ARTICLE IN PRESS

Global Food Security xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Global Food Security

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

Food security and the environment: Interdisciplinary research to increase productivity while exercising environmental conservation

Miguel F. Acevedo[a,b,*], David R. Harvey[c], Florencia G. Palis[d]

[a] Electrical Engineering Dept. and Advanced Environmental Research Institute, University of North Texas, Denton, TX 76203, United States
[b] Center for Simulation and Modeling (CESIMO), Universidad de Los Andes, Mérida, Venezuela
[c] School of Agriculture, Food and Rural Development, The University of Newcastle upon Tyne, NE1 7RU UK
[d] Department of Social Sciences, University of the Philippines, College, and International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines

ARTICLE INFO

Keywords:
Food security
Production
Productivity
Environment
Interdisciplinary
Technology
Social science

ABSTRACT

Global food insecurity is increasing in absolute terms despite recent decreases in percentage terms. Options to increase food production while protecting the environment exclude further expansion of cropland, leaving increased agricultural productivity as an option assuming we address its associated technological and societal challenges while exercising environmental conservation. Improving productivity requires redoubled efforts in interdisciplinary work to design and implement sound agricultural management practices and efficient use of inputs. Based on a historical perspective of the last few decades on hypothesized environmental limits to food production and looking at prospective futures, we analyze the required type of interdisciplinary research to improve productivity. We conclude that bringing together increased food supply and environmental conservation requires research that integrates engineering, technology, science, policy, and action.

1. Introduction

There are ~800 million undernourished people in the world (~11% of the population), an improvement in the last decade that meets the First Millennium Development Goal of halving the proportion of people who suffer from hunger by 2015 (FAO et al., 2015) (Fig. 1). The world 2015 Global Hunger Index (GHI) improved by 27% relative to 2000 (von Grebmer et al., 2015). This is a consistent trend; according to the United Nations (UN) the proportion of undernourished people decreased from 20% to 16% in the previous decade (UN, 2010).

The Food and Agriculture Organization (FAO) considers four dimensions of food security: food availability, food access, utilization, and stability (FAO, 2006). In this paper, we focus on food availability and in particular food production and its limiting factors related to environmental conditions (e.g., climate, water, soils) and human related factors – such as lack of infrastructure (e.g., irrigation, roads, and food storage), lack of agro-bio-technology (e.g., seeds of water-efficient crops), and inadequate socio-political systems (e.g., fair trade, food justice, governance, and policy).

Several institutions sustain interdisciplinary (ID) research teams to examine impediments to food production; for instance, FAO, the International Food Policy Research Institute (IFPRI), the UN World Food Programme (WFP), the World Bank, the UN Committee on World Food Security (CFS), the International Water Management Institute (IWMI), and the Cereal Systems Initiative for South Asia (CSISA). Global climate change compounds some of these impediments to improve food security and ID approaches to study climate change have become relevant (Ziervogel and Ericksen, 2010).

Societies may not expand cropland without significant environmental risks, leaving increased productivity as the major avenue to increase food production, which demands ID research (IDR) (Acevedo, 2011). In this paper, we provide a historical perspective of the last few decades on environmental limits to food production. While acknowledging the progress made due to the Green Revolution, we look at prospective futures, to realize that the type of IDR required should integrate technology, science, policy, and action. In particular, we advocate more use of the capabilities of qualitative social sciences in order to address the multiplicity of human factors that may impede improvement in food production and more generally in food security.

Our analysis relates to worldwide food production and environmental quality, but we focus on those regions where there is large need to increase the number of people with access to food which in many cases coincide with those regions where food production and environmental quality are in greatest need of reconciliation.

* Corresponding author at: Electrical Engineering Dept. and Advanced Environmental Research Institute, University of North Texas, Denton, TX 76203, United States.
E-mail addresses: acevedo@unt.edu (M.F. Acevedo), david.harvey@ncl.ac.uk (D.R. Harvey), florenciagpalis@gmail.com (F.G. Palis).

https://doi.org/10.1016/j.gfs.2018.01.001
Received 10 March 2017; Received in revised form 2 January 2018; Accepted 2 January 2018

Please cite this article as: Acevedo, M.F., Global Food Security (2018), https://doi.org/10.1016/j.gfs.2018.01.001

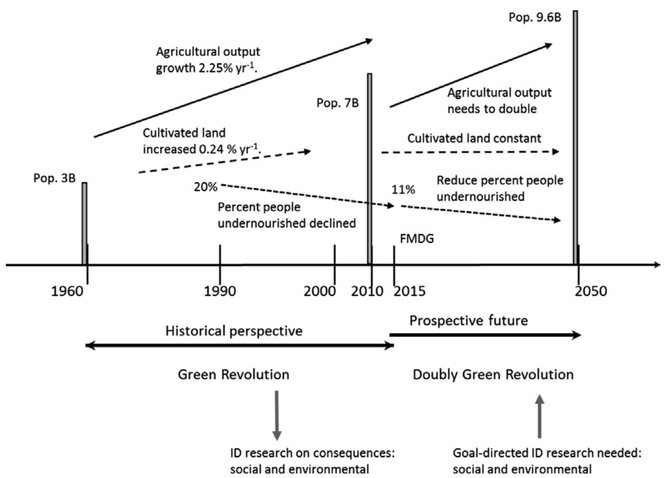

Fig. 1. Historical perspective leading to prospective future. Pop. = Human population. FMDG = First Millennium Development Goal.

2. Historical perspective: the last half of the past century

In the 1960s, the accelerated growth of the world's population led to predictions of increased famines and mortality, and of reaching the limits of growth within a century (Fig. 1) (Meadows et al., 1972). The Malthusian proposition that food demands, growing exponentially with population, would exceed food supplies, growing only arithmetically, seemed inevitable. Yet in the last 50 years, world population has more than doubled while the number of world's starving has not increased, albeit remaining obscenely large.

Our food production per head has generally increased and the prices of food had not shown a substantial tendency to increase but they may start to do so according to recent signals (FAO, 2015). Since 1961, global agricultural output has increased by 2.25% per year, while the increase in land devoted to farming has only increased by 0.24% per year (Fig. 1) (Pardey et al., 2012). Global population increased by 1.7% per year, but the people engaged in farming only grew by 1.2% per year. This apparently good performance has occurred through geographical shifts in global production; most of the increase of the value of food production per head, has happened in the upper middle-income countries (Pardey et al., 2012). For instance, in 1961, Russia accounted for 15% of global wheat production and was the world's largest producer, but by 2008, Russia only accounted for just over 8% of global production, with India and China together accounting for almost 29% (up from 12% in 1961).

The achievements of the last 50 years largely due to the Green Revolution (based on higher-yield varieties of rice, wheat, and maize) have also caused adverse effects on the environment and human health (Kedia and Palis, 2008). Negative effects on agro-ecological functions have in turn resulted in decreased crop yields (Boutsen, 2009). Concerned that the pace of yield improvement had slowed by the turn of the century, Conway (1999) proposes a 'Doubly Green Revolution' (Fig. 1) which would be more productive and more 'green' (in environmental terms) than the first, and targeted towards the poor.

Indeed, Pardey et al. (2012) provide evidence of the slowdown in world crop yield growth and question whether current trends in agricultural R&D are likely to reverse the decrease in productivity. Global R&D spending has grown impressively in real terms (2005 purchasing power parity, PPP, rates), but this growth has largely happened in the middle-income countries, especially Brazil, India and China. Disappointingly, there is little sign of strong spending growth rates in sub-Saharan Africa, Latin America and the Caribbean, which indicates a growing divide with the poorest countries falling farther behind (Pardey et al., 2012). A major contribution to food production would be to make results from R&D spending in high income and middle-income economies available to the poor farmers in south Asia and Sub-Saharan Africa where R&D is still lagging (Pardey et al., 2016). IDR on effective technology adoption by farmers should accompany the transfer of such R&D output.

3. Prospective futures: the first half of this century

By 2050, human population may grow to 9.6 billion or ~ 2.0 people ha^{-1} of cultivated land (per 2010 land area when we had ~1.5 people ha^{-1}) which calls for sizable increases in agricultural production (Bruinsma, 2009) (Fig. 1). Increasing food production requires expanding cultivated area (extensification) or increasing yields on presently cultivated land (intensification); the latter either by direct increased yields, or through changes to crop mix (fiber, feed, and biofuel). As Hertel (2011) notes, 77% of the growth in global crop production over the last half century resulted from increased yields, 9% from increased cropping intensity, and only 14% from expansion of crop area. Bruinsma (2009) projects that only 9% of future output increases (to 2050) may come from extensification.

Indeed, it is commonly accepted that there is little scope for expansion of agricultural land without encroaching on land devoted to environmental protection. Available land is unevenly distributed between regions and countries, being skewed against those countries that have most need to raise production (Godfray et al., 2010). Irrigated agriculture on prime land has relieved some pressure on land expansion, but many irrigation systems are performing below their potential, calling for improvements in water use efficiency (HLPE, 2015) and the global expansion of irrigated area has stalled to 0.6% per year after growing twice as much in the 1990s.

Yields can be improved with new varieties, produced with sustained R&D, better capable of coping with adverse conditions, but they can also be improved by closing the 'yield gap' – the difference between the yield potential of crops in a given agro-ecological and climatic zone and the yields actually achieved by farmers in those zones. Although much of irrigated agriculture around the world, and much of developed country agriculture show rather small yield gaps, the gaps remain very substantial (~50%) in rain-fed agriculture, in much of Africa and of Eastern Europe. If these gaps could be closed, some analysts conclude that we can feed another 2 billion with present technologies, and with present cultivated land areas (Hertel, 2011).

The parts of the world exhibiting substantial yield gaps are also those regions lacking market infrastructure and supply chains. Furthermore, closing these gaps requires more inputs and resources, which will become more constraining in the future. Nevertheless, the emerging price signals should encourage more sustainable adaptations and innovations, providing there is sufficient investment in both agricultural R&D, infrastructure, and institutional reform.

Poverty and lack of access to food are as important as limited food production in determining food insecurity (Scanlan, 2001). Areas with the greatest water loss and land degradation correspond with areas of the highest rural poverty and food insecurity (deVries et al., 2003). Improving food security while limiting impacts on ecosystems calls for both the development of sustainable practices and the appropriate economic and institutional environment (FAO, 2011).

Providing enough, for all, forever, requires more than generating the capacities of supplying food. It also requires adaptation and innovations in what we consume, and in our abilities to generate sustainable incomes to re-create worthwhile livelihoods. Aside from the impressive growth in global food production over the past half century, a major factor in the reduction of relative food insecurity has been the growth in incomes – providing the previously poor with the wherewithal to purchase food. Without growth in incomes, we condemn people to food insecurity, poverty, and ill health. Economic growth is therefore a necessary requirement for both food and livelihood security, and will lead inevitably to both greater demands on our increasingly scarce land resources as well as to substantial changes in diets and