Global Food Security 4 (2015) 46–50

Contents lists available at ScienceDirect

Global Food Security

journal homepage: www.elsevier.com/locate/gfs

How do weather and climate influence cropping area and intensity?

Toshichika Iizumi [a,*], Navin Ramankutty [b,1]

[a] National Institute for Agro-Environmental Sciences, Tsukuba, Ibaraki 305-8604, Japan

[b] Liu Institute for Global Issues and Institute for Resources, Environment, and Sustainability, University of British Columbia, 6476 NW Marine Drive, Vancouver, BC, Canada V6T 1Z2

ARTICLE INFO

Article history:
Received 16 July 2014
Received in revised form
26 November 2014
Accepted 29 November 2014

Keywords:
Climate
Cropping intensity
Cropping area
Weather

ABSTRACT

Most studies of the influence of weather and climate on food production have examined the influence on crop yields. However, climate influences all components of crop production, includes cropping area (area planted or harvested) and cropping intensity (number of crops grown within a year). Although yield increases have predominantly contributed to increased crop production over the recent decades, increased cropping area as well as increases in cropping intensity, especially in the tropics, have played a substantial role. Therefore, we need to consider these important aspects of production to get a more complete understanding of the future impacts of climate change. This article reviews available evidence on how climate might influence these under-studied components of crop production. We also discuss how farmer decision making and technology might modulate the production response to climate. We conclude by discussing important knowledge gaps that need to be addressed in future research and potential ways for moving forward.

1. Introduction

Numerous studies have suggested that climate variability and climate change can have adverse impacts on global food production and food security. Climate variability driven by major interannual-scale climate modes, such as the El Nino Southern Oscillation, has been playing a key role by often leading to droughts and decrease in crop yields that could further result in famine in some food insecure regions (Hansen et al., 2011; Maxwel and Fitzpatrick, 2012; Iizumi et al., 2014a). For example, droughts in the United States in 2012, heat waves and associated Russian wheat embargo in 2010/2011, and droughts in Australia in 2006/2007 and 2007/2008 led to low levels of cereal stock and steep increases in food prices, likely worsening the access to affordable food for many consumers, including the poor in import-dependent countries (Food and Agriculture Organization (FAO), 2007, 2010, 2012). Ongoing climate change and associated changes in the intensity, frequency and duration of weather/climate extremes, in conjunction with growing population, dietary shift and increasing biofuel demand, are additional concerns for global food security. For example, Lobell et al. (2011) estimated that climate change from 1980 to 2008 has already reduced global production of maize by 3.8% and wheat by 5.5% relative to a counterfactual without climate change.

Such studies, however, have mainly focused on estimating the climate impact on crop yields. Annual crop production, on the other hand, consists of two other components in addition to yield: harvested area (cropping area) and number of harvests per year (cropping intensity):

$$P = \sum_{i=1}^{n} A_i \times Y_i, \quad (1)$$

where P (tonnes) is the annual production of a crop of interest in a given year, A (hectares) and Y (tonnes per hectare per harvest) is, respectively, the harvested area and yield of an intended crop for the cropping season i in a given year and n (times) is the number of completed cropping cycles within a given year. Climate variability and change, along with other factors such as demand, price, policy and technology, can influence these other components of production as well. However, our current knowledge of the climatic impacts on cropping area and intensity is limited. The latest report of the Intergovernmental Panel on Climate Change (Porter et al., 2014) reminds us about this contrasting situation across the different components of crop production. Undoubtedly a major portion of the increase in crop production in the recent past owes to vast improvements in yield. However, the contribution of cropping area expansion to increased production and export in some regions (e.g., Brazil and Argentina, Schnepf et al.,

* Corresponding author. Tel.: +81 29 838 8236; fax: +81 29 838 8199.
E-mail addresses: iizumit@affrc.go.jp (T. Iizumi), navin.ramankutty@ubc.ca (N. Ramankutty).
[1] Tel.: +1 604 827 1745; fax: +1 604 822 6966.

http://dx.doi.org/10.1016/j.gfs.2014.11.003

2001) should not be underestimated. And the contribution of cropping intensity to production and export on at least a regional level is not negligible if we consider, for instance, the reported number of annual harvests of rice in the tropics (three times, Sakamoto et al., 2006; Kotera et al., 2014; Gray et al., 2014) and that of maize in Brazil (two times, U.S. Department of Agriculture (USDA), 2007).

Therefore, the main objective of this article is to review our current understanding of how weather and climate influences cropping area and intensity, through a literature review to piece together available information on the climatic impacts on the respective components of crop production in the historical past. We further consider how farmer decision making and technology can modulate how climate influences the different components of crop production. We end our review by outlining major knowledge gaps and suggesting potential ways forward.

We chose relatively broader definitions of cropping area and cropping intensity to help cast a wide net while reviewing the literature. Cropping area considered here includes both area planted (transplanted or sown) and area harvested. Cropping intensity includes both the cultivation of the same crop multiple times within a year (multiple cropping) and cultivating different crops in a sequence within a year (crop rotation).

2. Influence of weather and climate on different components of crop production

Climate and weather influence crop production in different ways. If a weather event that is fatal to crops takes place during the crop growth period, an indicator of the impact of the fatal event may be more relevant than that of growing-season mean climate to explain variations in crop production in that year. For example, the Missouri floods of 1993 in the United States that ruined extensive amounts of cropland in American Midwest fall into this category (Rosenzweig et al., 2002). However, if no fatal weather event occurred, then growing-season mean climate would explain the major variations in crop production, as seen in various crop progress reports.

The influence of weather and climate on the different components of crop production can vary, and often happen at the same time. Further, different types of climatic extremes can affect crop production differently. This makes it difficult to understand the climatic impacts on respective components of crop production. To take an extreme hypothetical case for the purpose of illustration, let us say a landslide associated with a tropical cyclone occurs and a portion of cropland is buried in dirt; in this case harvested area would decrease, but yield in the harvestable area would not necessarily decrease. In another extreme case, an unfavorable growing-season climate, such as insufficient solar radiation associated with modulated monsoon, would lower yield, but not necessarily decrease harvested area. Both cases would result in a decreased production, but the affected component of crop production is totally different.

However, actual climatic influences are far more complex. For instance, in the Philippines, wet-season (July–December) rice yields in rainfed conditions show a strong positive correlation with rainfall at the beginning of crop growth period (thus the availability of soil moisture in the earlier growth stage) (Koide et al., 2013). But the same factor seems to influence planted (and harvested) area also. The strong dependency of planted area on accumulated rainfall around the beginning of crop duration is observed for both wet- and dry-season rice in the Philippines (Koide et al., 2013) and wet-season rice in Java, Indonesia (Naylor et al., 2001). In addition to year-to-year variations in monsoonal rainfall, varying topographic conditions and resultant variations in rainfall accumulation rate in June–July, the typical peak of monsoonal rainfall in Northeast Thailand, influences the progress of transplanting and thus the extent of transplanted area completed for a certain time interval in rainfed lowland rice cropping system in that area (Sawano et al., 2008).

An unfavorable climate, such as too wet or too dry condition, affects the cropping intensity as well. For instance, in the Vietnam Mekong Delta where triple rice cropping system is operated, the annual number of completed cropping cycles is affected by variations in the timing and areal extent of flooding in wet season as well as those of salinity intrusion in dry season (Sakamoto et al., 2006; Kotera et al., 2014). Due to the severe floods in 2000, the second-season rice (planted in the middle of dry season and harvested before the onset of wet season) in that year grown in the upstream area of this region was fully and continuously submerged immediately after the heading, leading to crop failure except for the floating rice varieties (Kotera et al., 2014). In contrast, the below-normal seasonal rainfall in 2004 reduced water availability for irrigation due to high salinity, and the dry-season rice in that year could not be harvested. Another example is a severe flood that occurred in Mekong and Chao Phraya river basins in Thailand in 2011, and ruined 14% of rice paddies, had little impact on the Thai national production, export and domestic stock of rice in that year, although it was one of the severest floods in terms of the amount of discharged water and affected number of people (FAO, 2011). In fact, the Thai annual rice production in 2011 hit a record high despite the floods due to compensating increased production during the second-season (January–June) rice (Sinpeng, 2012).

As seen above, climate evidently affects cropping area and intensity. A few studies have estimated the separate responses of production, harvested area and yield to climate (Lobell et al., 2008; Koide et al., 2013). Although the difference in these responses potentially informs about the varying climate impacts across the components of crop production, this was not analyzed. In addition, most available information is based on regional studies. A global overview of climatic impacts is available only for yield, but not for cropping area and intensity. This is mainly because a global data set of yield for different crops at subnational spatial resolution has only recently been developed (Ray et al., 2012; Iizumi et al., 2014b) while a global data set of cropping area and intensity and their changes do not yet exist.

3. Influence of farmer decision making and technology

The agronomic technology available to farmers can influence how climate influences different components of production. For instance, direct seeding, which is a more time- and labor-saving planting method than transplanting, is often used in Northeast Thailand to compensate for the delayed seedbed preparation when the monsoon onset is late (Sawano et al., 2008). Because of the photoperiod-sensitive rice varieties used in that area, the crop duration of directly-seeded rice is always shorter than that of transplanted rice and the shorter crop duration leads to lower yield. Another example is that rice varieties used – floating type or non-floating type – affect harvestable area, number of harvests and yield after floods, as reported in Kotera et al. (2014). These facts suggest the importance of knowing the technology used by farmers to improve our understanding of how climate affects respective components of crop production. It is also worth emphasizing that the technology available for farmers is linked with their economic conditions and affects their decision making on how to deal with climate risk.

Farmer decision making also greatly influences which component of crop production is affected by climate. On the one hand,