2013

Yield gap analysis—Rationale, methods and applications—Introduction to the Special Issue

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Field Crops Research 143 (2013) 1–3

Contents lists available at SciVerse ScienceDirect

Field Crops Research

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

Editorial

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ARTICLE INFO

Keywords:
Global food security
Food production
Yield potential
Water-limited production

ABSTRACT

Yield gap analysis is an increasingly popular concept. It is a powerful method to reveal and understand the biophysical opportunities to meet the projected increase in demand for agricultural products towards 2050, and to support decision making on research, policies, development and investment that is needed. This Special Issue presents the state-of-the-art about concepts, methods and applications of yield gap analysis. The methodological papers emphasize the need for agronomically sound and relevant analyses, from local to global scales. The fourteen papers provide examples of applications to different crops, climate zones and production conditions, at various spatial extents and with different approaches and data availability. The overall goal of this Special Issue is to provide the scientific foundation for improvement and interpretation of yield gap analyses.

1. Context

The projected 60% increase in demand for agricultural production by 2050 (FAO, 2012) is very large, but not unprecedented. Between 1960 and 2010 the world population increased from 3 to 7 billion while at the same time agricultural production per capita went up, with only 10% more agricultural land to produce it (Fig. 1). This production increase was possible because of the release of new cultivars with much higher share of grain as a proportion of total biomass (increased harvest index), an increase of external inputs of water, nutrients and crop protection agents, and massive investment in expansion of irrigated crop production area. But, the present situation shows some crucial differences with that of 50 years ago. In many areas, yields per hectare are much higher now than in 1960, and in some countries yields are plateauing. A further increase in genetic yield potential, or in water-limited yield is at the very least challenging, because the room to further increase the harvest index is small (Fischer and Edmeades, 2010), and prospects for significant breakthroughs in genetic improvement of photosynthesis or drought tolerance remain elusive (Hall and Richards, 2013). And, pressure on the available land and other natural resources is much higher now than in 1960.

Until ca. 2005 real prices of agricultural commodities were projected to further decrease into the foreseeable future (Rosegrant et al., 2002; Cranfield et al., 1998). The price peak in 2008 and the high prices of major cereals since 2010 have clearly changed this outlook. Major institutions now forecast sustained higher prices for the short and medium term (OECD-FAO, 2012). Although at the global level yields of the major cereals still increase at a fairly steady pace (Fig. 2A), in some countries there are clearly signs of levelling off (Fig. 2B; see also Cassman, 1999; Cassman et al., 2003; Brisson et al., 2010; Grassini et al., 2011; Olesen et al., 2011). There is some evidence to support the proposition that where national yields are plateauing the average farm yields have reached 75–90% of the yield potential ceiling (Cassman et al., 2003; Grassini et al., 2011). In those regions the difference between actual farmers' yields and what can be theoretically achieved under optimum management has become so small that further increasing farmers' yields is theoretically difficult and economically less and less profitable.

It is in this context that the concept of yield gaps becomes useful. The yield gap of a crop grown in a certain location and cropping system is defined as the difference between the yield under optimum management and the average yield achieved by farmers. Yield under optimum management is labelled as potential yield under fully irrigated conditions or water-limited yield under rainfed conditions (Evans, 1998; Van Ittersum and Rabbinge, 1997). Because of rising grain prices and concerns about global food security, research on yield gaps is receiving rapidly increasing attention over the last few years. Over the last five years (2008–2012) 30 peer reviewed publications held the term 'yield gap' in their title, while until 2008 only 14 papers could be found (Web of Science). In 2010, the guest editors of this Special Issue organized a symposium on yield gap analysis during the XIth conference of the European Society of Agronomy, Agro2010, in Montpellier (Wery et al., 2010). The present Special Issue has been developed after a workshop (August 31–September 2, 2011) organized by Prof. Fusuo Zhang and his team from the Chinese Agricultural University in Beijing, jointly with the University of Nebraska, William B. Daugherty Water for Food Institute and Wageningen University. The workshop was organized to help launch the Global Yield Gap Atlas project (www.yieldgap.org). Our objective was to convene a group of recognized leaders in agronomic research from around the globe to present and discuss methods and applications for estimating yield gaps based on best-available science and using consistent, transparent approaches with relevance from local to global scales.

0378-4290
http://dx.doi.org/10.1016/j.fcr.2012.12.012

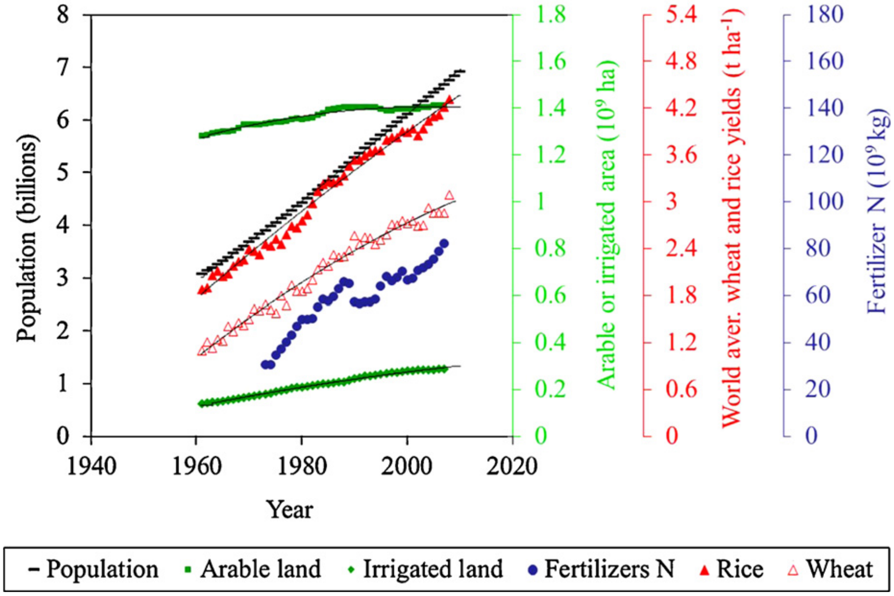

Fig. 1. Evolution of population, arable land area, world average wheat and rice yields, fertilizer N use and irrigated area between 1960 and 2010. Updated from Evans (1998) in Van Ittersum (2011).

2. Special Issue papers

The fourteen papers of this Special Issue are presented in what we believe is a logical sequence. The first paper provides an overview of definitions and approaches used to date to estimate crop yield gaps, performs several case studies that allow direct comparison of the most widely used methods, and from this makes recommendations on "best-practice" for yield gap analysis (Van Ittersum et al., 2013). A second review paper considers possibilities for further genetic progress in potential and water-limited crop yields (Hall and Richards, 2013). A set of five papers then address some of the methodological aspects of yield gap analysis. Finally, a series of seven papers applies yield gap analysis, using a variety of methods in case studies with different crops, climate zones and production conditions, size of yield gaps, spatial extent and data availability. These case studies document both the potential power in use of yield gap assessment to better quantify and understand potential for improving food production in a given region or system, as well as the challenges posed by lack of appropriate data for the factors that determine yield potential and the highly

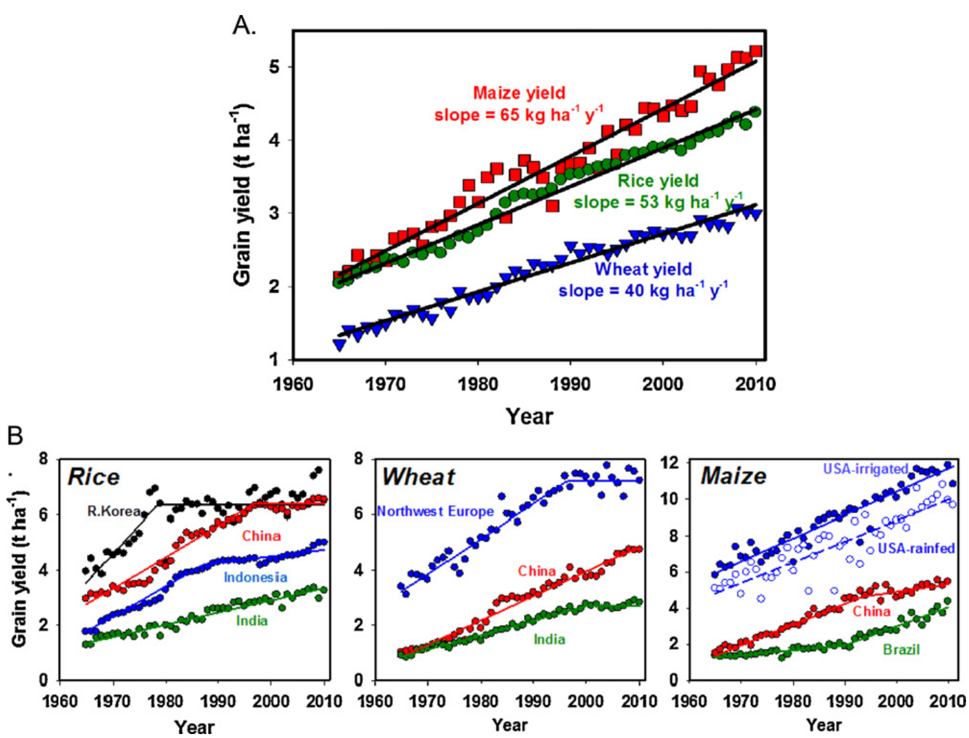

Fig. 2. (A) The increase in maize, rice and wheat yield, as global averages. (B) Examples of major rice, wheat and maize producing countries with yield trends. Source: FAOSTAT and Cassman et al. (2010).

variable performance that is inherent in crop production due to non-uniformity in soils, climate, and crop management over time and space.

In conclusion, we believe this series of papers provides a wealth of methodological approaches and guidelines for yield gap analyses with local to global relevance. We are optimistic that the papers in this Special Issue help move towards a stronger scientific consensus about appropriate methods, data requirements and sources, and models for yield gap analysis, and also how to use yield gap analysis to evaluate food security and constraints to increased crop production at different spatial scales. We are convinced that more transparent, scientifically robust, and reproducible methods will enhance the agronomic relevance and impact of yield gap assessments. Ultimately it is our hope that both the methods and case studies in this Special Issue contribute to better informed decisions to enhance food production and food security, such that the required 60% increase in food supply by 2050 can be realized in the right places and with the proper agronomy so that natural resources are conserved and environmental quality protected for future generations.

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