Review Article
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Semi-natural agroecosystems. challenge of the functional redesign of biodiversity during the agroecological transition towards sustainable food

Abstract

Various documents show that the design and management of agroecosystems, according to the principles of agroecology and the functions of biodiversity, facilitates the transition to sustainable food. Experiences in the participation of projects advised and facilitated in family farming systems allowed us to consider that humans, who for many years have been consumers of a few agricultural products, integrate agricultural fruits that have developed in semi-natural agroecosystems into their diet. This article discusses that sustainable food should integrate semi-natural foods, as a complement to the diet, due to their importance in digestion, nutrition and immunity to certain diseases

Keywords: ecological functions, nutrition, immunity, semi-natural foods

Volume 11 Issue 5 - 2024

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Received: September 2, 2024 | **Published:** September 19, 2024

Introduction

Conventional food is usually valued for its ability to satisfy the quantity of fresh food needed by human populations, by establishing long supply chains to transport these products to large markets located in human settlements, a global model that has predominated for many years and considers these foods as products, under the same scheme as those processed industrially.

It is a system that leaves aside the biological characteristics and interactions of the foods that are offered through these technical chains, which is why the diet of human populations has been simplified into: (a) a few basic products, (b) obtained through intensive production technologies, (b) that are transported over long distances, (c) with risks due to remanipulation and contamination, (d) whose access by the population is relative

The modern diet is vastly different from that of our Paleolithic ancestors, who had an annual base of some 500 different plants, whereas ours has fewer than 50; they ate their food raw and often fermented, while we preserve, dry and cook our food, processes known to destroy many sensitive nutrients and antioxidants. This may be the reason why we are now seeing an increase in various atopic diseases, infections and so-called Western diseases.[1]

In fact, the predominant agricultural production model, whose main characteristic is hyper-technification to achieve higher crop yields, which is based on the use of massive doses of inputs (fossil fuels, pesticides, fertilizers, hybrid seeds, machinery, water for irrigation and a long list continues), failed to solve the problem of hunger in the world population, because there are currently 800 million hungry people.[2]

A radical transformation of the system and food is urgently needed to optimize the health of people and the planet.[3] The redesign of agroecosystems under the principles of Agroecology facilitates the functional interactions of biodiversity that contribute to its capacity for ecological self-regulation and that of the intestinal ecosystem of people who consume such foods.[4]

Agroecology provides a broad approach, which allows us to understand agricultural action in holistic terms, stating that the contemporary problem of production has evolved from a merely technical dimension to one of more social, economic, political and ecosystem dimensions. In other words, the central concern today is that of the sustainability of agriculture, conceived as an economic, social and ecological system.[5]

Precisely, the objective of this article is to promote that the agroecological design and management of biodiversity in agricultural production systems contributes to facilitate its transformation into semi-natural agroecosystems, where crops are developed free of toxic residues, are more nutritious and preserve their microbiota

Material and methods

To prepare this article, the results of diagnoses, workshops and notes of several projects advised and facilitated in territories of Cuba were reviewed: (a) agroecological resilience to drought of peasant farms in municipalities of Guantánamo and Santiago de Cuba (2019-2021); agroecological design and management of family garden in the municipality of Marianao, Havana (2021); agroecological transition of family farms in municipalities of Camagüey (2022-2023); integrated systems of agroecological livestock in municipalities of Havana (2014-present).

In these projects, diagnoses were carried out on the design and management of the systems (farms and patios or family gardens), innovations were facilitated for their agroecological transformation towards systems with sustainability attributes, and collective exchange and valuation workshops were held, in which the issue of the characteristics of the agroecosystems where fresh agricultural products were obtained was transversal.

These experiences in primary food production systems, the appropriation of the theoretical basis of Agroecology and the recent links with the agroecological transition towards sustainable food systems, constituted the inputs used for the elaboration of this article.

Results

Transition towards sustainable food. For years, most debates on agriculture and rurality have concluded that agriculture is in crisis worldwide, mainly due to negative impacts and high dependence on synthetic pesticides, fertilizers and agricultural machinery, among other causes.[6,7]

At the same time, the unsustainability of the globalized food system is denounced and its influence is sought to be reduced, support resistance processes and propose elements so that they can achieve the ecological, economic and social sustainability of all its components: production, processing, distribution and consumption.[8]

The purpose is to provide the population with healthy food without degrading the natural resource base and at the same time addressing broader aspects of sustainable rural development such as governance, solidarity markets, access to livelihoods, family planning, management of production systems, reduction of losses and waste among others.[9]

The transition to sustainable food is a process of transformation of agroecosystems, with a predominance of the design and management of biodiversity, with the purpose of facilitating functional interactions that contribute to agroecological self-regulation, from primary production to the ingestion of food by people.[10]

Agroecology is currently considered an area of knowledge and praxis that addresses broad issues inherent to the socio-environmental complexity of the field, such as food security and sovereignty, the decentralization of profits and the market, local self-determination, technology transfer, and similar elements of development and governance systems.[11]

With the rise of Agroecology, as a science that offers the scientific and methodological bases to move towards sustainable food, a dynamic of participatory research is occurring that influences the reconfiguration of the attributes of food; because, in addition to those related to quality, safety, nutrition and health, those that consider the production and post-production processes in aspects related to social and environmental responsibility, equity and solidarity, among others, are integrated; a trend that reorients the attitude in food towards the restoration and conservation of natural and social resources.[10]

The design of agroecological systems is based on the application of the following ecological principles[5]:

I. Plant and animal diversification at the level of species or genetics in time and space.

II. Recycling of nutrients and organic matter, optimization of nutrient availability and balances of nutrient flow.

III. Provision of optimal soil conditions for crop growth by managing organic matter and stimulating soil biology.

IV. Minimization of soil and water losses by maintaining soil cover, controlling erosion and managing the microclimate.

V. Minimization of losses due to insects, pathogens and weeds through preventive measures and stimulation of beneficial fauna, antagonists, allelopathy.

VI. Exploitation of synergies that emerge from plant-plant, animal plants and animal-animal interactions.

A main strategy of Agroecology is to exploit the complementarity and synergy that result from the different combinations of crops, trees and animals in agroecosystems, so that, through spatial and temporal arrangements, they favor polyculture, agroforestry and agricultural systems.[12] his diversity and multifunctionality of their interactions are characteristics of each agroecosystem, and when they are facilitated with agroecological designs and management, they contribute to increasing the efficiency of the system.

The evidence of traditional agriculture, advances in permaculture, organic agriculture, urban agriculture and agroecology, provide experiences on the potentialities of the functions of biodiversity to move towards sustainable food; However, a holistic understanding of biodiversity and its functions is needed to redesign primary production systems, as well as to influence human populations on the importance of the bioecological characteristics of foods and their contribution to nutrition and immunity.

Functional redesign of biodiversity in agroecosystems

Current biodiversity conservation strategies tend to focus on natural ecosystems, often ignoring opportunities to increase biodiversity in agricultural landscapes Compared to the simplified landscapes of conventional agriculture, complex agricultural landscapes host significantly greater diversity among taxa and functional groups, including species beneficial to agricultural production, ecosystem functioning, resilience, and human well-being.[13]

Although natural ecosystems and agroecosystems have in common their broadest and best-known definition that describes them as: the set of organisms that live and interact in a given environment and the physical part of the environment that in one way or another affects them; however, an agricultural system differs in several fundamental aspects from a natural ecosystem. These differences would be[14]: (a) agroecosystems, depending on their level of artificialization, require auxiliary sources of energy, which can be human, animal and fuel to increase their production; b) their diversity is, as in the case of monocultures, very low; (c) the animals and plants that dominate in the agroecosystem are selected artificially and not by natural selection; (d) system controls are mostly external, through human action, and not internal; (e) biomass production is preferentially intended for consumption outside of it, therefore the level of biomass reinvestment is low.

While in the past many biodiversity conservation initiatives were based almost exclusively on its intrinsic values or ethical criteria, in recent years more pragmatic arguments have begun to gain strength, taking into account the contribution of biodiversity to the quality of life and well-being of human societies.[15]

As a relative synthesis, the main differential characteristics in the design and management of cultivation systems based on conventional, organic and agroecological transition, which considers productive diversity, the design of cultivation systems, the integration of living barriers and other auxiliary vegetation structures, the use of technical products for crop nutrition and health and the intensity of work on the soil and cultivation, allows us to visualize their contribution to the safety, nutritional value and microbiota of the harvested products (Figure 1).

		CONVENTIONAL	ORGANIC	AGROECOLOGIC
DESIGN AND HANDLING	Productive diversity	Specialized	Diversified	Diversified
	Cultivation system design	Single crop	Multiple	Functional
	Integration of living barriers	None	Sides	Lateral and intercalated
	Use of technical products	Agrochemicals	Bioproducts	As needed
	Intensity of agricultural work	High	Medium	Low
PRODUCTS HARVESTED	Safety	-	+++	+++
	Nutrition	+	++	+++
	Microbiota	+	++	+++

Figure 1 Relative synthesis of the characteristics of the design and management of the main types of cropping systems and their contribution to the safety, nutrition and microbiota of the harvested products.

The functions of biodiversity for sustainable food consider: a-recovery of populations and activity of pollinators, natural enemies of harmful organisms, epiphytic, rhizospheric and soil biota; b-no presence of chemical residues, toxins and human pathogens in fresh products; c-increased moisture retention in the system; d-reduction and optimization in the use of water; e-increase in microclimate self-regulation; f-recovery of soil properties; g-greater land cover; h-increased capacity for ecological self-regulation of harmful organisms; i-Increasing economic circularity; j-increase in the productive efficiency of the system; k-increase in the productive stability of the system; l-improvement of energy efficiency; m-improvement of economic efficiency; n-contribution to the supply of nutritious products; o-contribution to the recovery of traditional diets; p-contribution to the enrichment of the human microbiome; q-Increased resilience to extreme events; r-contribution to the one health approach.[10]

The nutrient composition of plants, which are consumed by animals and humans, is determined by the nutrient and microbial composition of the soil in which they grow. The health of animals and plants then determines the health of an overall ecosystem. Without taking these connections into account, industrial agricultural practices have altered the chemical and microbial composition of soils and the quality and availability of water, having a direct influence on ecosystem health and nutrient availability.[16]

The importance of nutrient diversity for human well-being calls for dietary diversification. However, the quality of nutritional supply and human health are at risk due to biodiversity losses. The benefits of biodiversity affect all socio-ecological systems along the food value chain, from agricultural activities, food processing and consumption patterns to nutrition and health status. There is a call for systemic approaches to capture the dynamic processes between and within food system activities, nutrition and health, and the environment.[17]

As a result of co-evolutionary processes, mainly with respect to habitat and nutrition, whether of plants (cropping systems), animals (livestock systems) or people (community), the functions of associated biodiversity play a main role in health, a natural characteristic that has been underestimated with socioeconomic development.[18]

Semi-natural agroecosystems

Semi-natural agroecosystems are considered an imitation of nature, where in addition to the ability to regulate populations of harmful organisms without the need for pesticide interventions, the nutrition of the crop without chemical fertilizers, facilitates the balanced development of the plant, mainly in the chemical composition of its organs and the interactions of its microbiota. contributing to the fact that fresh agricultural fruits are considered as semi-natural.

As evidence, it is very common to observe semi-natural environments in the surroundings of crop fields and other uncultivated sites in agricultural production systems, whose functions of connectivity and reservoir of associated biodiversity are documented.[19,20] These develop the capacity for ecological self-regulation, due to the cumulative multi-effects that contribute to the regeneration and conservation of biota in the soil, recovery and conservation of associated biota (rhizospheric, epiphytic, natural enemies, pollinators) and higher food quality, with less environmental impact, among others.[21]

In the territories of Cuba, systems where fresh agricultural products that can be considered as semi-natural are obtained are common, mainly the following: (a) areas of fruit trees (groves) on traditional peasant farms, where the family has planted a diversity of fruit species for many years, mainly for the purpose of family self-sufficiency; (b) in urban and peri-urban agriculture, where family gardens are promoted, where people grow crops in small spaces to be self-sufficient in food; (c) agroforestry farms, where a diversity of crops are integrated into complex designs.

The communities that are organized around the self-management of food constitute areas of family and community agriculture, which are complemented by a diversity of products during the different seasons of the year, interacting directly with the population with safe food, with very little handling after obtaining, due to the short distance and time that elapses between its obtaining and ingestion by people. that leave behind the consumer focus for sustainable food.[22]

Families from periurban communities, sometimes socially marginalized, are more likely to obtain food in small spaces, which provide them with a diversity of seminatural fresh products, because they are obtained with minimal physical interventions, not chemicals and very little manipulation, whose biotic direct interactions contacts with family members influence nutrition and health, facilitating a sustainable quality of life despite living with low income In fact, these periurban communities constitute coinnovation niches that can serve as a reference for designing the food systems of the future.[23]

In the search for a healthy diet, the redesign of food production systems under the principles of Agroecology, facilitates the functional interactions of biodiversity that contribute to its capacity for ecological self-regulation and that of the intestinal ecosystem of the people who consume said foods foods.[4]

The intestinal ecosystem is a complex environment in which dynamic and reciprocal interactions occur between the epithelium, the immune system and the local microbiota.[24] Likewise, the concept of a nutrient as any assimilable substance contained in food, which allows the body to obtain energy, build and repair tissues and regulate metabolic processes, has passed to that of an immunonutrient, which is a substance that, unlike a nutrient conventional, is capable of enhancing the immune system.[25]

In the future, food will not only allow optimal growth and development from pregnancy and in all stages of life, but will also enhance physical and mental capacities, as well as reduce the risk of disease,[26] because billions of microorganisms inhabit the human body and influence its development, physiology, immunity, and nutrition.[1]

Agricultural practices in different countries have resulted in a great diversity of semi-natural habitats that harbour specific biodiversity and are linked to the culture and history of the local population.[27]

The feeding of human populations has gone from the collection of fresh vegetables in nature, to specialized production in large monoculture extensions, with high mechanization and use of agrochemicals; that is, from natural foods to those manipulated through different technological processes. The latter have become a few basic products, whose negative effects are well known, due to prolonged exposure over many generations to a low diversity of foods and their associated microbiota, which is why nutrition and immunity functions have been reduced naturally in the human microbiota.[4]

In fact, healthy and sustainable eating is a dietary pattern that promotes all dimensions of people's health and well-being, with low pressure and environmental impact, accessible, affordable, safe, equitable and culturally accepted It enables the optimal growth and development of people at all stages of their lives, both present and future generations, contributing to the prevention of malnutrition in all its forms and to the reduction of the risk of non-communicable diseases.[2]

Agri-food systems have the potential to move us in a more sustainable direction than other commodities, because they entangle each of us as consumers not only in networks of relationships with producers, but also connect us to ecological processes and services, many of which are under threat.[28]

The benefits of biodiversity affect all socio-ecological systems along the food value chain, from agricultural activities, food processing and consumption patterns to nutrition and health status. There is a call for systemic approaches to capture the dynamic processes between and within food system, nutrition and health, and environmental activities.[17]

As an extension of ecosystem functioning, given the primary goal of agroecosystems to produce food for human nutrition and health, the nutritional functions of agroecosystems should be measured alongside their ecological counterparts.[29]

Health is a continuum from the soil to our bodies, dictated by the interconnectedness and interrelationship between humans, nature's biodiversity and its systems. The interrelationship between human health and nutrition is determined by the connecting pathways between soil health, plant health, animal health and, therefore, human health.[16]

It is not a question of all primary agricultural production being carried out in semi-natural agroecosystems, but that these are valued as complementary, to integrate fresh semi-natural products, as a contribution to reducing the effects of many years of biologically altered basic foods.

Discussion

The transition to sustainable food is the result of a process that begins with adjustments in the design and management of conventional cropping systems, mainly the reduction of agrochemicals and their substitution by bioproducts, while also replacing simple cropping systems (single crops) with complex ones (multiple crops, polycultures), technological change that is brought about by the establishment of Organic Agriculture and the adoption of Agroecology. In fact, the agroecological transition also implies the transformation in the design of the structural matrix of the production system, so that ecological multifunctions are facilitated.

It is characteristic of semi-natural agroecosystems when there is evidence of the regeneration of soil properties, ecological self-regulation of critical levels of harmful organisms, among other ecological functions, and cropping systems do not need subsidization with technical products or are limited to some bioproducts. This is evidence that the production system facilitates functional interactions of biodiversity, mainly of the biota associated with productive species, from the seed to the agricultural fruit that is ingested by people.

Agroecology emerges as a discipline that provides the basic ecological principles on how to study, design and manage agroecosystems that are productive and conserving natural resources and that are also culturally sensitive and socially and economically viable. At a more regional level, design a network of agroecosystems within a landscape unit, mimetic with the structure and function of natural ecosystems.[5]

The agroecological transition is a process of transformation from conventional production systems to agroecological-based systems, which includes not only technical, productive and ecological elements, but also sociocultural and economic aspects of the farmer, his family and his community.[30]

It is a complex process, because it means much more than transforming the production system, since it must achieve internal capacities, the recovery and conservation of natural resources and improve quality as a habitat for productive species and workers, as well as being efficient in the productive, economic, ecological and social order, so that sustainability can be achieved.[31] It includes not only technical, productive and ecological elements, but also sociocultural and economic aspects of the farmer, his family and his community.[30]

Farm redesign attempts to transform the structure and function of the agroecosystem by promoting diversified designs that optimize key processes. The promotion of biodiversity in agroecosystems is the key strategy in farm redesign, since research has shown that: (a) greater diversity in the agricultural system leads to greater diversity of associated biota; (b) biodiversity ensures better pollination and greater regulation of pests, diseases and weeds; (c) biodiversity improves nutrient and energy recycling; (d) complex and multispecific systems tend to have higher total productivity.[32]

For a long time, agricultural production has faced the dilemma of food safety for human consumption and this is one of the justifications for the alternative known as "organic agriculture." However, in general there is a short-sightedness in this regard, because humans do indeed require fresh food to be free of toxic residues; but it is also necessary for them to be grazers of their natural microbiota, so that it interacts with the microbiota of the abdominal ecosystem of people when they ingest them, mainly due to its importance in the digestion of food, nutrition and immunity against certain diseases.

Conclusion

The agroecological design and management of biodiversity can facilitate the transition to semi-natural agroecosystems, where crops are developed under conditions very close to the natural ones, so that their nutrients and original microbiota of the species are better preserved.

Agricultural fruits obtained in semi-natural agroecosystems can be considered a complement in people's diets, as they are harmless, nutritious and carry the microbiota that contributes to immune functions in the people who eat them.

Acknowledgments

None.

Conflict of interest

Authors declare that there is no conflict of interest.

Funding

None.

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Citation: Vázquez LL. Semi-natural agroecosystems. challenge of the functional redesign of biodiversity during the agroecological transition towards sustainable food. *J Appl Biotechnol Bioeng.* 2024;11(5):146–150. DOI: 10.15406/jabb.2024.11.00371