Mini Review

Open Access

Functional biodiversity and agroecological self-regulation for sustainable food

Summary

Functional biodiversity is a determining factor in the agroecological transformation towards sustainable food systems. The agroecological design and management of productive, associated and auxiliary biodiversity accumulates agroecological self-regulation capacities from the primary production process to food ingestion.

Keywords: functional biodiversity, agroecological self-regulation, sustainable food

Volume 11 Issue 2 - 2024

Luis L Vázquez
Research Associate, Latin American Center for Agroecological Research (CELIA), Cuba

Correspondence: Luis L Vázquez, Research Associate. Latin American Center for Agroecological Research (CELIA), Cuba, Email llvazquezmoren@yahoo.es

Received: March 11, 2024 | **Published:** March 22, 2024

Introduction

Agroecosystems face new challenges in the context of a growing and increasingly interconnected human population, and a paradigm shift is needed to successfully address the many complex questions these challenges will raise.[1]

The nutrient composition of plants, which are consumed by animals and humans, are 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 ecosystem as a whole. 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.[2]

Although in the past a good part of 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, which take into account the contribution of biodiversity to the quality of life and well-being of human societies.[3]

The conservation of biodiversity and the generation of ecosystem services constitute strategies that are promoted and executed by the institutions that manage ecological systems, which is also being assumed by the governance of socioeconomic systems; however, it is evident that a more integrated vision is required at the scale of agricultural and urban landscapes, due to the pressure that development exerts on anthropogenic self-extinction.[4]

By the way, in the future, foods will not only allow optimal growth and development from pregnancy and in all stages of life, but they will also be able to enhance physical and mental capacities, in addition to reducing the risk of suffering from diseases,[5] because billions of microorganisms inhabit the human body and influence its development, physiology, immunity and nutrition.[6]

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.[7]

The importance of nutrient diversity for human well-being requires dietary diversification. However, the quality of nutritional supply and human health is 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.[8]

In fact, 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 the people who consume said foods.[9]

The transition towards 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, an aspect that is valued in this article.

Functional biodiversity in agroecosystems: Agricultural biodiversity, or agrobiodiversity, is the subcomponent of biodiversity that refers to the biological variety and variability of living organisms that are involved in agriculture and food.[10,11]

Biodiversity, described in terms of number, abundance, composition and spatial distribution of its entities (genotypes, species, or communities), functional characters, as well as the interactions between its components,[12] is of great importance for the functioning, maintenance and stability of ecosystems.[13]

The need to approach the study of biodiversity from a more systemic perspective led to the emergence of the concept of functional diversity,[14] which has been gaining more and more popularity among the scientific community, given its close links with ecological processes. Therefore, attention is currently turned towards a more functional approach, which tries to establish causal relationships between the characteristics of the organisms present and the processes and services of the ecosystems.[12]

This conceptual evolution that is happening on functional biodiversity, expressed as the variety of interactions with ecological processes at different spatio-temporal scales, the range and value of the characteristics of organisms that influence ecological functioning and the relative abundance of characters as key component; that is, the type, range and relative abundance of the functional characters present in a community.[14]

In agroecosystems, agrodiversity is the different ways in which farmers use natural diversity in the production system, which includes not only semi-domesticated crops, but also water, biota and soil;[15] also, the result of interactions with biotic and abiotic environmental factors and management practices in agricultural systems.[16]

There are two types of biodiversity components in agroecosystems: "planned or productive biodiversity", which includes the crops and animals introduced by the farmer, which will vary according to the management and crop arrangements, and "associated biodiversity", which includes the soil flora and fauna, herbivores, decomposers and predators that colonize the agroecosystem from the surrounding environments, and that will remain in said agroecosystem depending on the type of management adopted. Planned biodiversity has a direct function with the functioning of the ecosystem, and the associated biodiversity also has a function, but through planned biodiversity. In this way, planned biodiversity has an indirect function that is carried out through its influence on the associated biodiversity.[17]

A third functional component is "auxiliary biodiversity" (living barriers and fences, groves, semi-natural environments), which are structures of uncultivated vegetation, which grow spontaneously or are encouraged and perform various functions in their interactions with the productive and associated biota.[18] Auxiliary vegetation structures (EVA) are designs composed of one or more species of tree, shrub or herbaceous plants, which are planted or grow spontaneously and facilitate certain ecological and socioeconomic functions.[4]

The interrelationships between multiple species of plants and animals, along with natural processes, work to co-create our natural world. They provide clean air and water, rejuvenate soil fertility, create niches for multiple species, and provide a wide variety of food and genetic resources, functions that make healthy ecosystems resilient to sudden climate changes, natural disasters, or disease outbreaks; processes that have a direct and tangible link with human health, since there is an intimate connection between soil biodiversity, microorganisms, plants and their seeds, wild and crop varieties and species, animals and the biodiversity of our diet and intestine.[2]

As an extension of ecosystem functioning, was proposed that, given the primary goal of agroecosystems to produce food for human nutrition and health, the nutritional functions of agroecosystems should be measured along with their ecological counterparts. Although their study proposed an indicator of nutritional function (nutritional functional diversity), a broad set of nutritional functions has rarely been considered in assessments of agroecosystem performance and resilience, nor have nutritional functions been explicitly linked to underlying ecological functions.[19]

Design and agroecological management of biodiversity: Because agroecosystems are dynamic and subject to different types of management, crop arrangements in time and space are continually changing, according to biological, socioeconomic and environmental factors, variations in the landscape that determine the degree of characteristic heterogeneity of each agricultural region, which in turn conditions the type of biodiversity present.[20]

That is, agroecology emerges as a discipline that provides basic ecological principles on how to study, design and manage agroecosystems that are productive and at the same time conservative of natural resources and that, in addition, are culturally sensitive and socioeconomically viable.[21]

Property redesign attempts to transform the structure and function of the agroecosystem by promoting diversified systems that optimize key processes, since, research has shown that: (1) greater diversity in the agricultural system leads to greater associated biota diversity; (2) biodiversity ensures better pollination and greater regulation of pests, diseases and weeds; (3) biodiversity improves nutrient and energy recycling; (4) complex and multispecific systems tend to have higher total productivity.[22]

In the design and management of production systems, it must be considered that, in their spatial and temporal structure, several main levels are favored in the functional interactions between crops and the rest of the vegetation. That is, a first level of interactions is achieved in the design and management of cultivated fields (including livestock and forestry), with associations, intercropping and crop rotations, among others; A second level of interactions can be achieved when crops are connected to living fences, groves and semi-natural environments through living barriers, which together constitute ecological corridors of biodiversity on farms;[23] that is, expressed, polycultures are systems in which two or more crops are established simultaneously and close enough together for interspecific competition or complementarity to occur.[17]

For example, a study of 24 designs of multiple cropping systems (MCS) in different agricultural regions of Cuba, determined that the types of designs that predominated in the systems studied were herbaceous polycultures (75%), followed by tree polycultures, herbaceous and polyfruit trees with 12.5% each. The highest Functional Coefficient (FC) in the ecological self-regulation of insect pests was achieved by the design that integrates cassava-corn-beans (FC=0.87), followed by the sweet potato-corn and cassava-corn designs (FC=0 .77), bananas-cassava (FC=0.73), beans-corn, banana-beans-corn (FC=0.70) and avocado-mamey-coffee (FC=0.67). The designs that integrated corn, plantain or banana and fruit trees were grouped into different conglomerates and preliminarily proposed these crops as Functional Types of Productive Plants.[24]

Multifunctions of agroecological self-regulation: With functional biodiversity it is possible to initiate synergisms that contribute to favoring processes in agroecosystems, by offering ecological services such as the activation of soil biology, nutrient cycling, the promotion of arthropods and beneficial antagonists,[25,26] providing a new way of evaluating biodiversity in agroecosystems, by considering the species, the designs and management carried out, in contrast to the classic indicators that only include the species and their population, which It allows us to have more complex information that brings us closer to the evaluation of ecosystem functions, properties and services from multiple dimensions.[27]

Traditionally, agricultural systems and their diets have co-evolved over millennia in local ecological contexts, forming specific situated knowledges and deep stewardship relationships between farmers and the land. This is the interconnected network of biodiversity, where each factor equally constitutes the other. Health is a continuum from the earth to our bodies, dictated by the interconnection and interrelationship between humans, nature's biodiversity and its systems. The interrelationship between human health and nutrition is determined by the connection pathways between soil health, plant health, animal health and, therefore, human health.[2]

A systemic analysis of the contribution of agroecological practices (designs and management) allows us to understand that each practice facilitates various functions of biodiversity and that, as a whole, these achieve multifunctions that are determinants in the capacities of ecological self-regulation (Table 1). Observe that the greatest contribution is achieved with the integration of designs of multiple cropping systems, followed by integrating designs for livestock silvopasture, the diversity and seasonality of harvested products, redesign of the structure of the production system, among others that imply transformational changes.

Citation: Vázquez LL. Functional biodiversity and agroecological self-regulation for sustainable food. *J Appl Biotechnol Bioeng.* 2024;11(2):24‒28.
DOI: 10.15406/jabb.2024.11.00355

Table 1 Contribution of agroecological designs and management to the functions of biodiversity. Construction based on studies carried out in cuban agroecosystems[4,9,18,23,24]

	Agroecological designs and management	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
		Functions of biodiversity*																	
1	Have supply sources and water storage capacity										■	■	■					■	
2	Integrate renewable energy sources									■		■	■	■				■	
3	Carry out soil conservation work	■		■	■		■	■	■	■	■	■	■	■				■	■
4	Replace agrochemicals with bioproducts	■	■				■		■	■					■		■	■	■
5	Reuse agricultural and livestock waste						■			■			■	■				■	
6	Synergies in the incorporation of organic fertilizers into the soil	■	■	■	■		■		■	■	■		■	■			■	■	
7	Self-manage agricultural and livestock reproductive material								■	■		■		■				■	
8	Self-manage bioinputs for crop nutrition and health									■		■		■				■	
9	Self-manage food for animals									■		■		■				■	■
10	Self-sufficiency in food for the family									■		■		■		■	■	■	■
11	Integration of agricultural, livestock and forestry items in the production system	■		■		■	■	■	■	■	■	■	■	■				■	
12	Diversity and seasonality of productions	■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	
13	Recover and integrate traditional species, varieties and races											■			■	■	■	■	■
14	Carry out crop sequence and rotation with functional design	■		■	■	■	■	■	■	■	■	■	■	■				■	
15	Integrate functional designs of multi-cropping systems	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	
16	Integrate functional designs for livestock silvopasture	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	
17	Functional redesign of the production system structure	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	
18	Integrate functional designs of auxiliary vegetation structures	■	■	■	■	■	■	■	■	■			■				■	■	
19	Carry out agroecological management of organisms harmful to plants and animals	■	■						■		■								■
20	Establish biosecurity measures for crops, animals and people		■								■								■
21	Add value to fresh products									■	■	■		■				■	
22	Privilege short marketing circuits												■	■		■	■	■	■
23	Prioritize equity in employment											■		■		■	■	■	

(*) Functions of biodiversity: 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 of water use; e-Increased self-regulation of the microclimate; f-Recovery of soil properties; g-Increased ground cover; h-Increased ecological self-regulation capacity of harmful organisms; i-Increase in 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 offer 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.

The effects of agroecological transformation are cumulative over time. For agroecological self-regulation capacities to be expressed in systems, the realization of a coherent and systematic process is required regarding the reduction of degrading practices (agrochemicals, excess mechanization, single cultivation, bare soil, others) and the progressive integration of agroecological practices (designs and management), so that the selection pressure of resistant populations of the biota associated with negative functions (harmful organisms) is reduced and the biota associated with positive functions (decomposers of organic matter, pollinators, natural enemies of harmful organisms, rhizospheric and epiphytic microbiota, plant, animal and human microbiome) is regenerated.

Of course, the agroecological transition towards sustainable agroecosystems has an initial period of "incremental innovation", which begins with the substitution of inputs (products for bioproducts, national varieties for regional ones), the adjustment of production technologies (high for low dependence on fossil energy and integration of renewable energy), among other practices.

While, "transformative innovations" are those that consolidate sustainability, mainly due to changes in: the knowledge and innovation management system; the redesign of the production system (complex matrix) and the cultivation systems (polyculture), livestock (silvopasture) and forestry (agroforestry, polyfruit); the effective articulation of the post-production system (processing, collection, transportation, marketing, others) and the change in the population's attitude towards food (safety, traditional diets, immunonutrition, among others).

Regarding the enrichment function of the human microbiome, the intestinal ecosystem is a complex environment in which dynamic and reciprocal interactions occur between the epithelium, the immune system and the local microbiota.[28] Likewise, the concept of a nutrient

Citation: Vázquez LL. Functional biodiversity and agroecological self-regulation for sustainable food. *J Appl Biotechnol Bioeng.* 2024;11(2):24‒28. DOI: 10.15406/jabb.2024.11.00355

as any assimilable substance contained in food, which allows the body to obtain energy, build and repair tissues and regulate metabolic processes, has been changed to that of an immunonutrient, which is a substance that, unlike a nutrient conventional, is capable of improving the immune system.[7]

The benefits of agroecological approaches on food security and nutrition have been reported in a variety of studies.[29,30] However, the results of the true impact of agroecology on nutrition and diet have not yet been fully understood.[29,31] In particular, the multiple pathways through which agroecological methods can impact nutrition and the food system, both from consumer demand and aspects of food supply, deserve further investigation.[32,33]

Conclusion

The study of biodiversity is traditional, due to its importance in the socioeconomic life of planet Earth, which is why there is extensive documentation, which has also been evidenced in agroecosystems. Although, scientific research is not yet systemic enough to identify and characterize the interactions of the biota that cohabits the food system and the functions that are achieved, from the primary production process to the eating food.

Acknowledgments

None.

Conflicts of interest

Authors declare that there is no conflict of interest.

References

1. Stokes A, Bocquého G, Carrere P, et al. Services provided by multifunctional agroecosystems: Questions, obstacles and solutions. *Ecological Engineering.* 2023;191:106949.
2. Shroff R, Cortés CR. The biodiversity paradigm: building resilience for human and environmental health. *Development.* 2020;63:172–180.
3. Martín–López B, González JA, Díaz S, et al. Biodiversity and human well–being: the role of functional diversity. *Ecosystems.* 2007;16(3):68–79.
4. Vázquez LL. Multifunctions of the auxiliary vegetation structures on conservation habitat quality. A challenge for the agro and socio ecosystems redesigns. *Journal of Applied Biotechnology and Bioengineering.* 2024;1(1):10–13.
5. Koletzko B, Aggett PJ, Bindels JG, et al. Growth, development and differentiation: a functional food science approach. *Br J Nutr.* 1998;80(Suppl1): S5–45.
6. Bengmark S. Nutritional modulation of acute and "chronic" phase response. *Nutrition.* 2001;17:489–495.
7. Chandra RK. Nutrition and immunity: lessons from the past and new insights into the future. *Am J Clin Nutr.* 1991;53(5):1087–1091.
8. Allen T, Prosperi P, Cogill B, et al. Agricultural biodiversity, social–ecological systems and sustainable diets. *Proceedings of the Nutrition Society*. 2014;73:498–508.
9. Vázquez LL. Human microbiota, functional biodiversity and agroecological designs: in search of a healthy diet. *J Biotech Biores*. 2022;4(1)000578.
10. Heywood V, Fanzo J, Hunter D, et al. Overview of agricultural biodiversity and its contribution to nutrition and health. In Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health. In: J Fanzo, D Hunter, T Borelli, et al. editors. London and New York: Routledge; 2013. p. 35–67.
11. United Nations. Convention on biological diversity. New York: United Nations; 1992.
12. Hooper DU, FS Chapin JJ, Ewel A, et al. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs.* 2005;75:3–35.
13. Gliessman SR. Agroecosystem sustainability: developing practical strategies. *Book Series Advances in Agroecology*, CRC Press, Boca Raton, FL; 2001.
14. Tilman D. Functional diversity. In: *Encyclopedia of Biodiversity*. In: R Levin, editor. Academic Press, San Diego, CA; 2001. p. 109–120.
15. Brookfeld H, Padoch C. Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices, *Environment.* 1994;36(5):8–11, 37–43.
16. Almekinders C, Fresco L, Struik P. The need to study and manage variation in agro–ecosystems, *Netherlands Journal of Agricultural Science.* 1995;43:127–142.
17. Vandermeer J, Perfecto I. Breakfast of biodiversity. Food First Book, Oakland, California; 1995.
18. Vázquez LL, Matienzo Y, Griffon D. Participatory diagnosis of biodiversity on farms in agroecological transition. *Revista Fitosanidad.* 2014;18(3):151–162.
19. DeClerck FAJ, Fanzo J, Palm C, et al. Ecological approaches to human nutrition. *Food Nutr Bull*. 2011;32:S41–S50.
20. Altieri MA, C Nicholls. Biodiversity and pest management in agroecosystems. Perspectivas agroecológicas No. 2, Icaria editorial, Barcelona; 2007.
21. Altieri MA. The state of the art of agroecology: reviewing advances and challenges. In: T León, MA Altieri, editors. Aspects of agroecological thought. Fundamentals and applications. Fundamentos y aplicaciones. Bogotá, Colombia: IDEAS Universidad Nacional de Colombia; 2010;21:77–104.
22. Power AG. Cropping systems, insect movement and spread of insecttransmitt ed diseases in crops. 1990. p. 47–69.
23. SR Gliessman. Agroecology: researching the ecological basis for sustainable agriculture, New York; 1990.
24. Vázquez LL, Matienzo Y, Alfonso J, et al. Contribution to the agroecological design of urban and suburban production systems to promote ecological processes. *Revista Agricultura Orgánica* (La Habana). 2012;18(3):14–18.
25. Vázquez LL, Porras A, Alfonso–Simonetti J. Functional types of productive plants integrated into complex crop system designs innovated by farmers. In: Proceedings of the V Latin American Congress of Agroecology. 2015.
26. Altieri MA. Agroecology: the science of sustainable agriculture, Westview Press, Boulder; 1995.
27. Gliessman SR. Agroecology: Ecological processes in agriculture, *Ann. Arbor Press*, Chelsea, Michigan; 1999.
28. Mouchet MA, Villéger S, Mason NW, et al. Functional diversity measures: an overview of their redundancy and their ability to discriminate community assembly rules. *Functional Ecology* 2010;24:867–876.
29. Almada C de, Nuñez de Almada C, Martinez RC, et al.Characterization of the intestinal microbiota and its interaction with probiotics and health impacts. *Appl Microbiol Biotechnol*. 2015;99:4175–4199.
30. Bezner R. Can agroecology improve food security and nutrition? A review. *Glob Food Sec*. 2021;29:100540.

31. Bellon MR, Ntandou–Bouzitou GD, Caracciolo F. On–farm diversity and market participation are positively associated with dietary diversity of rural mothers in southern Benin, West Africa. *PLoS ONE.* 2016;11:e0162535.
32. Bezner R. In sustainable diets: linking nutrition and food systems. In: Burlingame B, Dernini S, editors. 2019. p. 53–63.
33. Zutphen van KG, van den Berg S, Gavin–Smith B, et al. Nutrition as a driver and outcome of agroecology. *Nature Food*. 2022.

Citation: Vázquez LL. Functional biodiversity and agroecological self-regulation for sustainable food. *J Appl Biotechnol Bioeng.* 2024;11(2):24–28. DOI: 10.15406/jabb.2024.11.00355