Agriculture and Sustainable Development: A Look at the Past, Present, and Future

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Abstract. The activity of agriculture, which dates to the origins of human civilization, has always been a topic of discussion due to the growing demand for food. As it requires finite resources, it can have an impact on its surroundings, making sustainability a crucial concept for the development of new methods of food production. In this regard, this paper has as objective to analyze crop diversification as a strategy for sustainable rural development. To accomplish this, it has delved into the history and evolution of agriculture, followed by the concept of sustainable rural development, with a focus on crop diversification as a strategy. As part of the results, the threats to the Anthropocene are reasons of concern and should also be addressed by agriculture since the stability of food systems is directly dependent on this activity. The study has revealed a wealth of scientific evidence supporting the effectiveness of crop diversification to achieve sustainability in agriculture, which is important to subsidize public policies based on scientific evidence. More than ever, promoting the sustainability of agriculture is a necessity for humanity to survive the ongoing changes to the planet, and crop diversification is seen as an effective strategy for accomplishing this goal, inside the theoretical framework of sustainable rural development.

Keywords. Agriculture, Sustainability, Crop Diversification, Sustainable Rural Development.

1. Introduction

The significance of agriculture cannot be underestimated as it has been an integral part of human civilization since its birth. However, as it requires resources that are limited, mismanagement can lead to environmental degradation. Therefore, it is crucial to explore sustainable ways to ensure that agriculture can be practiced indefinitely without causing harm to the environment.

The United Nations defined sustainability or sustainable development as the development "... that meets the needs of the present without compromising the ability of future generations to meet their own needs." Based on that, it was also proposed the Sustainable Development Goals. [1,2]

In this way, development agencies that once promoted crops considered important for food security shifted the focus towards diversification. The Food and Agriculture Organization is one of these agencies and considers it as an effective strategy for dealing with food and nutritional security, sustainable rural development, job creation, reduction of poverty, and environmental and ecological preservation and conservation. [3,4]

Then, this study is about crop diversification as a strategy for sustainable rural development. This subject of research is justified by the need to understand the history of agriculture, how it has evolved, and how to guide its evolution towards a sustainable path.

The general objective of this research is to analyze crop diversification as a strategy for sustainable rural development. The specific objectives are: a) to review the evolution of agriculture; b) to review sustainable rural development as a framework for agriculture.

Finally, this paper has three sections, the introduction is the first one, followed by a literature review that covers the history of agriculture and the

conclusions.

2. Literature Review

2.1 Pre-Conventional Agriculture

Agriculture first appeared in the Neolithic period around 10,000 years ago. People started to domesticate animals and vegetables and used rudimentary tools and fire. Over time, they developed more advanced agricultural work instruments, transforming ecosystems according to their needs. Agriculture developed independently in different parts of the world, with wheat and barley cultivated in Europe and the Middle East, corn, beans, and potatoes cultivated in the Americas, and rice cultivated in Asia. [5,6]

From the analysis of the innovations that took place during this period, it is possible to observe that the forms of agriculture carried out at a given time varied depending on the location. It is also possible to see that they vary depending on the season. In other words, agriculture is manifested as a set of local forms, susceptible to variations in space and time. [5]

Prehistoric farmers settled in tropical and subtropical plateaus with dry temperate climates where they found diverse vegetables due to mountain ranges. They established habitats on plateaus where herbaceous plants grew. Privileged cantons had better geographic conditions, frequent rains, and more food. Neolithic Agricultural Revolution had six centers of origin where humans abandoned the hunter-gatherer profile for cultivating plants and domesticating animals. [7,8]

Six centers of civilization emerged at different times and places in history. These centers were located in Syria-Palestine, southern Mexico, northern China, central Papua New Guinea, the Peruvian and Ecuadorian Andes, and the middle Mississippi basin. These regions were established between 10,000 and 1,800 years BC. Some argue mountainous Western Asia has primacy in the invention and expansion of cultivation and the spread of cultures and that the villages on the Nile and those in Baluchistan were the cradle of wheat. [8]

Einkorn wheat and starch wheat were domesticated Around 9,500 years ago when agriculture and cultivation practices were established in the Middle East. Later, wheat, barley, lentils, peas, flax, goats, pigs, sheep, and ox were domesticated. Then, rice and corn were cultivated in different parts of the world, while wheat expanded in Asia Minor, the Nile Delta, Mesopotamia, and China. Crops such as corn, pumpkin, potatoes, cocoa, cassava, and sunflower were among the first signs of agriculture in the Americas around 5,000-4,000 BC. During this period, farming techniques such as irrigation, fertilization, and stepped terrace construction were developed. Additionally, hunting and fishing were important food sources for American inhabitants. [8–10]

Antiquity refers to the period between the beginning of agriculture and writing until the fall of the Roman Empire. During this time, several ancient civilizations emerged such as Egyptians, Mesopotamians, Greeks, Romans, Persians, Hebrews, Phoenicians, Celts, and Etruscans. City life emerged and institutions were opened to maintain the food supply for non-food-producing citizens. The diet mainly comprised wheat, barley, broad beans, vegetables, and wine and olive oil produced from vine and olive trees. [10,11]

At the end of Antiquity, due to the invasions suffered, the Roman landowners went to live on their properties in the countryside. Poor people left the cities with the aim of seeking protection and work on the land and, to maintain their stay and use the land, they handed over part of what was produced to the owner. Thus the feudal regime was born, in which the rural worker is a servant of the large landowner. At that time, production in cultivable areas was low, due to the lack of interest of farmers who had to deliver a large part of the production to landowners. [10]

In the 11th to 13th centuries, heavy traction cultivation spread across northern Europe, replacing light traction cultivation of the 10th century. As the population grew, deforestation resumed, abandoned regions were reclaimed, and techniques for easier land cultivation were created. Innovations such as iron plows, water and wind-powered mills, and horse labor were developed during this time. [8,10]

Around 1000 AD, Europe faced signs of overpopulation due to limited agricultural production capabilities. This resulted in famines, disturbances, and worsened living conditions for peasants. Despite the population growth, agricultural production increased slowly. The shift towards heavy traction cultivation had a significant impact on Europe's agricultural output. [8]

Populations consumed food in the places where it was produced and at the end of the Middle Ages they sold it in points further away from where it was produced. The rural territory in Europe at that time was a mix of land destined for cultivation and uncultivated land and the cities preserved rural characteristics, as they were infested with fields, vegetable gardens, meadows, and woods. The products grown on the land were joined by hunting, fish, and cattle raised in the clearings and forests. Different dietary regimes depended on the social groups, even so, the diet of all inhabitants was rich and varied. [10]

Medieval people had different types of meat such as pig, sheep, beef, and hunting. They preserved meat by salting and drank wine frequently. Cereals like rye, oats, and sorghum were consumed with legumes like peas, beans, and broad beans. Vegetables were grown in small gardens and the agroforestry system guaranteed subsistence. Their in-depth knowledge of plants and animals enabled the exploitation of resources and ensured daily survival. [10]

Thanks to the growth of cities, subsistence

agriculture became market agriculture and the State began to organize supply. As there was no relevant progress in agricultural techniques, the land under cereal cultivation expanded. It is estimated that the population in Europe began to eat more cereals, with a decrease in the presence of meat in the popular diet. While the amount of land for cereal cultivation increased, the amount of livestock pastures decreased. [11]

When Columbus arrived on the American continent, around ten million natives had corn, potatoes, sweet potatoes, and cassava as their diet. Intensive pre-Columbian agriculture was discontinued and the remaining crops were decimated by the colonizers' cattle. The exchange of products between different continents took place thanks to navigation. Asian spices and American edible plants reached Europe. Tropical plants, such as sugarcane, arrived in the New World, where they developed greatly. African and oriental plants, such as bananas, vines, and yams, were cultivated throughout the world. In Brazil, the plantation was the basis of colonization, when crops were cultivated on a large property, with slave labor, aiming for export. [9,12]

Throughout the Modern Age and Post-Medieval period, scientific knowledge in agriculture underwent significant changes and advancements. Numerous notable individuals contributed to this progress, including John Woodward, who experimented with distilled water on plants, and Stephen Hales, who authored the first book on nutrition. Joseph Priestley discovered that plants dispelled the same gas (oxygen) as mercury oxide when heated, and Jan Ingen-Housz found that plants released a gas (oxygen) when exposed to light. Additionally, Lavoisier refuted the phlogiston theory and established the Law of Conservation of Mass. Jean Senebier discovered the relationship between the amount of expelled gas (oxygen) and the quantity of another gas (carbon dioxide) dissolved in water. Malthus introduced demographic studies, Saussure applied Lavoisier's knowledge to plant nutrition, and Boussingault provided evidence of nitrogen fixation, among other significant discoveries. [10,13–21]

2.2 Conventional Agriculture

During the 20th century, there were significant advances in science and technology that led to increased food production, which surpassed the rate of population growth, thereby reducing chronic hunger. Pesticides, which were initially developed as a means to combat plant diseases, became commonly used after World War II. Additionally, the use of fertilizers has increased significantly due to the productivity benefits it provides. [22]

During the Contemporary Agricultural Revolution, mechanization and selection of varieties, along with the use of fertilizers, occurred mainly in developed countries. In contrast, the majority of the rural population in developing countries did not have access to these technological advances. As a result, only the agricultural elite had access to the technological advances of agricultural revolutions, such as the Green Revolution. [8,23]

The Green Revolution was a type of Contemporary Agricultural Revolution that focused on varietal selection for high yields, along with fertilizers and irrigation control. It was mainly aimed at export crops like rice, corn, wheat, and soybeans. This practice of genetically selecting plants has been used since the beginning of agriculture, but the Green Revolution took it to new levels, making modern agriculture more productive. [8,22,24]

Intensive soil cultivation, monoculture, synthetic fertilizers, irrigation, chemical pest control, and manipulation of plant genomes are common practices. While they can increase production and efficiency, they also have negative impacts on soil fertility, erosion rates, water consumption, public health, and the environment. These practices prioritize profit and production over the health of agroecosystems. This has led to a reduction in crop diversity and an over-reliance on simplified processes to meet productivity metrics. Unfortunately, this has resulted in weakened adaptive capacity, leaving us vulnerable to climate change, biodiversity loss, and food insecurity in the long run. It has become a vicious cycle that we must address. [22,25,26]

Certain practices prioritize present productivity at the expense of future productivity. These practices can have detrimental effects, including soil degradation, excessive use of water and waste, environmental pollution, dependence on external inputs, loss of genetic diversity, loss of local control over agricultural production, and global inequality. These effects can lead to a reduction in biodiversity and a simplification of rural landscapes. [22,27]

Conventional agriculture heavily relies on chemical agents and financial incentives, making it less resilient and unsustainable in the long run. Its practices lead to the degradation of natural resources that are essential for production. [22,28]

The current model of agriculture is not sustainable and poses what is called the “Anthropocene Triple Threat”. This consists of climate change, loss of biodiversity, and food insecurity. [25,28]

The sustainable development of agriculture is facing a growing threat in the form of climate change. Extreme weather conditions like droughts, floods, heat waves, and cyclones are becoming more frequent and affecting agricultural productivity, food security, rural poverty, and natural resource exploitation. Additionally, it is leading to emigration and decreased demand for industrial goods and services. [29]

2.3 Sustainable Rural Development

In the aftermath of World War II, the idea of sustainable rural development (SRD) was primarily centered around economic growth. As such, there was not much concern about the excessive use of

natural resources, as it was viewed as a means for developing nations to catch up with already developed countries. However, this concept failed to take into account the environmental and social implications, and solely focused on developmental goals. [30,31]

In the second half of the 20th Century, sustainable development evolved through key international environmental events. In 1968, the Club of Rome established the limits of growth due to finite resources. The Stockholm Conference in 1972 expanded on environmental degradation and the difference between industrialized and non-industrialized countries. The term "Sustainable Development" was coined in 1987 by the United Nations. Finally, in 1992, the Rio Conference recognized developed countries' greater responsibility for environmental degradation. [6]

When it comes to sustainable development, there are two different approaches. One approach focuses solely on economic growth, while the other takes into account other dimensions such as the environment and society. The former is known as eco-technocratic and the latter as eco-social, which aims to achieve a balance between economic growth, environment, and society. [5,6]

An ecosystem refers to a complex system that consists of interdependent relationships between living organisms and their surrounding environment, encompassing both living and non-living components, that are confined within a defined boundary. The balance of an ecosystem is maintained by its diversity, which ensures its stability over time and space. The ecosystem is disrupted when its complexity is reduced, leading to an imbalance. [22,23]

Agroecosystems are ecosystems that are involved in agricultural production. Therefore, the principles of ecology and natural ecosystems can be applied to analyze food production systems. To achieve sustainability, agroecosystems must aim for self-regulation. This involves considering not only agronomic and ecological issues but also socioeconomic ones, which means that agriculture is both an ecological and social process. It is important to say technology should also be utilized as a valuable tool in rural development to meet economic and social needs. [22,23]

Then, natural resources are finite, and economic growth should not come at the expense of social well-being and environmental stability. This approach, known as sustainable development, seeks to enhance human life while also protecting the capacity of ecosystems to support us. By recognizing the limits of our planet, we can work towards a better quality of life for all. [23,31]

It is vital to consider six key dimensions of sustainability in any project or initiative. These dimensions are Ecological, Social, Economic, Cultural, Political, and Ethical. Ecological sustainability involves preserving and conserving natural resources for the sake of continuity. Social sustainability entails ensuring that everyone in society can access and benefit from the product equitably. Economic sustainability is not just about making a profit, but also about promoting subsistence, sovereignty, and food security. Cultural sustainability means respecting local knowledge and values. Political sustainability requires giving rural populations a voice in decision-making and addressing their interests and needs. Finally, ethical sustainability involves taking responsibility for environmental preservation and conservation for the sake of future generations. [30]

To promote Sustainable Rural Development, it is crucial to provide support for family farming, alternative marketing strategies, and a focus on local communities. This is where the concepts of multifunctionality and polycultures come in. Building sustainable agricultural systems requires a forward-thinking approach that takes into account the development of local and regional economies, incorporating the use of indigenous crops and varieties to enhance agrobiodiversity. In doing so, we can achieve a balance between economic growth, environmental conservation, and social equity. [23,30]

2.4 Crop Diversification

The need for agricultural diversification and ensuring food security has been a long-standing concern. Even during the colonial era, the Portuguese Crown focused on diversifying agricultural production in Brazil to ensure a steady food supply. As a result, there were large sugarcane exporters and a peasantry comprised of small producers involved in the food supply. [12]

In times of global shocks like pandemics or prolonged droughts, diversification of production systems offers a viable way to deal with complexity and uncertainty. Instead of relying on simplified or monoculture systems, diversified systems tend to be more effective. Additionally, integration between animal and plant production is crucial. However, it is important to keep in mind that each agrosystem is unique, and there is no single recipe that fits all. Therefore, it is important to have a good understanding of the specificities of each agrosystem and adopt appropriate forms of diversification. [25,32]

Achieving multiple objectives can be made possible through agricultural diversification. It's important to take cultural legacies into account while considering suitable alternatives for diversification. Additionally, reducing dependence on agrochemicals is crucial for sustainable agriculture. [25,33]

It's important to note that traditional crop production systems can hinder agricultural diversification, as the benefits may not be immediate or obvious. Nonetheless, diversification can enhance the capacity for adaptation and resilience, allowing

for better resistance to potential threats and challenges. Therefore, diversification can be a virtuous cycle that brings additional advantages. [25,34]

To address the challenges posed by climate change and sociopolitical inequality, it is necessary to shift away from the productivist paradigm and towards more diversified agricultural systems. This requires a policy shift at all levels of government, with a focus on climate adaptation as a priority for agricultural systems. Biophysical factors, including climate variability, must be taken into account when developing these policies. [33]

A wealth of scientific literature is available that provides compelling evidence supporting agricultural diversification. [35–40]

3. Conclusion

This paper begins by contextualizing sustainability and explaining what this research is about. Then, it reviews the history of agriculture, dividing it into pre-conventional and conventional, followed by the introduction of sustainable rural development as a framework for agriculture and finally, crop diversification as a strategy. This last section concludes the paper.

The history of agriculture shows there is a great impact of science and Humanity has always thrived facing enormous threats. If once people were afraid of the population surpassing the food production, today the fear is about the Triple Threat of the Anthropocene. Therefore, it is important to exploit sustainable ways of practicing agriculture. Crop diversification is one of them and there is great evidence in the scientific literature about its benefits to smallholders.

Ensuring sustainability in agriculture is crucial to maintaining a healthy environment while meeting the food demands of the growing population. With the world facing more frequent and severe climate alterations, it is imperative to improve the reliability of food systems.

Finally, with enough scientific evidence, public policies can be elaborated without fear of making mistakes, to address climate change in agriculture and avoid destabilizing agrifood systems. This paper, therefore, aims to contribute to this issue.

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