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Review

Proposing an interdisciplinary and cross-scale framework for global change and food security researches

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ABSTRACT

Food security is greatly affected by the consequences of global change, especially its impact on agriculture. Currently, global change and food system interaction is a hot issue across the scientific community. Scientists have tried to explain this interaction from different perspectives, and the issues related to this interaction can be classified as (1) crop yield and productivity in response to global change; (2) crop distribution and allocation in relation with global change; (3) general impacts on food security. However, most of the existing studies lack consistency and continuity. As food systems exist at the intersection of the coupled human and natural system, the interdisciplinary context of global change and food security requires an integrated and collaborative framework for better describing their importance and complexity. To do so, we decompose global change/food security studies into different levels in accordance with the previous mentioned issues, field, regional, and global, and categorize them into the life sciences, earth and environmental sciences, and social and sustainability sciences, respectively (yet not necessarily one to one correspondence). At the field level, long-term observations and controlled experiments in situ are important for exploring the mechanism of how global change will affect crop growth, and for considering possible adaptation methods that may maximize crop productivity. At the regional level, priority should be given to monitoring and simulating crop production (animal production and fishery are not included here) within large areas (a region or a continent). At the global level, food security studies should be based on scenario assessments to prioritize human adaptations under the changed environment, using integrated socioeconomic–biogeophysical measures.

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1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) defines a food-secured world as "a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Unfortunately, our planet is currently food insecured with approximately 1 billion people undernourished globally (FAO, 2011). According to the United Nations Population Fund (UNFPA), the world population has exceeded 7 billion in October 2011. It is estimated that by 2050, this number is likely to reach 9 billion. In addition, there will be 2 billion to 3 billion more people with three times more per capita income, consuming twice food as much as now (Clay, 2011). The situation of population growth and dietary change will result in an overwhelming demand for food in the future.

If the effects of global environment change are taken into account on food production, that challenge grows even more daunting. Climate change threatens agricultural productivity in many regions around the world (Nelson et al., 2010). On our finite planet, most of the land that is suitable for growing food is already in use, but agricultural expansion is still ongoing in some developing economies, at the large cost of natural habitat and biodiversity loss (Godfray, 2011). In contrast, some high quality farmlands are converted into non-food uses, including human settlement, animal feed, seed, bioenergy and other industrial products (Foley et al., 2011). In addition to land degradation, water shortage and other severe environmental constraints, human is facing unprecedented pressures.

In the face of challenges, food production must grow substantially as a priority for processing, distributing, preparing, and consuming food in the human society. Some studies suggest that, in the best of circumstances, current crop production is needed to be doubled again[1] to keep pace with future global food demand (Foley et al., 2011). Information about the actual and potential impacts of global change on food supply is badly needed by policymakers to plan. In this context, scientists from various fields are responsible in quantifying the complex interactions among environment, agriculture, and food security for making sustainable solutions. Can science feed the world? To date, the issue of global change and food security has been widely discussed by the scientific community.[2]

Although many endeavours were made for tackling the issue, there are still no significant interdisciplinary and collaborative efforts. Scientists often restrict themselves to their area of speciality and exchange little knowledge and information to others. With so much at stake, researches relating to this context require a collaborative framework that involves interdisciplinary integration at multiple scales. In this case, we reviewed a wide range of recent relevant studies, trying to put forward a feasible framework that can address global change and food security issue as a whole—in respect of crop productivity, crop production, and food system vulnerability. The paper is organized by discussing global change and food security issue from both a multi-system perspective and an interdisciplinary perspective in the first place. Then a cross-scale framework is proposed for carrying out specific researches at different levels and different disciplines. Outcomes at each research level should be integrated for comprehensive assessment.

2. Global change and food security: a multi-system perspective

Since the beginning of human history, humans have continuously interacted with natural systems. The interconnected human societies and global environments are called social–ecological systems (SESs) (Ostrom, 2009), or coupled human and natural systems (CHANS) (Liu et al., 2007). In particular, an agricultural system is defined as a complex, human-managed land use system intended to provide food and services for humans (Volk and Ewert, 2011). Compared to agricultural system, a food system is a little more inclusive because it includes all aspects of activities ranging from crop production to food consumption (Ericksen, 2008). It can be easily concluded that agricultural system is the essential part in the human–environment relations, without which human can hardly live and develop in their own society. While the status of food system implies a multidimensional nature of food security, including food availability, access, stability, and utilization.

As the natural environment with biophysical processes is always changing in ways beyond human's control, the term "global change" originated from the International Geosphere–Biosphere Programme (IGBP) in the mid 1980s and was used to refer to the rapid and planetary-scale changes in the earth system. In traditional global change studies, more concern is paid to biogeophysical mechanisms and processes in the natural ecosystem, such as earth system dynamics modelling and numerical simulation, global carbon cycles in response to climate change, global land use consequences, ecosystem production structures and functions, and ecosystem feedbacks to the global environment. However, little consideration has been given to the interactive impacts of natural ecosystem and social system in the coupled systems. The understanding and addressing of both global change and its effects are not well integrated with interdisciplinary research (Reid et al., 2010).

A multi-system perspective is therefore important in addressing complex problems in the coupled systems with multiple drivers and feedbacks resulting from interconnections among interdependent components. In the environment–agriculture–food security interactions, agriculture is the basic link between natural ecosystem and human society, and the core part of food systems. Global change driver from the coupled systems greatly affects crop production and food consumption. Food systems are vulnerable to global change drivers from the atmosphere, lithosphere, hydrosphere, biosphere, and anthroposphere. Although environmental stresses contribute significantly to food insecurity, they do so

[1] World total crop production has already doubled since 1960s thanks to the "green revolution" (FAOSTAT Online).

[2] For a wide ranging discussion on current global change and food security, see the following recent special issues: *Science*, 2010, vol. 327 (Feeding the Future); *Nature*, 2010, vol. 466 (Can Science Feed the World?); *Proceedings of the National Academy of Sciences*, 2007, vol. 104 (Climate Change and Food Security) and 2010, vol. 107 (Climate Mitigation and Food Production in Tropical); *Philosophical Transactions of the Royal Society B*, 2005, vol. 360 (Food Crops in a Changing Climate) and 2010, vol. 365 (Food Security: Feeding the World in 2050).