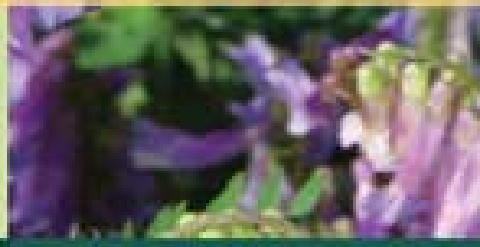
BIOMASS AND BIOFUELS SERIES

Biofuel Crop Sustainability



Bharat P. Singh

WILEY Blackwell

Contents

Biofuel Crop Sustainability

Edited by

Bharat P. Singh
Fort Valley State University
Fort Valley, GA, USA

WILEY Blackwell

This edition first published 2013 © 2013 by John Wiley & Sons, Inc.

Editorial offices:
2121 State Avenue, Ames, Iowa 50014-8300, USA
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Library of Congress Cataloging-in-Publication Data

Biofuel crop sustainability / editor, Bharat P. Singh. – 1st ed.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-470-96304-3 (hardback : alk. paper) – ISBN 978-1-118-63564-3 (epdf) –
ISBN 978-1-118-63572-8 (epub) – ISBN 978-1-118-63578-0 (emobi) – ISBN 978-1-118-63579-7
1. Energy crops. 2. Sustainable agriculture. I. Singh, Bharat P.
SB288.B565 2013
631.5–dc23
2013002832

A catalogue record for this book is available from the British Library.

Cover design by Nicole Teut

Contributors

Shaun D. Berry, Becker Underwood, Gillitts, South Africa

Nanthi Bolan, Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Mawson Lakes, Australia

K.B. Cantrell, USDA-ARS Coastal Plains Soil, Water, and Plant Research Center, Florence, SC, USA

Dmitri Chatskikh, George Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Catholic University of Louvain, Louvain-la-Neuve, Belgium

Christina Eynck, Linnaeus Plant Sciences Inc., Saskatoon Research Centre, Saskatoon, Canada

Kevin C. Falk, Agriculture and Agri-Food Canada, Saskatoon Research Centre, Saskatoon, Canada

Andrew Fieldsend, Research Institute of Agricultural Economics, Budapest, Hungary

John H. Fike, Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA

Wonae B. Fike, Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA

Thein Maung, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, ND, USA

Bruce McCarl, Department of Agricultural Economics, Texas A&M University, College Station, TX, USA

Eric Obeng, Fort Valley State University, Fort Valley, GA, USA

Anna Ovchinnikova, Cargill Europe BVBA, Mechelen, Belgium

Sudhanshu S. Panda, GIS/Environmental Science Gainesville State College, Oakwood, GA, USA

David J. Parrish, Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA

József Popp, Faculty of Applied Economics and Rural Development, University of Debrecen, Debrecen, Hungary

David Ripplinger, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, ND, USA

K.S. Ro, USDA-ARS Coastal Plains Soil, Water, and Plant Research Center, Florence, SC, USA

David Saxowsky, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, ND, USA

Balaji Seshadri, Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Mawson Lakes, Australia

Dev Shrestha, Biological and Agricultural Engineering Department, University of Idaho, Moscow, ID, USA

Bharat P. Singh, Fort Valley State University, Fort Valley, GA, USA

Hari P. Singh, Fort Valley State University, Fort Valley, GA, USA

P. Smith, Institute of Biological and Environmental Sciences, School of Biological Sciences, University of Aberdeen, Aberdeen, UK

Jeff Smithers, School of Engineering, University of KwaZulu-Natal, Pietermaritzburg, South Africa

Kenneth C. Stone, USDA-ARS Coastal Plains Soil, Water, and Plant Research Center, Florence, SC, USA

Rianto van Antwerpen, South African Sugarcane Research Institute, Mount Edgecombe, Department of Soil, Crops and Climate Sciences, University of Free State, Bloemfontein, South Africa

Tania van Antwerpen, South African Sugarcane Research Institute, Mount Edgecombe, South Africa

Michael van der Laan, Department of Plant Production and Soil Science, University of Pretoria, Hatfield, Pretoria, South Africa

Johann Vollmann, Division of Plant Breeding, Department of Crop Sciences, University of Natural Resources and Life Sciences, Vienna, Tulln, Austria

J. Yeluripati, Institute of Biological and Environmental Sciences, School of Biological Sciences, University of Aberdeen, Aberdeen, UK

Preface

Agriculture by nature is an unsustainable system. Crops take more out of soil than it has the ability to replenish under normal conditions. Being aware of this fact, throughout history man has tried to supplement the difference by various means with different degrees of success. It was no accident that the location of the first agriculture-based civilization was Mesopotamia, meaning “land between two rivers.” The flood water every year brought new rich alluvial soils down the river to enrich the farmland with nutrients. With increases in population, people migrated from the optimal to the best land and climate they could find, and in time were forced to settle for marginal soils and climates. However using ingenuity, mankind found ways to supplement what soil was not able to offer and used the climate to the fullest. Man's incessant desire for more, while at the same time having more mouths to feed started to take toll on the soil, the primary agricultural resource. Ancient scholars saw the development of this trend and warned against tendencies that made agricultural systems unsustainable. The evidence of such warnings is found in the literary archives of the Indus Valley, Chinese, and the Middle Eastern civilizations. In modern times, detriment to soil and climate became endemic with the large-scale use of chemicals and machineries in agriculture starting in the 1930s. Present scholars, like their ancient predecessors, raised the alarm and the “dust bowling” by mechanical agriculture created general awareness of the awaiting catastrophes from the overexploitation of agricultural resources.

The World Commission on Environment and Development of the United Nations General Assembly of 1987, also known

as the Brundtland Commission provides the latest definition of sustainable agriculture. Under this definition, sustainability includes the long-term survival of agriculture as an economic enterprise benefitting not only the farmer, but the society as a whole, with due regard to the preservation of the quality of life in aesthetics, health, and culture by preserving the wholeness of the surrounding environment. It is similar to the concept followed during ancient agrarian times, components of which were lost during the Industrial Age. For example, Indian villages were a cluster of households; farming families were the nucleus and other families provided essential services to farmers, with the right of a portion of the harvest. Thus, essentially the part of the harvest a farmer could keep for his family in relation to other families in the village was fixed. Nonfarm families sold part of the harvest to exchange goods and services among themselves. This model of agrarian economy was sustainable because it created a system of exchange of goods and services that benefitted all members of the village. It also put the responsibility upon farmers to follow agricultural practices that guaranteed land to produce harvests year after year because the whole village depended on them. The farmer grew up sharing farm responsibilities from childhood and learning from his elders how to keep land productive and safe before assuming a decision-making role. People paid tribute to trees, rain, and animals and folklores were built around even the virtues of crows and vultures to ascribe their important contribution to human sustainability and to perpetuate this knowledge to future generations.

Biofuel is as old as man's discovery of how to light fire. Use of solid biofuel for cooking and the burning of plant oils for light was common until the start of the twentieth century. Using liquid biofuels for light and later as automotive fuel was not uncommon during the early 1900s.

Cheap coal, kerosene, and later petroleum, however, slowly eroded plants' monopoly as energy providers and ultimately pushed them into subservient roles. Uncertainty regarding uninterrupted petroleum availability from disturbed regions of the world, which coincidentally have the greatest petroleum reserves, along with the intentions shown by petroleum-owning nations to use fuel as a political tool and fix prices outside the market domain have necessitated the shift to alternate fuel sources. Added to it was the clear evidence of detrimental impact of petro-fuels on the environment and, specifically, their connection to global warming. Thus, in the search for alternatives, there were two broad requirements: energy sources that are reliable and available year after year and secondly is environment friendly. Solar, wind, geothermal, hydro, and biofuel were perceived to meet the criteria. Biofuel is unique in the energy mix; it is the only fuel available both in solid and liquid forms and with the potential to match the multi-byproduct generation ability of petro-fuel. It is also the most suitable form of transportation fuel for the vehicles currently on the road. As the feedstock for biofuel comes from agriculture, the sustainability of feedstock production systems automatically becomes a matter of importance in consideration of this energy source. Keeping in mind that agriculture currently is mainly a food and fiber enterprise, noninfringement by biofuels of this primary function is also of paramount importance.

This book covers all aspects of sustainability as defined under the Brundtland Commission's definition, with the adage of food-over-fuel-priority underpinning all chapters. I have been fortunate to assemble the ablest authors from different countries. My sincere appreciation and thanks to all of them for graciously accepting my invitation to join in this exercise of providing a comprehensible scientific treatise on the different aspects of sustainability as it relates to biofuel

crop production. The food-versus-fuel debate is highly emotional and some scientists have taken sides. I have tried my best to select authors who can provide objective deliberation and to examine each chapter carefully for science-based description. I hope this book proves useful to all concerned with agriculture, sustainability, and biofuel.

In closing, I would like to extend my sincere thanks and gratitude to my associate, Eric Obeng, for his assistance at every step of this editorial exercise. Without his help, this burden would have been lot heavier. I would like to dedicate this book to my 4-year-old grandson, Ayan—he never ceases to amaze me with his voracious appetite for reading anything with pictures and constantly attempts to discover things that are around him and which are intentionally hidden from him. What his parents call mischief, to me is just an innovative mind—the sign of a genius.

Bharat P. Singh
Fort Valley State University
Fort Valley, GA, USA

Chapter 1

Biofuel Crop Sustainability Paradigm

B.P. Singh

Fort Valley State University, Fort Valley, GA, USA

Introduction

Relevance of Sustainability

The topic of biological sustainability has been covered comprehensively by Morse (2010). In this review, the author contends that sustainability is more of a human centric term concerned with the survival of *Homo sapiens*. The origin of life by most accounts dates back some 3.5 billion years, to within just a billion years of Earth's own coming into existence. Living organisms evolved in many different forms and shapes (commonly referred to as species) to have multiple options of survival available for the various changes Earth may undergo over time. Sure enough, climate change is built into nature, yearly rotation with the change of season, occasional changes resulting from ocean current temperature variations, and drastic changes from gradual buildup or abrupt geological behavior such as ice age, volcanic eruptions, etc. At the same time, change through evolution is built into the constitution of living organisms, this continuous process is commonly known as

mutation. Endowed with this gift of adaptability, living organisms have learned to flourish when the environmental conditions are optimal, sustain themselves when conditions become limiting, and survive when conditions turn harsh. Indeed, numerous species have disappeared in the course of time, but on the other hand, new resilient species have emerged. Sepkoski (2002) has developed a compendium of fossil marine genera, which is helpful in understanding the historical course of generation and extinction of marine species. There have been several periods of mass species extinction, one most noteworthy being Permian–Triassic event (about 250 million years ago) that killed up to 96% of marine species (Raup and Sepkoski, 1982; Rohde and Muller, 2005). As a matter of fact, though it has been stipulated that the extinction rate of living species has hovered around 99%, planet Earth remains the flourishing habitat of life. Reassuringly, there also appears to be an increase in the number of marine genera in the past 500 million years (Morse, 2010). Thus, it can be safely concluded that life has evolved a large window of survivability from catastrophic climatic events by continually transforming itself to adjust to widely different surroundings.

Human beings are only one among approximately 8.7 million eukaryotes inhabiting Earth. So, in nature's scheme of things, human extinction would be a mere footnote in its long history of evolution. However, for human beings, the subject of survival of *H. sapiens* is personal and of paramount importance. Creativity and innovation has been the hallmark of human existence. This human capability was first evidenced in the change from hunter/gatherer lifestyles with the constant search for food and water to being settled at a reliable water source and practicing agriculture for year-round reliable supply of food. The constant modernization since that period has brought us where mankind is today. Inventing preventions against diseases

and developing shelters that provided safety from the vagaries of weather have drastically improved chances of human beings to live through the kinds of nature's episodes that resulted in the extinction of other species. These efforts have also cut the rate of mortality resulting in an exponential human population growth giving the species a better chance of being left with enough residual stock to repopulate in the event of a catastrophe. Human beings were cognizant of the fact that they were able to achieve all these feats due to their unique ability to exploit the earth to their benefit. All these successes, however, made mankind overconfident and led to the development of the notion that it was immune to nature's consequences and has the inalienable right to use Earth's resources at pleasure. However, the apparent gap between resource demand and resource availability became obvious to the wise centuries ago, and voices of concern have been raised intermittently for generations. More recently, it has become very clear that what many people and nations consider development, if not carried out more thoughtfully and better planned, will ultimately wipe out the very essential resources that man had taken for granted and the consequences could be calamitous. The book *Population Bomb* (Ehrlich, 1968), the United Nations Conference on the Human Environment (UNCHE) (UNEP, 1972), World Commission on Environment and Development (WCED) (United Nations General Assembly, 1987) (also known as the Brundtland Commission after its chairman), from which the definition for sustainable development was derived, and several subsequent worldwide forums are manifestations of concerns regarding resource availability and resource consumption. Sustainable development was defined by the WCED as “the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Thus, parity in the right of the present and future generations in sharing the earth's resources was

brought to clear focus. The details of the report also emphasized the importance of sharing the resources so that the poor of the world are not left behind. Thus was born the current version of the term “sustainability,” which imbibes the theme of the survival and the perpetuation of high quality of life for all mankind of the present and future generations inhabiting different regions of planet Earth. The domain of sustainability born out of the environmental concern, thus, was expanded to incorporate the ingredients of sharing and social justice. Part of the reason for this change was the realization that the environment had no boundaries and all mankind must partake in its preservation, but this was only feasible if material benefits provided by resource exploitation were shared.

Sustainable Agriculture—Definition and Description

Agriculture is at the forefront of any sustainable development deliberation. This is because mankind exploits the earth most for agriculture than for any other enterprise. Agriculture, on the one hand, has the potential to provide many essentials of human life in perpetuity if harnessed appropriately, but on the other hand, if proper precautions are not exercised, can lead to the destruction of the very resources on which mankind desperately depends for survival and lifestyle support.

Many definitions of sustainable agriculture are available in the literature. The following are samples:

> Allen *et al*. (1991): A sustainable agriculture is one that equitably balances concerns of environmental soundness, economic viability, and social justice among all sectors of society.
>
> Lehman *et al*. (1993): Sustainable agriculture consists of agricultural processes, that is, involving biological

activities of growth or reproduction intended to produce crops, which do not undermine our further capacity to successfully practice agriculture.

Yunlong and Smit (1994): Sustainable agriculture refers to the use of resources to produce food and fiber in such a way that the natural resource base is not damaged and that the basic needs of producers and consumers can be met over the long term.

The U.S. Code Title 7, Chapter 64, Subchapter 3103 gives the legal definition of sustainable agriculture for use by the United States Department of Agriculture. It is described as an integrated system of plant and animal production practices having a site-specific application that will over the long term:

- Satisfy human food and fiber needs
- Enhance environmental quality and the natural resource based upon which the agriculture economy depends
- Make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls
- Sustain the economic viability of farm operations
- Enhance the quality of life for farmers and society as a whole.

The phrase “sustainable agriculture” is often used in the limited sense to describe agricultural practices that lower input requirement and preserve soil quality while maintaining economic yield. It is not unusual to associate it with organic farming. Singh *et al*. (2005) summarized the intent of sustainable agriculture into four farm-level goals: (1) to make better use of farm-based resources, (2) to minimize the needs of external inputs, (3) to prevent loss and degradation of farm soil and water resources, and (4) to maintain the quality of farm and rural life. The practice of sustainable agriculture requires the knowledge of interactions between soil and crop that result in optimum

harvests at minimal economic and environmental cost. The methodologies include precision agriculture, integrated pest management, green manuring, crop residue management, soil carbon and nitrogen cycling, and other prudent farm resource managements. To be clear, sustainable agriculture does not call for going back to the farming practices that forced farmers to subsistence living and urban migration, but on the other hand, to guide them toward the right ways to adopt new agricultural innovations for maximum benefit today and times to come.

This concept of sustainability came into sharp focus during the 1980s. The need to reconsider the strategy of employing highly profitable machinery and chemical inputs at that time arose from the realization that the short-term profitability was being achieved at the expense of long-term continued fitness of the farm to produce crops and generate income on the long term. The turn-over plowing led to soil structural instability and erosion, and excessive chemical use led to pollution of the surrounding and broader environment. In addition, the constant increase in the demand for bigger machinery to plow deeper and more acres and more chemicals to control all kinds of pests rendered farming enterprise unstable, with inputs and their costs continuing to spiral upward, yields fluctuating year to year due to exacting climatic requirements, and increasing losses from pathogens and pests as they became resistant to chemicals. This created the need to develop a strategy whose aim, simply put, was to make sure that the gains made in the agricultural productivity are preserved in perpetuity. This can only happen if the soil and water resources are prudently used and rejuvenated and the soundness of farm ecology is maintained. Thus, while sustainable farmers continue to use tractors, they use new plows that disturb the soil to a minimum, thereby preventing erosion. The emphasis on the control of weeds,

insects, and diseases on crop plants remains unchanged; however, new methods consist of a combination of chemicals, pest–predator control, crop rotation, and increased plant resistance, and other innovative means to prevent a toxic combination of soil, water, and crop. Farmers continue supplementing nutrients to increase the crop yield, but they use not only chemical fertilizers, but also rely on leguminous nitrogen fixation, increased availability of bound soil nutrients through enhanced microbial activity, etc. Sustainable agriculture, thus, is not a movement against industrialized agriculture, but one for an economically and environmentally viable option.

Relevance of Sustainability to Agriculture through Time

Awareness to sustainable agriculture has been shaped by the wisdom of generations starting from prehistoric times to the present, born out of experience and events of centuries. “He who plants even one tree, goes directly to Heaven and obtains *Moksha* (salvation)” (*Matsya Purana*, 59.159; period unknown, prehistoric) proclaims ancient Hindu scripture. The cutting of trees and destruction of flora were considered sinful acts. The Indian thinker Kautilya's *Arthashastra* (Aristotle's period; ~300–400 BC) prescribed various punishments for destroying trees and plants. Rapid agricultural expansion in different societies were accompanied by environmental problems. While Watson (1974, 1983) describes the “Arab Agricultural Revolution” as part of the Islamic Golden Age between the eighth and thirteenth centuries, Gari (2002) has accounted the concern expressed by several environmentalists of the period of the pollution of air, water, and soil that this revolution created as a result of wrong agricultural practices.

In the near-term historical context, the “Dust Bowl” period in American agriculture serves as a reminder to the detriment of unsustainable practices on agriculture itself, and to the environment at large. With the newly introduced farm tractors mounted with moldboard plows, farmers developed the notion that more and deeper plowing translated into better yields. They did not realize that they were endangering the most precious commodity on the farm —the soil itself. Drought is a part of nature's weather cycle and the American Great Plains went through it during the 1930s. The dry winds over the barren fields with loose soil created storm clouds stretching hundreds of miles. The dust clouds created severe health hazards and disrupted normal daily life stretching across all Great Plain States and reaching as far as the nation's capital. On Sunday, April 14, 1935, the dust cloud was so dense that the day has been remembered as Black Sunday and the whole region was referred to as “Dust Bowl” (Figure 1.1). It was estimated that 100 million acres of farm top soil were lost to the wind. This led to the passing of soil conservation legislation and the adoption of better soil management practices.

FIGURE 1.1 Abandoned farmstead in the “Dust Bowl” region of Oklahoma, showing the effects of wind erosion, 1937. *Source*: USDA (1937).

The environmental movement of the 1950s and 1960s in the United States brought to focus the need of constant vigilance to ward disaster from the well-intentioned introduction of new practices or inputs to the agricultural systems. *Silent Spring* (Carson, 1962) was a wake-up call to the increased use of pesticides, especially DDT (1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane) post–World War II in agriculture. These pesticides were effective against crop pests, but their lethality was not targeted and DDT in particular was identified as causing the thinning of bird eggs and their failure to hatch; thus the book's title was chosen to bring to attention the ultimate consequence of DDT, namely the silencing of spring because of the absence of birds. These efforts hastened the research in the development of targeted chemicals for use in agriculture and the institution of a ban on DDT in the United States at the end of 1972.

A new reminder that constant vigilance is essential to maintain the delicate balance between the agriculture and nature comes from the current near-extinction status of vultures (the Great Indian Bustard) in India. Diclofenac (2-(2,6-dichloranilino) phenylacetic acid) is an anti-