CHOICES
The magazine of food, farm, and resource issues
2nd Quarter 2015 • 30(2)

A publication of the Agricultural & Applied Economics Association
AAEA Agricultural & Applied Economics Association

Climate Change, Vulnerability and Food Insecurity

John M. Antle

Keywords: Climate change, Food insecurity, Vulnerability
JEL Classifications: O1, Q1

Achieving and maintaining food security for all of humanity appears to be an important but daunting global challenge in the face of population growth, economic growth, environmental degradation and accelerating climate change. Indeed, much lip service is given to the risks posed by climate change to food security in the scientific literature and the popular press (Wheeler and Braun, 2013).

Despite this "conventional wisdom," our understanding of the likely impacts of climate change on food security is very limited. Indeed, the most recent assessment report by the Intergovernmental Panel on Climate Change concludes, "All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability (high confidence)". But the report then observes, "There remains limited quantitative understanding of how non-production elements of food security will be affected, and of the adaptation possibilities in these domains" (Challinor et al., 2014).

Two reasons for this gap in our understanding are that, first, food security is difficult to define and measure. This is true currently, and these challenges are much greater when attempting to project food security under uncertain future socio-economic conditions. Second, the economic impact assessment models used to project future agricultural production and food consumption are not well-suited to the task of projecting impacts on food security. These limitations extend to assessing other aspects of economic or environmental vulnerability, as well.

Quantifying Food Insecurity

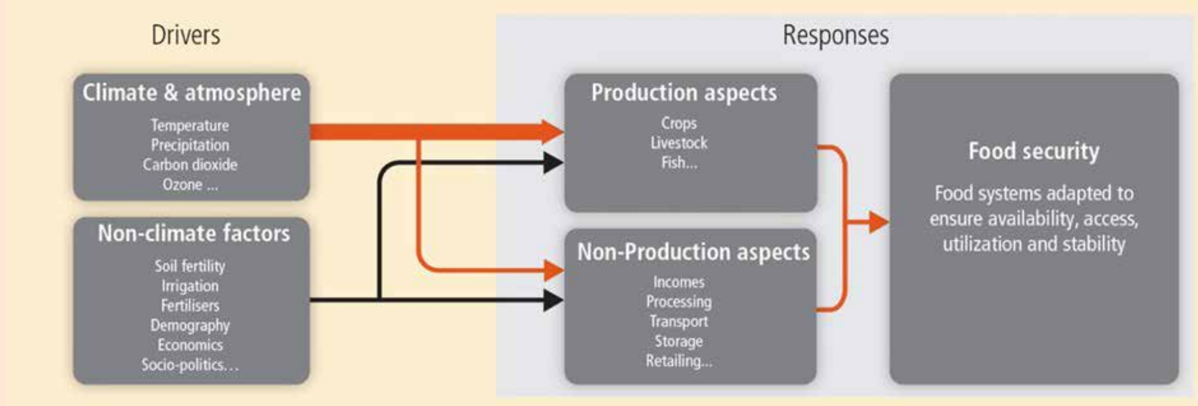
Food insecurity can be considered a type of vulnerability, that is, the risk of not having adequate food. Nutritional experts would extend the concept to nutritional security, going beyond the consideration of available calories to consider a broader set of nutrients available from food. These concepts can be defined at various scales: an individual person may be at risk of not having enough food to eat today or an entire country may be at risk of not having enough food for its population over a year or a decade. Different kinds of data and models are needed to quantify food insecurity at each of these scales.

Food security is difficult to quantify due to both conceptual and measurement issues (Barrett, 2010). Food security is conventionally defined in terms of availability, access and utilization of food, and the stability of these elements over time. It is evident that except in situations of subsistence agriculture, there is a very weak link between the production of agricultural commodities and the utilization of food by a household or an individual, because consumption of food in the household is separated from commodity production by a long chain of transportation, storage, processing, marketing, food preparation and utilization (Figure 1). Various quantifiable factors are used as food security indicators, including subjective feelings of hunger and objective measures of consumption or outcomes such as physical condition or health. All of these pose substantial data challenges as well as measurement problems.

Another major challenge to making future projections of food security is that scientific models (global climate,

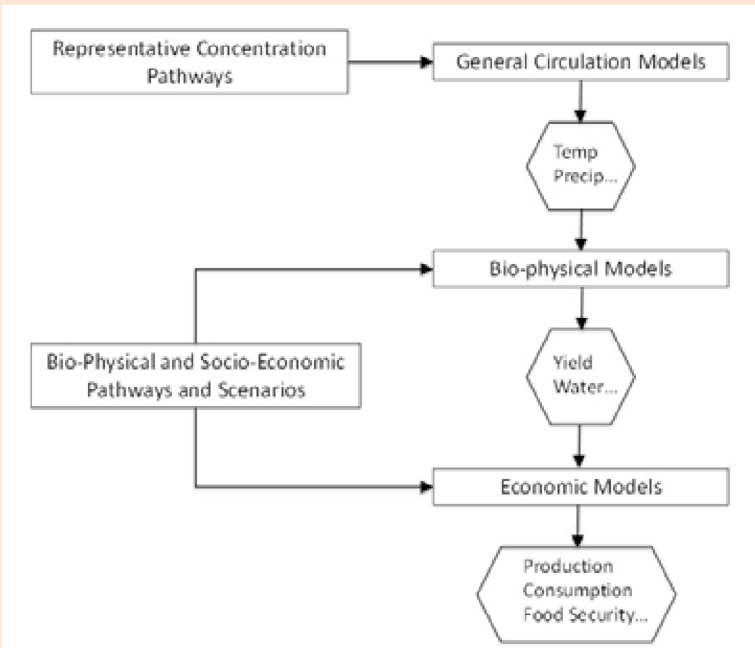
AAEA-0515-498

Figure 1. Drivers and Responses of Food Security



Source: Porter et al., 2014.

Figure 2. Integrated Assessment Framework for Agricultural and Food System Impact Assessments



Source: Wallach et al. 2015.

biophysical, and economic) are lacking for many of the food security outcomes that are identified in the scientific literature, although progress in modeling both nutritional and health outcomes and linking them to economic models is being made (Hawkesworth, Dagour, and Johnston 2010).

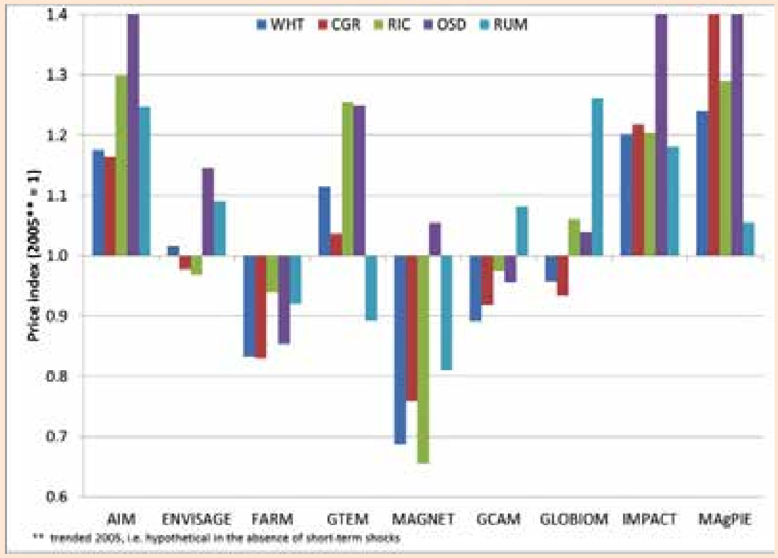
Quantifying Impacts of Climate Change on Agriculture and Food Systems

Figure 1 shows that the link from climate to food security involves a complex set of interacting systems. The main tools for projecting impacts of climate change on agriculture and food systems are models that represent some but not all of the components in Figure 2. Nelson et al., (2014) provide an overview of nine of the major modeling systems used for global agricultural assessments. In these assessments, climate projections from global climate models are used by biophysical models to simulate productivity effects of climate change as "shocks" or changes in exogenous conditions. These productivity impacts are then used as inputs to economic models that simulate equilibrium economic outcomes. Some economic models directly incorporate climate variables, thus bypassing the use of bio-physical simulation models. Each of the model components in Figure 2 are implemented using corresponding pathways and scenarios that define inputs into the models that represent the key non-climate future conditions. These factors define the socio-economic setting in which the analysis is couched and thus can strongly influence the outcomes of the analysis.

Global Model Projections and Uncertainties

In collaboration with the Agricultural Model Intercomparison and Improvement Project (AgMIP) and the Inter-sectoral Impact Model Intercomparison Project (ISI-MIP), a group of nine major modeling teams completed the first global agricultural economic model intercomparison of climate change impacts in which all of the models used a standard set of scenarios linked to one emissions scenario and two socio-economic scenarios (Nelson et al., 2014; von Lampe et al., 2014). Importantly, these scenarios did not embody effects of increasing carbon dioxide (CO2) concentrations on crop yields, and used climate projections based on (RCP) 8.5, so in these dimensions they can be viewed as relatively pessimistic scenarios. However, these scenarios did incorporate a relatively optimistic set of projected crop yield growth rates to represent the impacts of ongoing productivity improvements, ranging from 1- 2.5% for major crops (wheat, coarse grains, rice, sugar, and oilseed) across the major regions of the world (von Lampe et al. 2014), so in this regard the scenarios can be viewed as somewhat optimistic.

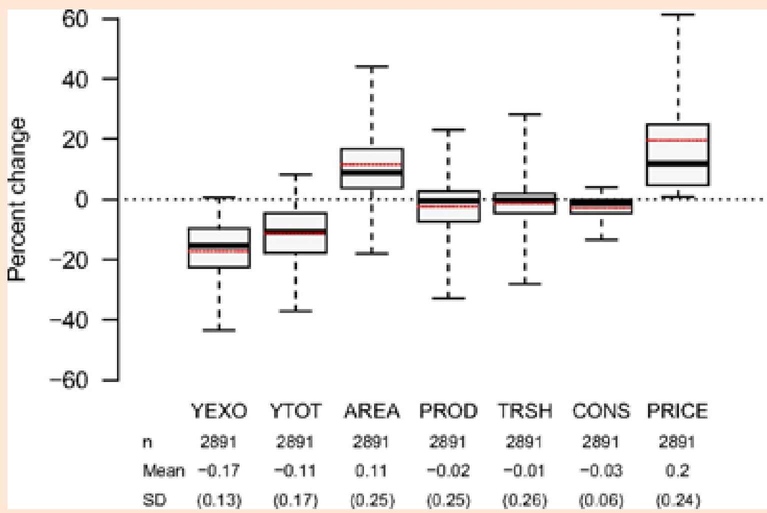
Figure 3. AgMIP Global Agricultural Economic Model Intercomparison, Projected Changes in Commodity Prices in 2050 without Climate Change



Note: WHT = wheat, CGR = coarse grains, RIC = rice, OSD = oil seeds, RUM = ruminant animal products
Source: Nelson et al., 2014.

Key findings of the AgMIP global agricultural model inter-comparison are summarized in Figures 3 and 4 (Nelson et al., 2014; von Lampe et al., 2014). Figure 3 presents price projections for five agricultural commodity groups (wheat, coarse grains, rice, oil seeds, and ruminant meat) for 2050 without climate change, but including other factors such as income growth, population growth, and trends in agricultural productivity. This figure shows how differently the nine models perform in terms of projecting future economic outcomes such as prices. The figure shows that some models project agricultural commodity prices could be up to 40% higher in the future relative to those observed today without climate change, while others show prices falling as much as 70%. Obviously, these findings indicate a high degree of uncertainty in these model projections, distinct from climate change effects, but they serve as a useful baseline for understanding potential changes due to climate change.

Figure 4. Ranges of Key Crop and Economic Model Results



Note: YEXO = yield effect of climate change without technical or economic adaptation, YTOT = realized yields with after management adaptation, AREA = agricultural area in production, PROD = total production, TRSH = net imports relative to domestic production, CONS = consumption, PRICE = prices Source: Nelson et al., 2014.

Projected crop yields are generally lower in most parts of the world with climate change, particularly in the latter half of this century, in the tropics, and under high emissions scenarios (Porter et al., 2014). Figure 4 summarizes the projected results for the impacts of climate change, using the nine global economic models in the AgMIP inter-comparison study. The lower yields are reflected in higher prices for most agricultural commodities, but the size of this effect varies widely across the models, and ranges from 0-20% for most models. Most models project some increases in land area under production, but little impact on trade or consumption.

Using Aggregate Model Projections to Assess Food Insecurity

In addition to the uncertainty in future price projections, another striking result from the model simulations presented above is that consumption is very stable, apparently because price increases stimulate production responses and trade. But how these changes would impact vulnerable populations—namely, the rural and urban poor—or how they would affect food access, availability, and utilization within countries or at the household level, cannot be ascertained from this data.

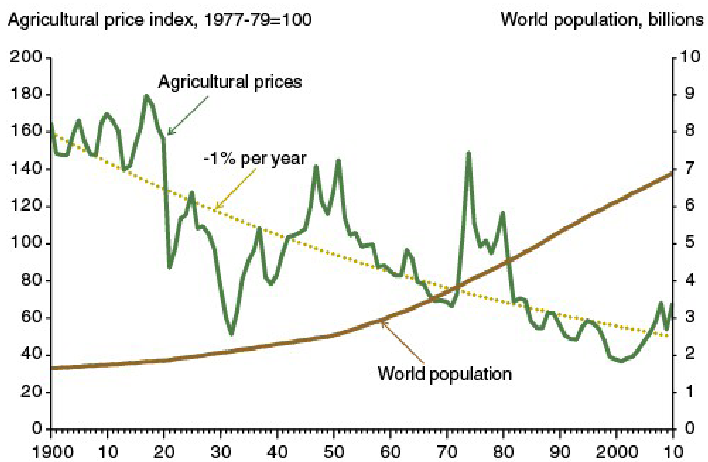
Several studies have attempted to bridge this analytical gap in global-scale models. One approach is to develop statistical links between projected changes in production or consumption to food security indicators. For example, Fischer et al., (2005) utilized the correlation between the share of undernourished in the population—as defined by the Food and Agriculture Organization (FAO)—and the ratio of average national food supply (including imports), relative to aggregate national food requirements, to assess the impacts of climate change on food security. Based on this relationship, and using a set of socio-economic scenarios, Fischer et al., (2005) projected an increase in the number of people "at risk of hunger," with their study projecting that an additional 175 million people could be undernourished in 2080 because of climate change. It is a projected 2.6% of the overall population of food insecure countries in 2080. Yet, this type of indicator is also highly aggregated and implies that undernourishment is only a problem of food availability. Moreover, this approach does not account for factors affecting food access, utilization, and stability within countries, and it must be assumed that the historical correlation between undernourished and food availability is stable over long periods of time.

Another example of an indicator used for economic outcomes on health and nutrition is the study by Nelson et al., (2010), which used per capita calorie availability from cereals and meat at the national level, and an index of child malnutrition. The percentage of malnourished children under the age of 5 was estimated using average per capita calorie consumption, assuming that other factors (life expectancy, maternal education, and clean water access) are constant in over time.

Based on this methodology, Nelson et al., (2010) found that climate change could result in price increases for the most important agricultural crops—rice, wheat, maize, and soybeans—and that higher feed prices will result in higher meat prices (the model used in this study is the IMPACT model which predicts higher baseline prices, and thus higher prices with climate change, see Figure 3). These price increases were projected to reduce the growth in meat consumption slightly and cause a more substantial fall in cereals consumption. Calorie availability in 2050 was projected to decline relative to 2000 levels throughout the developing world. By 2050, the decline in calorie availability will increase child malnutrition by 20% relative to a world with no climate change, and offset much of the improvement in child malnourishment levels that could occur without climate change.

This study shows how some aspects of food security can be elaborated, yet serious limitations associated with aggregate data and untested assumptions remain.

Figure 5. Long-run trend in real agricultural commodity prices



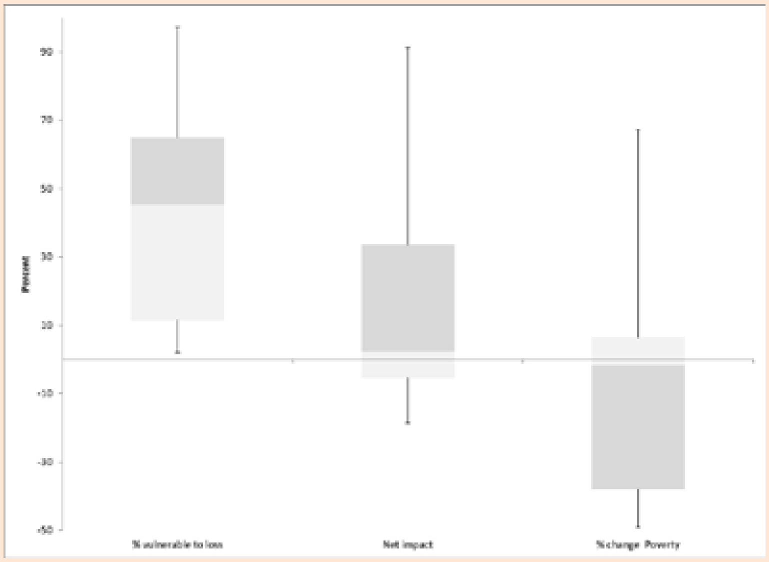
Source: USDA, Economic Research Service using Fuglie, Wang, and Ball (2012). Depicted in the chart is the Grilli-Yang agricultural price index adjusted for inflation by the U.S. Gross Domestic Product implicit price index. The Grilli-Yang price index is a composite of 18 crop and livestock prices, each weighted by its share of global agricultural trade (Pfaffenzeller et al., 2007). World population estimates are from the United Nations.

Prices, Price Instability, and Model Uncertainty

As the previously cited study suggests, a major factor in food security is the cost and availability of nutritious food, particularly for the poor who spend a large share of their income on basic food commodities.

We know that historically, agricultural commodity prices have declined in "real" terms for the past century or more, reflecting the fact that global agricultural production has increased at a faster rate than global demand, despite

Figure 6. Climate Change Impacts from AgMIP Regional Studies in Africa and South Asia Under Future Socio-Economics Conditions with Higher Agricultural Productivity and Higher Agricultural Prices, without Adaptation



Note: Vulnerability to loss and net impact are percent of farm income. Poverty is defined as the head-count ratio at a $1.25/person/day poverty line.

Source: Author's calculations based on data in Rosenzweig and Hillel (2015), various chapters.

population growth (Figure 5). A major question for the 21st Century is whether this long-term trend in prices is being reversed by the combined effects of demand growth, environmental degradation, reductions in productivity growth, and climate change. These considerations underscore the importance of the uncertainty in the baseline future price projections evidenced in Figure 3. Indeed, combining the data for prices in Figures 3 and 4, we have a remarkable implication: even though the global models generally project that climate change will tend to have a positive effects on future pries, it is possible that the downward effect of productivity increases could be larger, so that on net, future prices could be lower. We cannot say from these models whether one of the key factors for future food insecurity—food prices—will be higher or lower, due to the baseline model uncertainty.

This uncertainty is reinforced by Figure 5 which shows that the recent increases in food commodity prices observed in 2008-2009 and 2012 are relatively small in historical terms, and cannot be interpreted as evidence that the historical trend is being reversed. Indeed, as of this writing, real commodity prices have fallen back to near-historically low levels in real terms.

Figure 5 also shows that agricultural commodity prices have been unstable historically along this downward trend. One possible impact of climate change is an increase in extreme high temperatures by historical standards, as mean temperatures increase. Another important limitation of the impact assessment models is that they lack the storage and other mechanisms related to short-term market dynamics to meaningfully represent short term price variability caused by weather or other short-term events.

Regional Modeling Approaches

Since one of the limitations of existing models is their high level of aggregation, an alternative approach is to link global or national models to nationally disaggregated data (Hertel, Burke, and Lobell, 2010). While a step in the right direction, such efforts thus far use data averaged over relatively long time periods (for example, a year) and are not capable of dealing with short-term variability, due to data and model limitations.

AgMIP has developed a coordinated global and regional approach to integrated assessment to quantify the economic vulnerability of farm households. With better data, this approach can be applied to seasonally disaggregated data, and can be linked to food security indicators, such as those available in the Living Standards Measurement Surveys conducted by the World Bank (Antle et al., 2015). In this approach, global model simulations, such as those discussed above, are used to generate price changes and then used as inputs into regional assessments. The regional models simulate outcomes such as the regional distribution of production and income, and poverty rates and food security indicators.

AgMIP organized regional research teams in Sub-Saharan Africa and South Asia to assess climate impacts and adaptation in mid-century, all following the methodological design described in Figure 5 (Rosenzweig and Hillel, 2015). The AgMIP regional studies produced a number of indicators that are related to economic vulnerability, but did not include food security indicators (Figure 6). The results show a wide range of vulnerability to loss of farm income, on average 50% of the population under future conditions, even though the net or aggregate impact tends to be near zero so somewhat positive. Thus, it is clear that vulnerability to losses cannot be inferred from aggregate or average impacts.

Towards a Better Understanding of Vulnerability and Food Insecurity

How climate change will affect various economic, environmental and social vulnerabilities, including food insecurity, are very difficult questions.[1] In the aggregate, food availability does not appear to be threatened by climate change in the high-income regions of the world such as the United States (see Blanc and Reilly, 2015, this *Choices* theme). Yet it is clear that there are indeed significant risks to food security for the most vulnerable populations, even in rich countries. Data from the United States show that many poor households lack the income and other resources needed to ensure access and effectively utilize food, where the percentage of the food insecure population rose from 11 to over 14% during the recent economic recession (Coleman-Jensen, Gregory, and Singh, 2013). Even more severe food insecurity consequences have been documented for extreme weather events in other parts of the world (Coghlan et al., 2014). But to assess future food insecurity, we would have to be able to project how changes in income, food availability, and socio-economic factors affecting utilization and stability change over long periods of time. The challenges are even greater in the low and middle-income regions of the world that are likely to develop rapidly over the next decades. One only has to consider the large positive changes that have occurred in China over the past two decades, and that are likely to occur in Africa and South Asia in future decades, to realize the magnitude of the challenge.

What we do know is that our current methods of assessing vulnerability and food insecurity could be improved, through investments in better data and models. The data presented in Figure 6 demonstrate that economic vulnerability to climate change cannot be inferred from aggregate impacts, and this is likely to be even more true of food insecurity. This evidence suggests that better assessments of vulnerability and food insecurity will require better disaggregate data and corresponding models. Current efforts are underway by AgMIP in collaboration with the Center for Integrated Modeling of Sustainable Nutrition Security, and other organizations, to define a set of metrics for "sustainable nutrition security" and to improve data and models to quantify those metrics. These are positive steps towards achieving a better understanding of the risks to food security posed by climate change.

For More Information

Antle, J. M., R.O. Valdivia, K.J. Boote, S. Janssen, J.W. Jones, C.H. Porter, C. Rosenzweig, A.C. Ruane, and P.J. Thorburn. 2015. AgMIP's Trans-Disciplinary Agricultural Systems Approach to Regional Integrated Assessment of Climate Impact, Vulnerability and Adaptation. C. Rosenzweig and D. Hillel, eds. *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project Integrated Crop and Economic Assessments, Part 1.* London: Imperial College Press.

Acharya, T., J Fanzo, D. Gustafson, J. Ingram, and B. Schneeman. 2014. Assessing Sustainable Nutrition Security: The Role of Food Systems. ILSI Research Foundation, Center for Integrated Modeling of Sustainable Agriculture and Nutrition Security. Washington, DC. Accessible online: http://www.ilsi.org/ResearchFoundation/CIMSANS/Documents/CIMSANS-Sustainable-Nutrition-Security-FINAL%2030may2014.pdf.

Barrett, C. 2010. Measuring Food Insecurity. *Science.* 12 February: 825-828.

Challinor, A., K. Cochrane, M. Howden, M.M. Iqbal, D. Lobell, M.I. Travasso, N. Chhetri, K. Garrett, J. Ingram, L. Lipper, N. McCarthy, J. McGrath, D. Smith, P. Thornton, J. Watson, and L. Ziska (2013) "Food security and food production systems." In K.H. P. Aggarwal ed. *Climate change 2014: Impacts, adaptation, and vulnerability: Contribution of working group 2 to the fifth assessment report of the intergovernmental panel on climate change.* Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press.

Coghlan, C., M. Muzammil, J. Ingram, J. Vervoort, F. Otto, and R. James. 2014. A Sign of Things to Come? Examing Four Major Climate Related Disasters, 2010-2013, and Their Impacts on Food Security. Oxfam Resarch Report. https://www.oxfam.org/en/research/sign-things-come. Accessed April 9, 2015.

Coleman-Jensen, A., C. Gregory and A. Singh. 2013. Household Food Security in the United States in 2013. USDA Economic Research Report No. (ERR-173) 41 pp, September 2014.

Fuglie, K.O., S. L. Wang, and V.E. Ball (eds.). 2012. *Productivity Growth in Agriculture: An International Perspective.* CAB International, Oxfordshire, UK.

Hawkesworth S., A. D. Dangour, D. Johnston, K. Lock, N. Poole, J. Rushton, R. Uauy, and J. Waage. 2010. Feeding the World Healthily: The Challenge of Measuring the Effects of Agriculture on Health. Philos Trans R Soc Lond B Biol Sci 2010; 365: 3083–97.

Hertel, T. W., M. B. Burke, and D. B. Lobell. 2010. The Poverty Implications of Climate-Induced Crop Yield Changes by 2030. *Global Environmental Change, 20,* 577–585.

Nelson, G. C., H. Valin, R.D. Sands, P. Havlik, H. Ahammad, D. Deryng, J. Elliott, S. Fujimori, T. Hasegawa, E. Heyhoe, P. Kyle, M. Von Lampe, H. Lotze-Campen, D. Mason d'Croz, H. van Meijl, D. van der Mensbrugghe, C. Müller, A. Popp, R. Robertson, S. Robinson, E. Schmid, C. Schmitz, A. Tabeau, and D. Willenbockel. 2014. Climate Change Effects on Agriculture: Economic Responses to Bio-Physical Shocks. Proceedings of the National Academy of Sciences of the United States. 111(9): 3274–3279

Nelson, Gerald C., Mark W. Rosegrant, Amanda Palazzo, Ian Gray,Christina Ingersoll, Richard Robertson, Simla Tokgoz, Tingju Zhu, Timothy B. Sulser, Claudia Ringler, Siwa Msangi, and Liangzhi You. 2010. Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options. Washington, D.C.: International Food Policy Research Institute. doi:10.2499/9780896291867

Parry, M., C. Rosenzweig, and M. Livermore. 2005. Climate Change, Global Food Supply and Risk of Hunger. *Philosophical Transactions of the Royal Society B, 360,* 2125–2138.

Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S. M. Howden, M. M. Iqbal, D.B. Lobell, and M.I. Travasso. 2014. "Food Security and Food Production Systems." In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Available online: https://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap7_FINAL.pdf

Rosenzweig, C. and D. Hillel, eds. 2015. *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project Integrated Crop and Economic Assessments, Part 2.* London: Imperial College Press.

von Lampe, M., D. Willenbockel, H. Ahammad, E. Blanc, Y. Cai, K. Calvin, S. Fujimori, T. Hasegawa, P. Havlik, E. Heyhoe, P. Kyle, H. Lotze-Campen, D. Mason d'Croz, G. C. Nelson, R. D. Sands, C. Schmitz, A. Tabeau, H. Valin, D. van der Mensbrugghe, and H. van Meijl. 2014. Why do Global Long-term Scenarios for Agriculture Differ? An Overview of the AgMIP Global Economic Model Intercomparison. Agricultural Economics 45:3-20.

Wallach, D., L.O. Mearns, M. Rivington, J.M. Antle and A.C. Ruane. 2015. Uncertainty in Agricultural Impact Assessment. C. Rosenzweig and D. Hillel, eds. *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project Integrated Crop and Economic Assessments, Part 1.* London: Imperial College Press.

Wheeler, T. and J. von Braun. 2013. Climate Change Impacts on Global Food Security. Science 341:508-513.

John M. Antle (john.antle@oregonstate.edu) is Professor of Applied Economics at Oregon State University.

While responsible for the content of this article, the author wishes to thank the co-authors of a forthcoming USDA report on Climate Change, Global Food Security, and the U.S. Food System, to be published in the Fall of 2015, for discussion of some of the issues addressed in this article. The author acknowledges the support of the Agricultural Model Inter-comparison and Improvement Project and collaborators including UK-AID and USDA-ARS, and USDA-NIFA award #2011-68002-30191.