Chapter 1
Agricultural and Food System—Global Change Nexus: Dynamics and Policy Implications

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Abstract Agricultural and food system can unequivocally be described as major agent of global change since it has been responsible for more environmental externalities than any other technology in a variety of ways. This system has also had a major impact on humanity, notably through the process of development with which it is intimately associated. In the meantime, the converse aspect of the relationship between agriculture, environment, and people means that the environmental, socioeconomic, and technological developments have had, and will continue to have, repercussions for agricultural and food system. Thus, the real agricultural and food challenges of the future will differ according to their geopolitical and socio-economic contexts. From a policy viewpoint, however, it is also critical to understand the degree to which agriculturally related activities may contribute to global-scale environmental change and the extent to which policies to prevent, mitigate, or adapt to environmental change may themselves affect agriculture and food security. With reference to this multidimensional approach, the present chapter analyses the interactions between agriculture and global environmental change and highlights the related dynamics pertaining to socioeconomic drivers, science and technology. Policy implications are underlined within the perspective of making these interactions sustainable and human security-oriented.

Keywords Agriculture • Food • Environmental footprint • Global change • Science and technology

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M. Behnassi et al. (eds.), Science, *Policy and Politics of Modern Agricultural System,*
DOI 10.1007/978-94-007-7957-0_1,

1.1 Introduction

Humanity has relied solely on hunting, fishing, and gathering for food for most of its two million years of existence. Agriculture—the domestication of plants and animals—appeared only about 10,000 years ago, roughly corresponding to a period of widespread climatic and ecological fluctuations (Matthews et al. 1990) and to an acceleration of population growth. Whether the spread of agriculture was a trigger for more rapid population growth or was itself a response to increasing population or environmental pressures remains a controversial question. One explanation for this observation is that agriculture and related technological and social innovations may have emerged initially as a way to compensate for an unreliable or declining resource base arising from population pressures, environmental fluctuations, or both (Chen 1990).

Explaining the origins of agriculture are instructive because it highlights the close links that may have persisted for many millennia among environmental fluctuations, agriculture, and human welfare. In the long term, agriculture has clearly brought the potential for larger populations, expanded exploitation of climatic and other natural resources, and reduced vulnerability to many forms of environmental fluctuation and extreme climatic and natural events such as droughts and floods. At the same time, however, agriculture and the increasing globalization of food systems may have increased vulnerability to other problems, such as market failures and the unequal distribution of food (Chen 1990).

With reference to this multidimensional approach, this chapter analyses the interactions between agriculture and global environmental change and highlights the related dynamics pertaining to socio-economic drivers, science and technology. Policy implications are underlined while emitting recommendations within the perspective of making these interactions sustainable and human security-oriented.

1.2 Agriculture, Society, Technology, and Global Environmental Change

Agriculture can be seen as a technology that represents a fundamental bond between people and environment. It plays a pivotal role in the people-environment relationship and there is a reciprocal relationship among all three. Intrinsically, it comprises both the generator and recipient of stimuli for change. This relationship has existed since the pre-agricultural era; it intensified as permanent arable and pastoral farming developed between eight millennia and ten millennia ago in many centers of innovation. Essentially, agriculture manipulates biotic and abiotic resources to produce food, energy, and useful substances such as hides and fiber; specific plants and animals are selected for certain qualities and they are husbanded using the resources of soil, water, and climate (Mannion 2003; Fig. 1.1).

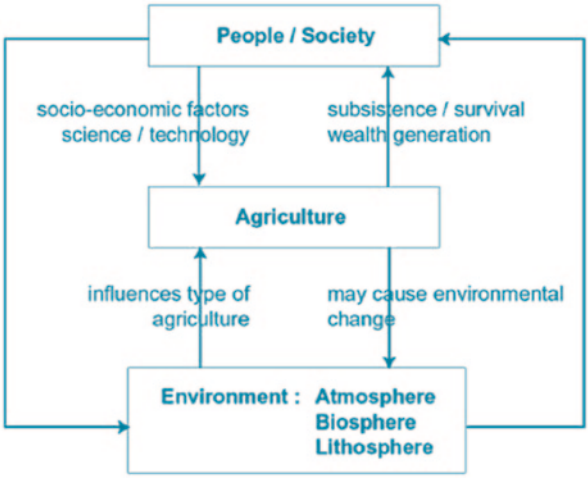

Fig. 1.1 The primary relationship between agriculture, people, and environment. (Source: Mannion 2003)

Based on these facts, agriculture can unequivocally be described as a major agent of global change[1]; since its inception 10,000 years ago, agriculture has been a direct cause of change in the biosphere. According to Mannion (2003), agriculture will continue to cause environmental change at scales from the local to the global and in the meantime global change will influence the extent and characteristics of agricultural systems. The likely roles of environmental change, notably climatic change and deteriorating soil and water quality, of socioeconomic developments—such as the spatial pattern of population growth and globalization, and the impact of new technologies, e.g., biotechnology and information technology—are matters of crucial scientific concern.

"Global change" is a term widely used to describe the effects of human activities on the Earth. Although the term sometimes refers only or primarily to global climate change, it covers also the interactions between natural changes in the Earth's physical and biological structure and the broader effects of human activity. Thus, global change includes changes in many aspects of the globe's environmental systems, including climate (BEST 2000).

Agriculture has been responsible for more environmental change than any other technology. As it has expanded and intensified, to sustain and promote population growth through the provision of food and commodities for trade in the process of wealth generation, agriculture has caused a wide range of environmental externalities. According to Chen (1990), the global food system may influence the global environment in a variety of ways. The direct impacts of agriculture on the environment include modification of land for agricultural purposes and byproducts

[1] The concept of global change is now well understood and to a large extent accepted amongst scientists, agencies and the informed public. Issues such as climatic change, desertification or the loss of biodiversity are not only major media topics, they are also regulated by international conventions aimed at finding solutions to these problems, inter alia through choices related to policy, technology, economics, and social awareness.

of production such as methane released by rice paddies and livestock. Activities such as food processing, distribution, and preparation use fossil fuels, fuel wood, refrigerants, and other inputs and generate wastes. Indirect impacts include the effects of energy, materials, and pollution entailed in constructing and maintaining equipment, transportation and storage facilities, and other infrastructure used in food production, fisheries, and related activities, and in supporting the populations involved in them.

Moreover, the loss of biodiversity is perhaps the most significant environmental problem because of its irreversibility. Deforestation and forest degradation, water depletion and degradation of irrigated land, soil degradation, global and regional climate change are all initiated or accelerated through injudicious agricultural practices (Mannion 2003). Of course, it is still difficult to quantify such problems, to attribute them consistently to particular activities, and to ascertain whether alternative uses of resources would have resulted in greater or lesser impacts (Chen 1990). These problems are highly interactive, making it difficult to predict or evaluate their combined impact. Likewise, the full extent of environmental damage from agriculture is still difficult to assess with available data and has only been attempted in a limited number of studies (Hazell and Wood 2008). The combined effects of most of these environmental problems have not threatened yet the overall capacity of the world to feed itself, despite its important local impacts on human well-being (Hazell and Wood 2008). Nevertheless, environmental problems associated with agricultural growth could, if not checked, threaten future levels of agricultural productivity at country and regional levels as well as impose future health and ecosystem service costs.

Agriculture has also had a major impact on humanity, notably through the process of development with which it is intimately associated. It is linked with population growth and wealth generation; where surpluses are produced people have been freed from food production. This, in turn, has contributed to trade, industrialization, technological endeavor, and service provision through its facilitation of division of labor (Mannion 2003).

The converse aspect of the relationship between agriculture, environment, and people means that the environmental, socioeconomic, and technological developments have had, and will continue to have, repercussions for agriculture. Soil erosion, desertification, and the impairment of water quality can, in extreme cases, result in the abandonment of agricultural land; even in cases of slight to moderate degradation, productivity and carrying capacity will decline. Thus, agriculture becomes self-defeating, a problem which is more common in poorer nations than in richer nations; the former have fewer safeguards, often little research on effective conservation measures, and limited access to technology. There is also much speculation as to the likely impact of global warming on the world's agricultural systems. Agriculture, through its part in altering the character of the biosphere and its consumption of fossil fuels, has played a significant role in global warming but how global warming will affect agricultural systems remain debatable; for some nations there will be advantages and for others there will be problems (Mannion 2003).

Included in the many socioeconomic factors that will continue to influence agriculture are population change, trade relationships (part of the globalization process),

and rising standards of living. None of these factors operate uniformly on a global basis but the repercussions may be global. The pressure on agricultural systems in developing nations will increase substantially, and at the same time there will be pressures to increase the productivity of agricultural goods for export. Where standards of living are increasing, as in emerging nations, changing food demands, and especially increasing consumption of meat and dairy products, will cause agricultural systems to change in response to consumer choice, i.e. market forces. Forces that are external to a nation will also influence agricultural systems. In some cases the production of goods for export takes precedence over the production of staple foods, which are sometimes provided through food aid[2] (Mannion 2003).

At the turn of the millennium, information technology and scientific developments have had significant impacts on agriculture. Information technology can facilitate the efficient use of resources through improved land-use practices. Knowledge-based systems can be used to control irrigation systems and to determine the quantity and location for artificial fertilizer treatments and applications of crop protection chemicals, i.e. they can be used to determine best management practices. In terms of scientific advances, biotechnology is likely to have the most profound effects on agriculture. The advent of genetic engineering in particular must be considered as a major agent of both agricultural and environmental change in the early twenty-first century. Genetic engineering has applications in medicine and environmental remediation, but its main and most controversial application to date has been in agriculture. The possibilities of engineering traits such as herbicide, drought and salinity tolerance, pesticidal properties, and so on, are exciting; all could increase productivity substantially. However, there are as many potential disadvantages as there are advantages. Genetic engineering could produce just as many environmental threats as it presents opportunities for conservation. It could also have repercussions for human health and, like most technologies, it is not available equitably (Mannion 2003).

1.3 Can Today Agriculture Meet the Food Security Challenge of Tomorrow?

Food is the most basic of all resources, and food production has effectively diverted more natural landscape to human purposes than any other ecologically significant human economic activity. Massive famines punctuate the history of human civilization—ironically, since civilization was made possible by agriculture—and, until relatively recently, fear of food shortages was a concern of most human groups (Rees 2004). Along with a few technological breakthroughs to increase yields, the food needs of growing populations were historically met by expanding the cultivated area. As the most fertile and irrigable lands became scarce, further expansion meant bringing poorer and lower yielding land into cultivation (Smith 1998). By the nineteenth century, there was growing pessimism about the possibilities of

[2] The case of Sudan can be given as example.

feeding ever-growing populations, as exemplified in the writings of Malthus. The task seemed even more overwhelming as advances in medicine and public health led to longer life expectancies and higher fertility rates.

Furthermore, not only poor countries are currently net importers of food. Wealthy countries such as Spain, the Netherlands and the United Kingdom have agricultural eco-footprints up to several times larger than their domestic agricultural land bases. Unlike the poorer developing countries, these wealthy nations have, so far, financed their considerable food-based "ecological deficits" with the rest of the world. Actually, countries that are net food importers are more the rule than the exception. Most of the world's 183 nations are partially dependent on food imports. Just five countries—the United States, Canada, Australia, France and Argentina—account for 80 % of cereal exports and most of the safety net in global food markets (Pimentel and Pimentel 1996). These countries have exceptionally high crop-land-to-population ratios and relatively few soil constraints, and use intensively mechanized, fossil-energy dependent production methods (Rees 2004).

Public investments in modern scientific research for agriculture has led to dramatic yield developments in recent decades. The achieved advances were fuelled by modern plant breeding, improved agronomy and development of inorganic fertilizers and modern pesticides. Most industrial countries had achieved sustained food surpluses by the middle of the twentieth century, and some developing countries did the same in the closing decades. However, not all countries have shared the global success of agriculture, and hunger and malnutrition persist in many parts of the world[3].

In general terms, the global food situation is very favorable today. Already more food is produced than needed to feed the entire world population and at prices that have never been so low. More precisely, agricultural production has grown much faster than the population in recent decades, leading to a steady increase in per capita agricultural output (including food) and a steady decline in world prices for most agricultural commodities. As a result of this unprecedented growth in agricultural productivity, the world now produces more than enough food to feed the entire population to minimum UN standards if it were distributed more equitably. Even more remarkably, this surplus has been achieved despite the diversion of considerable land, labor and other rural resources to the production of higher-value foods to meet the changing food demands of growing, more urbanized and more affluent populations. This includes the additional cereals needed as feed grains in intensive livestock systems and oil crops for inland aquaculture (Hazell and Wood 2008).

[3] Africa is the only continent that has yet to achieve food surpluses. This continent has not been able to increase its agricultural production to keep pace with population growth, leading to periods of decline or stagnation in its food and total agricultural outputs per capita. Africa has yet to experience the kind of technological revolution enjoyed elsewhere and still uses few modern inputs in agricultural production. As a result, yields of all major crops in Africa have grown little over the past 40 years and cereal yields have stagnated for the past 20 years. Moreover, and while hunger is now largely a distributional problem in most parts of the world, Africa still faces the additional burden of a classic food shortage problem. Sub-Saharan Africa still relies on food aid, and the food gap is projected to increase significantly in the future (Hazell and Wood, 2008), especially within the perspective of climate change, water shortage and conflicts.

Despite these accomplishments, serious hunger, health and environmental concerns remain and even in countries and regions that have performed better and now have food surpluses (e.g. much of South Asia), hunger and malnutrition are still widespread[4]. The fundamental hunger problem today is one of income distribution rather than food shortages. The hungry are simply too poor to buy the food that abounds, while, at the same time, obesity and chronic illnesses associated with excessive food intake are becoming a serious problem among richer people (WHO 2002, 2003). Based on this fact, simply increasing global supplies will not solve this distribution problem. Additionally, since food production, buying power, and consumption are not distributed evenly with population, large surpluses and deficits will persist at regional, national, and subnational levels (Chen 1990).

The real agricultural challenges of the future will, as today, differ according to their geopolitical and socio-economic contexts. The current divide between those who eat well and those who go hungry will continue, defined largely by differences in per capita incomes within and between countries. Factors that distinguish the various trajectories of agricultural development also exhibit significant spatial variability, such as differences in farming systems and productive capacity, population densities and growth, evolving food demands, infrastructure and market access, as well as the capacity of countries to import food or to invest in agriculture and environmental improvement. Environmental problems associated with agriculture too vary according to their spatial context, ranging from problems associated with the management of modern inputs in intensively farmed areas to problems of deforestation and land degradation in many poor and heavily populated regions with low agricultural potential. In short, despite globalization and increasing world trade in agriculture, there remain large, persistent and, in some cases, worsening spatial differences in the ability of societies both to feed themselves and to protect the long-term productive capacity of their natural resources (Hazell and Wood 2008).

1.4 Agricultural and Food Production with a Better Environmental Footprint

The current scientific attention to the threat of global environmental change has tended to focus on the possible impacts of a changing environment on agriculture and the implications for global and regional food security. From a policy viewpoint, however, it is also critical to understand the degree to which agriculturally related activities may contribute to global-scale environmental change and the ex-

[4] Food security is essential to support the health and nutrition that are vital for sustained progress in developing nations. Up to 1/3 of child mortality in these countries is a direct consequence of malnutrition (WHO, 2009). Diseases like malaria are also spreading to new geographic areas due to climate change (IPCC, 2007), further impeding the productivity of agricultural workers and others. Tackling the impacts of climate change on malaria, malnutrition and diarrheal disease could add as much as 1 % of current gross domestic product (GDP) in sub-Saharan Africa and South-East Asia up to 2030 (Accenture et al., 2011).

tent to which policies to prevent, mitigate, or adapt to environmental change may themselves affect agriculture and hunger. These two issues are likely to become especially important for decision making processes not only about how to reduce the magnitude of human perturbations to the environment but also about how to improve both food security and environmental sustainability in the overcrowded world of the future.

The OECD and FAO's Agricultural Outlook for 2010–2019 suggests that the world is on track to meet growing demand for food (OECD and FAO 2010). But the agricultural sector will need to overcome four key hurdles as well as coping with rising production and distribution costs: changing land use and availability, growing water scarcity, climate change, and food wastage.

- Land for agriculture is becoming more scarce. It is being lost to spreading urban and industrial areas, use for growing biofuel crops, soil erosion as a result of intensive and poor farming practices, and climate change. As people migrate to cities for better education and employment, there are also fewer families in rural areas to farm the land.
- Irrigated agriculture accounts for approximately 70 % (UN-Water 2009) of global water usage, and by 2030 almost half of the world's population will be affected by water scarcity (OECD 2008). In many developing countries, irrigation makes up over 90 % of water withdrawals (WBCSD 2009).
- Climate change impacts farming practices and is influenced by them. Extreme weather events, such as droughts and flooding, as well as longer-term changes in climate, damage crop yields and change growing cycles. The agricultural industry is currently responsible for around 30 % (IAASTD 2008) of the world's carbon emissions. This could increase as a result of poor farming practices, deforestation and growing demand for animal protein in people's diets.
- While improved agricultural productivity is essential, reducing waste will also increase availability. Around one third of the food in the supply chain is either lost or wasted at the farm, during storage and distribution, or in households (FAO 2011).

In addition to the above orientations, investments should be focused on other related areas with similar importance:

- Engage in trust-based free trade: The world's farmers are producing an all-time record level of calories which remain unevenly distributed and irregularly available. The world can go on providing food in economical fashion—with a better environmental footprint—if every farmer plants the right crop for his soil and climate and then freely trades with others based on the principle of comparative advantage. Although food security is a complex issue, this fundamental economic principle is simple. It recognizes that fertile soil, abundant rain and plentiful sunshine are not equally available across our planet. If every country on Earth tried to pursue self-sufficiency, there would be less food. The role of trust-based free trade becomes increasingly important if we are going to exploit the law of comparative advantage.

- Ecological agriculture, which works with nature rather than against it, can drastically reduce environmental externalities such as greenhouse gas emissions. Moreover, compared with today's destructive chemical and fossil energy intensive agriculture, ecological agriculture better adapts to and survives the effects of environmental change.
- Climate change has prompted a wide array of policy responses ranging from the creation of carbon markets to adaptation programs for vulnerable communities. Few of these policies have invited the degree of controversy that surrounds biofuels, as emerging evidence of the adverse environmental and social impacts of biofuel production indicates that biofuels may not be the climate change panacea that policy-makers had made them out to be. The promotion of biofuels as a fossil fuel alternative has been a significant aspect of the global quest for solutions to mitigate climate change. However, the quick-fix has proven to be problematic as food security and environmental concerns emerge. There are growing concerns about how increased biofuel production can assert upward pressure on food prices, increase GHG emissions, and exacerbate degradation of land, forest, and water sources[5]. Championed as a panacea to climate change, an agent for rural economic regeneration, and a means to securing energy independence, biofuels have not turned out to be the perfect solution. Questions surrounding the environmental and social costs of biofuels have overshadowed earlier optimism as evidence of the role of biofuels in rising food prices, accelerating deforestation and doubts about the climate benefits continue to emerge (Lin 2011). Clearly, we urgently need to engage in an honest discussion about balancing food and fuel and make biofuels more responsive to shifts in supply and demand.
- Africa should be made as a part of the solution. Africa represents about 60 % of the potentially available cropland in the world, and it is well suited to harvest the fruits of photosynthesis. Africa can contribute critically in feeding the planet's growing population but its agricultural productivity is still the lowest in the world. The challenges seem overwhelming: unclear property rights; limited access to fertilizer, quality seed and mechanized equipment; inadequate roads and storage facilities; lack of market institutions and prices that encourage farmers to invest in their operations year after year. For Africa to feed itself—and help feed the world—the issue of price adequacy is crucial. Today, there is more momentum than ever to tackle these issues. Under the Group of 8's New Alliance for Food and Nutrition Security, and the Grow Africa partnership, companies, nongovernmental organizations and African governments are working to develop sustainable markets for food grown on the continent. Global food security cannot be achieved without closing the agricultural productivity gap between Africa and the rest of the world.

[5] Concerns about the food security dangers of current biofuels development have prompted the United Nations Special Rapporteur on the Right to Food Jean Ziegler to call biofuels a "crime against humanity." In 2008, when food prices were soaring, he demanded an international five-year ban on biofuels production (Ziegler, 2008).

Orienting policy interventions, scientific research and private investment within the above perspective while reversing the current undesirable trends has the potential to ensure sustainability and less environmental footprint for agricultural and food production systems.

1.5 Concluding Remarks

We have reviewed a number of the key issues and drivers of significance to agriculture globally. We have seen that immense progress has been made from a humanitarian perspective in feeding a world population that has doubled in the past 40 years, become more wealthy, and increased its per capita demand for low-cost food in terms of quantity, quality and diversity. However, much still remains to be done both to further strengthen food security for the majority, and to attack the persistent, large and, in some places, still-growing pockets of hunger. Furthermore, all this needs to be done in ways that improve (or at least damage less) our long-term capacity to sustain food production. This means conserving biodiversity, soils, water and other resources that will provide the level and quality of ecosystem services necessary to support agriculture in the future.

However, while some drivers may be common, it is unlikely that appropriate responses to change—either positive or negative impacts—will likewise be similar. The geopolitical and agro-ecological contexts under which agriculture is conducted globally are very heterogeneous and consequently a specific approach is needed to tackle the relevant challenges.

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