Agriculture and Food Sustainability

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Ensuring a sustainable supply of food for the world's fast growing population is a major challenge in today's economy, as modern lifestyle and increasing consumer concern with maintaining a balanced and nutritious diet is an important challenge for the agricultural sector worldwide.

circular economy | Innovative products | surplus

1. Introduction

Over the years, food has been one of the main concerns of man, as the methods of search, production and distribution undergoes frequent changes, being closely linked to the way humans eat [1][2]. In addition to its importance in satisfying basic needs, food is the key factor in preserving human health [3][4], as the adoption of healthy eating habits is highly reflected in the acquisition of essential nutrients, which reduce the risk of developing certain diseases, improving longevity and promoting optimal physical and mental well-being [5].

Agriculture is one of the main activities practiced around the world and one of the main economic processes on which the general prosperity of civilization is based [6][7]. In parallel, all over the world the increasing scientific and technological development, alongside the exponential growth of the human population, create a large gap between the demand and supply of food. With the advent of modern civilization and industrialization, agriculture began to be commercialized and intensified on a larger scale, resulting in the generation of huge amounts of agri-food SWL, putting the entire environmental balance under threat [8]. However, modern agriculture must be able to address a wide range of challenges by promoting environmental conservation and the effective management of natural resources, ensuring food security and sustainability. Consequently, in recent years, researchers have been dedicated to the development of approaches that enable the integrated management of agri-food SWL, preventing them from accumulating in nature and, consequently, negatively affecting the environment.

Agriculture SWL are one of the most abundant and renewable sources of compounds of interest on the planet (e.g., oils, proteins, fibers, phenolics and other bioactive compounds) which have the potential to be used in secondary processes, serving as food, feed, fuel, and/or as a source of a wide range of chemicals [7][8][9], thus being identified as number one priority for the application of European Circular Economic Strategy by the European Commission [10]. According to FAO [11], about a third of the food produced worldwide is lost or wasted every year, with about 22% of this loss consisting of agri-food SWL from fruits and vegetables. These residues are responsible for 8 to 10% of greenhouse gas emissions, 23% of fertilizer consumption, 25% of fresh water used in agriculture and for the use of arable land [6][12].

2. Agriculture and Food Sustainability

Currently, the establishment of an agricultural sector capable of continuously supplying food and other essential resources for a world population in constant growth is of critical importance for the existence and preservation of any human activity. However, the ability of agriculture to meet the current and future human needs is threatened by a number of issues that include climate change, loss of biodiversity, soil degradation and pollution, rising production costs and poverty, among others [13][14].

According to the United Nations [15], agriculture production is expected to reach 8.5 billion people by 2030, rising further to 9.7 billion by 2050. However, intensive agriculture is associated with several problems such as the depletion of non-renewable natural sources, soil damage, adverse effects of agricultural chemicals on human health and the environment, and poor food quality [16][17][18]. At the same time, the availability of arable land also becomes a major issue, with the demand of greater volumes of production in shorter periods of time, resulting in serious problems of global pollution [19]. Thus, the implementation of sustainable approaches becomes of vital significance, with the ultimate purpose of addressing climate adaptation and mitigation, reduction of greenhouse gas emissions, prevention of natural disasters and maintenance of soil health [20]. Here, sustainable agriculture is presented as an ecosystem-oriented approach that involves the use of biological resources to increase production, avoiding the risk of pests and diseases, and taking into account the base of natural resources and their conservation [6].

According to FAO, sustainable agriculture is defined as a system that improves the efficiency of the use of natural resources, while preserving, protecting and improving natural ecosystems, sustaining rural livelihoods and social well-being, and increasing the resilience of people, communities and ecosystems [21]. One of the main challenges agriculture is facing around the world is reconciling growing food production with more sustainable agricultural practices. The growing concern about the harmful effects resulting from increased production has promoted changes in the paradigm of how agricultural systems can be used more efficiently, both in food production and in reducing environmental impacts, translating into many calls for a more sustainable agriculture [22]. Three transactional phases for sustainability in the agricultural environment have been proposed (**Figure 1**), among them efficiency, replacement and redesign. The first two, while crucial, are not sufficient for maximizing the co-production of favorable agricultural and environmental outcomes [23]. In the efficiency stage, a more sustainable use of existing agricultural resources is promoted, since many of these are wasted, culminating in the degradation of the farm's natural capital or the flight of agrochemical products, which entails increased costs for the said farm and associated branches [23]. An example of this is post-harvest losses, which reduce the availability of food, directly contributing to the loss of efficiency and income generated by other means. Rationalizing the use of fertilizers, pesticides and water, on the other hand, promotes efficiency gains on the farm, causing less impact on the environment and human health [24][25][26]. In the replacement phase, the development of new crop varieties and livestock species allows for the replacement of less efficient components of the system with more efficient ones, such as certain plant varieties with greater capacity to convert nutrients into biomass, that are drought tolerant and/or resistant to salinity changes and are resistant to specific pests and diseases. Other substitution strategies focus on the use of biological control agents to the detriment of synthetic agrochemicals [1]. The third phase, the redesign, is fundamental for achieving sustainability on a larger scale, given that the redesign of ecosystems is essential in taking advantage of ecological processes, such as predation, parasitism, N fixation, and trophic dependencies, among others [27][28]. At this stage, the main objectives are modulating greenhouse gases, providing clean water, maximizing carbon sequestration, promoting biodiversity and dispersing pests, pathogens and weeds. The redesign phase is likely to be the most transformative, presenting social, institutional, and agricultural challenges [27][28][29][30].

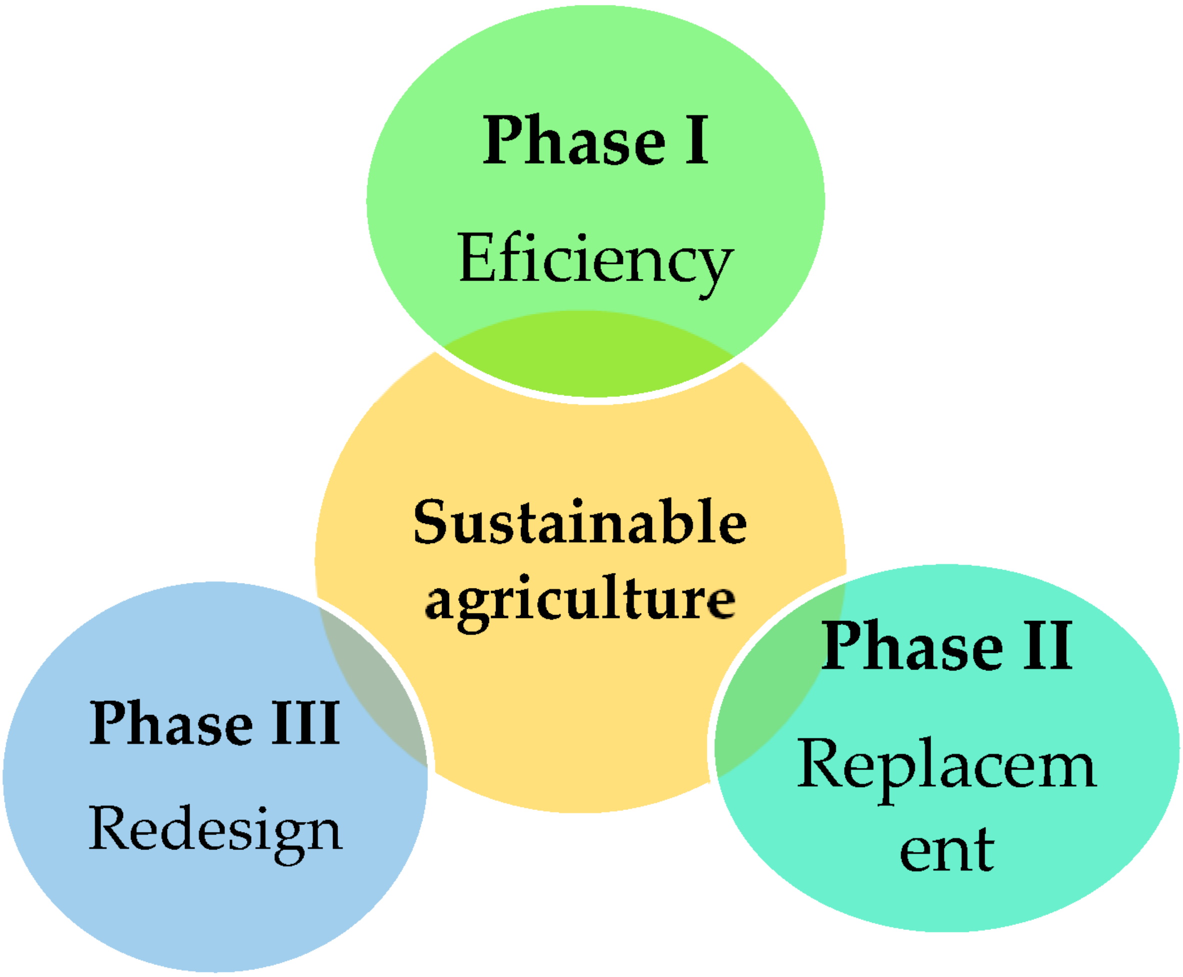

Figure 1. Transactional phases for sustainability in the agricultural environment.

The food supply chain begins with the production of food in the agricultural sector, from which large amounts of waste or by-products are produced. These can be organic or derived from agri-food SWL, as is the case of low quality fruits and vegetables, damaged and/or unharvested products in the fields, by-products of low or zero commercial value, among others [31]. From an environmental point of view, the generation of agri-food SWL contributes to the upsurge of greenhouse gas emissions by its final discarding in landfills and during activities related with the production, processing, manufacturing, transportation, storage and distribution of food. Moreover, the generation of SWL also potentiates the lessening of natural resources in terms of soil, nutrients, water and energy, the disruption of biogenic cycles due to exhaustive agricultural activities and all other impacts typical of any stage of the food supply chain. At the economic level, the expenses related to food waste negatively affect the income of farmers and end users (consumers) and, socially, endorse greater food insecurity worldwide [32][33]. Hence, the reduction of food waste through the recovery of its valuable constituents presents an important approach towards increasing the overall sustainability of food systems, which gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.), the events linked to the production, processing, distribution, preparation, and consumption of food, and their socioeconomic and environmental outcomes [34][35].

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