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Climate Shocks Constrain Human Fertility in Indonesia

Samuel Sellers[a,*] and **Clark Gray**[b]

[a.]Center for Health and the Global Environment, University of Washington. 4225 Roosevelt Way NE Suite 100 Seattle, WA USA 98105

[b.]Department of Geography, University of North Carolina at Chapel Hill. Carolina Hall, CB 3220, Chapel Hill, NC USA 27599

Abstract

Climate change is likely to induce a large range of household- and individual-level responses, including changes in human fertility behaviors and outcomes. These responses may have important implications for human and economic development and women's empowerment. Drawing on the literature linking climate conditions to rice cultivation in Indonesia, we use longitudinal household survey and high-resolution climate data to explore changes in childbearing intentions, family planning use, and births following community-level climate shocks from 1993 to 2015. We find that fertility intentions increase and family planning use declines in response to delays in monsoon onset occurring within the previous year, particularly for wealthier populations. However, women on farms are significantly more likely to use family planning and less likely to give birth following abnormally high temperatures during the previous five years. We also measure parallel shifts in household well-being as measured by rice, food, and non-food consumption expenditures. Our findings advance the environmental fertility literature by showing that longer duration environmental shocks can have impacts on fertility behaviors and outcomes. Collectively, our results illustrate human fertility responses to climate change in a country vulnerable to its effects, and demonstrate that in some cases, climate shocks can constrain human fertility.

Keywords

family planning; reproductive health; environmental shock; Indonesia; Southeast Asia

1. Introduction

The adverse consequences of climate change for livelihoods and population well-being in low-income countries are well-documented (Morton, 2007; Vermeulen, Campbell, & Ingram, 2012). This is particularly concerning given that climate change is likely to accelerate in the coming decades, with substantial implications for crop yields and by extension poverty reduction (Porter et al., 2014). Responses to environmental shocks such as those associated with climate change are often complex, varying within and between households, and may include changes in demographic behaviors, including fertility

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[*]Corresponding Author: sellers1@uw.edu, +1 206 543 6342.

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(Bilsborrow, 1987; K. Davis, 1963). Earlier research exploring relationships between climate change and fertility has focused largely on the impact of acute disasters such as hurricanes in relation to births (J. Davis, 2017; Pörtner, 2008) or on the impacts of crop loss from climate shocks on births and family planning use (Alam & Pörtner, 2018; Kim & Prskawetz, 2010), generally over short time periods. This literature suggests that fertility responses vary widely, with increases or decreases in births reported depending on local social and environmental contexts. These changes are also likely to have important subsequent implications for women's life satisfaction (Klemetti, Raitanen, Sihvo, Saarni, & Koponen, 2010; McQuillan, Torres Stone, & Greil, 2007), empowerment (Cleland et al., 2006), and human development (Barro, 2001; Li & Zhang, 2007).

These issues motivate us to examine the relationship between temperature and precipitation anomalies and three fertility-related outcomes: intention to have another child, current use of family planning, and births. We advance previous studies by combining high-resolution climate data over short- (1–12 month) and medium-term (1–60 month) time scales with a large household survey dataset spanning more than two decades in Indonesia, a major developing economy that is heavily affected by climate change. This approach enables us to explore a wide array of experiences to climate change, and in particular, to capture variation between agricultural and non-agricultural households which have different livelihood strategies. Additionally, drawing on literature linking climate change with shifts in the timing and volume of rice production—Indonesia's most important staple crop—we also assess how changes in household expenditures are affected by climate shocks, which in turn, may help to explain changes in fertility behaviors.

We build on existing literature exploring household responses to climate change by examining the effects of climate shocks on fertility, an area that has received relatively little attention by scholars compared to effects on other demographic outcomes such as mortality and migration (Grace, 2017). Specifically, we understand shocks as short- or medium-term events where local temperature or precipitation conditions deviate substantially from historical climate conditions. We contribute to the environmental fertility literature by exploring the effects of annual or multi-year climate shocks on fertility, something largely unexplored to date (as opposed to the effects of an acute shock, such as a hurricane or earthquake), providing new evidence through which to understand the relationship between environmental change and human fertility responses. Additionally, by using climate data specific to a particular community, we are able to account for variation in exposure to climate shocks across communities.

Our results suggest that exposure to recent monsoon onset delays—which has consequences for wet season rice planting—are associated with increases in the intentions of women to have another child in the future and a lower likelihood of using family planning. These results are particularly strong among non-agricultural populations, as well as among wealthier and better educated women. Medium-term temperature shocks also significantly influenced fertility behavior, particularly among farm households. For these women, higher temperatures were negatively associated with intention for another child and positively associated with family planning use, suggesting that women may be deliberately reducing their fertility in the wake of environmental stress.

2. Theorizing Demographic Responses to Environmental Stress

Environmental change has the potential to affect households in a variety of ways, including through the viability of livelihood and income-generating opportunities as well as via access to adequate nutrition, schooling and health services (Bremner, López-Carr, Suter, & Davis, 2010; de Sherbinin, Carr, Cassels, & Jiang, 2007). Responses to these shocks may include changes in demographic behavior, including decisions about whether, when, and how many children to have (de Sherbinin et al., 2007). Theoretical frameworks examining demographic decisions following environmental shocks, such as multiphasic response theory (Bilsborrow, 1987; K. Davis, 1963), note that households in the same region facing similar environmental pressures often exhibit heterogeneous and complex demographic responses, which may differ depending on the resources available to the household, such as various forms of capital, as well as the vulnerability of households to environmental stressors, including whether a household is financially dependent on agriculture for its livelihood (de Sherbinin et al., 2008).

We draw from the literature exploring household responses to environmental change to hypothesize several pathways through which changes in fertility intentions, family planning use, and births may result from climate shocks. We emphasize that limitations of the data in our empirical analysis prevent us from testing all of these pathways; however, we suggest based on our findings that some of these pathways are more likely to be operating than others. A simplified conceptual model illustrating these pathways is presented in Figure 1.

Changes in livelihood opportunities, often as a result of shifts in crop or resource prices and availability, can lead households to make a range of adaptation choices. These may include changing farming practices, consumption patterns, and demographic behaviors, including choices regarding fertility (J. Davis & Lopez-Carr, 2010; Lambin, Geist, & Rindfuss, 2006). Decisions about household consumption in the face of scarcity also interact with decisions regarding fertility, and families make a tradeoff between investment in each child and the quantity of children born (Becker & Lewis, 1973). Because of differing household endowments, not all households respond in the same way to similar stressors, including those related to climate change, providing an opportunity for researchers to explore how environmental and demographic change interact in different settings (de Sherbinin et al., 2008). Drawing from the environmental fertility literature, we hypothesize that climate change affects fertility behaviors through three main pathways: health/physiology responses, household resource constraints responses, and family bonding responses.

2.1 Health/Physiology

Climate change may generate physiological effects in mothers and children, through mechanisms such as nutritional deficiencies or thermal stress, which can affect the number of live births observed. Climate change has adverse effects on global crop yields (Ray, Ramankutty, Mueller, West, & Foley, 2012) and crop nutritional content (Zhu et al., 2018) with substantial implications for global food security (Wheeler & von Braun, 2013). Nutritional status may be directly affected by climate shocks (such as lower crop yields of subsistence crops or the production of less nutritious crops), or mediated through changes in household income (such as reductions in income associated with climate-sensitive livelihoods activities, resulting in less food purchased and/or decisions to substitute more expensive, higher-quality foods with less-expensive, lower-quality foods).

A wide body of literature linking pregnancy outcomes with maternal characteristics finds that poor maternal nutritional status is associated with higher rates of stillbirth (Bhutta et al., 2013; McClure, Nalubamba-Phiri, & Goldenberg, 2006; Saigal & Doyle, 2008). Increased risk of stillbirth is also directly linked to exposure to higher temperatures (Auger, Fraser, Smargiassi, Bilodeau-Bertrand, & Kosatsky, 2017; Basu, Sarovar, & Malig, 2016; Strand, Barnett, & Tong, 2012) and may also be associated with elevated risks of miscarriages (Asamoah, Kjellstrom, & Östergren, 2018). In addition, environmental shocks may elevate maternal stress levels during pregnancy (King, Dancause, Turcotte-Tremblay, Veru, & Laplante, 2012; Zahran, Snodgrass, Peek, & Weiler, 2010), which in turn is linked with higher rates of stillbirth and miscarriage (Arck et al., 2008; Nepomnaschy et al., 2006). When food is scarce, intrahousehold food consumption patterns may shift. For instance, mothers of young children during Indonesia’s 1998 economic crisis showed signs of reduced food intake, such as weight loss, as they often lowered their own food intake in order to preserve their children’s food consumption, effects that may have had ramifications on future pregnancy outcomes (Block et al., 2004). Thus, parents who experience nutritional deficiencies resulting from climate-related crop losses, who experience higher temperatures, or who experience stress as a result of the economic and social consequences of climate shocks may be more likely to lose their offspring *in utero*, making a live birth a less likely outcome.

Moreover, poor maternal nutrition is often linked to worse child survival outcomes, which can stimulate additional fertility. Maternal nutritional deficiencies resulting from climate conditions are associated with higher rates of low birth weight and stunting (Davenport, Grace, Funk, & Shukla, 2017; Deschenes, Greenstone, & Guryan, 2009; Grace, Davenport, Hanson, Funk, & Shukla, 2015), outcomes that can increase the risk of infant and child mortality (Black et al., 2013; Katz et al., 2013). Fertility transition theory posits that lower infant mortality is an important factor in helping to reduce fertility rates (Caldwell, 1982).

2.2 Household Resource Constraints

Household resource constraints may also affect fertility, as the effects of climate shocks on household economic activities may trigger changes in consumption choices, including decisions regarding fertility. However, the direction of these changes is ambiguous. On the one hand, raising children poses significant financial costs for households and environmental shocks may reduce household incomes and/or family or community support to help defray the burdens of raising children (Eloundou-Enyegue, Stokes, & Cornwell, 2000). On the other hand, children may serve to bolster long-term household income security and diversification, creating an incentive for fertility in times of economic distress (Cain, 1981). A previous analysis linking self-reported shocks with fertility from Indonesia suggests that crop loss has no significant effect on fertility, although unemployment is associated with short-term increases in fertility, followed by decreases as more time elapses following the job loss (Kim & Prskawetz, 2010). Other analyses examining the fertility-related aftermath of financial shocks in low- or middle-income country settings show that affected households may change their consumption patterns to conserve household resources, including reducing fertility (Eloundou-Enyegue et al., 2000; McKenzie, 2003), and may increase their use of contraception, albeit marginally (McKelvey, Thomas, & Frankenberg, 2012). Thus, to the extent that livelihoods serve as a pathway linking environmental change and fertility, the consequent changes in fertility appear to be relatively small with the directionality varying depending on local contexts.

2.3 Family Bonding

Various studies also note that while livelihood shocks or disasters may strain familial and partner relationships, such events may also strengthen relationships, bringing couples and families closer together than they were before the event (D. Henry, Tolan, & Gorman-Smith, 2004; Kessler, Galea, Jones, & Parker, 2006; Lowe, Rhodes, & Scoglio, 2012). Placing a greater importance on familial relationships may in turn change intentions and decision-making around fertility. For instance, after Hurricane Hugo, greater bonding and time spent among family members may have contributed to increased post-disaster fertility (Cohan & Cole, 2002).

3. Background on Fertility Behaviors and the Environment

Given the substantial impacts of climate change on livelihoods, there is unsurprisingly a growing body of literature linking these effects with demographic responses. However, the bulk of the research linking demographics and climate change centers on the potential for climate-driven migration in response to changes in livelihood conditions (Bohra-Mishra, Oppenheimer, & Hsiang, 2014; S. Henry, Schoumaker, & Beauchemin, 2004; Mueller, Gray, & Kosec, 2014; Thiede & Gray, 2017). By contrast, relatively little research has explored the relationship between climate change and aspects of fertility, including intentions for additional children, family planning use, and births. We are interested in all three of these outcomes because the number of live births highlights how couples adapt to climate disruptions (whether couples invest in the quality or quantity of children). Fertility intentions and family planning use are important proximate determinants affecting the number and timing of births. Intentions for an additional child are associated with use of family planning services (Feyisetan & Casterline, 2000), and the provision of family planning can also impact fertility intentions (Bongaarts, 2011). Family planning use is generally associated with reduced fertility, greater spacing of births, as well as improved health outcomes for women (Canning & Schultz, 2012; Cleland, Conde-Agudelo, Peterson, Ross, & Tsui, 2012). Thus, these outcomes are important in and of themselves for explaining fertility decision-making pathways. Below, we briefly review previous studies on the relationships between environmental shocks and fertility intentions, family planning use, and births.

3.1 Fertility Intentions

Few studies have empirically explored the linkages between environmental shocks and women's self-reported fertility intentions. Demographic theories of "insurance" births posit women exposed to risky environmental conditions become concerned about the survival of their own children and seek to have additional births in order to hedge against the elevated risk of mortality, thus changing their intended fertility levels (Cain, 1981; Rosenzweig &

Schultz, 1983). However, as noted below, the bulk of the existing literature examining linkages between fertility and child mortality shocks explores the effects on fertility directly, without examining how fertility intentions may be differently affected by shocks than realized fertility (Benefo & Schultz, 1996; Lindstrom & Kiros, 2007; Nobles, Frankenberg, & Thomas, 2015). Two exceptions from developing countries suggest that local environmental variability and resource constraints may influence intended fertility. In Ghana, neighborhood-level mortality shocks are significantly associated with increases in self-reported fertility intentions (Owoo, Agyei-Mensah, & Onuoha, 2015). In Nepal, increased collection times of fodder and fuelwood resources as a result of local scarcity are associated with increases in intended family size (Brauner-Otto & Axinn, 2017).

3.2 Family Planning

As with fertility intentions, relatively few studies have explored the effects of environmental shocks on family planning use. To our knowledge, only one study has examined longitudinal effects of climate-related shocks on family planning use. Alam and Pörtner (2018) use data from the Kagera Health and Development Survey to examine the effects of self-reported crop failure on family planning use and fertility, finding that contraceptive use significantly increases in response to crop failure. Other research exploring the effects of contraceptive access following natural disasters such as hurricanes and earthquakes finds that contraceptives may not be readily available following a major disaster, particularly among the poorest and most marginalized populations, resulting in reduced contraceptive use (Behrman & Weitzman, 2016; Carballo, Hernandez, Schneider, & Welle, 2005; Hapsari et al., 2009). Additional studies examining the effect of income or household shocks on contraceptive use have generally found small, if any, significant effects between diminished incomes and reduced family planning use (Dinkelman, Lam, & Leibbrandt, 2007; Frankenberg, Sikoki, & Suriastini, 2003; McKelvey et al., 2012). Earlier work exploring the effects of the 1998 Indonesian economic crisis on contraceptive use finds that demand for contraceptives in Indonesia is relatively price inelastic, suggesting that environmental shocks that affect household expenditures have small effects on contraceptive use (McKelvey et al., 2012).

3.3 Births

Several papers that examine changes in resource scarcity and climate conditions generally find small, but significant effects of environmental shocks on fertility. Research examining births in the United States finds that births decrease approximately nine months after abnormally high temperatures (Barreca, Deschenes, & Guldi, 2018; Lam & Miron, 1996). In Nepal and Pakistan, increasing scarcity of natural resources due to environmental variability and growing demand is also associated with increased births as the amount of time required by a household to collect resources grows, which may provide an incentive for births as a form of providing additional household labor (Biddlecom, Axinn, & Barber, 2005; Filmer & Pritchett, 2002). Increased demand for labor (in the form of greater share of land devoted to agriculture) can boost returns to childbearing, in turn stimulating fertility (Ghimire & Axinn, 2010). Regular fluctuations in environmental conditions may result in seasonal patterns in births; research from West Africa highlights a strong relationship between agro-climatic zone and conceptions disproportionately occurring near harvest periods (Dorélien, 2016; Grace & Nagle, 2015).

In addition to resource scarcity and climate, other research examines the role of short-term environmental shocks on births. Much of this literature centers on the relationships between disasters, such as hurricanes, and fertility. Some studies find that hurricanes are associated with increased births in the years following the event, potentially as a result of losing access to contraceptives or couples becoming more closely attached during the course of a disaster (Cohan & Cole, 2002; J. Davis, 2017). Conversely, other studies argue that the displacement caused by heavy hurricane exposure is associated with reduced births in the aftermath of the event (Evans, Hu, & Zhao, 2010; Pörtner, 2008). As hurricanes often disproportionately impact certain subpopulations, these events may also change the racial or ethnic composition of the population by affecting which women give birth following the storm (Seltzer & Nobles, 2017). Although studies examining fertility-hurricane relationships differ in the directionality of the effects they find, authors which examined births several years following a disaster find that the fertility rate generally reverts back to pre-disaster levels well after the event, and the effects of the hurricane do not appear to have long-term impacts on fertility (J. Davis, 2017; Pörtner, 2008). Other studies exploring fertility changes in the aftermath of disasters not related to climate change find that, following events with high levels of child mortality, fertility often rises among parents who have lost children as a result of these disasters, such as after the 2004 Indian Ocean Tsunami (Nobles et al., 2015), the 2009 L’Aquila earthquake (Carta et al., 2012), and the 2008 Sichuan earthquake (Qin, Luo, Li, Wang, & Li, 2009).

4. Indonesian Agricultural Practices and Reproductive Health Services

We examine the effects of climate change on fertility intentions, family planning use, and births in Indonesia, which is a desirable setting to explore these questions for several reasons. First, although declining due to urbanization, a relatively high proportion of the population remains engaged in agricultural activities, enabling us to examine whether climate change disproportionately affects those reliant on farm activities (McCulloch, 2008). Second, Southeast Asia is heavily affected by climate change, with impacts such as warmer average temperatures and greater rainfall variability already being observed (Hijioka et al., 2014). These effects are projected to worsen in the coming decades, providing an important impetus for this research. Third, Indonesia has had a successful history with promoting family planning as a tool for reducing fertility rates (Angeles, Guilkey, & Mroz, 2005), providing an opportunity to explore fertility changes in a setting where women may readily access contraceptives, and can thus control their fertility if they so choose. Fourth, there is high-quality longitudinal household survey data available for a large portion of the country (see Section 5).

4.1 Rice Cultivation in Indonesia

Over the past 25 years, Indonesia has undergone a process of widespread urbanization (Firman, 2016), with 53% of the country’s population living in cities as of 2014 (United Nations, 2015). However, agriculture continues to provide a major source of employment, particularly among the poor and in rural areas (McCulloch, 2008). While smallholder farmers cultivate a variety of crops, rice continues to have outsized importance in livelihoods decisions as it is consumed by the vast majority of the population and provides an important source of income for farmers, but is also vulnerable to the effects of climate change (Redfern, Azzu, & Binamira, 2012).

Rice cultivation in Indonesia generally takes place during two periods throughout the year—a wet season planting and a dry season planting. The larger wet season planting typically occurs between late October and early December, with planting in more northerly Sumatra generally happening before Java (Naylor, Battisti, Vimont, Falcon, & Burke, 2007). This planting precedes the peak of the monsoon rains, which usually occur in December and January. The smaller dry season planting generally takes place in April and May. For both seasons, harvesting takes place roughly 3–4 months following planting (Falcon, Naylor, Smith, Burke, & McCullough, 2004). Most rice crops in Indonesia are irrigated, though many irrigation systems are rain-fed or run-of-the-river, and require rainfall for their operation (Naylor et al., 2007). However, lack of investment in irrigation infrastructure has reduced the reliability of many such systems, making adequate rainfall important for ensuring crop growth (Simatupang & Timmer, 2008).

Indonesia’s climate is affected by El Niño-Southern Oscillation fluctuations in sea surface temperature and pressure, which produce variation in precipitation timing and volume. These phenomena in turn affect rice production. During warmer sea surface temperature (El Niño) years, monsoon rainfall is delayed by up to two months, which in turn delays rice plantings as farmers wait for enough rainfall to sufficiently moisten the soil in order to have a successful planting (Falcon et al., 2004; Naylor, Falcon, Rochberg, & Wada, 2001). While rice production increases somewhat later in the year, dry season production is often delayed as a result of the delay in wet season production, and production increases later in the growing year are generally insufficient to compensate for losses as a result of rainfall shortages. La Niña years display the opposite pattern, with low sea surface temperatures associated with above average rice plantings earlier in the September-December period (Naylor et al., 2001).

This research finds that changes in overall rice production as a result of rainfall variability stem primarily from changes in the amount of land devoted to growing rice, and not to yields (Falcon et al., 2004). This is confirmed by more recent findings suggesting that overall Indonesian rice yields have largely stagnated during the past two decades (Ray et al., 2012), which is attributed both to precipitation as well as temperature variability (Ray, Gerber, MacDonald, & West, 2015). Overall, increases in yearly rainfall from long-term averages are associated with small, but significant increases in Indonesian rice production. A 10% annual precipitation increase is associated with a 0.4% increase in rice produced (Levine & Yang, 2014). Projections of future climate conditions suggest that there is likely to be a greater frequency of years with delayed monsoon onset which in turn may result in lower rice production (Naylor et al., 2007).

Shortfalls in rice production may have important implications for fertility outcomes through nutritional mechanisms. As noted by Naylor et al. (2007), delays in monsoon onset extend the “hungry season” between the most recent dry season harvest and the wet season harvest. Birth weights are significantly higher in Indonesia for children born immediately following the main rice harvest than children born at other times of the year (Yamauchi, 2012). Based on Indonesian data from 1999 and 2000, monsoon onset delays, but not reductions in post-onset precipitation volume are significantly associated with reductions in food expenditures among rural households (Skoufias, Katayama, & Essama-Nssah, 2012).

Despite previous experiences with crop shortfalls, public policies aimed at mitigating the effects of delays in harvest or crop failure on hunger are inadequate to prevent adverse nutritional impacts. Indonesia has a government-sponsored rice distribution program designed to target households affected by food shortages. The current program, Raskin, is a successor to the OPK program initially launched after the 1998 economic crisis (Sumarto, Suryahadi, & Widyanti, 2005; World Bank, 2012). However, this program has been regarded as ineffective at reaching the poorest and most vulnerable households, in large part due to the effects of corruption, with many of the benefits siphoned off by wealthier households or government officials (Olken, 2006; World Bank, 2012).

Related to the nutritional impacts of delays in rice production are the financial consequences associated with changes in rice prices and agricultural wages. According to data from the Indonesian National Socio-Economic Survey, rice production is undertaken predominantly in rural areas among poorer households (McCulloch, 2008). However, poor households are also large consumers of rice as well as beneficiaries of income from rice sales; thus, relatively few poor households benefit from increases in rice prices as they tend to spend a greater proportion of their income on rice (McCulloch, 2008). Moreover, poorer agricultural households in Indonesia are not as diversified as wealthier households, receiving less income from non-agricultural sources (Booth, 2002). Additionally, McCulloch (2008) notes that agricultural wages tend to decrease as rice prices increase, suggesting that a scarcity of production and strong competition for work among farm laborers drives down wage rates.

4.2 Family Planning in Indonesia

Couples in Indonesia have ample opportunities to control their fertility due to the existence of a strong national family planning program. Indonesia’s National Family Planning Coordinating Board (BKKBN) has been highly successful since its inception in the 1960s at expanding contraceptive access and is widely seen as a model for family planning programs worldwide (Hull, 2007). Research examining BKKBN shows that family planning services provided through the program have facilitated declines in fertility rates (Angeles et al., 2005; Gertler & Molyneaux, 1994). However, this achievement masks the fact that over the past two decades, changes have been much more modest. Contraceptive use among currently married women has slowly increased from 55% in 1994 to 62% in 2012, while fertility rates have only fallen slightly, from a total fertility rate (average number of children born per woman) of 2.9 in 1994 to 2.6 in 2012 (Statistics Indonesia, National Population and Family Planning Board, Ministry of Health, & ICF International, 2013). Although these recent changes are small, they are arguably somewhat of an achievement, given the effects of Indonesia’s severe economic crisis in 1998, which raised fears that an increase in poverty and cutbacks to government services would reduce contraceptive use and lead to a rebound in fertility, concerns that were later proved to be largely unfounded (Hull, 2007; Schoemaker, 2005). According to the most recent Indonesian Demographic and Health Survey, family planning services are widely available throughout the country, including in rural areas, through a mix of public and private providers (Statistics Indonesia et al., 2013).

Drawing on the frameworks and research discussed above, we examine how the effects of climate shocks are associated with fertility intentions, family planning use, and births in Indonesia. The combination of potential nutritional shortfalls as well as changes in household income and expenditures suggest that agricultural, rice-dependent households are the most likely to be most affected by climate shocks, and in turn, are most likely to shift their fertility behaviors as a result of climate shocks. Indeed, this is partly what we find; women in agricultural households have lower fertility intentions and use family planning at higher rates after experiencing long periods of higher-than-average temperatures, and also are less likely to give birth after experiencing delays in monsoon onset during the previous year. However, we also find effects on fertility behaviors among non-agricultural households, with reductions in family planning use and births following short-term temperature and monsoon shocks.

5. Data and Methods

We use all five publicly-available waves of the Indonesian Family Life Survey (IFLS) for our analysis (Frankenberg & Karoly, 1995; Frankenberg & Thomas, 2000; Strauss et al., 2004; Strauss, Witoelar, & Sikoki, 2016; Strauss, Witoelar, Sikoki, & Wattie, 2009). IFLS is a longitudinal household survey conducted in Indonesia, with waves in 1993/94, 1997/98, 2000, 2007/08, and 2014/15.[1] IFLS contains questions on fertility intentions, family planning use, and births, as well as on household expenditures, agricultural production, education, health, and livelihoods, among other topics. IFLS was designed as a cluster-randomized sample, with households nested in approximately 320 communities spread across 16 of Indonesia's 34 provinces, largely in western and central Indonesia.[2] These provinces contained approximately 81% of the country's population as of the most recent census (Statistics Indonesia, 2011). Ever-married women of reproductive age (15–49) are asked to answer various questions on reproductive health. IFLS tracks all household members in subsequent rounds, and is known for having very low attrition (Thomas et al., 2012). [3]

We supplemented the IFLS survey data with the Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA-2) data from NASA, which provides global estimates of mean temperature and total precipitation for 0.5° x 0.625° cells at a daily time scale from 1981–2015 (Rienecker et al., 2011). This dataset is desirable to use because it

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[1] A sixth wave of IFLS, conducted on a subsample of respondents in 1998 in response to the Indonesian economic crisis, is not publicly available.

[2] Indonesia's provincial boundaries have changed within the span of the survey, with the net creation of seven new provinces since 1999. In Waves 1 and 2, IFLS communities comprised 13 of the then-27 provinces in the country.

[3] According to the 2012 Indonesia DHS survey, roughly 7.5% of women 18–49 in Indonesia married before age 15, putting them outside the range of the IFLS fertility module. However, the potential bias this presents is small, and tempered by the fact that child marriage rates are higher in rural provinces not included in IFLS, and that child marriage rates have declined markedly during the span of IFLS (Malé & Wodon, 2016).

covers the entirety of the IFLS survey period (and earlier), includes information on both temperature and precipitation, and contains daily estimates, which is necessary to generate a variable for monsoon onset delay (discussed below). We obtained GPS coordinates of 303 original IFLS study communities (17 additional communities were excluded due to missing data) from RAND Corporation, which conducts the survey. [4] These points show the exact locations of communities and are not offset (as in the Demographic and Health Surveys). We then matched the grid cells of the MERRA-2 data to the 303 IFLS community GPS points in order to create a community-level dataset of climate conditions over time.

We generated three measures of climate shocks to test in our models. First, we used mean surface temperatures to create monthly temperature averages. To do this, we collapsed daily mean temperature data to a monthly level, and created 12- and 60-month running means of monthly mean temperatures for the months immediately prior to the IFLS interview (but excluding the interview month itself). Second, we generated running means of precipitation data using the same protocol. Third, following Naylor et al. (2007) we generated delays for monsoon onset by calculating the number of days after August 1 until cumulative rainfall reached 20 cm. The 20 cm value was chosen because it represents the approximate amount of rainfall necessary in order for wet season rice planting to take place. Thus, monsoon onset delay serves as a measure of relative rainfall *timing*, rather than rainfall volume. We generated monsoon delay values for the previous monsoon year (August 1-July 31), and the average of the previous five monsoon years.

After generating 12- and 60-month averages, we transformed these values to z-scores by community, using community-level averages from 1981–2015. We elected to transform data into z-scores, which are equivalent to standardized climate anomalies, as they are arguably more effective at illustrating deviations from expected patterns and can better predict other social responses to climate shocks, such as migration (Gray & Wise, 2016). Given strong correlation between precipitation volume and monsoon onset delay, most of our model specifications are run without the precipitation volume variable, as monsoon onset delay is more established in the literature as a predictor of rice production (Korkeala, Newhouse, & Duarte, 2009; Naylor et al., 2007; Skoufias et al., 2012). These climate variables were then linked to the month and year that the survey was administered to an individual, thus generating climate variables unique to each community by month pairing. For example, if two members of the same community were interviewed during two consecutive months, the values used in their climate variable calculations would differ by one month. Figure 2 visually depicts how we created the climate shock variables.

In the regressions below, we included standard demographic indicators such as age at time of survey, level of education, and number of previous live births (parity). As we hypothesize that climate shocks may impact fertility intentions, family planning use, and births through changes in economic and livelihood processes, we include indicators for susceptibility to these shocks. We generated an asset quartile indicator using the sum of assets from the

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[4] IFLS aims to track all individuals who move between survey waves, even those who move to communities outside the IFLS survey area. As non-IFLS communities are not geocoded, we were unable to include these individuals in our sample.

household as well as an indicator for whether household members operated any farm businesses. [5] Table 1 presents summary statistics for the model variables.

Using the IFLS reproductive health modules, we generated three dichotomous outcome variables. Regarding fertility intentions, women were asked whether they wished to have another child in the future (yes/no). Regarding family planning use, women were asked whether they currently use any form of contraception (yes/no). Regarding births, we generated an indicator variable denoting if a woman had a live birth in the two complete calendar years following the survey. We opted to use data from the following two calendar years because IFLS data on births contains high levels of missing values of birth month (up to 22% of all births, depending on the wave). Calendar years were also selected in part because climate shocks close to the survey are not likely to immediately affect fertility due to the lag between conception and birth. Using calendar years provides an average of six months between when the survey is conducted and when births are recorded. A two-year period was selected in order to provide sufficient time for women to conceive and give birth after experiencing a climate shock, but not so long as to be unlikely to be affected by the shock. We selected a dichotomous indicator for births (rather than number of births) to avoid complications associated with women who had multiple births from a single pregnancy event. We also excluded pregnancy outcomes recorded as stillbirths or miscarriages due to concerns about under- or misreporting of these events.[6] For all analyses, we restrict our sample to currently married women of reproductive age who reported the ability to conceive. We also restrict our sample to women who were resident in the community at least one calendar year prior to the survey date, as they were definitively exposed to the climate shock, or two years for the case of longer-term shocks. [7]

Using the household survey and community-level climate data described above, we created a woman-wave dataset using predictor and outcome data from the same survey wave. As a result, for family planning use and fertility intentions we used outcomes from all five surveys based on predictors from the same survey wave. The births models are slightly different, as we used births occurring after the date of the household survey. For these models, birth data were taken from the pregnancy history module of the subsequent survey round and combined with predictors from the previous wave. Thus, for these models we used demographic and livelihoods data from Waves 1–4 and paired each wave with birth data from the subsequent wave (Waves 2–5). As a woman needed to be present in at least two consecutive rounds of the survey, and as only four waves of predictor data are used, the

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[5] A small number of households have missing data for a control variable. For these individuals, we imputed the mean community-level value for the variable and included a binary indicator of missingness in the regression models (not shown).

[6] Stillbirths and miscarriages make up roughly 10–13% of recorded IFLS pregnancy outcomes, depending on the survey wave, though many miscarriages are not reported as such during the first trimester. Moreover, IFLS does not include an option for induced abortion, which is largely illegal in Indonesia. Despite this, estimated abortion rates in Southeast Asia since 1990 have been broadly similar to global averages, suggesting that illegal abortion regularly takes place in the country (Sedgh et al., 2016). As a consequence, some induced abortions may be reported as miscarriages or stillbirths in IFLS.

[7] For the 1–60 month shocks, we restricted models to women who were resident at least two calendar years prior to the survey date. We opted not to restrict models to women present for at least five calendar years because of how IFLS asks questions regarding migration, where migrations after age 12 are known, but migrations prior to that age are not recorded. Thus, for younger women of reproductive age, it is not possible to know whether they were fully exposed to a five-year shock, and eliminating these women would bias the analysis. Thus, restricting eligibility to presence of at least two calendar years in the community allows a 15-year old who had not migrated since age 12 to be included in the analysis.

births models have a smaller sample size than the fertility intentions and family planning models.

We use a series of logistic fixed effects regression models to test for climate effects on our three outcome variables of interest. The logistic regression model is structured such that the log odds of the outcome are being measured with reference to the predictors (Cameron & Trivedi, 2005).

$$\log\left(\frac{\pi_{bit}}{\pi_{nit}}\right) = \alpha_{bt} + \alpha_{bc} + \beta_b X_{it} + \varepsilon_i$$

Where π_{bit} represents a fertility-related outcome (intention for another child, currently using family planning, or gave birth in the two calendar years following the survey), π_{nit} represents the odds of the outcome not occurring, α_{bt} and α_{bc} represent time and community fixed effects respectively, X_{it} is a vector of individual-level time-varying predictors used to predict birth outcomes with coefficient vector β_b, and ε_i represents individual-level error. Model results below report odds ratios, which may be interpreted as the multiplicative effect of a one unit change in the independent variable on the odds of a particular outcome occurring.

In order to account for unobserved heterogeneity between communities and over time, we included community fixed effects and indicators for the survey wave. As some of the communities are spatially clustered, a number of them are located within the same MERRA-2 pixel, and thus have the same temperature and precipitation values. To account for this, we clustered standard errors by the 107 MERRA-2 pixels that the IFLS communities fell into in order to control for correlation between communities that experienced similar shocks.

In addition to fertility-related outcomes, we also explore how expenditure patterns vary following climate shocks to examine these changes may help to explain shifts in fertility dynamics. To highlight the potential effects of nutrition, we constructed a variable representing household spending on rice within the seven days prior to the survey (the period examined in IFLS). Separately, we constructed a variable for the value of all food purchases (excluding beverages, alcohol, and tobacco) in the same seven day period. In both cases, these variables include the value of items purchased as well as the market value of self-produced items consumed at home in the week prior to the survey. Additionally, to examine the effects of climate shocks on non-food expenditures, we generated a measure of consumption within the previous 30 days of utilities, transportation, household goods, and other miscellaneous expenditures (data available from Waves 2–5 only). All values are adjusted by a consumer price index (World Bank, 2015), divided by the number of household residents, and log-transformed to account for the non-normality in the distribution of spending across households, generating log per capita consumption. As we believe that these small slices of consumption behavior are most likely to be affected by recent climate shocks, we only present models and interactions for shocks occurring 1–12 months prior to the survey. Expenditure models were restricted to households with a female of reproductive age to improve comparability to the fertility-related models. As before, we also include wave and community fixed effects and cluster for correlation within MERRA-2 pixels.

6. Results

We present evidence of climate linkages with fertility-related outcomes in Table 2. Delayed monsoon onset in the year prior to the survey is significantly associated with lower odds (OR=0.904; p=0.011) of using contraception at the time of the survey. Despite these results, we find no significant association between our climate variables and births in the two calendar years following the survey. Control variables are generally associated with outcomes in the directions expected. Age and parity play significant roles in predicting all outcomes. Younger women are more likely to want additional children, use family planning, and give birth. Similarly, women with many births are more likely to use family planning and less likely to give birth. Better educated women are less likely to want additional children (although the coefficient for tertiary and above is not statistically significant), and are also substantially more likely to use family planning compared to women with no formal education.[8]

In Table 3, we provide alternative model specifications showing extended duration of temperature and monsoon onset delays (1–60 months prior to the survey date) as well as a 1–12 month model including an indicator for precipitation volume. In the 1–60 month shock model, monsoon shocks are no longer significant, rather, a one standard deviation increase in community temperatures reduces the odds of wanting another child by more than half (OR=0.443; p=0.011). However, a similarly significant effect is not found for family planning use or births. Including precipitation has no material effect on any of the models.

To better understand the effect of climate variables on our outcomes of interest, we add interaction terms between our climate variables and three of our categorical predictors (one at a time) to assess the differential effect of climate shocks on fertility behaviors for individuals with farm businesses, different levels of education, and different levels of wealth. Joint tests are chi-squared tests of whether the interaction terms are different from zero. Table 4 shows that women in households with farm businesses are marginally less likely to use family planning and also less likely to give birth after a short-term monsoon shock, while women without farm businesses experienced no significant effects on births. When examining medium-term shocks, temperature anomalies are more important predictors of fertility behavior, particularly among women in farm households. For instance, women exposed to a 1 standard deviation increase in the mean temperature in the five years preceding the survey have twice the odds of using family planning and roughly one quarter the odds of desiring another child if they are in a household with a farm business. To summarize, less educated women respond to medium-term high temperature shocks by increasing family planning use and/or by reducing fertility intentions, whereas wealthier, better educated women are less likely to use family planning after short-term monsoon shocks.

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[8] These results are also robust to the inclusion of a control variable for whether a village has a government-sponsored midwife, a policy rolled out in the 1990s in order to improve maternal and child health outcomes with some success (Frankenberg, Suriastini, & Thomas, 2005).

We now turn to the effects of climate shocks on household expenditures (Table 5). When examining the value of recent rice and food expenditures, climate variables have no significant effects. However, short-term monsoon onset delays are associated with lower non-food expenditures. When examining interactions between climate shocks, demographic characteristics, and expenditure patterns, we find that monsoon onset delays have different effects on expenditures among particular subgroups (Table 6). Monsoon onset delays are associated with lower food and non-food expenditures in non-farm settings, as well as among women with tertiary or greater education. By contrast, high temperature shocks are associated with decreases in rice spending among households with farm businesses, but increases in non-food expenditures.

7. Discussion

Our study expands earlier research on fertility responses to environmental shocks in several ways. First, we combine high-resolution climate data with household panel survey data to provide estimates over a 22-year period, an improvement on many existing studies that use shorter time spans and lower levels of spatial resolution. Second, we incorporate a continuous measure of climate shock exposure through the use of temperature and monsoon onset delay z-scores, providing estimates of effects that span beyond whether or not households experienced crop losses. Third, we present one of the relatively few studies that contain estimates for how intended fertility and family planning use respond to environmental shocks, providing additional insights into how various determinants of fertility change in addition to fertility itself. These innovations represent an important contribution to the environmental fertility literature by highlighting dynamics over several decades in a relatively low fertility setting, an important complement to work already published on post-disaster fertility (J. Davis, 2017; Nobles et al., 2015) and climate impacts on fertility behavior in poorer and higher fertility settings (Alam & Pörtner, 2018).

Combining household panel data over more than two decades with high-resolution climate data, we find that recent delays in monsoon onset are associated with an increased intention to have another child and reduced family planning use, but have no effect on births. Medium-term temperature shocks are associated with reductions in fertility intentions. Results from the interactions models depict two clusters of responses to climate shocks. First, delays in monsoon onset during the past year are associated with higher fertility intentions and lower family planning use, particularly among wealthier, more educated women. Second, long periods of above average temperatures are associated with sharply lower fertility intentions and greater family planning use, particularly among poorer, less educated women and those in farm households. Short-term temperature shocks had minimal effect on fertility behaviors. Together, these patterns suggest divergent fertility responses to climate shocks, depending on household endowments.

The pathways through which these responses occur is not always clear, however. Table 6 shows that households without a farm business were most impacted by the delay in monsoon onset, as illustrated by decreases in their food and non-food expenditures, which may have motivated an increase in births. These households may intend for more children in order to compensate for worsening living conditions and potentially provide income for the household in the future (a quality-quantity tradeoff), in line with earlier research which found increases in Indonesian fertility following unemployment shocks (Kim & Prskawetz, 2010). By contrast, poorer agricultural households cope with temperature shocks by increasing the use of capital (such as for educational expenses or migration) to reduce household vulnerability, rather than by increasing fertility, as highlighted by the strong increase in non-farm expenditures among such households following temperature anomalies.

While the effects of climate shocks on births are weaker than those for fertility intentions and family planning use, there is an important commonality between the responses from non-farm and farm households to short-term monsoon shocks, which is that births were lower than would be expected in both settings, given changes in fertility intentions and family planning use. Despite an observed reduction family planning use in non-farm settings (as well as among wealthier and better educated women), these groups did not observe a statistically significant increase in births in the interaction models. However, despite no significant effect on fertility intentions and a marginally significant drop on family planning use, births fell among farm households following delayed monsoon onset during the previous year. These patterns suggest that there may be other factors preventing live births.

Changes in nutritional intake may offer a partial explanation. Among non-farm households, food expenditures were substantially reduced in response to short-term monsoon onset delays, suggesting that some mothers may have skipped meals and/or substituted for cheaper foods following these shocks. Among farm households, the pattern is a bit trickier to decipher as spending on rice increased following monsoon onset delays, while food and non-food expenditures did not change significantly. Rice expenditures as a share of households' food spending is more than three times greater among households with a farm business as compared to households without a farm business in our sample. One possibility is that given its importance in the diet, households may have simply consumed similar quantities of rice, but at higher prices to adjust for monsoon-related price effects, without reducing spending in other categories. As these data are at the household level, we are unable to detect intrahousehold changes in nutritional allocation, which may be important, particularly between mothers and young children (Block et al., 2004).

An additional potential explanation for the gap between fertility intentions/family planning use and live births that we observe arises from previous research exploring environmental influences on fertility processes. Studies in various climates have linked higher temperatures with elevated risks of stillbirth (Auger et al., 2017; Basu et al., 2016; Strand et al., 2012), while heat stress may also reduce conceptions and subsequently births (Barreca et al., 2018). Additionally, the effects of climate shocks on livelihood and expenditure patterns may have increased maternal stress levels, affecting the probability of a live birth, although the health-related variables in IFLS are not sufficiently refined to allow us to test this hypothesis. Thus, while not conclusive, there is reason to believe that changes in both nutrition and stress may have played some role in influencing the gap between fertility intentions/family planning use and live births observed in both farm and non-farm households.

Based on our findings, we do not believe that a decrease in reported family planning use after monsoon onset delays is due to supply constraints, as has been reported in some settings after natural disasters (Behrman & Weitzman, 2016; Carballo et al., 2005; Hapsari et al., 2009). Recent Indonesian Demographic and Health Survey data shows high levels of family planning use throughout the country (Statistics Indonesia et al., 2013), and we have no evidence supporting the idea that rainfall delays affected family planning supplies. Moreover, we believe that the patterns of higher fertility intentions observed here are distinct from patterns observed in some studies noting that fertility may be stimulated by high levels of child mortality in a disaster, which is not the case in our sample (Carta et al., 2012; Nobles et al., 2015; Qin et al., 2009).

There are several limitations of our analysis. Because we linked climate data to specific individuals, were unable to include women who move outside the original geolocated IFLS communities.[9] Additionally, because of concerns about under- or misreporting, we opted not to use IFLS data on stillbirths and miscarriages, which are important fertility outcomes in and of themselves and can be influenced by environmental shocks (Basu et al., 2016; Strand et al., 2012). Finally, IFLS data on consumption are limited to either 7- or 30-day periods, making it difficult to understand household socioeconomic responses following climate shock exposure and their relationship to fertility.

As climate change is likely to substantially affect livelihoods throughout the world in the coming decades, with implications for fertility behaviors, we believe that our analysis could be extended in several ways. We found strong effects of climate shocks on fertility intentions and family planning use in non-farm populations, yet there is relatively little research in Indonesia exploring the mechanisms linking climate shocks with economic and livelihood impacts among individuals not dependent on agriculture or natural resource extraction for their livelihoods, despite the country's rapid urban growth. More research on how urban livelihoods, fertility behaviors, and climate shocks interact would be welcome. Additionally, while Indonesia is a much studied setting in part because of the high quality of IFLS data, we recognize that the pattern of fertility-related responses to climate shocks is likely to vary considerably depending on local contexts. Studies exploring climate-fertility linkages in other regions such as South Asia and sub-Saharan Africa that combine household survey and spatial data are needed. Finally, as previous studies have shown, migration sometimes serves as a coping mechanism for individuals experiencing climate shocks (Gray & Wise, 2016; S. Henry et al., 2004). Moreover, other research has examined the fertility behavior of women who have previously migrated, sometimes finding differences between the fertility behavior of migrants and non-migrants (Jensen & Ahlburg, 2004; Lindstrom & Saucedo, 2002). Research that seeks to combine these literatures may find new and unexpected patterns of fertility among individuals migrating after climate disturbances relative to other types of migrants, allowing for more holistic understandings of demographic responses to climate change.

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[9] A robustness check found that neither temperature nor monsoon onset delay, at either 12- or 60-month intervals, has a statistically significant effect ($p < 0.05$) on appearing in the subsequent survey wave, suggesting that climate does not play a meaningful role in attrition.

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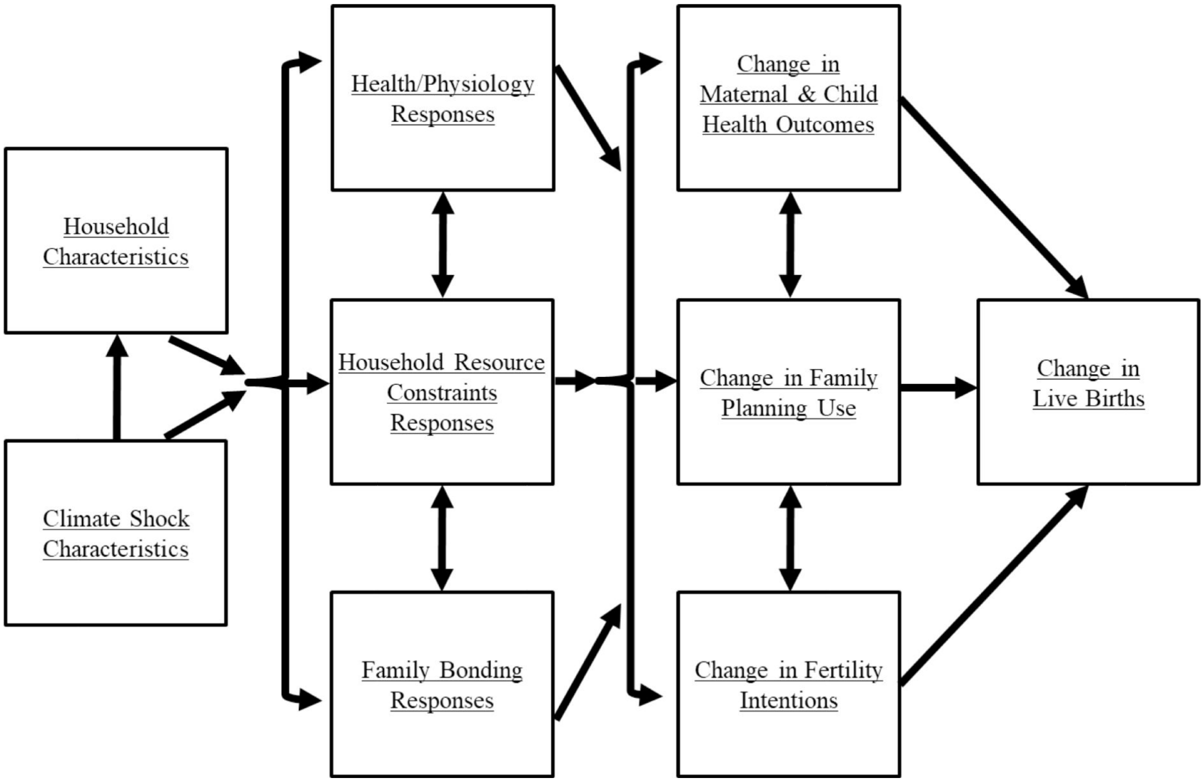

Figure 1.

Conceptual model depicting pathways between household and climate shock characteristics, household- and individual-level responses, and fertility-related outcomes

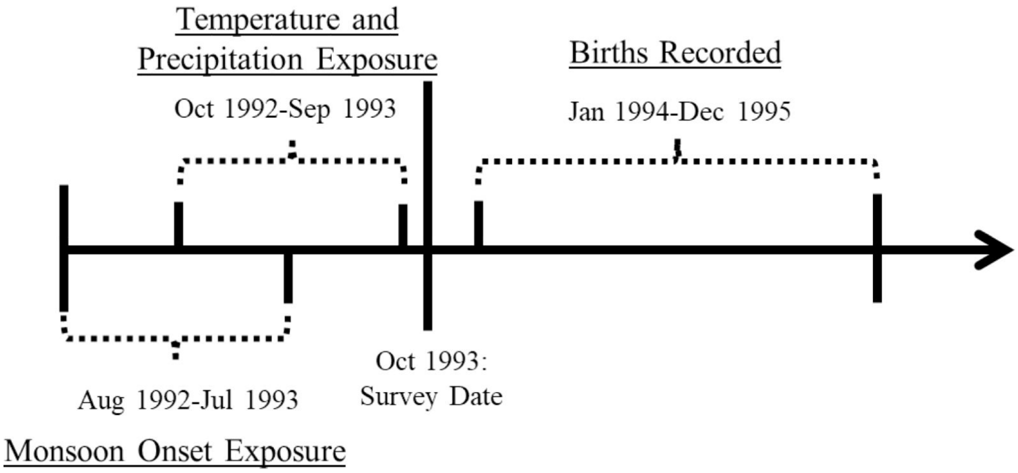

Figure 2.

Timeline showing 12 month periods over which temperature, precipitation, and monsoon onset delay predictors were calculated for survey conducted in October 1993. Births are recorded in the two calendar years following the survey.

Table 1.

Summary statistics for fertility-related models

Outcome Variables[a]

Variable	Unit	Mean	Std. Dev.	Definition
Fertility Intentions	0/1	0.50	0.50	Woman intends to have another child sometime in the future (N=20,390)
Family Planning Use	0/1	0.62	0.49	Currently uses family planning method as of survey date (N=20,357)
Births	0/1	0.16	0.37	Had live birth in the two calendar years following survey (N=14,304)

Predictor Variables[b]

Variable	Unit	Mean	Std. Dev.	Definition
				Demographic Variables
Age	Years	32.24	7.56	Age on survey date
No Education[c]	0/1	0.07	0.25	Respondent reports no formal educational attainment
Primary Education	0/1	0.46	0.50	Highest educational attainment is some or completed primary school
Secondary Education	0/1	0.20	0.40	Highest educational attainment is some or completed secondary school
Tertiary Education	0/1	0.27	0.45	Highest educational attainment is greater than secondary school completion
Parity	# Live Births	2.49	1.81	Number of live births as of survey date
				Socioeconomic Variables
Overall Assets[d]	Adj. IDR (‘000)	133000	355000	Sum of household, farm, and nonfarm assets in thousands of IDR
Farm Business	0/1	0.40	0.49	Member of household has a farm business
				Climate Variables
Temperature (1–12)	z-score	−0.053	0.286	Z-score of mean daily temperature measured for 1–12 month periods
Precipitation (1–12)	z-score	−0.007	0.184	Z-score of mean daily precipitation measured for 1–12 month periods
Monsoon Onset Delay (1 year)	z-score	−0.211	1.105	Z-score of number of days after Aug 1 when cumulative rainfall reaches 20 cm averaged using a one-year period
Temperature (1–60)	z-score	0.027	0.148	Z-score of mean daily temperature measured for 1–60 month periods
Precipitation (1–60)	z-score	−0.068	0.219	Z-score of mean daily precipitation measured for 1–60 month periods
Monsoon Onset Delay (5 year)	z-score	−0.100	0.367	Z-score of number of days after Aug 1 when cumulative rainfall reaches 20 cm averaged using a five-year period

Observations by Wave: 3,314 (Wave 1); 3,662 (Wave 2); 4,230 (Wave 3); 4,503 (Wave 4); 4,681 (Wave 5)

Notes

[a] All models limited to currently married women of reproductive age (15–49) able to conceive who were exposed to a shock (in community at least one year before survey)

[b] Summary statistics for predictor variables refer to observations eligible for fertility intentions models (greatest sample size of the three outcome variables)

[c] Used as reference category in regression models

[d] IDR=Indonesian Rupiah. Asset values are adjusted for inflation index based on 2010 IDR value. Quartiles of the natural log of asset values generated by wave are used in models in Tables 2–6

Table 2.

Primary specifications of climate on fertility intentions, family planning use, and births

Odds ratios presented with standard errors (in parentheses) clustered by pixel

	Fertility Intentions	Family Planning	Births
Temperature z-Score	0.916	0.979	0.769
	(0.192)	(0.134)	(0.172)
Monsoon z-Score	1.079	0.904*	0.976
	(0.0513)	(0.0359)	(0.0417)
Age	0.900**	0.966**	0.913**
	(0.00426)	(0.00313)	(0.00504)
Primary Education	0.714^{+}	1.895**	0.981
	(0.135)	(0.184)	(0.115)
Secondary Education	0.647*	2.061**	1.012
	(0.130)	(0.231)	(0.126)
Tertiary^{+} Education	0.820	1.782**	1.283^{+}
	(0.167)	(0.203)	(0.165)
Parity	0.409**	1.332**	0.902**
	(0.0275)	(0.0316)	(0.0240)
Assets Q2	0.997	1.061	1.037
	(0.0571)	(0.0486)	(0.0812)
Assets Q3	0.999	1.007	1.074
	(0.0533)	(0.0492)	(0.0677)
Assets Q4	0.980	1.084	0.937
	(0.0691)	(0.0581)	(0.0743)
Farm Business	1.164**	0.947	0.984
	(0.0630)	(0.0397)	(0.0677)
Wave 2	0.721**	1.232**	0.945
	(0.0520)	(0.0792)	(0.0824)
Wave 3	0.730**	1.271**	0.785**
	(0.0689)	(0.0859)	(0.0555)
Wave 4	0.476**	2.213**	0.720*
	(0.0689)	(0.259)	(0.0943)
Wave 5	0.732*	1.919**	-
	(0.101)	(0.232)	-
Sample Size	**20,378**	**20,353**	**14,126**

Notes:

Q1 assets and Wave 1 are reference categories

Community fixed effects and indicators for missingness included but not shown

Models present information from all five survey waves except births (Waves 1–4)

[+] $p<.10$

[*] $p<.05$

[**] $p<.01$

Table 3.

Alternative specifications of climate on fertility intentions, family planning use, and births

Odds ratios presented with standard errors (in parentheses) clustered by pixel

	1–60 Month Temperature and Monsoon Intervals		
	Fertility Intentions	**Family Planning**	**Births**
Temperature z-Score	0.443*	1.266	0.829
	(0.141)	(0.387)	(0.349)
Monsoon z-Score	1.233	0.860	0.867
	(0.163)	(0.0933)	(0.106)
Sample Size	**19,834**	**19,809**	**13,715**
	1–12 Month Intervals Including Precipitation		
	Fertility Intentions	**Family Planning**	**Births**
Temperature z-Score	0.916	0.979	0.767
	(0.192)	(0.134)	(0.173)
Monsoon z-Score	1.008	0.904*	0.977
	(0.0515)	(0.0359)	(0.0414)
Precipitation z-Score	1.029	0.963	0.940
	(0.129)	(0.0950)	(0.110)
Sample Size	**20,378**	**20,353**	**14,126**

Notes:

Controls, wave and community fixed effects, and indicators for missingness included but not shown

Models present information from all five survey waves except births (Waves 1–4)

+p<.10

*p<.05

**p<.01

Table 4.

Fertility outcome interactions between climate and socioeconomic variables

Table shows odds ratios with significance of interaction and chi square joint test of interactions of interaction terms below

	1–12 Month Temperature and Monsoon Intervals			1–60 Month Temperature and Monsoon Intervals		
Farm Business Interactions	**Fertility Intentions**	**Family Planning**	**Births**	**Fertility Intentions**	**Family Planning**	**Births**
Farm Business: Temperature	0.739	1.248	0.931	0.260^{**}	2.335^{*}	0.697
Farm Business: Monsoon	1.064	0.920^{+}	0.889^{*}	1.127	0.779^{+}	0.806
No Farm Business: Temperature	1.027	0.851	0.647^{*}	0.605^{+}	0.811	0.907
No Farm Business: Monsoon	1.077	0.902^{**}	1.028	1.256^{+}	0.955	0.894
Joint Test of Interactions	**5.18^{+}**	**12.84^{**}**	**8.33^{*}**	**14.11^{**}**	**15.81^{**}**	**0.93**
Assets Interactions	**Fertility Intentions**	**Family Planning**	**Births**	**Fertility Intentions**	**Family Planning**	**Births**
Q1 Assets: Temperature	0.991	0.984	0.815	0.503	1.629	0.754
Q1 Assets: Monsoon	1.054	0.963	1.010	1.188	0.889	0.855
Q2 Assets: Temperature	0.754	1.103	0.705	0.257^{**}	1.584	0.373^{+}
Q2 Assets: Monsoon	1.033	0.925	0.895^{*}	1.232	0.813	0.884
Q3 Assets: Temperature	0.954	1.031	0.830	0.408^{*}	1.242	0.849
Q3 Assets: Monsoon	1.074	0.890^{**}	0.987	1.336^{+}	0.860	0.923
Q4 Assets: Temperature	1.000	0.767	0.687	0.692	0.729	2.384
Q4 Assets: Monsoon	1.159^{**}	0.830^{**}	1.013	1.202	0.878	0.777
Joint Test of Interactions	**11.78^{+}**	**22.36^{**}**	**9.48**	**6.45**	**12.08^{+}**	**10.95^{+}**
Education Interactions	**Fertility Intentions**	**Family Planning**	**Births**	**Fertility Intentions**	**Family Planning**	**Births**
No Education: Temperature	0.375^{*}	1.010	1.420	0.287	8.172^{**}	0.411
No Education: Monsoon	1.019	1.023	0.911	0.909	0.824	0.577^{+}
Primary Education: Temperature	0.932	1.121	0.684	0.369^{*}	1.914^{*}	0.571
Primary Education: Monsoon	1.068	0.938	0.958	1.270^{+}	0.863	0.887
Secondary Education: Temperature	0.970	1.099	0.667	0.421^{*}	1.734^{+}	1.057
Secondary Education: Monsoon	1.147^{*}	0.900^{*}	1.064	1.465^{**}	0.847	1.032
Tertiary^{+} Education: Temperature	1.032	0.762	0.931	0.569	0.474^{*}	1.287

Tertiary^{+} Education: Monsoon	1.086	0.803**	0.959	1.154	0.899**	0.850
Joint Test of Interactions	**9.69**	**39.78****	**7.94**	**4.27**	**35.88****	**8.64**

Notes:

Controls, wave and community fixed effects, and indicators for missingness included but not shown

Models present information from all five survey waves except births (Waves 1–4)

$^{+}$p<.10

*p<.05

**p<.01

Table 5.
1–12 month climate effects on recent rice, food, and non-food expenditures

Ordinary least squares regression coefficients presented with pixel-corrected standard errors (in parentheses)

	Rice Expenditures	**Food Expenditures**	**Non-Food Expenditures**
Temperature z-Score	−0.472	−0.443	0.103
	(0.297)	(0.276)	(0.106)
Monsoon z-Score	0.0755	−0.0734	−0.0597 *
	(0.0675)	(0.0754)	(0.0270)
Wave 2	0.541 **	−4.753 **	–
	(0.117)	(0.381)	–
Wave 3	1.071 **	−3.472 **	0.865 **
	(0.133)	(0.328)	(0.0630)
Wave 4	0.761 **	−3.276 **	2.330 **
	(0.219)	(0.260)	(0.0921)
Wave 5	1.514 **	−2.199 **	3.067 **
	(0.230)	(0.267)	(0.0773)
Sample Size	**24,533**	**24,533**	**20,011**

Notes:

Rice and food expenditures is defined as the natural log of the total value of products purchased by any household member in the seven days prior to the survey

Non-food expenditures is defined as the natural log of the total value of non-food products purchased by any household member in the 30 days prior to the survey

Expenditures per capita values adjusted for inflation using consumer price index value based on 2010 consumer price values

All IFLS waves included, except for non-food expenditures (Waves 2–5). Community fixed effects and indicators for missingness included but not shown

Wave 1 is reference category except for non-food expenditures where Wave 2 is the reference category

+ p<.10

* p<.05

** p<.01

Table 6.

Expenditure outcome interactions between 1–12 month climate and socioeconomic variables

Table shows regression coefficients with significance of interaction and chi square joint test of interactions of interaction terms below.

Farm Business Interactions	**Rice Expenditures**	**Food Expenditures**	**Non-Food Expenditures**
Farm Business: Temperature	−0.719^{+}	−0.431	0.276**
Farm Business: Monsoon	0.136^{+}	0.126	−0.025
No Farm Business: Temperature	−0.209	−0.200	0.049
No Farm Business: Monsoon	0.020	−0.212**	−0.076*
Joint Test of Interactions	**4.71***	**16.35****	**7.79****
Assets Interactions	**Rice Expenditures**	**Food Expenditures**	**Non-Food Expenditures**
Q1 Assets: Temperature	−0.480	−0.459^{+}	0.193*
Q1 Assets: Monsoon	0.103	−0.0383	−0.0199
Q2 Assets: Temperature	−0.325	−0.387	0.333**
Q2 Assets: Monsoon	0.0825	−0.0422	−0.0382
Q3 Assets: Temperature	−0.409	−0.409	0.166
Q3 Assets: Monsoon	0.0823	−0.0203	−0.0358
Q4 Assets: Temperature	−0.503	−0.429	−0.0193
Q4 Assets: Monsoon	0.113	−0.154	−0.0338
Joint Test of Interactions	**0.16**	**0.61**	**3.92****
Education Interactions	**Rice Expenditures**	**Food Expenditures**	**Non-Food Expenditures**
No Education: Temperature	−0.032	−0.254	0.368**
No Education: Monsoon	0.196	0.118	0.0261
Primary Education: Temperature	−0.632*	−0.509^{+}	0.212*
Primary Education: Monsoon	0.089	−0.022	−0.0486^{+}
Secondary Education: Temperature	−0.423	−0.477	0.132
Secondary Education: Monsoon	0.055	−0.0731	−0.0729*
Tertiary^{+} Education: Temperature	−0.371	−0.296	−0.0950
Tertiary^{+} Education: Monsoon	0.029	−0.234**	−0.0965**
Joint Test of Interactions	**1.27**	**3.42****	**10.74****

Notes:

Rice and food expenditures is defined as the natural log of the total value of products purchased by any household member in the seven days prior to the survey

Non-food expenditures is defined as the natural log of the total value of non-food products purchased by any household member in the 30 days prior to the survey

Expenditures per capita values adjusted for inflation using consumer price index value based on 2010 consumer price values

Community and wave fixed effects included but not shown

All IFLS waves included, except for non-food consumption (Waves 2–5)

[+] $p<.10$

[*] $p<.05$

[**] $p<.01$