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Editorial

Agroforestry for Sustainable Food Production

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Agricultural production is considered to be among the largest drivers of global environmental degradation. Agricultural activities are behind a substantial share of greenhouse gasses emissions, occupy a large amount of the Earth's land surface, consume vast quantities of freshwater, and are responsible for the degradation and fragmentation of forests and the loss of biodiversity. At the same time, feeding an increasing global population in the coming decades will be a global challenge. The lack of suitable arable land in the scenario of climate change is argued as the main factor that will increase the gap between food production and demand. The food production gap is magnified by persistently poor management that has degraded the soil in many areas of the world, limiting the land available for agriculture. In this context, there is an increasing interest in the adoption of practices that maintain the productive capacity in a changing climate and limit the degradation of the environment.

Agroforestry, defined as the deliberate combination of woody vegetation with crops and/or animal systems, has been proposed as a suitable method for agricultural management capable of facing the current environmental challenges. The ecological and economic benefits resulting from the integration of various elements that are part of an agroforestry system can foster the multifunctionality of agricultural lands and limit the various trade-offs associated with food production. Agroforestry has been shown to benefit carbon sequestration, reduce soil erosion, limit negative effects on biodiversity, reduce greenhouse gas emissions and nutrient leaching, buffer extreme weather events for crops, and increase the temporal stability of crop production. Moreover, agroforestry systems increase the provision of sociocultural benefits. Nevertheless, there are several challenges, such as a perceived negative view of trees in agricultural lands, poor definition and policy support, or the lack of know-how to manage complex systems, which prevent the widespread adoption of agroforestry systems.

This Special Issue of Sustainability on Agroforestry and Sustainable Agriculture Production gathers several studies on agroforestry systems from around the world, including a variety of types of agroforestry systems, from traditional wood-pastures to tropical cocoa-based systems, and approaches, from literature reviews to state-of-the-art ecological-economic models. The Special Issue highlights the potential of agroforestry as a promising approach for the creation of multifunctional landscapes able to face contemporary environmental challenges.

The loss of soil quality due to decades of mismanagement is a major concern for food production in many areas of the world. The negative consequences of soil loss are especially relevant in uplands, where high slopes can amplify erosive processes. In these locations, the presence of woody elements has proven to be an effective measure for soil conservation. Hussain et al. [1] provide an example and show how soil loss is substantially reduced in an intercropping system of maize–chili and leucaena (*Leucaena leucocephala*) trees hedgerows, while the productive potential of the land increases, all with a minimum usage of tillage and fertilizers. The increased usage of fertilizers is a common approach to reverting the negative effects of soil degradation on crop yields in agriculture. Xing et al. [2] tackle this challenge in the Loess Plateau in China. They propose a soil quality index to evaluate soil fertility and assess the availability of nutrients for sustainable production in potato

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farmlands. It is well-known that trees have a positive effect on soil fertility, in part due to their ability to uptake nutrients from an extended volume of soil that are incorporated into the soil via litterfall or root decay. Karagatzides, Wilton, and Tsuji [3] provide an example of the positive effect of trees on nutrient availability. By using in situ ion exchange membranes, they found that agroforestry plots had a higher availability of PO_4, Ca, and Zn, which were positively related to crop yield. This pattern is also observed in Mediterranean silvopastoral systems; however, in this system, tree's long-term persistence is jeopardized by the lack of successful regeneration. López-Sánchez et al. [4] report the potential negative effect of high stocking rates on tree regeneration. They argue that only by allowing for the presence of nurse shrubs and through the adequate management of livestock will the sustainability of trees be guaranteed.

The positive effect of the trees of the agroforestry systems on soil's organic carbon content, as well as on the carbon stored in their above- and below-ground biomass, can stimulate the sequestration of atmospheric C in agricultural landscapes. However, the presence of trees can reduce yields if the interaction between vegetation layers is mainly competitive. Ballesteros-Possú, Valencia, and Navia-Estrada [5] assess the potential of various agroforestry settings of cocoa (*Theobroma cacao*) with Melina (*Gmelina arborea*) trees to improve yields and carbon sequestration as compared to traditional systems. They develop a series of allometric equations, measure the soil's organic carbon content, and calculate several indices of economic returns. They conclude that alternative agroforestry settings can improve yields and the carbon-sequestration potential of traditional systems. For sensitive crops to endure climate change, by contrast, the presence of trees can be an opportunity to ameliorate less favorable climatic conditions due to their provision, for instance, of shade. This may be the case with coffee plants that naturally originated from the understory of an African forest, but that are currently mainly cultivated under the sun. The negative effects of shade on yields are a concern, but mixed results and a lack of knowledge of the effect on different coffee varieties are the norm. Ehrenbergerová et al. [6] assessed various yield components of coffee plants growing under the shade and did not find significant differences as compared to those growing in full light. In addition, they reported a positive effect on the soil water content, which can help to build resilient systems in a future drier climate scenario.

Agroforestry can ease the negative effects of the scarcity of arable land for food production because it increases the productivity per unit of land. The lack of arable land is of particular concern in developing countries, where the expansion of agriculture activities is associated with a shear increase in forest degradation and fragmentation. Traditional agroforestry has been practiced for decades in these locations, but they are usually small systems and manage as a subsistence practice in many households; therefore, they do not unlock the full potential of agroforestry. There are still many barriers that limit the wide adoption of agroforestry or that hinder the productive potential in already established agroforestry systems. Achmad et al. [7] examine the available literature about the factors that prevent an increase in the productive capacity of smallholder subsistence agroforestry. The socio-economical background, including the literacy level, financial support, and land tenure, are the main handicaps to increasing the productive potential of small agroforestry systems. They report that these barriers are not overcome by the adoption of technological innovations because of the low literacy level. Octavia et al. [8] performed an analysis on the same lines and concluded that policies should target the mainstream adoption of agroforestry systems. They stress that a successful adoption may be achieved by a careful selection of the species and planting arrangements. The introduction of new species or the alternative usage of local crops can boost the rural development and resilience of local communities. Bas et al. [9] report an example of this and argue that the alternative use of a common crop can enhance the socio-economic resilience and nature conservation of native forests. They found that involving local communities in the process of decision making is key to the sustainable development of rural economies.

In developed countries, the challenges that face traditional agroforestry systems are completely different. Policies that support nature conservation are common, but they may still be insufficient to guarantee the long-term persistence of traditional agroforestry systems. Despite the ecological benefits that this system provides to society, the financial support offered by nature conservation policies may not fully cover the maintenance cost of the system. Nishizawa et al. [10] model the effect of subsidies on farmers' decisions regarding trees and biodiversity conservation in Orchard meadows in Switzerland. The authors highlight that the effectiveness of the payments was highly dependent on the farm type. The integrated model that the authors developed allows them to conclude that policies would be more effective if target specific farm types instead of offering the same solution for all farms.

Overall, this Special Issue of Sustainability collects several case studies that address the potential of agroforestry to foster food production while minimizing the negative effects on the environment, thereby empowering local communities, and building resilience against future climate scenarios.

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