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Climate Change, Perceptions and the Heterogeneity of Adaptation and Rice Productivity: Evidence from Indonesian Villages¹

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Abstract

This paper examines how change in rainfall patterns induces autonomous adaptation of farmers and affects their rice production. Based on recently collected household data from seven provinces in Indonesia, the analysis clearly demonstrate delays in the onset of rainy season and increased uncertainty in rainfall patterns in the region. Farmers make sequential decisions: adjusting planting timing in response to delays in the onset of rainy season while changing crop variety responding to delays in the end of the previous year's rainy season. In the case of rice production, (i) delay in the onset significantly decreases land productivity growth in rice production; one month delay offsets the average growth observed in 1999-2007, and (ii) though irrigation share significantly explains the growth of land productivity, delayed onset increasingly constrains the role of irrigation.

Key words: climate change, rainy season, adaptation, rice production, irrigation, Indonesia

1. Introduction

Climate change is currently highlighted in the international community as a potential threat to food security. Increasing sets of evidence support the linkages between global warming, natural disaster and changes in climate patterns including unpredictability of monsoon rainy season (e.g., Adrian and Susanto, 2003; Hamada et al., 2002; Haylock et al., 2001; Morton, et al., 2007; Naylor, et al., 2007; Robertson, et al., 2007). Rice farming system is sensitive to draught and change in rainfall patterns, thus some adaptation practices are necessary with climate change (Tabi et al. 2012).

Rice is the most important strategic crop in Indonesian agriculture, which comprise about a half of the country's per capita calorie consumption (C. Peter Timmer 2010). However, the growth in rice productivity in the recent decade has been stabilized at low rate around 1% (Simatupang and Peter Timmer 2008). Rice production in Indonesia largely falls short of the demand at times, especially when a delay in the rainfall onset caused by El Nino-Southern Oscillation (ENSO) brings delay in planting date and following decrease in planting area. Such delay in the onset of rainy season may happen more frequently in future with the effect of climate change (Naylor et al. 2007). Climate change is also told to add drought risk in Indonesian agriculture (Roehlano M. Briones 2011). Although regional scale climate projection entails large uncertainty (Naylor, et al., 2002, 2007).= climate change adaptation of the rice farming systems will be critical for mitigating dire impact of climate change. The relevant research in Indonesia is,

however, still limited.

Climate change adaptation is possible through farmers' perception on changes and their autonomous response to the changes, aside from planned implementation of adaptation policy. Such autonomous adaptation usually happens on ad-hoc basis, triggered by climate variability and extreme events. Economic wealth, technology, information and skills, infrastructure, institutions, and equity all affect adaptive capacity of a community (Smit and Pilfsova 2001). Maddison (2007) found that in African continent, experienced farmers are likely to sensitively perceive the climate change, and the perception is influenced by neighbors. Quality of weather information also affect their success in perceiving the change (James W Hansen et al. 2007; Vermeulen et al. 2010), as a gap increases between ongoing changes and empirical knowledge on climate.

In effect, Indonesian farmers report that the start of the rainy season has become ambiguous, and thus it is becoming harder for them to identify the onset of rainy season (see Section 2). Even after the rainy season has started, or appears to have started, farmers often experience discontinuities of rainfall. Furthermore, farmers find that the rainfall pattern they observed has become more erratic, causing excessive rainfall and more frequent floods.

Farmers' abilities to adapt to the change they detect depend on their capacity and resources. For example, more educated farmers, or large scale farms tend to be able to adapt (Maddison 2007). Rice farmers in Africa who perceive change in

climate adopt through various measures such as change of the planting date, use of fertilizer, change of crop varieties, or use of herbicide (Tabi et al. 2012), but only small number of farmers change water management control practice with limited capacity of irrigation facilities.

Indeed, one of the most critical resources to cope with the delay in the rainfall is the availability, access and the capacity of irrigation systems and technologies. In Indonesia, however, irrigation system relies predominantly on surface water sources, such as river and swamp, while the use of groundwater is still limited (FAO, 2010). In addition, there is a serious rate of degradation of irrigation systems in Indonesia with decreasing government funding since end of 1999 (Fuglie and Piggott 2006). These facts imply that rainfall may affect the capacity of irrigation systems to stabilize water, while the functionality of the systems is deteriorating. The availability of surface water sources tend to be variable relative to groundwater (Schoengold and Zilberman, 2007) and may be more directly affected by the rainfall.

Furthermore, due to an increasing competition for water with the urban sector of the country (Kristianto and Sitompul, 2007), irrigation may increasingly rely on more marginal water sources which are more susceptible to rainfall variability. Change in certain rainfall patterns, particularly delayed onset of rainy season, may therefore reduce the water availability even in the areas equipped for irrigation at the planting time. In addition, rapid deforestation in various parts of Indonesia in recent years (Hunt, 2010; Klasen et al 2010) might have reduced the

stable water supply. With such limiting factors of water allocation and supply to agriculture, irrigation may not be able to overcome the water shortage at the planting time when onset of rainy season is delayed. and therefore, the benefit of irrigation may be reduced, compared to the environment with timely onset of rainy season.

We collected the information directly from farmers in Indonesia in 1999 and 2007, to understand (i) how farmers perceive the change in rainfall patterns? (ii) how the perception affects their adaptation strategy? and, (iii) how the perceived change in climate affects rice productivity and roles of irrigation

The next section describes our data. Section 3 summarizes changes in rainfall patterns that farmers reported and their adaptation behaviors. In general, the rainfall pattern has shifted during the last twenty years. We, however, observe some interesting heterogeneity across provinces. In Lampung, Central and East Java, and West Nusa Tenggara (NTB, hereafter), the perceived patterns of rainfalls are different from those of South Kalimantan, North and South Sulawesi. Farmers in the former group of provinces perceived that the duration of rainy season became shorter and the total number of rainy days declines, while in the latter province group, the opposite trends emerged in the perceptions. However, in all the provinces that we surveyed, farmers perceived that the onset of rainy season tends to be delayed.

Sections 4 and 5 analyze (i) adaptation behaviors and (ii) the effect of perceived

change in rainfall onset on land productivity (yield) in rice farming, respectively. We focus on the perceived onset of rainy season because it dominantly influences planting date, which affects the yields (e.g., Rosenzweig and Binswanger, 1993; Naylor et al., 2007). The result of our research reveals unique interactions between the delayed onset of rainfall, effect of irrigation and rice productivity in Indonesia. The results have two important implications. First, the analysis shows that farmers change planting date in response to the delays in the onset of rainy season. Farmers also change crop variety in response to the delays in the end of the previous year's rainy season. Therefore, farmers make decisions sequentially. Second, we found that irrigation significantly increases rice land productivity, but the positive effect of irrigation can be offset by the delayed onset of the rainy season. Policy implications are discussed in the conclusion.

2. Data

In this study, we use two rounds of household survey conducted in Indonesia: PATANAS 1999 by ICASEPS and Indonesian Millennium Development Goals (IMDG) project in 2007.² The PATANAS surveys covered agricultural production activities in 48 villages chosen from different agro-climatic zones in seven provinces (Lampung, Central Java, East Java, NTB, South Sulawesi, North Sulawesi, and South Kalimantan). In 2007, we revisited the PATANAS sample

² See also Yamauchi (2012) and Yamauchi et al. (2011) for more details of the survey and data characteristics.

villages, except those in Ache, to build household panel data on the sample of the 1994/95 and 1999 PATANAS survey. However, we added new villages in each province. In total 98 villages were covered. Figure 1 shows locations of surveyed villages.³

Data for rice production and the production growth are obtained from the panel constructed from the 1997 and 2007 data. The IMDG in 2007 differs from PATANAS 1999 in the following aspects: (i) we reduced the number of households per village from 50 to 20 (however, it is on average 25 if including split households), and added new villages in each province. (ii) the production data in 2007 is calculated based on the management unit which is not necessarily plot, but PATANAS 1999 captures production activities of households for each plot and season. In 2007, the survey only covers production for main commodities including paddy rice. (iii) In 2007, for each management unit, we collected the information on irrigation type. (iv) The value and size of unique market arrangements such as Tebasan and Ijon are also collected if they are applicable. (v)

IMDG 2007 also captured households split from the original households after 1999, residing in the same villages as the original ones. We aggregated the original and split households so as to make the unit of observations comparable with the 1999 production unit.

⁴ Province codes are as follows. 18: Lampung, 33: Central Java, 35: East Java, 52: West Nusa Tenggara (NTB), 63: South Kalimantan, 71: North Sulawesi, 73: South Sulawesi.

We dropped South Kalimantan from the 1999 data, since the 1999 PATANAS data had some technical problems in the province. All the other methods of data collection and treatment used in the 1999 survey are also applied to the 2007 survey.

Quantity of rice is standardized by converting all the units of production into kilogram unit of 'wet paddy' by using SUSENAS conversion, as data for four different types of rice products were collected: (i) wet paddy; (ii) unhusked rice; (iii) unhusked rice for storage and (iv) rice ready for sales. Productivity of rice is measured as the value of production per land. In the area surveyed, the rice is cultivated only during the rainy season. For households who had a non-market portion of the crop output, we used the average of village prices to impute the value. We also estimated the approximate production value for the Tebasan system using the prices computed in the above method. Lastly, we computed the proportion of irrigated land at the household level. The proportion of each type is the weighted average of irrigation type indicator using plot sizes as weights.

3. Climate Change - Rainfall, Magnitude, and Heterogeneity

This section describes changes in rainfall pattern that farmers reported in the 2007 survey. Our data directly elicit farmers' perceptions on changes in rainfall patterns during the recent decades, including the change in the onset of rainy

season, and their response to adapt perceived changes.

Figure 1 to be inserted

Farmers perceive the changes in rainfall patterns in various ways. Perceptions among farmers vary even within a village, which also explains the variations in farmers' reactions to the changes.

Figures 2 to be inserted

Figures 2 shows the distribution of the reported changes in the onset of rainy season (in months) in 2005 and 2006 crop years, within each of the seven provinces.⁴ We use as a benchmark the date which farmers reported to be the standard onset of rainy season twenty years ago, and take the difference between the date and the reported onset time for 2005 and 2006.⁵ Farmers recognize that, on average, over the past twenty years the onset of rainy season has been delayed by 0.86 months. The perceptions of the delayed onset of rainy season are common across the provinces, although some variations among the provinces are observed (Figure 4). We also confirm that, in farmers' recognition, the end of rainy season tends to be delayed, though this change is not as clearly recognized as that of the onset. The commonly observed delays in the onset of rainy season motivate this paper.

⁴ Province codes are as follows. 18: Lampung, 33: Central Java, 35: East Java, 52: West Nusa Tenggara (NTB), 63: South Kalimantan, 71: North Sulawesi, 73: South Sulawesi.

⁵ Tables A1 and A2 show tabulations of delays in month for the onset and end of rainy season for each of 2005 and 2006 compared to 20 years ago.

Farmers also perceive other types of changes in rainfall patterns, as are observed through their responses to following questions: (i) difficulty in identifying the onset of rainy season - more difficult, same, easier, (ii) change in the onset date - sooner, same, later, (iii) change in duration - longer, same, shorter, and (iv) change in the total number of rainy days - larger, same, smaller.

Figures 3 to 6 to be inserted

Farmers in all the provinces perceive that it is more difficult to identify onset of rainy season than before (Figure 3) while the onset is generally getting late (Figure 4).⁶ On the other hand, regarding both the duration of rainy season as well as the total number of rainy days, perceptions vary across regions (Figure 5 and 6). Farmers report that the duration has become shorter in Lampung, Central Java, East Java, and especially, in NTB. On the contrary, farmers in South Kalimantan and North Sulawesi perceive it has become longer and unclear. In South Sulawesi, the perception of change of the duration varies among farmers. Consistent with the change of the duration, the total number of rainy days declined in Lampung, Central Java, East Java and NTB, whereas it increased in South Kalimantan, North and South Sulawesi.

Importantly, farmers' initial perceptions on the change in the onset of rainy seasons may influence their subsequent perceptions on changes in the other aspects of rainfall patterns. We analyze the effect of the perceived changes in

onset on the above mentioned other changes in rainfall patterns, using ordered probit (Tables 1a and 1b). The results show that, when province dummies are controlled, delays in the onset of rainy season significantly explains the other changes in rainfall patterns (Table 1a).

Tables 1a and 1b to be inserted

Similar effects are observed when we control village fixed effects to examine the effect of within-village variations (Table 1b). We confirm that the delays in onset significantly explain the other changes in rainfall patterns, although the parameter of the estimates becomes smaller in absolute value (due to bias that arises from a correlation between village-level unobserved fixed error components and delays in onset). Heterogeneity in the perceived changes of the onset therefore also affects the perceived changes of rainfall patterns.

4. Adaptations: Planting Timing and Crop Variety

This section summarizes the empirical results regarding the effect of delays in the onset of rainy season on farmers' decisions in production. We first examine how delays in the onset explain farmer's choices to adapt the changes. We define an indicator variable which takes the value of one, if a farmer considers each of the

⁶ The Meteorological Department defines onset of rainy season based on a threshold point in rainfall in

two adaptation measures as the first or second strategy, and zero, otherwise. Farmers answered the change in planting date and the change in crop variety as the first or second priority among various other options asked in our survey. Our analysis focuses on the two choices since these two are the most common strategies revealed in the survey. We run probit models to identify factors that determine whether farmers prioritize the change in planting timing and crop variety.

Tables 2 and 3 to be inserted

Results in Table 2 indicate that farmers who reported delay in onset are likely to change planting date, but not crop variety. If they cannot adapt the change in this way, they will probably change the crop variety. The results are qualitatively same when bivariate probit model are used (lower panel in Table 2). Though this model shows a significant positive correlation between the errors, which suggests that both of the two adaptation choices are positively related. This correlation is, however, not statistically significant.

In contrast, we find that the changes in the end of the rainy season in the previous crop year significantly explain the decision on the choice of crop variety in the subsequent year (Table 3). In the bivariate probit estimation, we also obtain a similar result, showing a significant effect of the ending date of the previous year's the rainy season on the choice of crop variety in the subsequent

decade data (10 days). Correspondingly we asked farmers to report which week rainy season has started.

year. On the other hand, the shift in the end date of rainy season does not affect planting date of the next year. These behaviors seem reasonable, considering the fact that a choice of crop variety requires a sufficient time and investment while decision on planting date is a result of judgment based on day-to-day observations around the beginning of the rainy season.

5. Case Study: Rice Production

Next we examine the effects of changes in the rainfall patterns on rice productivity growth during the period of 1999 to 2007 (Table 4). The dependent variable is the growth rate of rice output value per harvested area. In all the specifications for regressions we perform, we include either province or village dummies to control province-wise price changes. Note that logarithm transformation separates the price change from the real growth rate of rice production.^{7 8} In this analysis, adaptation behavior is not explicitly structured since we do not have identifying instruments for this component, and therefore the estimated impact below includes both direct effects of climate change and partly offsetting effects of adaptation behavior.

⁷ The numbers of rice farmers in IMDG 2007 and PATANAS 1999 surveys are 676 (including South Kalimantan) and 633 (not including South Kalimantan), respectively. A half of the sample villages of IMDG 2007 are PATANAS 1999 villages and a half of sample households in PATANAS 1991 (and 1994/1995) were revisited in IMDG 2007 since we decided to reduce sample size within each village to 20 original households. Nearly 100 rice farmers discontinued farming until 2007.

⁸ We also bootstrapped the estimation with 100 repetitions to obtain asymptotic standard errors overcoming the small sample size problem. Though t-values slightly decreased with bootstrapping, the results remain robust.

Table 4 to be inserted

Column 1 in Table 4 shows the direct effect of the perceived change in the onset of rainy season on rice output growth. We also found from the data that, the effects of the delayed onset on productivity growth are heterogeneous across farmers, depending on the irrigation shares. In Column 2 and 3, we added the irrigation share in 1999 as well as the interaction term of the irrigation share and the delays in onset. The coefficient of the first variable indicates that, a farmer who already had a higher irrigation share in 1999 generally experienced a slower productivity growth than a farmer with a lower irrigation share in 1999. This is possibly due to the diminishing marginal benefit of the capitals. On the contrary, the coefficient of interaction term implies that the adverse effect of the delayed onset on the productivity growth is mitigated by the initial stock of irrigation. When we control village fixed effects to analyze intra-village variations, the results remain qualitatively the same. Interestingly, if farmers are fully equipped with irrigation on all plots, the impact of climate change is nil.

The changes in the irrigation share between 1999 and 2007 seem to have the opposite effects from ones of irrigation share on the productivity growth. In Column 4, we replace the irrigation share in 1999 with the change in irrigation share between 1999 and 2007. We confirm that the change in irrigation share significantly increases rice production growth. On the other hand, the interaction term of the changes in the irrigation share and the delays in the onset significantly decreases the returns to the increased irrigation share. These

coefficients indicate an interesting finding: one-month delay of the rainy season onset almost cancels the marginal benefit from the increase in irrigation. Both of the results employing province fixed effects and village fixed effects (Columns 4 and 5), are qualitatively the same, although statistical significance is slightly lower with village fixed effects.

It is also important to describe additional findings that we didn't describe in the table. We observed heterogeneity within the villages both of the impact of irrigation share. The heterogeneity remains present even after the village-specific effects are controlled from productivity growth. In addition, we found that a dynamic productivity gain of the farmers with the increased irrigation share is significantly smaller in villages that experienced larger delays in onset of the rainy season. These findings are robust to spurious correlations arising from unobserved village-specific factors.

Our results show the negative effects of the delayed onset on the rice productivity growth. They also highlighted both the potential and the limitation of irrigation to mitigate such effects. A high irrigation share in 1999 indicates that the farmer's productivity growth after 1999 has been slower, since he/her already attained high productivity at that time of 1999. On the contrary, an increase in the irrigation share after 1999 generally drove the productivity growth. When coupled with the delayed onset in the rainy season, however, the effect of the increase in the irrigation share becomes smaller and heterogeneous among farmers and villages.

These characteristics are possibly due to the newly developed irrigation system's susceptibility to rainfall patterns. Farmers who had larger irrigation share than others in 1999 are likely to have had a better access to stable water sources being less susceptible to the change in rainfall patterns. Their irrigation systems may also be less influenced by water uptake by other farmers. On the contrary, the increase in the irrigation share after 1999 might have been achieved using more marginal water sources such as downstream, which are less stable and more susceptible to the change in rainfall patterns. When the onset of the rainy season is delayed, therefore, the newly irrigated areas may not be able to avoid the water shortage.

In sum, our empirical results show that returns to irrigations can be eroded when onset of the rainy season is delayed. Such trend has been increasingly common in Indonesia, potentially due to the expansion of irrigation using marginal water sources. For rice farming in Indonesia, climate change decreases rather than increases returns on irrigation infrastructure. Such reduced benefit from irrigation is consistent with our earlier observations. While irrigation technology may stabilize the water supply from the erratic rainfall during the rainy season, either the technology employed in the surveyed villages may not have the capacity to obtain water from deep aquifer underground. The limited capacity of irrigation to overcome the water shortage at the time of planting is also consistent with our findings that many farmers delay their planting when the onset is delayed. The farmers choose the option of the delayed planting despite

the various risks associated such as lower yields and longer lean season for rice. This suggests that the irrigation system is not functioning enough as an adaptation to the changes in climate.

6. Summary and policy implications

This paper analyzed Indonesian rice farmers' perceptions on rainfalls, adaptive behaviors according to their perceptions, and the effects of such changes on the rice productivity. The perceived changes in rainfall patterns induce farmers' adaptive behaviors, such as shifting the planting date. Such patterns of adaptation behavior are similar to other geographic regions but yet partially unique. In Indonesia, some other strategies such as changing crop varieties are less commonly observed, which could be a tendency specific to rice farming. The possible reason is because farmers feel difficulty in converting paddy rice field to other purposes, and/or because it requires large investments in converting the land to suit for other crops than rice production. It is worth investigating the relevance of the change in crop variety in non-rice production as an adaptation behavior, though this is beyond the scope of our paper.

Our empirical results show that the delays in the onset of the rainy season substantially decrease the rice production growth. Indeed, in the areas of study, one-month delay in the onset of the rainy season cancels the average growth of

rice production. Furthermore, the results reveal some important insights on returns to irrigation when rainfall patterns are under the change. Irrigation has a potential to mitigate negative effects of the delayed onset in areas where relatively stable water supply are available and accessible to the users of the system. The supply should be less susceptible to rainfall to mitigate the adverse effect of the change in the rainfall patterns. Irrigation in Indonesia, on the other hand, may be increasingly relying on the marginal water sources, which are more susceptible to the rainfall. Therefore, the return on irrigation in Indonesia may be increasingly constrained by the delayed onset of the rainy season.

These insights lead to several important policy implications. First, a strong initiative by policy makers for planned adaptation is important. Farmers' autonomous adaptation has a limitation both in predicting short and long term change and variability (Howden et al). An effective climate information services can increase the success rate of adaptation and efficiency of resource use for rice production. Farmers' interest in such information service is in general reported to be high (Hansen et al.). Coordinated investments are needed into increasing resources for monitoring, data collection, data processing and delivery on climates in Indonesia.

Second, as the capacity of irrigation becomes increasingly limited to mitigate the effect of delayed onset of the rainy season, public investment may be needed to support farmers to take alternative adaptation strategies, including a new seed variety that can mitigate their exposures to climate effects. For example, farmers'

access to varieties with shorter growth duration can be improved.

References

- Adrian, E. and R.D. Susanto, 2003, Identification of Three Dominant Rainfall Regions within Indonesia and their Relationship to Sea Surface Temperature, *International Journal of Climatology*, 23: 1435-1452.
- Food and Agricultural Organization (FAO). 2010. *AQUASTAT: Indonesia*. Available online at <http://www.fao.org/nr/water/aquastat/countries/indonesia/index.stm>. Accessed May 18, 2011.
- Fuglie, C., Keith O., and Roley R. Piggott. 2006. Indonesia: Coping with Economic and Political Instability. In *Agricultural R&D in the Developing World: Too Little, Too Late?*, ed. Philip G. Pardey, Julian M. Alston, and Roley R. Piggott, 65-104. Washington, D.C.: International Food Policy Research Institute.
- Hansen, James W., Walter Baethgen, Dan Osgood, Pietro Ceccato, and Robinson Kinuthia Ngugi. 2007. "Innovations in Climate Risk Management: Protecting and Building Rural Livelihoods in a Variable and Changing Climate." *Journal of Semi-Arid Tropical Agricultural Research* 4 (1): 1-12.
- Hamada, J.L., M.D. Yamanaka, J. Matsumoto, S. Fukao, P.A. Winarso, and T. Sribimawati, 2002, Spatial and Temporal Variations of the Rainy Season over Indonesia and their Link to ENSO, *Journal of Meteorological Society of Japan*, 80: 285-310.
- Haylock, M., and J. McBride, 2001, Spatial Coherence and Predictability of Indonesian Wet Season Rainfall, *Journal of Climate*, 14: 3882-3887.
- Maddison, David. 2007. *The Perception of and Adaptation to Climate Change in Africa*. Washington, DC.
- Morton, V., A. Robertson and R. Boer, 2007, Spatial coherence and seasonal predictability of monsoon onset over Indonesia, Manuscript, CEREGE, France.
- Naylor, R., D. Battisti, D. Vimont, W. Falcon, and M. Burke, 2007, Assessing Risks of Climate Variability and Climate Change for Indonesian Rice Agriculture, *The Proceedings of the National Academy of Sciences (PNAS)*, 104: 7752-7757.
- Naylor, R.L., W. Falcon, N. Wada, and D. Rochberg, 2002, Using El-Nino Southern Oscillation Climate Data to Improve Food Policy Planning in

- Indonesia, *Bulletin of Indonesian Economic Studies*, 38: 75-91.
- Robertson, A. W., V. Moron, and Y. Swarinoto, 2007, On the Seasonal Predictability of Daily Rainfall Characteristics over Indonesia, Manuscript, International Research Institute for Climate and Society (IRI), Columbia University.
- Roehlano M. Briones. 2011. Regional Cooperation for Food Security: The Case of Emergency Rice Reserves in the ASEAN Plus Three. Manila, Philippines.
- Rosenzweig, M.R., and H.P. Binswanger, 1993, Wealth, Weather Risk and the Composition and Profitability of Agricultural Investments, *Economic Journal*, 103: 56-78.
- Schoengold, K. and D. Zilberman. (2007). Chapter 58: The Economics of Water, Irrigation, and Development. *Handbook of Agricultural Economics* 3, 2933-2977.
- Simatupang, Pantjar, and C. Peter Timmer. 2008. "Indonesian Rice Production: Policies and Realities." *Bulletin of Indonesian Economic Studies* 44 (1) (April): 65-80. doi:10.1080/00074910802001587.
<http://www.tandfonline.com/doi/abs/10.1080/00074910802001587>.
- Smit, Barry, and O Pilfosova. 2001. Adaptation to Climate Change in the Context of Sustainable Development and Equity. In *Climate change 2001: impacts, adaptation, and vulnerability-contribution of working group II to the third assessment report of the intergovernmental panel on climate change*, 876-912. Cambridge: Cambridge University Press.
- Timmer, P.C.. 2010. The Changing Role of Rice in Asia's Food Security. Manila, Philippines.
- Tabi, Fritz Oben, S G K Adiku, Kwadwo Ofori, Nhamo Nhamo, Michel Omoko, E Atika, and A Mayebi. 2012. Perceptions of Rain-Fed Lowland Rice Farmers on Climate Change , Their Vulnerability , and Adaptation Strategies in the Volta Region of Ghana. In *Technologies and Innovations for Development*. Springer- Verlag France. doi:10.1007/978-2-8178-0268-8.
- Vermeulen, S.J., P.K. Aggarwal, A. Ainslie, C. Angelone, B.M. Campbell, A.J. Challinor, J.W. Hansen, et al. 2010. *Agriculture , Food Security and Climate Change : Outlook for Knowledge , Tools and Action*. CCAFS Report No. 3. Agriculture. Copenhagen, Denmark.

Yamauchi, F., 2012, "Prenatal Seasonality, Child Growth and Schooling Investments: Evidence from Rural Indonesia," Forthcoming, *Journal of Development Studies*.

Yamauchi, F., M. Muto, S. Chowdhury, R. Dewina, and S. Sumaryanto. 2011. "Schooling and Roads are Complementary? Evidence from Income Dynamics in Rural Indonesia," *World Development* 39: 2232-2244.

Figure 1. Locations of surveyed villages

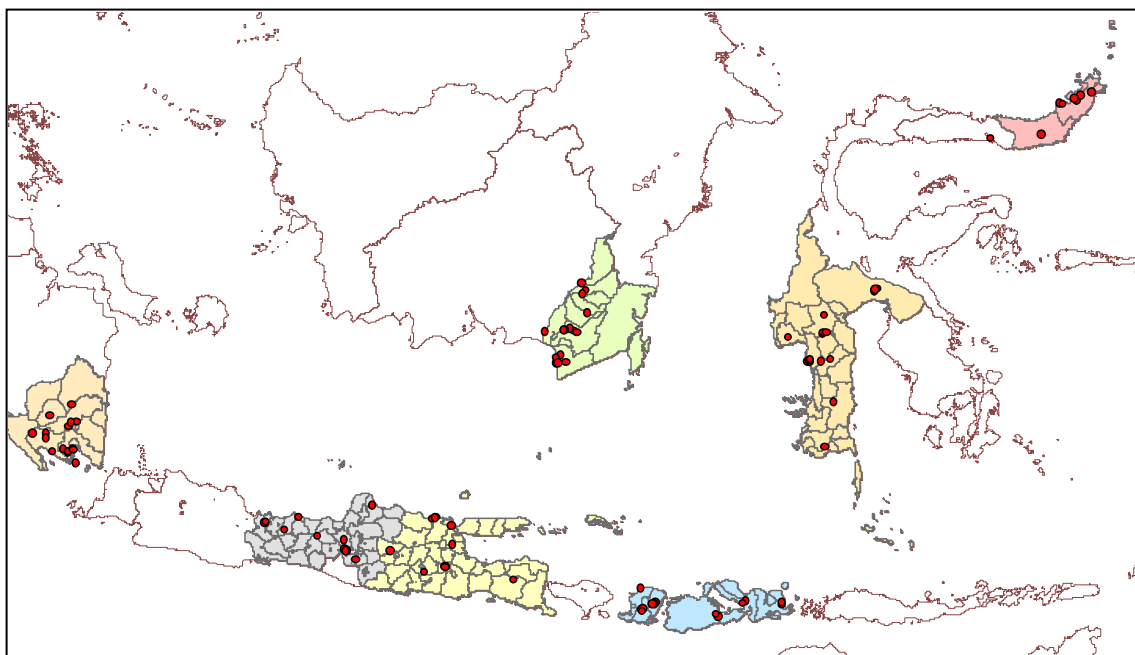
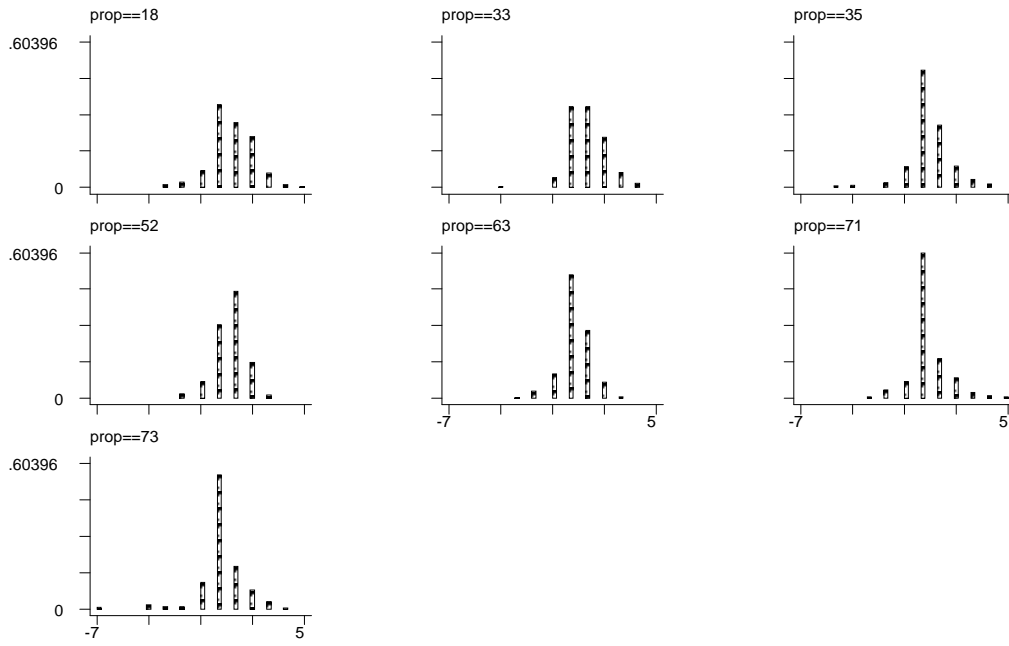


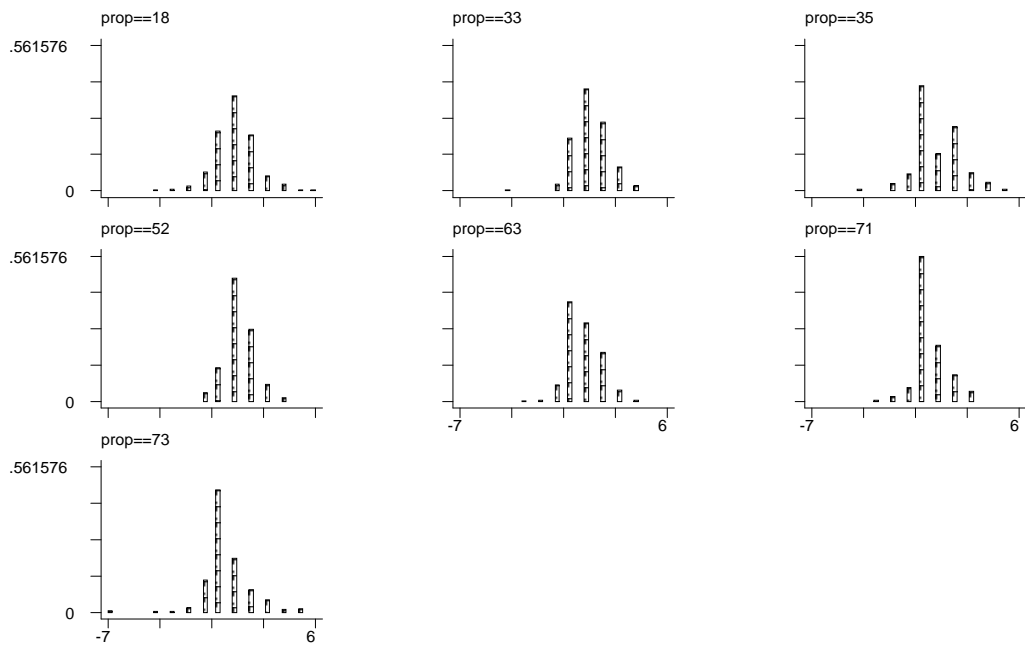
Figure 2 Change in onset (delay in months)

2005



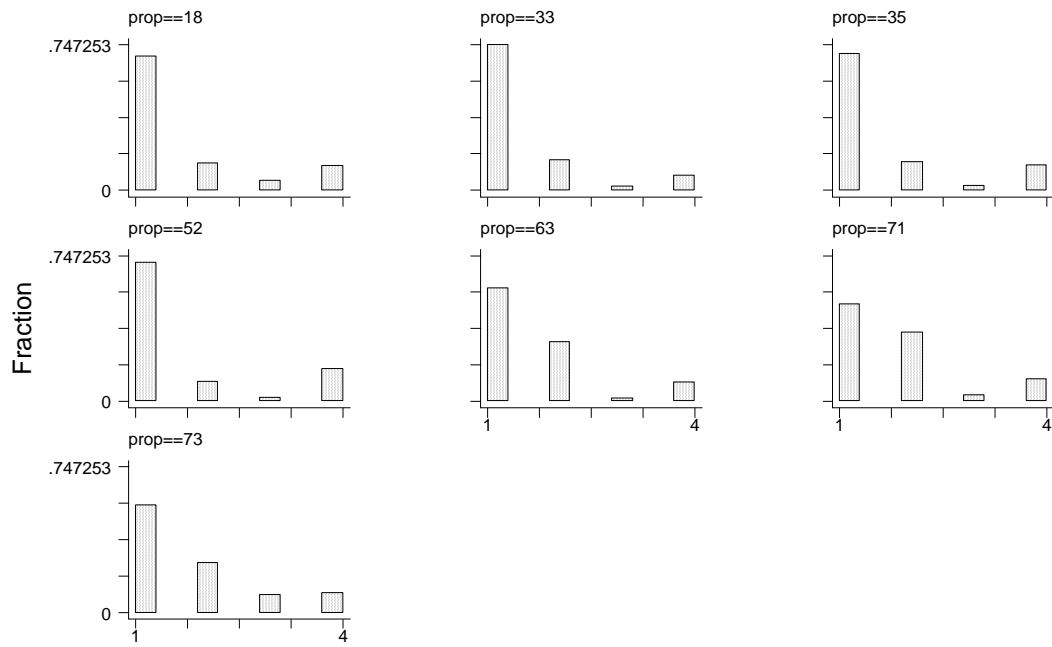
Change in onset 2005

2006



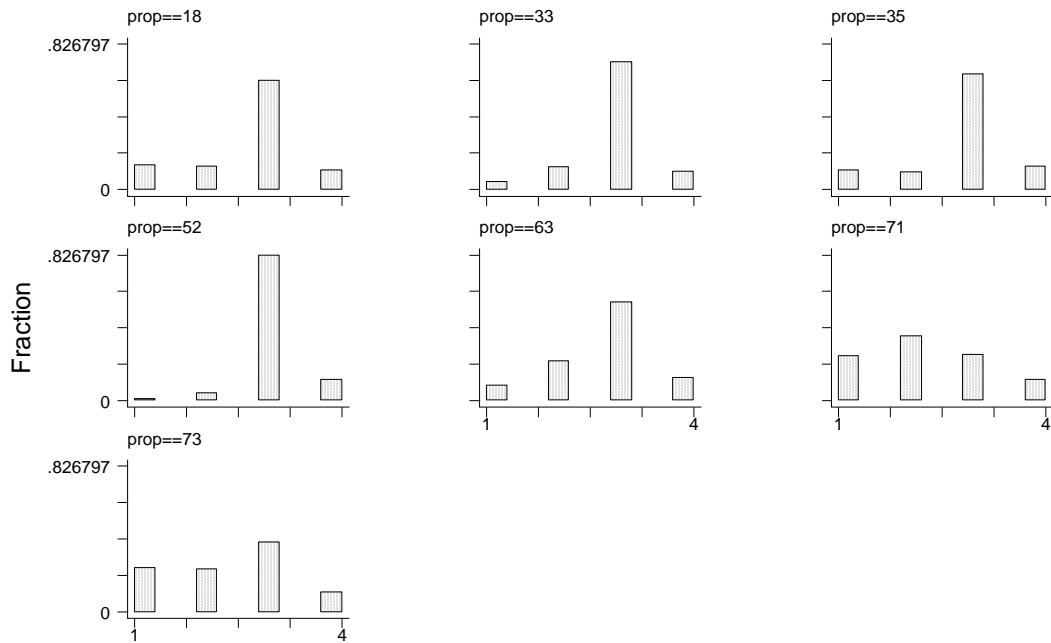
Change in onset 2006

Figure 3 Difficulty in identifying onset



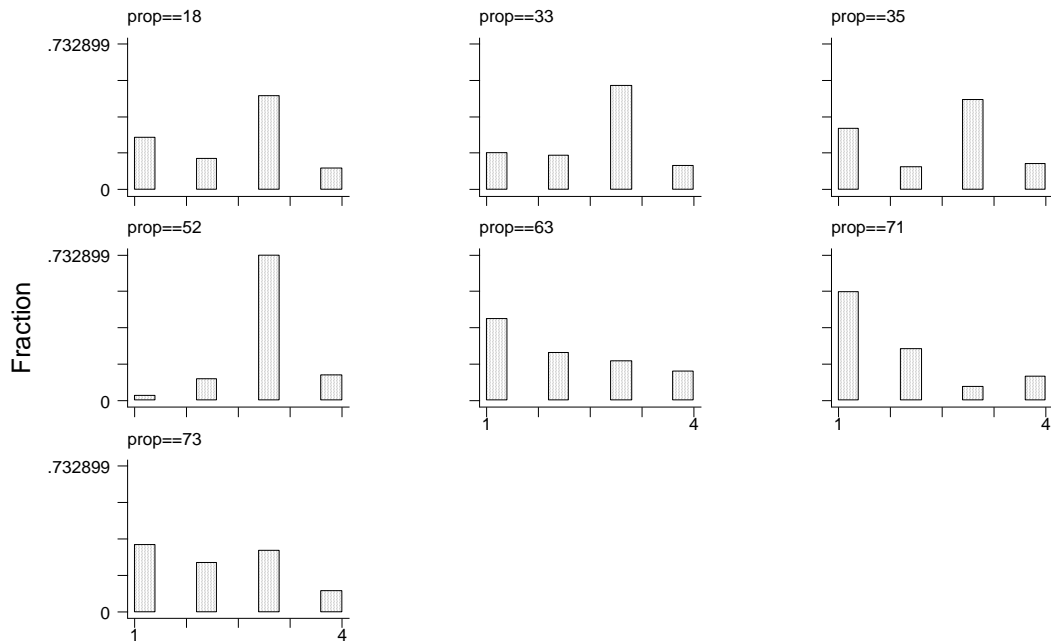
1: more difficult, 2: same, 3: easier, 4: don't know

Figure 4 Change in onset date



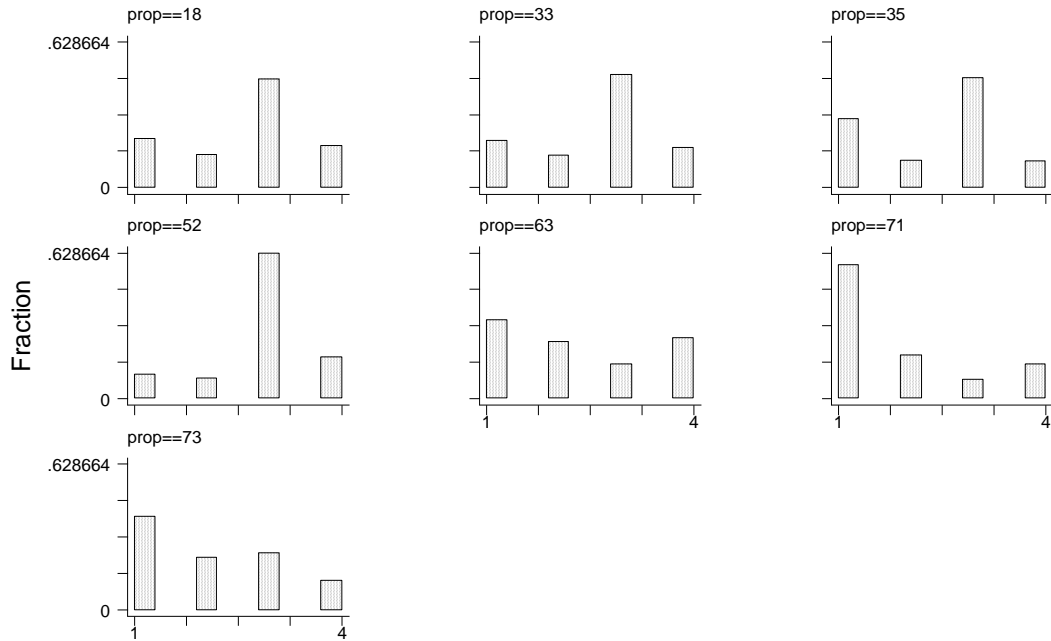
1: sooner, 2: same, 3: later, 4: don't know

Figure 5 Change in duration



1: longer, 2: same, 3: shorter, 4: don't know

Figure 6 Change in total number of rainy days



1: larger, 2: same, 3: smaller, 4: don't know

Table 1a Effects of Onset Delay on Rainfall Patterns – Ordered Probit

	Identifying starting date	Change in starting date	Change in duration	Change in total rainy days
	1 More difficult	1 Sooner	1 Longer	1 Longer
	2 Same	2 Same	2 Same	2 Same
	3 Easier	3 Later	3 Shorter	3 Smaller
Change in onset	-0.1812 (4.380)	0.3694 (7.500)	0.1158 (3.120)	0.0788 (2.250)
Province dummies	yes	yes	yes	yes
Number of obs	1750	1747	1738	1634
Pseudo R squared	0.0593	0.1671	0.1202	0.1014

Numbers in parentheses are absolute t values using robust standard errors.

Table 1b Effects of Onset Delay on Rainfall Patterns – Ordered Probit

	Identifying starting date	Change in starting date	Change in duration	Change in total rainy days
	1 More difficult	1 Sooner	1 Longer	1 Longer
	2 Same	2 Same	2 Same	2 Same
	3 Easier	3 Later	3 Shorter	3 Smaller
Change in onset	-0.1372 (2.830)	0.2267 (4.760)	0.1256 (3.100)	0.0649 (1.680)
Village dummies	yes	yes	yes	yes

Number of obs	1750	1747	1738	1638
Pseudo R squared	0.0492	0.1269	0.1175	0.0977

Numbers in parentheses are absolute t values using robust standard errors.

Table 2 Effects of Onset Change on Adaptation Strategy

Dependent:	Changing planting date		Changing crop variety	
Change in onset	0.0389	0.0407	0.0047	0.0016
	(2.60)	(3.51)	(0.56)	(0.21)
Province dummies	yes		yes	
Village dummies		yes		yes
Number of obs	1579	1579	1579	1579
R squared	0.0472	0.2954	0.0101	0.2397

The

Estimation: Bivariate Probit

Dependent:	Planting date	Crop variety
Change in onset	0.0998	0.0254
	(2.570)	(0.680)
Province dummies	yes	yes
Correlation coefficient	0.5453	Wald = 42.14 (0.00)

The dependent variable takes the value of one if farmer adopt the above strategy as the first or second choice and zero otherwise. Numbers in parentheses are absolute t values using robust standard errors. Change in onset is the difference between the reported onset month for crop year 2006 and the reported month 20 years ago. The sample consists of households who reported answers of 1 to 3 in Figures 3 to 6.

Table 3 Effects of End Change on Adaptation Strategy in the subsequent year

Dependent:	Changing planting date		Changing crop variety	
Change in end	-0.0002 (0.02)	0.0084 (0.81)	0.0165 (2.22)	0.0162 (2.10)
Province dummies	yes		yes	
Village dummies			yes	
Number of obs	1454	1454	1454	1454
R squared	0.0328	0.2909	0.0152	0.2432

Estimation: Bivariate Probit

Dependent:	Planting date	Crop variety
Change in end	0.0351 (1.15)	0.0719 (2.09)
Province dummies	yes	yes
Correlation coefficient	0.5112	Wald = 36.17 (0.00)

The dependent variable takes the value of one if farmer adopt the above strategy as the first or second choice and zero otherwise. Numbers in parentheses are absolute t values using robust standard errors. Change in end is the difference between the reported ending month for crop year 2005 and the reported month 20 years ago. The sample consists of households who reported answers of 1 to 3 in Figures 3 to 6.

Table 4 Land productivity in rice farming

Dependent: Growth land productivity (value) from 1999 to 2007

Change in onset (village average)	-1.232	-1.914		-0.8064	
	(2.47)	(3.23)		(1.95)	
Irrigation share 1999		-1.073	-1.567		
		(1.99)	(2.12)		
Irrigation share 1999 * Change in onset		1.406	1.261		
		(2.51)	(1.54)		
Change in irrigation share				0.9334	1.113
				(2.47)	(2.16)
Change in irrigation share * Change in onset				-1.245	-0.9423
				(2.91)	(1.71)
Province fixed effects	yes	yes		yes	
Village fixed effect			yes		yes
Number of observations	133	133	133	133	133
R squared	0.2362	0.2910	0.5386	0.2970	0.5367

Numbers in parentheses are absolute t values, using robust standard errors. Sample consists of rice farmers.

Table A1 Change in onset (Delay in months)

2005	Freq	Percent	Cum
-7	2	0.10	0.10
-5	2	0.10	0.21
-4	8	0.42	0.63
-3	9	0.47	1.10
-2	36	1.88	2.98
-1	150	7.85	10.83
0	847	44.32	55.15
1	536	28.05	83.20
2	242	12.66	95.87
3	62	3.24	99.11
4	14	0.73	99.84
5	3	0.16	100.00
Total	1,911		

2006	Freq	Percent	Cum
-7	2	0.10	0.10
-4	4	0.21	0.31
-3	5	0.26	0.57
-2	23	1.20	1.77

-1	122	6.37	8.14
0	634	33.09	41.23
1	596	31.11	72.34
2	381	19.89	92.22
3	112	5.85	98.07
4	29	1.51	99.58
5	7	0.37	99.95
6	1	0.05	100.00
Total	1,916		

Table A2 Change in end (Delay in months)

2005	Freq	Percent	Cum
-6	2	0.11	0.11
-5	3	0.17	0.28
-4	11	0.61	0.89
-3	15	0.83	1.72
-2	76	4.22	5.95
-1	220	12.23	18.18
0	962	53.47	71.65
1	325	18.07	89.72
2	118	6.56	96.28
3	47	2.61	98.89
4	12	0.67	99.56
5	4	0.22	99.78
6	4	0.22	100.00
Total	1,799		

2006	Freq	Percent	Cum
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-5	2	0.11	0.11
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-4	7	0.39	0.50
-3	10	0.55	1.05
-2	45	2.48	3.53
-1	190	10.47	13.99
0	865	47.66	61.65
1	414	22.81	84.46
2	175	9.64	94.10
3	75	4.13	98.24
4	24	1.32	99.56
5	5	0.28	99.83
6	3	0.17	100.00
Total	1,815		
