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Editorial

Social-Ecologically More Sustainable Agricultural Production

Moritz von Cossel [1,*], Joaquín Castro-Montoya [2] and Yasir Iqbal [3]

[1] Biobased Resources in the Bioeconomy (340b), Institute of Crop Science, University of Hohenheim, 70599 Stuttgart, Germany
[2] Institute of Agri-Food and Environmental Sciences, Faculty of Agricultural Sciences, University of El Salvador, San Salvador 01101, El Salvador
[3] College of Bioscience and Biotechnology, Hunan Agricultural University, Changsha 410128, China
* Correspondence: moritz.cossel@uni-hohenheim.de

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Planet Earth is facing numerous imminent challenges, from climate change to ecological dysfunction, which are largely attributed to anthropogenic activities. In the long term, this puts humans as a species under threat. It is understandable that humanity's survival depends primarily on the provision of food, drinking water, and a safe habitable environment [1,2]. However, to ensure this, the current production methods employed in leading sectors such as agriculture must adopt a more holistic approach rather than focusing only on food production. On top of that, a large part (in the European Union, a whole 50%) of the plant and animal kingdom is directly or indirectly linked with agricultural systems, making agrobiodiversity a fundamental component of basic agricultural productivity [3]. It would therefore be foolish not to consider the full repertoire of ecosystem services within safe and just Earth system boundaries when developing social-ecologically more sustainable agricultural systems, or at least to strive towards achieving a more holistic view [1,4,5].

Social-ecologically more sustainable agricultural production intends to (i) meet the increasing food demand, (ii) reduce environmental degradation, and (iii) improve a number of other ecosystem services such as the provision of medicinal resources, climate regulation, erosion mitigation, groundwater protection, disturbance modulation, nutrient cycling, habitat functioning, and aesthetic information. Given the importance and relevance of these aspects, this Special Issue has been established to bring together the latest findings from current research. Within the aforementioned overarching theme, this Special Issue received a total of 21 contributions in forms of research articles, review articles, and communications. To facilitate reading, these contributions are briefly presented below.

The first contribution to this Special Issue, a study by Von Cossel et al. [6], reported on the potential trade-off between biomass provision and biodiversity support when species-rich polycultures of perennial flowering wild plant species are cultivated instead of maize (*Zea mays* L.) monocultures [6]. The biomasses of perennial flower-rich wild plants mugwort (*Artemisia vulgaris* L.), brown knapweed (*Centaurea nigra* L.), and common tansy (*Tanacetum vulgare* L.) were found to produce only 72 to 74% of methane compared to maize. This knowledge can help biogas plant operators better implement these types of more biodiversity-friendly biogas substrates to their biogas production value web. Future research should look at the process-relevant biochemical and physical effects caused by the admixture of wild plants as a co-substrate during anaerobic fermentation in the biogas plant [7,8].

In terms of bioenergy crops for combustion, woody species such as aspen (*Populus tremula* L.), Siberian elm (*Ulmus pumila*), and willow (*Salix* spp.) are among the commonly used species [9,10], followed by perennial herbaceous crops such as miscanthus (e.g., *Miscanthus* × *giganteus* Greef et Deuter) [11–13] and *Sida* (*Sida hermaphrodita* L. var. Rusby) [14]. All of these perennial bioenergy crops have in common that they are potentially suitable to grow on certain types of marginal land, that is, land that is only marginally suitable for food crop cultivation [9,10,13–16]. Thus, the cultivation of perennial bioenergy crops on unused marginal agricultural land could expedite the development of the bioeconomy and facilitate transition towards a fossil-free future without impeding food security.

For optimal cultivation of bioenergy crops, it is advisable to ensure that genetic material is always adapted to the growing economic and environmental challenges [2]. In this context, Liu et al. [11] applied a sampling strategy on a miscanthus primary core collection to evaluate its role in reducing the size of the initial collection whilst retaining genetic diversity in the collection. This approach was found to improve the range of the coincidence rate without affecting the mean difference percentage. Overall, these findings could contribute to a social-ecologically more sustainable agriculture by reducing the trade-off between biomass provisioning and other ecosystem services through the efficient development of novel miscanthus genotypes in the face of increasing environmental challenges such as climate change-related impacts on agricultural production [2].

However, not only climate change but also soil-related marginality constraints might affect future designs of social-ecologically more sustainable agriculture [15]. A particularly important aspect in this context is the contamination of soil with heavy metals [13]. Liao et al. [13] found that in regions with high concentrations of heavy metals in the soil, the above-ground increment of miscanthus accumulates large amounts of heavy metals each year. According to the authors, this means that if the miscanthus biomass is not used, the heavy metals organically bound in the miscanthus can spread further and impair the balance of natural nutrient cycles in surrounding ecosystems. From Liao et al.'s findings, it can be concluded that, in terms of lower environmental impacts, it would, therefore, make more sense to harvest the annual miscanthus biomass grown in such regions, use it as a bioresource (e.g., for bioenergy purposes), and dispose of the heavy metals contained in the remaining biomass residues in a controlled manner or use them elsewhere. The latter would be a win–win scenario for the bioeconomy approach of growing miscanthus for bioenergy or biobased products on marginal agricultural land.

In addition to nutrient cycling, biomass production systems on marginal land can also affect plant diversity, according to Zuševica et al. [17]. This research group from Latvia found that the establishment of woody crops on organic soils (from former peat extraction) can positively affect plant diversity, whereby the application of ash-based fertilizers and the distances to drainage ditches require special consideration [17]. Furthermore, a better understanding of plant–root bacterial interactions may help to improve the nutrient use efficiency in biomass production on low-yielding (poor) soils. This was found by Wu et al. [18] using the example of ramie (*Boehmeria nivea* L.), which offers great breeding potential for the more efficient use of soil nitrogen and phosphorus, subsequently increasing and stabilizing long-term biomass yields. In addition, Kitzcak et al. [14] succeeded in determining both the minimum organic fertilizer amounts and the optimal seeding rates for the economically feasible cultivation of *Sida* on light (sandy) soils in Poland.

Beyond maintaining agricultural productivity, there are also many chances for its recovery, for instance, through ameliorating contaminated or poor soils with the help of dedicated crops, as was recently reported by Testa et al. [19] and Wu et al. [18]. Given the ever-continuing degradation of agricultural soils worldwide [20], it would therefore be of existential importance to further intensify research on the challenges in modeling bioenergy crop performance, as highlighted by Haberzettl et al. [21], in order to adequately plan and implement bioenergy cropping systems at the interface of provisioning and regulating ecosystem services. Many of the problems for realistic and meaningful modeling approaches lie in the fact that there are not yet sufficient empirical data on the long-term performance of biomass crops on marginal land [21]. Neither for shallow soils [10] nor for soils with adverse soil texture [22] is there sufficient information available to derive biomass production projections for different site conditions worldwide, especially considering the uncertain impacts of climate change on agricultural systems.

A very fundamental effect of climate change is the shift in the water supply and available agricultural land, as reported by Li et al. [23] in their study on spatiotemporal changes in the geographic imbalances between crop production and farmland–water resources in China from 1990 to 2015. From their study, it can be concluded that the cultivation areas of the most important staple foods of rice, wheat, and maize in China will have to be shifted significantly due to climate change-induced fluctuations in precipitation distribution patterns in order to ensure a secure food supply in the future.

Looking at the cropping concept level, Zimmermann et al. [24] elaborated on an option beyond organic and conventional farming that certainly deserves more attention to further optimize the long-term sustainability of crop production. The approach is called mineral–ecological cropping and it aims to increase the benefits of agricultural production for agrobiodiversity whilst maintaining productivity. It builds on the many potential synergies between traditional and modern agricultural practices in a cropping system that exclude the use of synthetic chemical pesticides but allow the use of mineral fertilizers [24]. In this way, Zimmermann et al. suggest that ecosystem services can be increased without reducing productivity. However, further optimization is still needed to implement this new cultivation concept, as it currently appears very difficult to maintain both food crop quality and yield while dispensing with the usual synthetic chemical crop protection agents. In contrast, a new farming concept reported by Arunrat and Sereenonchai [25] seems to be more successful. It is a mixed farming system of rice and fish coculture, which is already used on many farms in Thailand [25]. As the study reveals, the holistic ecosystem services of rice and fish coculture can be increased by 14% in monetary terms compared to the monoculture of rice [25]. Unlike the outdoor farming concepts addressed by Zimmermann et al. and Arunrat and Sereenonchai, indoor farming concepts seem to be more focused on the provision of biomass because they are much less interlinked with the nutrient- and lifecycles of the natural environment. Here, Cichocki et al. [26] provided valuable insights on the opportunities and challenges of providing food directly in and for office buildings [26].

A more holistic recognition of the ecosystem services provided by agricultural value webs could take the form of a true cost–benefit assessment, as Wagner et al. [16] have shown using the example of growing miscanthus. Such insights into the true dimensions of agricultural value webs that have so far been rather neglected could then ideally be incorporated into the design of social-ecologically more sustainable certificates for food, fodder, and other agricultural products in the long term. This would enable a fairer compensation for any opportunity costs on the part of farmers and other involved stakeholders. This is already being sought, for example, for viticulture and wine production worldwide, according to Marques and Teixeira [27] and Wagner et al. [28].

Nevertheless, fairer remuneration must be preceded by the application of more sustainable cultivation practices, and here the views and perceptions of the decision makers directly or indirectly involved also play decisive roles, as Sereenonchai and Arunrat [29] and Huang et al. [30] report. In terms of opportunities for farmer influence, Sereenonchai and Arunrat [29] found that more sustainable cropping systems are usually implemented only when farmers are also aware of the ecosystem benefits. Presenting non-burning uses of rice straw and rice stubble as examples, Sereenonchai and Arunrat found that appropriate communication strategies are needed to ensure that more sustainable farming practices are implemented in a meaningful way in the long term [29]. A similar situation applies to the management strategies of companies that have an indirect link to agricultural production, according to Huang et al. [30]. In their communication article, based on a hierarchical linear modeling approach, Huang et al. suggest to promote the implementation of more sustainable environmental strategies through targeted increases in social responsibility [30].

However, all efforts to encourage farmers or gardeners (in urban areas) to implement social-ecologically more sustainable agricultural production will fail unless the community, as well as political decision makers, endorse it. In this area of research, Wu et al. [31] have made great strides using the example of urban community gardens. Wu et al. [31] have outlined new ways to create more clarity in communities about the potential advantages and disadvantages of such social-ecologically more sustainable urban land use systems. As also highlighted in the studies by Sereenonchai and Arunrat [29] and Huang et al. [30], an appropriate communication strategy about the pros and cons seems to be the key to success in implementing urban community gardens [31]. A trivial solution at first glance, but its justification requires elaborate research adapted to local socio-political as well as geophysical conditions [31].

In summary, this Special Issue offers a wide range of insights into problems, solutions, and next steps towards social-ecologically more sustainable agricultural production. The articles of this Special Issue cover almost at all levels of agricultural production and thus make an important contribution to the agricultural systems of tomorrow.

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