sustainability

MDPI

Editorial

Agricultural Innovation and Sustainable Development

Michael Blakeney [1,2]

[1] School of Law, The University of Western Australia, Crawley, WA 6009, Australia; michael.blakeney@uwa.edu.au
[2] Institute of Agriculture, The University of Western Australia, Crawley, WA 6009, Australia

Global agriculture is confronted by a number of substantial challenges, with some of them being existential. The principal challenge is climate change, which threatens desertification, with attendant increases in salinity, insect and animal infestations, and floods (as well as droughts). These impacts will remove some areas from cultivation at a time when the global population is projected to increase from 7.2 billion persons today to 9.7 billion persons in 2050. The agricultural sector in developing countries and less-developed countries is a source of employment and livelihood for the majority of the population, a major foreign exchange earner and supplier of raw materials to local industry, and has important potential for the economic development of those countries. However, the sector has been weak. It has not succeeded in ensuring secured income to small farmers and food security at national and household levels, or in supporting other sectors and serving as a basis to boost socio-economic development. The reasons behind this include the use of agricultural technologies and practices that have been transmitted from generation to generation with no or little improvement; storage and transportation difficulties; and structural problems with the marketing of agricultural products.

Significant sustainable agricultural innovation is required to deal with these challenges. Intellectual property rights (IPRs) may be of crucial importance for modern agriculture. They serve to make R&D in agriculture attractive by encouraging investment in new technologies and generating tradeable assets. The principal IPRs relevant to agricultural innovation are: (i) patents, which protect inventions; (ii) plant variety rights, which protect the breeding of new and distinct plant varieties; and (iii) trademarks and geographical indications, which facilitate the marketing of products by providing protection for the symbols of their manufacturing or geographic origin. Also relevant, but of lesser significance, are: (iv) layout designs of integrated circuits, which are relevant to smart agricultural technologies; (v) confidential information law, which protects know-how or trade secrets; and (vi) copyright, which protects works of cultural creativity, such as books, articles, scientific papers, and arrangements of data.

Through patenting, genetic sequences which enable plants to withstand agricultural stresses have been identified and protected. Plant variety rights protection encourages the breeding of new varieties which can also meet contemporary agricultural challenges. Trademarks and geographical indications can be used to identify the sources of agricultural products, which can reassure consumers by their traceability. The protection of layout designs of integrated circuits can encourage the investment in digital farming technologies, which allow for the monitoring of inputs such as water, fertilizers and herbicides in order to harmonize them with changing climatic conditions. Confidential know how is particularly important in applying proprietary technologies to agriculture. Finally, copyright protects a wide variety of works which can have an agricultural application. These range from scientific books, articles, and research papers through to questionnaires, surveys, training manuals, and even to computer programs encompassing algorithms which are used to monitor crops in the field.

The significance of IPRs in encouraging sustainable agricultural innovation is slowly being recognized. The World Intellectual Property Organization (WIPO), which is the

Citation: Blakeney, M. Agricultural Innovation and Sustainable Development. *Sustainability* **2022**, *14*, 2698. https://doi.org/10.3390/su14052698

Received: 10 February 2022
Accepted: 23 February 2022
Published: 25 February 2022

United Nations' specialized agency dealing with IPRs, has adopted a 'Development Agenda' which takes into account the Sustainable Development Goals (SDG) of the United Nations.

This Special Issue of *Sustainability* on agricultural innovation and sustainable development contains a number of case studies on the impacts of climate change upon agriculture and on the adaptive agricultural practices which have been adopted to deal with agricultural stresses in a number of key countries.

The vulnerability of energy and food source crops to climate change impacts has led a search for sustainable new and orphan crops. Rahiel Hagos, Abdulwahab Saliu Shaibu, Lei Zhang, Xu Cai, Jianli Liang, Jian Wu, Runmao Lin and Xiaowu Wang look at the available literature about Ethiopian mustard as an alternative energy source and its sustainable economic importance as a new promising Brassicacea crop. The literature suggests that Ethiopian mustard has many advantages and can be adopted to replace crops that are susceptible to adverse environmental conditions (although the focus has been largely on it as an energy source). The authors suggest a shift of focus to Ethiopian mustard edible oil varieties, in which case further agronomic, quality, and genomic studies on oilseed nutritional traits for efficient breeding and utilization are required (Contribution 1).

China has carried out remarkable work in feeding 22% of the world's population with only 9% of the world's arable land, but it has paid a huge environmental price with problems such as water eutrophication, soil acidification, air pollution, and the reduction of biodiversity. China has realized the need to coordinate the relationship between agricultural development and environmental protection and promote the green transformation of agriculture. Different methods have been adopted in different provinces in the process of agricultural green development with varying degrees of effectiveness. Hongpeng Guo, Shuang Xu and Chulin Pan, focus on the spatial complexity of agricultural green development (AGD) in different regions. They construct an evaluation index system for the level of AGD from four dimensions: social development, economic benefits, resource input, and ecological environment. The article uses an improved entropy weight method to evaluate the level of AGD with panel data of 31 provinces in China from 2007 to 2018. Their study provides a reference for understanding the status of China's agricultural green development level and policy recommendations on how to improve the level of agricultural green development. The results imply that some effective policy measures, such as prompting the integrated development of the three major industries and optimizing the industrial structure, should be taken to coordinate "green" with "development" from national and regional perspectives (Contribution 2).

Phenological variables are closely correlated with rice (*Oryza sativa* L.) yields, as they play important roles in influencing and controlling the carbon allocations between plant organs. However, their impacts on rice yields and their relative importance compared with climatic variables have not yet been investigated thoroughly. Yahui Guo, Wenxiang Wu, Yumei Liu, Zhaofei Wu, Xiaojun Geng, Yaru Zhang, Christopher Robin Bryant, and Yongshuo Fu assess the impacts and the relative importance of climatic and phenological variables on the yields of early mature rice using the trial data from 75 agricultural stations across China, spanning from 1981 to 2010. They found that phenological variables were the dominating influencing factors on rice yields at 63% of the sites, suggesting that the relative importance of phenology to rice yields may be even higher than that of climate. The climatic variables were closely correlated with rice yields. However, their results highlight that phenology should be precisely evaluated in crop models to improve the accuracy of simulating their response to climate change, and that due to the limited understanding of phenological processes, manipulative experiments are urgently needed to improve our understanding of rice phenology and rice yield response to ongoing climate change (Contribution 3).

The per capita food output in sub-Saharan Africa (SSA) has declined considerably, exacerbating food and income insecurity. With climate change, there has come an increase in pests and diseases. In the SSA region, the propagation system is characterized by both formal and informal plant material supplies. For bananas (*Musa* spp.), the majority

of smallholder farmers depend on the informal supply (including home-saved material from previous season harvests) and propagating material sourced from friends, neighbors, relatives to either expand or establish new banana plantations. The high prevalence of pests and disease in this material has necessitated research to increase the use of high-quality, formal supplies of plant material. One such effort is the development of tissue culture (TC) planting materials, which are always free of pests and diseases. Lucy Mulugo, Florence Birungi Kyazze, Paul Kibwika, Bonaventure Aman Omondi, and Enoch Mutebi Kikulwe utilize the Double-Hurdle model on cross-sectional data of 174 banana farmers in Central Uganda to analyze the drivers for uptake of TC banana plant materials. Their study demonstrates that seed security factors, along with farmer competencies, social influence, and socioeconomic factors, influence farmer decisions on uptake of TC technology for banana production. Their findings emphasize the need for more involvement of extension services and research institutions in the education and promotion of TC plants in farming communities with attention given to banana varieties that are acceptable and adaptable to the environmental conditions confronting farmers (Contribution 4).

The United Nations Intergovernmental Panel on Climate Change has suggested that the cultivation of traditional crops might have something to offer in encouraging adaptation to climate change. Rice cultivation is significant for a substantial proportion of the world's population. However, traditional rice cultivars and cultivation are in decline in most rice-growing areas (mainly as a result of their low productivity). Packed with nutritionally, environmentally, and locally superior qualities, traditional cultivars hold the key for sustainability in rice cultivation. Jayasree Krishnankutty, Michael Blakeney, Rajesh K. Raju, and Kadambot H. M. Siddique explored the dynamics of traditional rice cultivation in Kerala, India. They examined the economic, institutional and socio demographic factors involved in the production and marketing of traditional rice. They found that holding size and institutional support were the main factors governing the marketing behavior of farmers. The study also found that traditional farmers are ageing, have a lower education, and use limited marketing channels. However, the majority of them were satisfied with their farm enterprise. By streamlining market support mechanisms and processing facilities, traditional rice would most likely gain momentum in key areas (Contribution 5).

Although traditional agriculture has a contribution to make to climate adaptation, it is characterized by the low adoption of new agricultural technology. This may be due to the expense and the unwillingness of farmers to try it due to the risk it entails. The Tanzanian government's strategy to bring about greater efficiency in the agricultural sector includes strengthening various agricultural development strategies and technical cooperation with local and international development partners to increase awareness and make technology easier to access. George Mgendi, Shiping Mao, and Fangbin Qiao analyzes the effect of training programs on the yield of smallholder rice farmers in the Mvomero district of Tanzania. The results indicate that the yield outcome among trained and non-trained farmers with water access for irrigation was significantly more than double. However, the yield difference between trained and non-trained farmers was insignificant in non-irrigated plots. These findings have policy implications for agricultural development in developing countries where training programs alone may not be a panacea for smallholder farmers' productivity improvement. Therefore, respective governments, policymakers, and other agricultural stakeholders should consider both farm and non-farm factors altogether, which may increase agricultural training effectiveness to address the challenges of low yields (Contribution 6).

As a kind of infrastructure that enables production of both food and energy, dams are a key component of climate change adaptation. They are meant to improve agricultural productivity and reduce vulnerability to droughts. In semi-arid regions experiencing desertification, water management infrastructure for food and energy production is necessary to sustain a growing human population and promote economic development in a changing climate. However, dams face many criticisms, ranging from cost overruns and population displacement to ecosystem disruption and increased transmission of infectious disease.

Andrea J. Lund, David Lopez-Carr, Susanne H. Sokolow, Jason R. Rohr and Giulio A. De Leo propose four agricultural innovations for promoting equity, health, sustainable development, and climate resilience in dammed watersheds: (1) restoring migratory aquatic species; (2) removing submerged vegetation and transforming it into an agricultural resource; (3) restoring environmental flows; and (4) integrating agriculture and aquaculture. They conclude that as investment in dams accelerates in low- and middle-income countries, appropriately addressing their livelihood and health impacts can improve the sustainability of agriculture and economic development in a changing climate (Contribution 7).

The Asian rice–wheat cropping system feeds billions across the globe. However, the productivity and long-term sustainability of this system are threatened by stagnant crop yields and greenhouse gas emissions from flooded rice production. The negative environmental consequences of excessive nitrogen fertilizer use are further exacerbating the situation, along with the high labor and water requirements of transplanted rice. Residue burning in rice has also severe environmental concerns. Under these circumstances, many farmers in South Asia have shifted from transplanted rice to direct-seeded rice and reported water and labor savings and reduced methane emissions. Aman Ullah, Ahmad Nawaz, Muhammad Farooq, and Kadambot H. M. Siddique argue that there is a need for adopting the precision agriculture techniques for the sustainable management of nutrients and that allelopathic crops could be useful in the rotation for weed management, the major yield-reducing factor in direct-seeded rice and that legume incorporation might be a viable option for improving soil health. This is particularly the case as governments in South Asia have imposed a strict ban on the burning of rice residues. They argue that the soil/climatic conditions and farmer socio-economic conditions must be considered while promoting these technologies in the rice-wheat system in South Asia (Contribution 8).

The challenge of sustainable agriculture development in light of population growth, resource shortage, ecological deterioration, and climate change has led many governments to support agricultural science, technology, and innovation (ASTI). However, innovation performance is dependent not only on the available innovation resources but also and maybe most importantly on their efficient and productive use. Innovation efficiency, which is the ability to translate inputs into innovation outputs, has become very important and attractive to scholars and governments. The limited attention to innovation efficiency at the national level could be a potentially significant omission from a policy-oriented perspective, since measuring the ASTI efficiency helps to both identify the best innovation practitioners for benchmarking and propose ways to improve efficiency by pinpointing areas of weakness. The agriculture of the G20 countries account for 60% of global arable land and 80% of global agricultural trade, thus having a significant effect on global agriculture development. An efficiency-oriented innovation analysis will enhance the understanding of the operational quality related to the transformation process of limited innovation investments for improving innovation outputs. Xiangyu Guo, Canhui Deng, Dan Wang, Xu Du, Jiali Li, and Bowen Wan sought to measure the static-dynamic efficiency of agricultural science, technology, and innovation (ASTI) and identify the efficiency determinants across the G20 countries. The empirical results indicated that: (1) the efficiency range of the G20 developing countries was relatively larger than the G20 developed countries; (2) the total factor productivity change (TFPC) of ASTI showed an alternating trend of "decline–growth–continuous decline–growth recovery", where the G20 developed countries experienced "growth–decline–growth" and the G20 developing countries underwent a fluctuating upward trend; and (3) The G20 developed countries usually had advantages in capacity, while the G20 developing countries performed better in efficiency (Contribution 9).

Digital technologies offer a potential solution to improve the economic, social, and environmental sustainability of agri-food systems around the globe. While developed countries have led the innovation and adoption of digital agriculture, the potential impact in developing countries, including in the Middle East and North Africa (MENA) regions is very substantial. Rachel A. Bahn, Abed Al Kareem Yehya, and Rami Zurayk synthesize existing evidence to review the potential and current contribution of digital

technologies to the agri-food sectors in MENA. They conclude that digital agriculture shows promise in addressing the key challenges facing the agri-food sector across MENA countries, particularly facilitating improvements in primary production, supply chain and logistics performance, and optimized use of scarce natural resources. They note that the available evidence shows that adoption of digital agriculture is at early stages, generally led by high-value agricultural production targeting domestic markets in Gulf countries and export markets in Mashreq countries. They suggest that public policies should not only foster the adoption of digital technologies in MENA but also ensure equity of access, transparency of use, data protection, and labor protection and that policymakers should move beyond traditional, production-centric views to privilege social and environmental sustainability (Contribution 10).

Farmers' adoption of agricultural practices and technologies that contribute to achieving sustainable intensification, sustainable development, and food security require some degree of risk taking and risk management by farmers. The risks confronted by farmers include those associated with climate change as well as market input and output price fluctuations and inadequate access to insurance. Despite smallholder farmers usually being thought to have homogeneous risk averse attitudes, Omotuyole Isiaka Ambali, Francisco Jose Areal, and Nikolaos Georgantzis point out that there is evidence that this is not the case. Thus, they stress that identifying and understanding the heterogeneity in farmers' risk preferences is crucial to guide policy formulation and implementation on risk management and investment decisions concerning the adoption of technology, the adoption of new crop varieties, or the adoption of sustainable agricultural practices. While existing studies have identified the socio-economic factors driving farmers' risk attitudes, spatial variables that may correlate with decisions have often been ignored in the risk models due to the difficulties involved in their measurement. The authors studied unobserved spatial heterogeneity in farmer's risk preferences by incorporating spatial dependency into a farmer's risk preference model using data from a survey conducted with Nigerian farmers between March and May 2016. They found that unobserved spatial heterogeneity (e.g., soil, topographic farmers emulating each other) was present in farmer's risk preferences (along with socio-demographic variables such as age, gender, marital status, and religion and farm characteristics such as farm size and road quality), and that these results are relevant for policy decision-making processes (Contribution 11).

Serena Mariani seeks to investigate the role of EU legislation in shaping innovation in cereal varieties. The research focuses on intellectual property and agricultural law. Her paper looks at the role played by European Community plant variety protection and EU legislation on the marketing of seed and plant propagating material in shaping innovation and stimulating plant breeding of new cereal varieties. She adopts a focus on cereal varieties due to the substantial socio-economic impact of innovation in this field, as well as strategic scientific and environmental implications. Her study concludes that it is necessary to simplify the existing legal framework by coordinating intellectual property and agricultural law, providing for legislative review and better coherence in order to effectively shape innovation and meet the changing demands of society and the sustainability challenges (Contribution 12).

The agricultural challenges that were outlined at the beginning of this editorial is trenchantly illustrated by the food security of Bangladesh which is largely depends on rice production (92% of the total food grain production). Although the country's agro-climatic conditions are perfect for cultivating rice all year, the national average rice yield (2.60 t/ha) is much lower than the potential national yield (5.40 t/ha). The population of Bangladesh is currently 162.7 million and projected to be 189.85 million by the year 2030, requiring an increase of the current rice yield to 3.74 t/ha to keep the production of rice in line with the growing population of the country. Inefficient and often imbalanced fertilizer use impedes farmers from achieving expected yields. Thahamina Bagum, Md. Kamal Uddin, Salim Hassan, Nitty Hirawaty Kamarulzaman, Md. Zulfikar Rahman, and Ahmad Numery Ashfaqul Haque explore the contribution of selected factors that influence farmers' work performance and determine the highest contributing factors on farmers' work performance towards fertil-

izer application in rice. They used a multistage simple random sampling method to select 355 farmers from twenty-one rice production areas of Bangladesh. Data, collected using a structured questionnaire, were subjected to multiple linear regression analysis to explore the contribution of selected factors and identify the highest contributing factors towards farmers' work performance. The results of their study revealed that the motivation of farmers was found to be the highest contributing factor, followed by knowledge influencing their work performance and concluded that farmers need to be equipped with essential knowledge and motivation crucial to strengthening their work performance as this will increase rice production (Contribution 13).

Contribution List:

1. Hagos, R.; Shaibu, A.S.; Zhang, L.; Cai, X.; Liang, J.; Wu, J.; Lin, R.; Wang, X. Ethiopian Mustard (Brassica carinata A. Braun) as an Alternative Energy Source and Sustainable Crop. *Sustainability* **2020**, *12*, 7492. https://doi.org/10.3390/su12187492.
2. Guo, H.; Xu, S.; Pan, C. Measurement of the Spatial Complexity and Its Influencing Factors of Agricultural Green Development in China. *Sustainability* **2020**, *12*, 9259. https://doi.org/10.3390/su12219259.
3. Guo, Y.; Wu, W.; Liu, Y.; Wu, Z.; Geng, X.; Zhang, Y.; Bryant, C.R.; Fu, Y. Impacts of Climate and Phenology on the Yields of Early Mature Rice in China. *Sustainability* **2020**, *12*, 10133. https://doi.org/10.3390/su122310133.
4. Mulugo, L.; Kyazze, F.B.; Kibwika, P.; Omondi, B.A.; Kikulwe, E.M. Seed Security Factors Driving Farmer Decisions on Uptake of Tissue Culture Banana Seed in Central Uganda. *Sustainability* **2020**, *12*, 10223. https://doi.org/10.3390/su122310223.
5. Krishnankutty, J.; Blakeney, M.; Raju, R.K.; Siddique, K.H.M. Sustainability of Traditional Rice Cultivation in Kerala, India—A Socio-Economic Analysis. *Sustainability* **2021**, *13*, 980. https://doi.org/10.3390/su13020980.
6. Mgendi, G.; Mao, S.; Qiao, F. Is a Training Program Sufficient to Improve the Smallholder Farmers' Productivity in Africa? Empirical Evidence from a Chinese Agricultural Technology Demonstration Center in Tanzania. *Sustainability* **2021**, *13*, 1527. https://doi.org/10.3390/su13031527.
7. Lund, A.J.; Lopez-Carr, D.; Sokolow, S.H.; Rohr, J.R.; De Leo, G.A. Agricultural Innovations to Reduce the Health Impacts of Dams. *Sustainability* **2021**, *13*, 1869. https://doi.org/10.3390/su13041869.
8. Ullah, A.; Nawaz, A.; Farooq, M.; Siddique, K.H.M. Agricultural Innovation and Sustainable Development: A Case Study of Rice–Wheat Cropping Systems in South Asia. *Sustainability* **2021**, *13*, 1965. https://doi.org/10.3390/su13041965.
9. Guo, X.; Deng, C.; Wang, D.; Du, X.; Li, J.; Wan, B. International Comparison of the Efficiency of Agricultural Science, Technology, and Innovation: A Case Study of G20 Countries. *Sustainability* **2021**, *13*, 2769. https://doi.org/10.3390/su13052769.
10. Bahn, R.A.; Yehya, A.A.K.; Zurayk, R. Digitalization for Sustainable Agri-Food Systems: Potential, Status, and Risks for the MENA Region. *Sustainability* **2021**, *13*, 3223. https://doi.org/10.3390/su13063223.
11. Ambali, O.I.; Areal, F.J.; Georgantzis, N. On Spatially Dependent Risk Preferences: The Case of Nigerian Farmers. *Sustainability* **2021**, *13*, 5943. https://doi.org/10.3390/su13115943.
12. Mariani, S. Law-Driven Innovation in Cereal Varieties: The Role of Plant Variety Protection and Seed Marketing Legislation in the European Union. *Sustainability* **2021**, *13*, 8049. https://doi.org/10.3390/su13148049.
13. Bagum, T.; Uddin, M.K.; Hassan, S.; Kamarulzaman, N.H.; Rahman, M.Z.; Haque, A.N.A. Contribution of Selected Factors on Farmers' Work Performance towards Fertilizer Application in Rice of Bangladesh. *Sustainability* **2021**, *13*, 10795. https://doi.org/10.3390/su131910795.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.