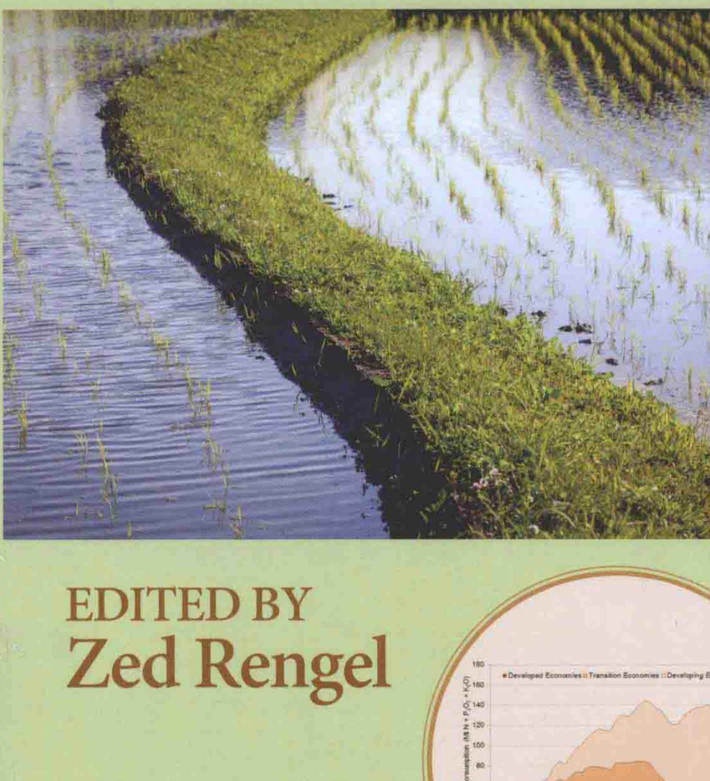
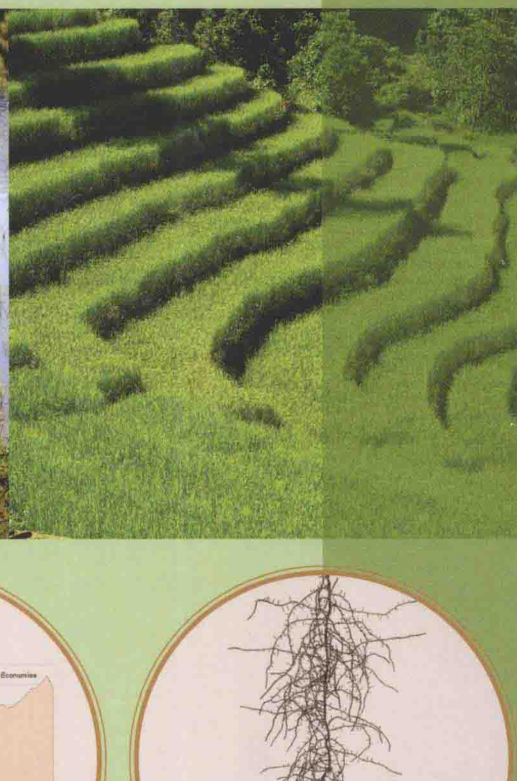
IMPROVING WATER AND NUTRIENT-USE EFFICIENCY IN FOOD PRODUCTION SYSTEMS





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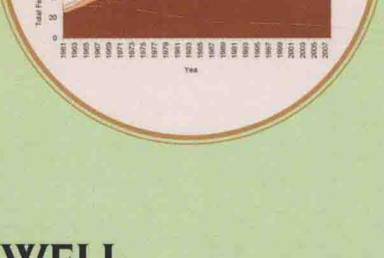

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Improving Water and Nutrient-Use Efficiency in Food Production Systems

Editor

ZED RENGEL

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Preface

With a world population having reached 7 billion in 2012, and with projections of a 50% increase in the next four decades, coupled with expected increases in the living standards and increased demand for milk and dairy products by a greater proportion of the world population, agriculture is faced with a huge challenge to double the food production in the next 40 years, but on a shrinking area of farmland. Providing food, feed, and fiber for the increasing population on this planet will also need to be achieved using declining water and nutrient resources. In many parts of the world, there is a severe shortage of good quality water that is to be used for irrigation, which is at least partly caused by increased frequency and severity of droughts in the rain-fed, food-producing areas as a result of climate change and variability. On the other side of the issue, raw materials used in producing some fertilizers (e.g., phosphorus [P] and potassium [K]) are becoming scarce and expensive, and the price of energy is also high (production of nitrogen [N] fertilizers is particularly energy demanding), pushing fertilizer prices up. As a result, agriculture must produce more food with lower water and nutrient input; therefore, increased water- and nutrient-use efficiency is of utmost importance.

Increasing efficiency of water and nutrient use (i.e., increasing food production per unit of water and nutrient input) will be crucial in (a) maintaining food security and food quality for increased global population as well as (b) decreasing potentially negative environmental impacts of growing food. In covering both water- and nutrient-use efficiency, this book takes a broad approach that includes social, economic, political, and agronomic aspects of maximizing water- and nutrient-use efficiency in food production, while maintaining healthy natural ecosystems.

The first five chapters provide a global context in which increased efficiencies of water and nutrient use need to be achieved. Historical perspectives are coupled with the regional case studies as well as future projections in terms of changing and variable climate and the population growth effects as they bear not just on increasing food production, but also on doing it sustainably. The food production and consumption patterns are also assessed. The past, present, and the future of fertilizer production and demand are analyzed. A particular emphasis is placed on the water and phosphorus cycling in agricultural and natural landscapes.

Chapters 6 to 11 deal with various agronomic means of improving water- and nutrient-use efficiency in food and feed production, with a strong emphasis on genetics and breeding. The basics of soil nutrient supply and crop nutrient demand (and how to match the two) are covered first, followed by physiology and genetics of nitrogen-use efficiency, and then breeding for water- and nutrient-use efficiency. Given the importance of roots in accessing water and nutrients, an attempt to aid breeding for important root traits by using three-dimensional computer models of root structure and function is particularly interesting.

The remaining five chapters (12 to 16) cover a range of issues relevant to increasing water- and nutrient-use efficiency in a variety of food-producing systems, from arid Mediterranean regions in Europe, Africa, and Australia to two most populous countries in the world, China and India, and to the country with the largest fresh-water resources in the world, Brazil.

This book is intended to provide professionals, students, and administrators with in-depth view of various aspects of water- and nutrient-use in production of food, feed, and fiber. The book takes a multidisciplinary approach in covering issues ranging from political, economic, and social to agronomic. Hence, professionals and scholars working in food policy, environmental regulation, and land conservation as well as agronomists, horticulturalists, plant and soil scientists, geneticists, breeders, soil microbiologists, and others may find an interest in the book.

All chapters have been reviewed according to the standards of international scientific journals. I would like to thank the authors for patiently revising the chapters, sometimes repeatedly, to meet the high standards.

Zed Rengel

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Color plate section is located between pages 180 and 181.

Improving Water and Nutrient-Use Efficiency in Food Production Systems

1 Current State and Future Potential of Global Food Production and Consumption

Christine Heumesser, Simon Thaler, Martin Schönhart, and Erwin Schmid

Introduction

The Food and Agriculture Organization (FAO) estimated the number of undernourished people in the world to be 925 million in 2010, which was 98 million below 2009 levels (FAO 2010c). Hence, more than 1 in 7 people live on a caloric intake below the minimum dietary energy requirement needed for light physical activity. However, the share of hungry people in the world has been declining since the mid-1990s and is at present below the 1970 level (FAO 2009c).

By 2050, global population is projected to reach 9 billion people (United Nations 2009). The continued population growth and the increasing per capita real income will further increase a total food demand for the next 40 years, with changing dietary patterns toward higher proportions of meat, dairy, and fish as well as processed food (Godfray et al. 2010). FAO (2009a) estimated that the current global food production needs to increase by 70% to meet the total food demand in 2050. On average, global agricultural production is projected to grow at 1.7% in the current decade, compared with 2.6% in the first decade of the 21st century (Organisation for Economic Co-operation and Development [OECD] and FAO 2011).

Meeting the increasing food demand is an unprecedented challenge. Even if attainable under the prospect of changing climate and decreasing growth rates of crop yields (Bruinsma 2003; Schmidhuber & Tubiello 2007), it will be difficult without severely exploiting and degrading natural resources, such as land, water, mineral nutrients, and fossil fuels. Additionally, the price hike of commodities and basic staples from 2006 onward and the subsequent financial and economic crisis from 2009 have drastically affected the number of people suffering from hunger and undernourishment (FAO 2009c). High commodity prices increased aggregated consumer price inflation, reduced purchasing power of poor populations, and negatively affected economic stability and food security (FAO-OECD 2011). For many developing countries, the global economic crisis led to a reduction in export earnings, remittances, foreign direct investment, and foreign aid, which led to employment and income losses (FAO 2009c). The price developments were driven by the connection between the agricultural and energy markets, increasing demands for cereals and oilseeds for biofuel production, weather-induced shortfalls of some food products, historically low grain stockpiles, a declining US dollar, increasing agricultural costs of production, and growing foreign exchange holdings by major food-importing countries (Trostle 2008).

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Food security does not only encompass food availability and supply, but it also includes food access (which is determined by political, social, and economic arrangements), food use, and food stability (FAO 2006). In this chapter, we focus on food availability and supply by investigating the current state of, and the future potential for, global, resource-efficient food production and consumption.

We first identify options and challenges in increasing global food production. This includes the expansion of agricultural land and competing usage paths (i.e., food, feed, biofuel, and nature conservation as well as increasing agricultural production by intensifying crop management). Furthermore, we discuss the impacts of changing climate and weather patterns on food production together with the options to decrease food demands by changes in human consumption behavior (i.e., less meat in the diet and reducing food waste). In addition, we provide an overview of the trends and challenges concerning the efficiency of water and nutrient use that will be a crucial factor in managing competing uses (i.e., food, feed, fiber, and biofuel) as well as negative environmental externalities.

Global Food Production

In this section we contrast frequently raised options and challenges to meet the increasing global food demand. We investigate the supply side of the global food production, focusing on the expansion of agricultural land and the productivity growth, in particular through use of fertilizers, irrigation, and biotechnology. We also account for climate change as an overarching challenge, affecting the future production strategies.

Agricultural Land Expansion

The world's total land area amounts to approximately 13 billion ha, of which approximately 5 billion ha (38.5%) are agricultural land. Of that land only 1.4 billion ha (28.6%) are arable land (FAO 2010a). Historically, the expansion of agricultural land has been a way to meet the rising food demand. From the 1960s onward, however, food production has been decoupled from cropland expansion as a result of considerable productivity increases (Lambin et al. 2003). Between the early 1960s and the late 1990s, arable land and land under permanent crops expanded by 155 million ha, or 11%, while world population almost doubled. Arable land per person fell by 40% from 0.43 ha to 0.26 ha on average, but land productivity growth through intensification compensated for this reduction in area per person (Bruinsma 2003).

To meet the increasing food demand, a remaining question is whether further expansions in agricultural land are necessary as well ecologically and socioeconomically feasible.

Drivers of Land Use Change

The causes of land use change and agricultural land expansion are manifold and complex, involving situation-specific interactions among a large number of factors at different spatial and temporal scales (Geist & Lambin 2002; Lambin et al. 2003; Smith et al. 2010). Lambin et al. (2003) identified five high-level causes of land use change: (1) resource scarcity and related pressures on natural resources, (2) changing market opportunities, (3) outside policy interventions, (4) loss of adaptive capacity and increased vulnerability of local land users, and (5) changes in social organizations, institutions, and human attitudes. Also, Smith et al. (2010) identified socioeconomic, technological and institutional factors, and social trends, such as population growth and urbanization, as the