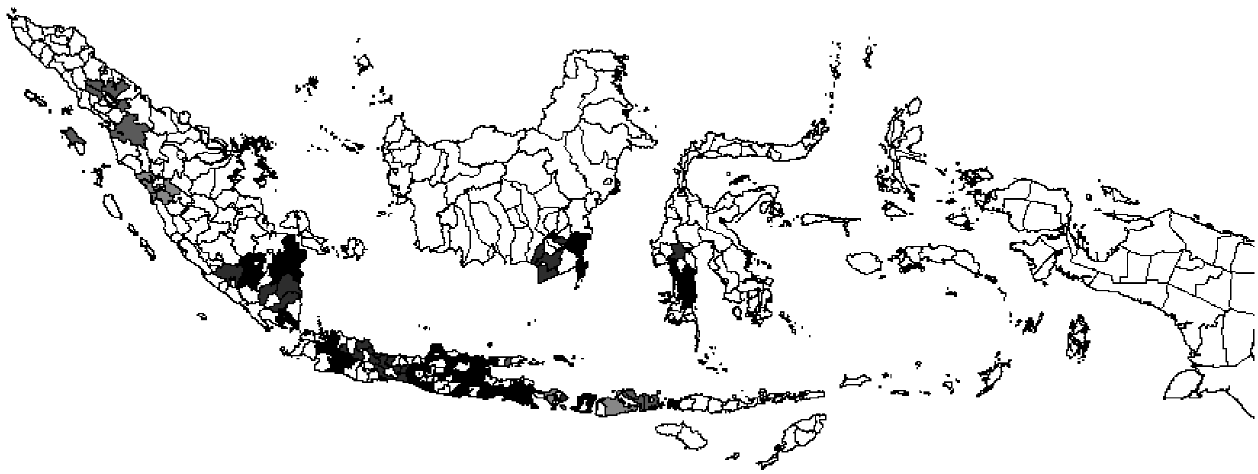


1999



Two year lag monsoon onset

1991



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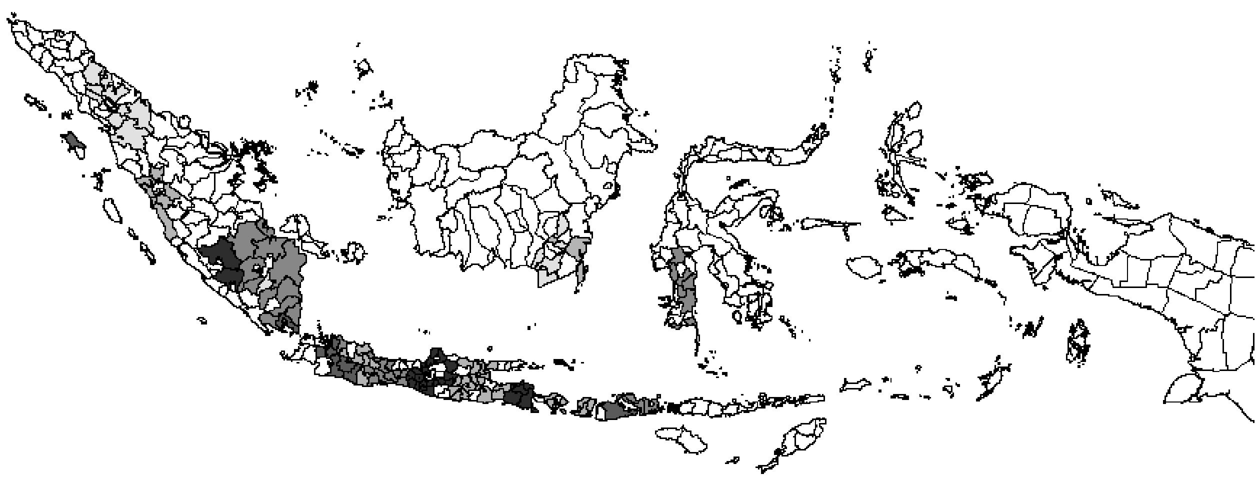

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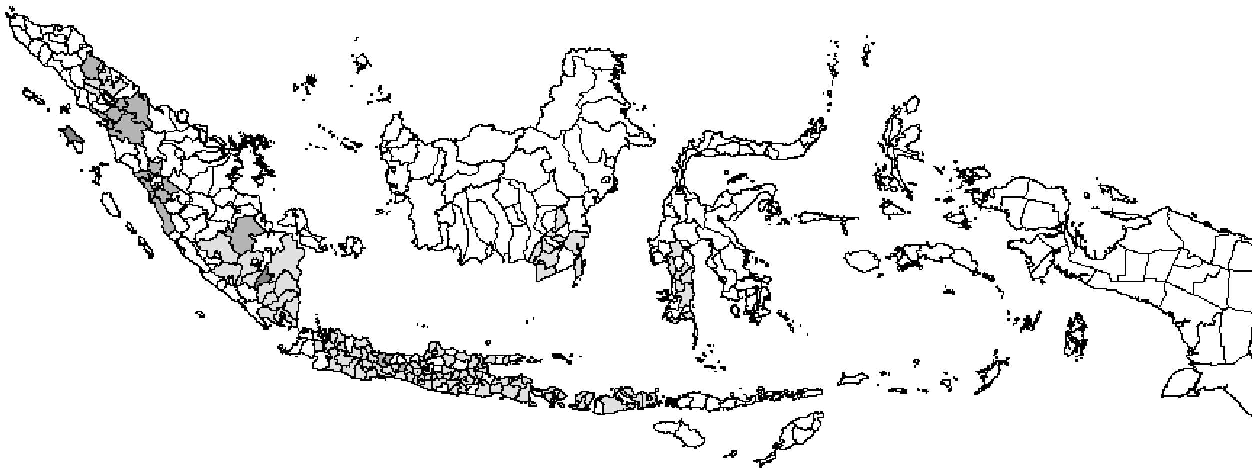
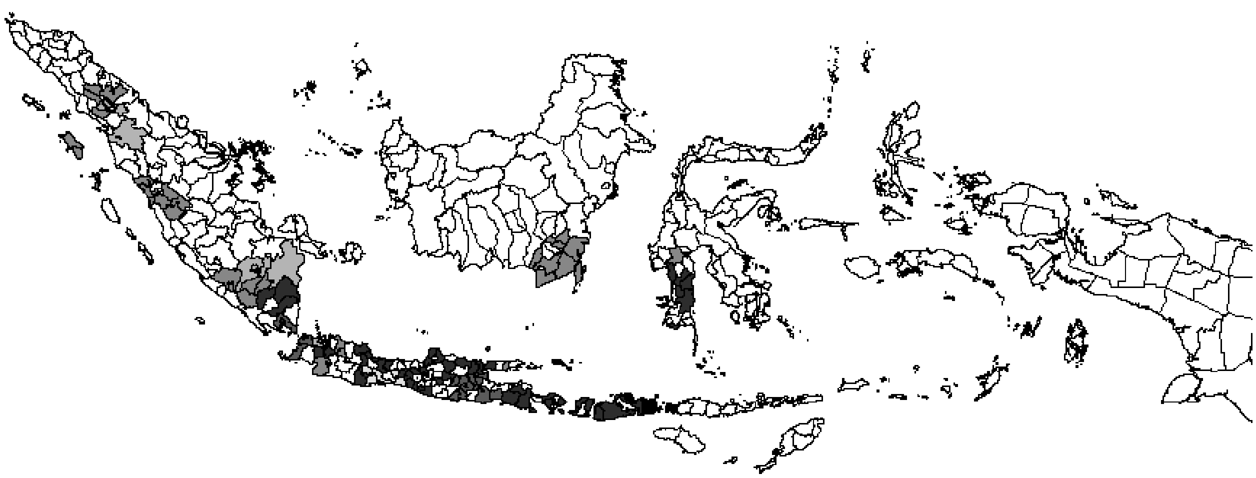


Three year lagged onset

1990



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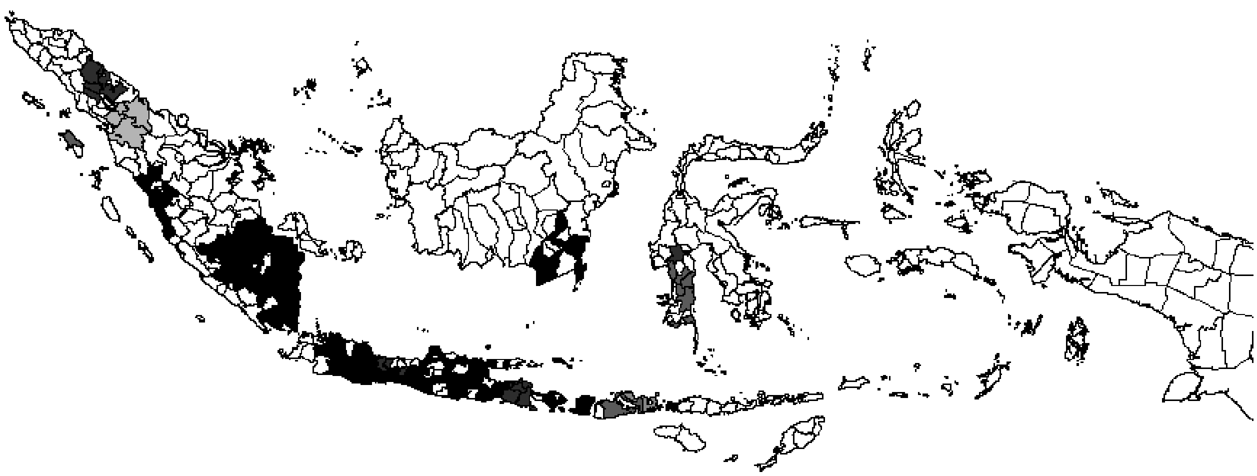

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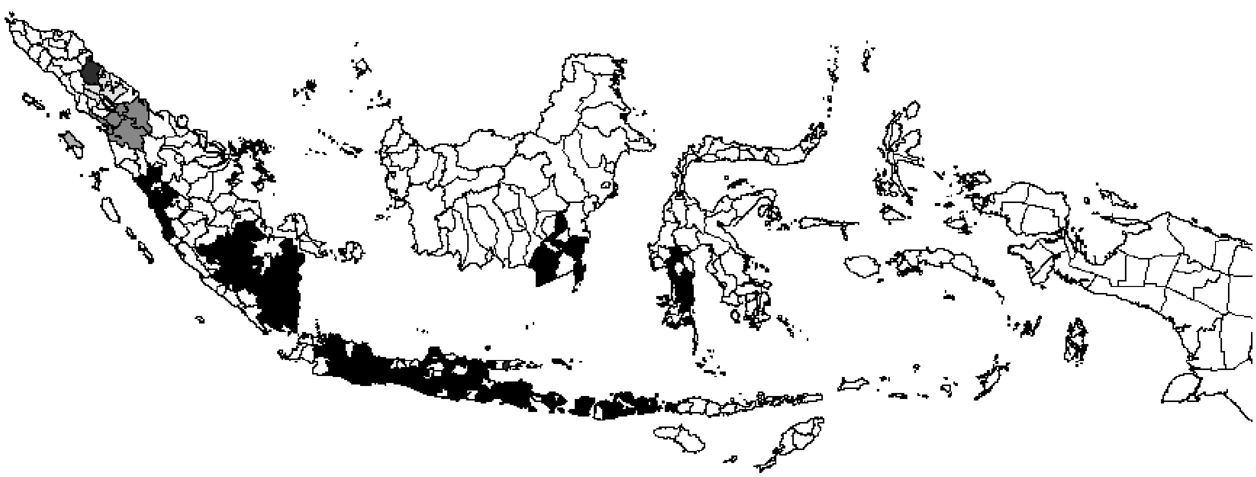

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