

# Sustainable Food Systems from Agriculture to Industry

## Improving Production and Processing



Edited by Charis M. Galanakis



**SUSTAINABLE FOOD  
SYSTEMS FROM  
AGRICULTURE TO  
INDUSTRY**

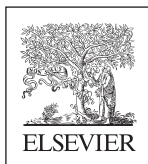
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CHARIS M. GALANAKIS



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# PREFACE

Until the end of the 20th century, food loss and disposal of food waste were not evaluated as matters of concern. The prevalent policy mainly aimed at increasing food production, without improving the efficiency of the food systems. This fact increased the generation of food lost or wasted along food supply chains. In the 21st century, escalating demands for processed foods have required identification of concrete opportunities to prevent depletion of natural resources, restrict energy demands, minimize economic costs, as well as reduce food losses and food wastes. Besides, recent changes in the legislative frameworks and environmental concerns have stimulated the industry to reconsider their management policy and in some cases to face the concept of “recovery” as an opportunity.

This tendency is becoming a major concern for the food industry around the world, as resources become more restricted and demand grows. Indeed, food industry is increasing its attention toward sustainability, which has been developed into a trendy word, characterizing a frame of advances and modernization in the years to come. However, sustainability is neither easy to specify nor to implement. In theory, it reflects the principle that we must meet the needs of the present generation without compromising the ability of future generations to meet their own needs. For instance, food processing ensures that the resources required to produce raw food materials and ingredients for food manufacturing are used most efficiently. Responding to this goal, sustainability requires the maximum utilization of all raw materials produced and integration of activities throughout all the stages of production and consumption. To maximize the conversion of raw materials into consumer products, efforts begin at the production stage, with activities to reduce postharvest losses and to increase the use of by-product streams (wastes). Efforts continue, through food manufacturing and beyond, to ensure that energy, water, and other resources are used most efficiently and environmental impacts are minimized. Refrigeration of fresh produce is an example of an action that reduces loss and increases the edible life of the product.

Subsequently, there is a need for a new guide covering the latest developments in this particular direction. The present book

fills this gap by providing certain solutions for industrial sustainability in spite of processing, production, and waste management. It covers important aspects of the sustainable food production and processing, at all relevant stages.

The book consists of three parts and 12 chapters. Part A (*Sustainable Food Production*) includes five chapters. [Chapter 1](#) provides an overview of the current food production methods and describes the options for making healthier foods with reduced environmental impact. [Chapter 2](#) highlights the importance of earthworms and reveals their role in sustainable agriculture, whereas [Chapter 3](#) elucidates the use of local plants and animals for food production, reflecting many challenges related to the industrial and sustainable use of biological resources. [Chapter 4](#) evaluates the environmental, economic, and social sustainability of agro-food systems through life cycle approaches, whereas [Chapter 5](#) explores the sustainability and corporate social responsibility in the food supply chain. Part B deals with *Sustainable Food Processing* in four Chapters. [Chapter 6](#) analyzes energy saving in food processing through the use of innovative technologies (e.g., in pasteurization, sterilization, extraction, evaporation, and so on). [Chapter 7](#) focuses particularly on sustainable drying and chilling/freezing methods of perishable foods in the organic sector to maintain their high nutritional values. [Chapter 8](#) discusses the existing and alternative packaging solutions, with an ultimate goal of denoting weaknesses and opportunities to improve sustainability and efficiency of the food sector. [Chapter 9](#) describes sustainable cleaning in the food industry, highlighting the efficacy of Electrolyzed Water as an interesting and ecological clean-in-place reagent, whereas [Chapter 10](#) explores the possibilities of applying microbial biosurfactants in food sanitation. Finally, Part C (*Sustainable Food Waste Management*) consists of two chapters ([Chapters 11](#) and [12](#)) dealing with food waste reduction and valorization, respectively.

In conclusion, the ultimate goal is to inspire the scientific community, professionals, and enterprises that aspire to optimize the efficiency of food systems and reduce environmental impact of involved industries. It is intended to support researchers, specialists, agriculturalists, chemical engineers, professionals, and strategy developers working in the agro-food industry, from farm to fork. It could be purchased by University libraries and Institutes all around the world to be used as a textbook and/or ancillary reading in graduate and postgraduate level multidiscipline courses dealing with sustainable food systems, agricultural and environmental science, food processing, bioresource valorization, and chemical engineering.

I would like to take this opportunity to thank all the contributors of this book for their fruitful collaboration and high-quality work in bringing together issues of food production, food processing, and food waste management in an integral and comprehensive text. I consider myself fortunate to have had the opportunity to collaborate with so many knowledgeable colleagues from Germany, Italy, India, Iran, Norway, Poland, Portugal, Romania, Turkey, United Kingdom, and United States. Their acceptance of editorial guidelines and book concept is highly appreciated. I would also like to thank the acquisition editor Nancy Maragioglio for her honorary invitation to lead this project and all the production team of Elsevier, specifically Barbara Makinster and Anusha Sambamoorthy for their assistance during the editing and in press process, respectively.

Last but not least, a message for the reader. In a collaborative project of this size, it is impossible for it to not contain any errors. Thus, if you find errors or have any objections, I would really appreciate if you contact me.

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PART

A

**SUSTAINABLE FOOD  
PRODUCTION**

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# INTRODUCTION TO SUSTAINABLE FOOD PRODUCTION

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## 1 Introduction

Historically, man has always sought his dominion over nature. The set of techniques used to grow plants for food, beverages, fiber, energy, raw material for clothes and construction, medicines, tools, or just for aesthetics contemplation is part of agriculture. Agriculture is the science, art, or practice of cultivating the soil, producing crops, and/or raising animals at different levels for marketing or for own consumption ([Merriam-Webster, 2016](#)). The very definition of agriculture is broad and refers to the most basic instincts of human beings such as the ability to produce food to satisfy his hunger and for the survival of the species. The etymology of the word agriculture comes from the Latin *agricultūra* “cultivation of the land,” composed of *ager* (field, territory) and *cultūra* (cultivation, growing), in the strict sense of cultivation. The history of agriculture is closely linked with human history, due to its importance in path followed by the human life, as the emergence of agriculture separates the Neolithic period from the immediately previous age, which was the period of the chipped stone ([Alexandratos et al., 2006](#)).

With the emergence of agriculture and the man shaping nature in his favor begins the development of new techniques, tools, and consequently the possibility of small settlements, which was previously impossible because the man was essentially hunter and

collector following the preys where they go. Therefore, the itinerant and nomad nature of man is changed and a new era begins.

The locations indicated in Fig. 1 show where the first regions of agricultural production were identified (Ladizinsky, 1998):

- (1) Mexico-Guatemala,
- (2) Peru-Ecuador-Bolivia,
- (2A) Southern Chile,
- (2B) Southern Brazil,
- (3) Mediterranean,
- (4) Middle East,
- (5) Ethiopia,
- (6) Central Asia,
- (7) Indo-Burma,
- (7A) Siam-Malaya-Java,
- (8) China and Korea.

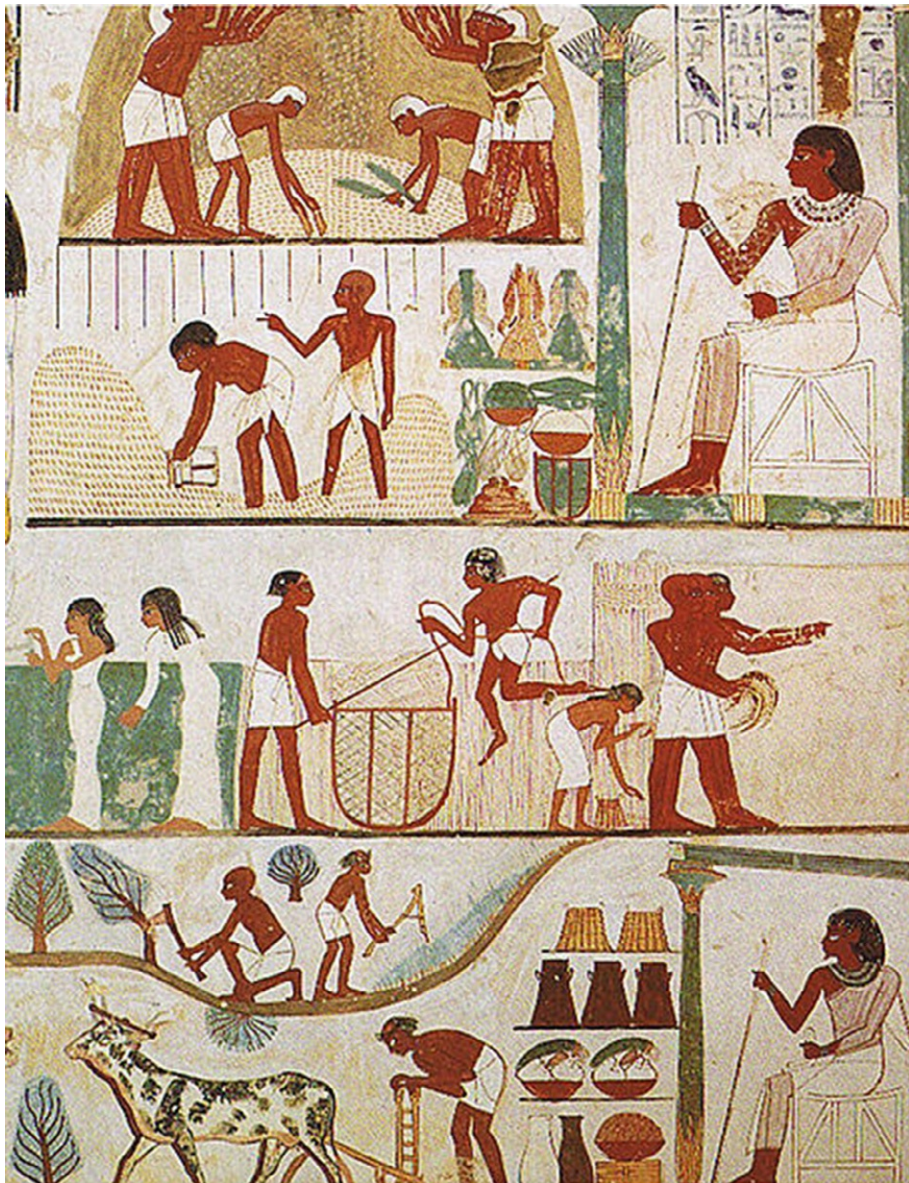
From the analysis of these sites, it can be seen that these locations subsequently formed the basis for large societies, thus demonstrating how the evolution of agriculture has affected and changed humankind and how it generally shaped our society.

The people who created and mastered new tools had an advantage compared with those who did not have this same capability and as today productivity is of paramount importance, more than just an economic advantage as it was and is still a strategic advantage.



Fig. 1 First regions of agricultural production (centers of origin identified by Nikolai Vavilov (Ladizinsky, 1998).

With the evolution of tools and techniques and with the increasing use of animal power in agricultural production (see Fig. 2), an increase in productivity was achieved, making the societies that mastered the techniques grow more than others and became empires and superpowers at their time.



**Fig. 2** Daily scenes of agricultural production in Egypt (note the use of animal force to ensure greater productivity) (Seidel & Shedid, 1991).

The agricultural production system underwent a large evolution during the Industrial Revolution. At approximately the same time, Great Britain was undergoing an agricultural revolution. This revolution was caused by the implantation of new tools, by the use of fertilizers (a new technology at the time) and new techniques of planting, resulting in a very significant increase of labor and land productivity. The evolution of the major commodities (weight and price) during this period is shown in Fig. 3.

Fig. 4 shows the farming area in Great Britain during that same period: the increase in agricultural production was ~340%, while the cultivated area decreased ~2%.

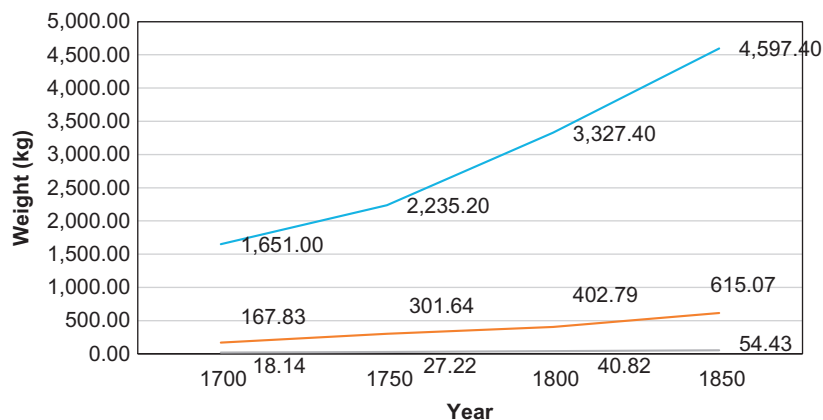
This outstanding increase in production despite maintaining practically the same cultivation area is explained by the several techniques and tools created during that period. Productivity values experienced a sharp increasing trend.

However, this productivity increase had consequences attached. The environmental impact that, before the Agricultural Revolution, was practically zero, increased with the use of fertilizers, machines with burning of fossil fuels, deforestation, mining, and other activities. According to Intergovernmental Panel on Climate Change (IPCC), these activities lead to the increase of the global warming.

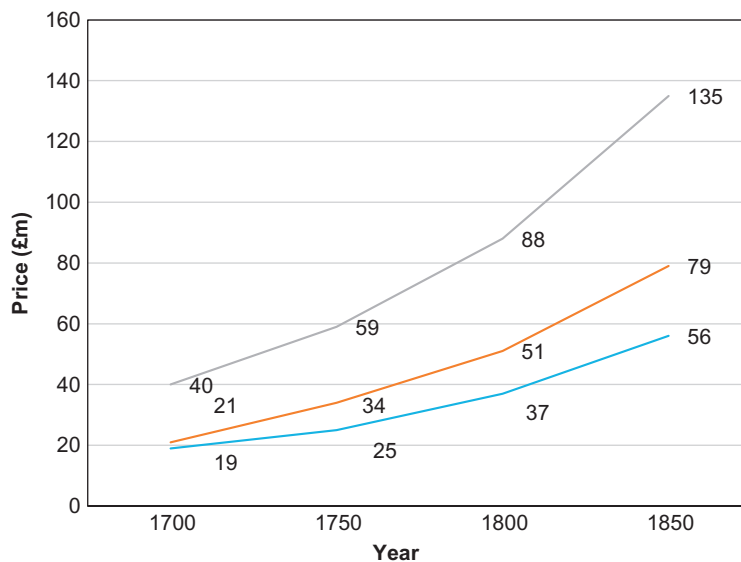
These human activities result in a high degree of concentration of greenhouse gases (GHGs) ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ ) in the atmosphere since the beginning of the Industrial Revolution around 1750 (Parry et al., 2007). Carbon dioxide ( $\text{CO}_2$ ) in the atmosphere increased from 280 parts per billion per volume (ppb) to an outstanding value of 379 ppb since the preindustrial revolution era to 2005. The same applies to methane ( $\text{CH}_4$ ) concentrations. This increase was even more significant since the increase of its atmospheric concentration was ~250%, from 715 to 1774 ppb over the same period. Nitrous oxide ( $\text{N}_2\text{O}$ ) had an atmospheric concentration of ~270 ppb before the Industrial Revolution, and increased to 319 ppb in 2005 (Parry et al., 2007).

Climate change poses various difficulties and aggravates the shortage of availability of drinking water on the surface of the planet. This increasing problem is due to significant changes and variables affecting the normal water circle, which would be precipitation, infiltration, runoff, evaporation, and condensation. The shift of the rainfall season in some places that previously had well-defined seasons of drought and rain had significant consequences on the local environment.

The quality of surface water also declined, which represents only 0.006% of the total volume of water in the planet. This is a direct consequence of the chemical inputs into the air, of the



(A) — Corn (million kg) — Meat (million kg) — Wool (million kg)

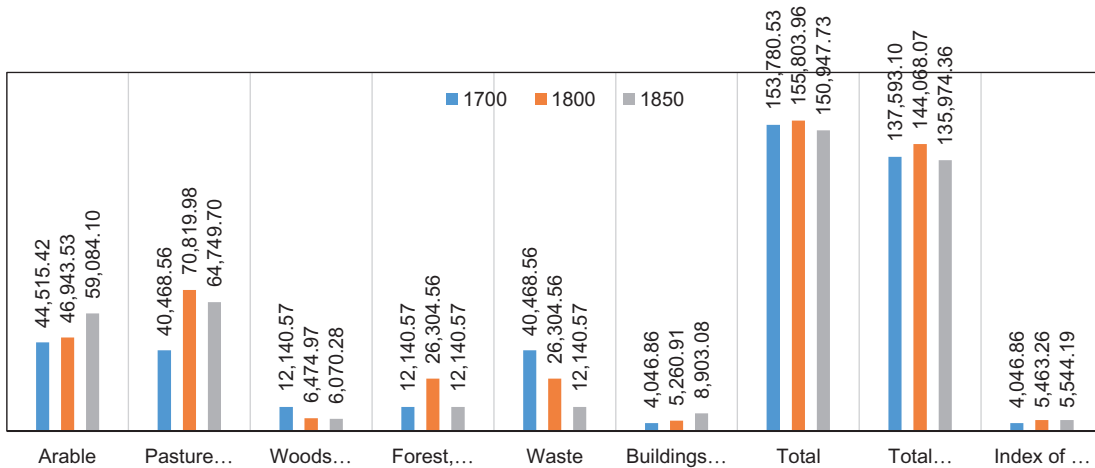


(B) — Corn and potatoes — Animal products — Total

**Fig. 3** Evolution of major commodities (weight and price) in Great Britain during the Agricultural Revolution: wheat, oats, beans, and turfs; seed nectar and oats are included in maize. Meat, wool, dairy products, and cheese are included in animal production) (Allen, 1994). (A) Increase in the production of major commodities and (b) increase in the price of major commodities.

environment where it is located, and of the biochemical processes that these inputs transform within the system itself. The inputs are from natural processes and/or human activities, such as the atmospheric deposition in the course of the aquatic system or direct discharge of pollutants in the watercourses, and direct





**Fig. 4** Distribution of the farming area in Great Britain during the Agricultural Revolution—utilization of English and Welsh land (km<sup>2</sup>) (Allen, 1994).

chemical injections of pollutants into the aquatic system (Anderson et al., 2011). The water flows into the river basins through several types of vegetation, soils, and ecosystems, contributing each one to extract, add or chemically transform it before reaching a stream. Although, the opposite can also happen, this water can chemically alter the region that it bathes. The path that the hydrological flow that water takes through the natural course of the river basins, and the resulting transformations that occur along that route will determine its chemical and physical characteristics when entering the surface water system (Anderson et al., 2011). The changes in the region's hydrological system are not only local but can and probably will be broader as chemical changes in water follow their natural course.

In agriculture, pesticides are a major pollutant of aquifer systems. The literature review concerning the use of pesticides estimates that commercial pesticide runoff losses in agricultural fields are around 0.5% or less of the quantities initially applied, unless severe precipitation occurs between 1 or 2 weeks after its application. Exceptions are related to the application of organochlorine insecticides, as the aquifer systems may absorb about 1%, regardless of the climatic pattern, due to their long persistence in the production fields. The chemical formulations of wettable powder herbicides applied to the soil surface can be lost up to 5%, depending on the time and inclination of the terrain, due to the ease of powder removal (Wauchope, 1978).