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Family farming systems as a co-innovation laboratory for restoring the nutritional and immunological role of food

Abstract

Family farming is a traditional way of life and food production, whose values have been documented in research and social communications; however, its potential contribution to restoring the nutritional and immunological role of food is suggested in this short article. This paper offers a reasoned summary of personal experiences, supported by bibliographic references, on the values of family farming and its potential for shaping the food of the future. Two main aspects are addressed: family farming systems as reservoirs of functional biodiversity and family farming as laboratories for co-innovation. The cultural and technological characteristics of family farming systems, which integrate a diversity of agricultural, livestock, and tree species, facilitate functional interactions between soil-dwelling biota and the root system and aerial parts of plants, as well as biodiversity flows with nearby natural ecosystems and semi-natural agroecosystems, becoming reservoirs of genes, nutrients, and the microbiome that contribute to sustainable food production.

Keywords: functional biodiversity, sustainable food, immunological role, biological characteristics

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Introduction

Human populations need to transform the conventional dietary model, developed after World War II, into a food system that facilitates the recovery of natural resources exploited in primary food production, traditional diets, and the microbiological interactions necessary to restore the nutritional and immunological role of food.

The modernization of agriculture worldwide and the implementation of the techniques of the "green revolution" were carried out with great institutional support, through agricultural research and extension (transfer) services well-endowed with human and economic resources.[1]

This model, known as the vertical and unidirectional model, was heavily criticized starting in the 1970s[2,3] for its inability to provide solutions to the majority of small family farmers in the world (those with low resources and those who managed ecologically sensitive areas) and for the intrinsic deficiencies of a model that incorporated numerous prejudices (overexploitation of natural resources, reduction of biodiversity functions, low economic and energy efficiency) and did not recognize knowledge (peasant knowledge) as a source of innovation.[4,5]

Conventional food is normally valued by its ability to satisfy the quantity of fresh food needed by human populations, through the establishment of long supply chains to transport these products to large markets located in human settlements, which has predominated for many years and considers these foods as products, under the same scheme as industrially processed foods. It is a system that leaves aside the biological characteristics and interactions of the foods offered through these technographic chains, which is why the feeding of human populations has been simplified into: (a) a few basic products, (b) obtained through intensive production technologies, (b) that are transported long distances, (c) with risks due to rehandling and contamination, (d) whose access by the population is relative.[6]

In fact, this 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, irrigation water, and a long list goes on), has not managed to solve the problem of hunger in the world population, because there are currently 800 million hungry people.[7]

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, there is a general shortsightedness in this regard, because humans do indeed require fresh foods to be free of toxic residues; however, it is also necessary for them to carry their natural microbiota, so that it interacts with the microbiota of the abdominal ecosystem of people when ingested, mainly due to its importance in food digestion, nutrition, and immunity to certain diseases.[6]

The modern diet is very different from that of our Paleolithic ancestors, who ate an annual diet of about 500 different plants, while 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 why we are now seeing an increase in various atopic diseases, infections, and so-called Western diseases.[8]

Indeed, healthy and sustainable eating is a dietary pattern that promotes all dimensions of human health and well-being, with low environmental pressure and impact, is accessible, affordable, safe, equitable, and culturally accepted. It enables optimal growth and development of people at all stages of their lives, both for present and future generations, contributing to the prevention of malnutrition in all its forms and the reduction of the risk of non-communicable diseases.[7] As an extension of ecosystem functioning, given the primary objective of agroecosystems to produce food for human nutrition and health, the nutritional functions of agroecosystems should be measured alongside their ecological counterparts.[9]

Most debates on agriculture and rurality have long concluded that global agriculture is in crisis;[10,11] however, it is encouraging to note that millions of peasant and small-scale farmers, both family and indigenous, continue to practice traditional agriculture, covering no less than 10 million hectares worldwide[12] and that they have demonstrated remarkable resilience to continuous environmental and economic changes, while contributing substantially to the conservation of agrobiodiversity and food security at the local, regional and national levels.[13]

Based on the above summary, complemented by a reasoned synthesis of our own experiences from more than 20 years of innovation in different territories and family farming systems, we have identified the need to consider these systems for their potential as laboratories of transdisciplinary innovations to design the food of the future, which is the objective of this short article.

Family farming systems as reservoirs of functional biodiversity: It is recognized that the greatest biodiversity richness and conservation status are found in natural ecosystems; while the lowest richness and deterioration are evident in anthropized ecosystems, whether those exploited for agricultural production or those affected by various types of facilities, including urbanization. However, family farming agroecosystems (indigenous, peasant, peri-urban, and urban) constitute potential reservoirs from a genetic perspective and in terms of their functional interactions, because they are managed by families based on traditional agriculture, in some cases influenced by organic agriculture (without agrochemicals) and agroecology (complex designs), functioning as semi-natural environments.

The cultural and technological characteristics of family farming systems, which integrate a diversity of agricultural, livestock and tree species, whose design and management obey traditions, skills to observe and understand nature, personal perceptions and peasant experimentation, facilitate functional interactions of the biota that inhabits the soil-root system and the aerial part of the plants, as well as the flows of biodiversity with natural ecosystems and nearby semi-natural agroecosystems, becoming reservoirs of what is known as agrobiodiversity (genes, nutrients and microbiome).

In agroecosystems, agrodiversity refers to the different ways in which farmers utilize natural diversity within the production system. This includes not only semi-domesticated crops, but also water, biota, and soil;[14] it is also the result of interactions with biotic and abiotic environmental factors and management practices in agricultural systems.[15]

It is very common to observe semi-natural environments around crop fields and other uncultivated sites in agricultural production systems, whose connectivity and associated biodiversity reservoir functions are documented.[16,17] These develop ecological self-regulation capacity, due to the cumulative multi-effects that contribute to the regeneration and conservation of soil biota, the recovery and conservation of associated biota (rhizospheric, epiphytic, natural enemies, pollinators), and higher food quality with a lower environmental impact, among others.[18]

Agricultural practices in different countries have given rise to a wide variety of semi-natural habitats that harbor specific biodiversity and are linked to the culture and history of the local population.[19] 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, crop nutrition without chemical fertilizers, and balanced plant development are facilitated, mainly in the chemical composition of its organs and the interactions with its microbiota, contributing to fresh agricultural fruits being considered semi-natural.[6]

In fact, health is a continuum from the earth 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.[20] In the search for healthy eating, 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 people who consume such foods.[21]

The intestinal ecosystem is a complex environment in which dynamic and reciprocal interactions occur between the epithelium, the immune system, and the local microbiota.[22] Furthermore, the concept of a nutrient, as any assimilable substance contained in food that allows the body to obtain energy, build and repair tissues, and regulate metabolic processes, has evolved into that of an immunonutrient, which is a substance that, unlike a conventional nutrient, is capable of boosting the immune system.[23]

It is very important to understand that, on their route from the agroecosystem to the abdominal ecosystem of people, food can be considered as hybrid vectors: positive, due to their nutritional and caloric content, in addition to an associated biota composed of microorganisms with functions in nutrient assimilation, immunity and brain function, among others; negative, because they are sensitive to carrying contaminants (chemical residues, particles, toxins, parasites and pathogens that cause disease).[24]

In fact, human health is closely related to environmental factors.[25] The various existing models on the determinants of health consider the environment as an important factor to consider.[26] Considering that the city is the primary setting for a large part of the population's life and, as already seen, is likely to increasingly accommodate a greater number of people, it seems appropriate to study how to make these ecosystems healthy spaces.[25]

Sustainable quality of life, although a highly complex socioeconomic challenge for health systems, can be considered one of the priorities for the survival of human populations. It is a holistic approach to health preservation, which is particularly diverse in urban, peri-urban, and rural systems, where factors determining habitat quality, healthy nutrition, and natural medicine converge.[27]

Family farming as laboratories for food co-innovation: Family farming systems, which are generally scattered across rural, peri-urban, and urban communities, constitute small- and medium-scale agroecosystems where families live and work. Their agricultural practices (species, designs, and management) and food culture (traditional diets) have adapted to the characteristics of the landscape, the socioeconomic conditions of the context, climate changes, and the effects of extreme socioeconomic events. They constitute innovation niches for redesigning the future of food.

Traditional agricultural systems have been developing over centuries, based on a cultural and biological co-evolution, and represent the accumulated experience of farmers in their interaction with the environment, without external inputs, capital, or so-called scientific knowledge. Using ingenious autonomy, experiential knowledge, and local resources, farmers have created agricultural systems based on a diversity of crops, trees, and animals across space and time, enabling them to maximize crop security in marginal and variable environments and with limited space and resources.[28]

Traditional farming communities have developed complex, diverse and locally adapted agricultural systems, managed with ingenious combinations of proven techniques and practices, which have usually led to food security for rural communities and the conservation of natural resources and biodiversity.[29]

Traditional agriculture, where families make a living from the farm, demonstrates several attributes of peasant rationality: (a) practices adapted to the characteristics of the landscape; (b) proactivity in recycling nutrients and utilizing waste; (c) capacity for self-management of inputs for the health and nutrition of crops and animals; (d) resilience to extreme events (climatic and others); (e) comprehensive efficiency (productive, energetic, economic, ecological, social); (f) conservation of traditional food culture; (g) greater safety, nutritional quality, and contribution to the immunity of agricultural and livestock products; (h) cultural self-management of natural medicine.[30]

Family farming systems have directly contributed to the rescue of traditional practices and have led to the participation of farmers in technological co-innovation processes facilitated by scientific centers and development programs, which can be considered as multi-level open socio-technical configurations.[31]

These systems, which have been built through different generations of peasant experimentation and local circulation of practices, demonstrate several ecological principles: (a) integration of agriculture, livestock and forestry; (b) diversity of productive species; (c) annual dynamics of seasonal sowing; (d) multifunctional soil rotation; (e) complex designs of crop and livestock systems; (f) agroforestry matrix of the system; (g) functional integration of auxiliary vegetation structures; (h) use of natural energy sources; (i) facilitation of biodiversity interactions.[31]

Farmers have organized and given rise to the movement of "experimental farmers", who are holders of knowledge and skills that are derived from years of experience and are frequently transmitted from generation to generation, integrated into sociocultural norms and often related to physical phenomena such as climate, among others, which constitute important sources of useful innovations in the development and increase of sustainable agricultural production and should be used as a valuable substitute and complement to scientific knowledge and formal technologies.[32]

These experimental/diffusion systems have developed from a foundation of knowledge based not only on observation but also on experiential learning. They have worked on the selection and breeding of local seed varieties and the testing of new cultivation methods to overcome certain biotic and abiotic obstacles. Most traditional farmers possess precise knowledge of their surroundings, especially within a close geographic and cultural radius.[33]

Regardless of the recognition by the scientific community, the ancestral knowledge that has guided the creation of these sustainable and resilient agricultural landscapes today constitutes a solid foundation of knowledge and strategic practices for the development of agricultural innovations and technologies capable of addressing the challenges that agriculture will face in the near future.[13]

A distinctive feature of family farming is the conservation of agrobiodiversity and seed self-management, which is the basis for food security and sovereignty. In most agricultural regions of the world, agroecosystems persist in which farmers plant multiple varieties of each crop, providing both intraspecific and interspecific diversity, which improves crop security.[34]

Although access to seeds has shifted toward specialized production, storage, and supply systems, where seeds constitute a commercial product, in the face of various contemporary crises that depress conventional food production, farmers are turning to traditional methods of seed collection, enriched by the experiences of organic agriculture and the contributions of participatory research, configuring local agroecological systems for seed self-management. This genetic, cultural, and contextual system is the one that most closely mimics what occurs in nature, making it appropriate for moving toward sustainable food, as the varieties will be better adapted to the contexts.[35]

It is recognized that there are many ways to access knowledge to achieve the sustainable transformation of food systems, all of them equally valuable and necessary. These forms of knowledge are inherently intercultural, interchangeable, dynamic, and fluid. These include scientific knowledge, Indigenous knowledge, peasant and traditional knowledge, civil society and community-based knowledge, lived experiences, and other forms of knowledge that form the foundational knowledge of agroecology, regenerative agricultural practices, and Indigenous foodways.[36]

We must not forget that the compartmentalization of human knowledge and hyperspecialization are nothing more than a product of industrial society; however, since the second half of the 20th century, we have witnessed the emergence of a multitude of multidisciplinary and transversal theoretical approaches and methods, based on the universal assumption that solving the challenges requires a holistic and systemic vision that allows us to understand these phenomena in all their complexity.[37]

Families in peri-urban communities, sometimes socially marginalized, are more likely to obtain food in small spaces, which provide them with a diversity of fresh, semi-natural products. Produce is obtained with minimal physical interventions, without agrochemicals, and very little manipulation. Direct biotic interactions with family members influence nutrition and health, facilitating a sustainable quality of life despite living on low incomes. Indeed, these peri-urban communities constitute niches of co-innovation that can serve as a reference for designing the food systems of the future.[27]

Particularly in territories that are moving towards building sustainable food systems, in the narratives of key actors and some actions, there is a tendency to reconfigure primary food production systems, types of food and the location of markets in three directions (Figure 1): (I) from the predominance and smaller number of extensive primary food production systems concentrated in certain areas, to a greater number of medium-small primary food production systems dispersed throughout the territory; (II) from obtaining some basic foods and priority for the supply of processed products, to a greater diversity of nutritious foods and priority for the supply of locally processed products; and (III) from large concentrated markets based on population density to medium-small decentralized markets based on the diversity of population settlements.

These co-innovation processes, facilitated in the territories to build sustainable food systems, constitute a hopeful path toward reconfiguring the food systems of the future. They facilitate the recovery of biodiversity's functions for human health, reduce the distance between primary food production and the places where food is supplied and where people live, and improve the sustainability of diets in urbanized areas, among other benefits that contribute to restoring health.

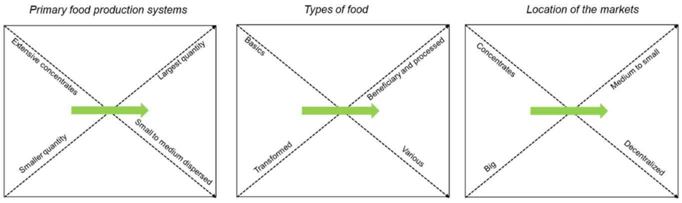

Figure 1 Observed trend in the reconfiguration of food systems.

Source: Personal perception based on observations in Cuban territories where local food systems are being built for food and nutritional security and sovereignty.

The benefits of agroecological approaches on food security and nutrition have been reported in a variety of studies.[38,39] However, the true impact of agroecology on nutrition and food outcomes remains to be fully understood.[38,40] In particular, the multiple pathways through which agroecological methods can impact nutrition and the food system, both through consumer demand and food supply, warrant further investigation.[41]

Sustainable diets have a low environmental impact and contribute to food and nutritional security and the healthy lives of present and future generations. They protect and respect biodiversity and ecosystems, are culturally acceptable, economically fair, accessible, affordable, nutritionally adequate, safe, and healthy, and optimize natural and human resources.[42,43]

In fact, the process of converting conventional primary food production takes time, as it requires a social unlearning of this approach and the development of public policies that foster sustainability. However, the convergence of socioeconomic and climate-environmental factors that demonstrate the unsustainability of these systems, combined with evidence of the sustainability of family farming systems undergoing agroecological transition, is crucial for progress.

Conclusions

Although extensive disciplinary research documents biodiversity in agroecosystems, the nutritional diversity of their agricultural and livestock production, and the relationship between the microbiome of fresh foods and the functioning of the human abdominal ecosystem, in recent years there has been an increasing demand to study the agroecosystem-food-nutrition-immunity complex as a determinant of sustainable nutrition and to justify the contribution of family farming systems to this goal.

The trend toward reconfiguring the food system, starting with primary food production systems, food types, and market locations, with a greater focus on family farming systems, represents a hopeful starting point for restoring the nutritional and immunological role of food.

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Conflict of interest

Authors declare that there are no conflicts of interest.

References

1. Guzmán GI, Alonso AM. Participatory research in agroecology: a tool for sustainable development. *Ecosistemas*. 2007;16(1):24–36.
2. Tripp R. The farming systems research movement and on–farm research. In planned change in farming systems. Progress in on–Farm Research. In: R Tripp, editor. John Wiley & Sons Ltd; Chichester. 1991. p. 3–16.
3. Chambers R, Ghildyal BP. Agricultural research for resource–poor farmers: the farmer first and last. *Agricultural Administration*. 1985;20:1–30.
4. Cernea MM, Coulter JK, Russell JFA. Building the research–extension–farmer continuum: Some current issues. En research–extension–farmer. a two–way continuum for agricultural development, In: MM Cernea, JK Coulter, JFA Russell, editors. The World Bank; Washington; 1985. p. 3–10.
5. Chambers R. Rural development. Putting the last first. Longman scientific and technical; Harlow, Gran Bretaña. 1983. 235 p.
6. 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.
7. FAO. The state of food security and nutrition in the world. Roma, Italia; 2020. 348 p.
8. Bengmark S. Nutritional modulation of acute and "chronic" phase response. *Nutrition*. 2001;17:489–495.
9. DeClerck FAJ, Fanzo J, Palm C, et al. Ecological approaches to human nutrition. *Food Nutr Bull*. 2011;32:S41–S50.
10. Altieri MA. Agroecology: the science of sustainable agriculture, Westview Press, Boulder; 1995.
11. Pimentel D, Houser J, Preiss E, et al. Water resources: agriculture, the environment, and society. *BioScience*. 1997;7(2):97–106.
12. ETC. Who will feed us? Questions for the food and the climate crises negotiators in Rome and Copenhagen. Communiqué. 2009;102:1–34.
13. Altieri MA. Linking ecologists and traditional farmers in the search for sustainable agriculture. *Frontiers in Ecology and the Environment*. 2004;2(1):35–42.
14. Brookfeld H, Padoch C. Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices. *Environment*. 2010;36(5):8–11.
15. Almekinders C, Fresco L, Struik P. The need to study and manage variation in agroecosystems, Netherlands. *Journal of Agricultural Science*. 1995;43:127–142.
16. Altieri MA. The ecological role of Biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment*. 1999;74:19–31.
17. Bennett AF. Linking Landscape: The role of corridors and connectivity in wildlife conservation. UICN–Mesoamerica. San José CR. 2004. 276 p.
18. Matienzo Y, Vázquez LL, Alfonso–Simonetti J. Quality of agroecosystems as habitats to natural enemies and biological control agents; chapter 3: In: Souza B, Vázquez LL, Marucci RC, Editors. Natural enemies of insect pests in neotropical agroecosystems biological control and functional biodiversity. Springer Nature Switzerland AG. 2019. p. 27–24.
19. Pita R, Mira A, Moreira F, e al. Influence of landscape characteristics on carnivore diversity and abundance in Mediterranean farmland. *Agricultu-re, Ecosystems & Environment*. 2009;132(1–2):57–65.
20. Shroff R, Cortés CR. The biodiversity paradigm: building resilience for human and environmental health. *Development*. 2020;63:172–180.
21. Vázquez LL. Human microbiota, functional biodiversity and agroecological designs: In Search of a Healthy Diet. *J Biotech Biores*. 2022a;4(1):000578.
22. 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.
23. Chandra RK. Nutrition and immunity: lessons from the past and new insights into the future. *Am J Clin Nutr.* 1991;53:1.087–101.

24. Vázquez LL. Redesigning sustainable management of the food chain: from the agroecosystem to the human abdominal ecosystem. *J Appl Biotechnol Bioeng.* 2025;12(4):184–186.
25. Mejías AI. Contribution of urban gardens to health. Hábitat y Sociedad No. 6: 2013. p. 85–103.
26. Evans RG, Barer ML, Marmor TR. Why are some people healthy and others not? The determinants of population health.. Madrid: Díaz de Santos. 1996.
27. Vázquez LL. Habitat, food and health. Three components that need to meet again to contribute to a sustainable quality of life. *PriMera Scientific Medicine and Public Health*. 2022b;1.4:12–15.
28. Wilken GC. Good Farmers: traditional agricultural resource management in Mexico and Guatemala. Berkeley: University of California Press; 1987.
29. Koohafkan P, Altieri MA. Forgotten agricultural heritage: reconnecting food systems and sustainable development. London, Routledge; 2017.
30. Vázquez LL, Chia E. Contribution of traditional peasant agriculture to the agroecological transition in Cuba. *Revista Latinoamericana de Políticas y Acción Pública*. 2025;12(1):95–121.
31. Geels FW. Technological transitions as evolutionary reconfiguration processes: a multilevel perspective and a case study. *Política de investigación*. 2002;31:1257–1274.
32. Monge JE, García JE. Traditional knowledge and pest control in Central America: a review of the archives of the ICEDU. *Manejo Integrado de Plagas (Costa Rica) No*. 1993;28:57–63.
33. Dewalt BR. Using indigenous knowledge to improve agriculture and natural resource management. *Human Organization.* 1994;5:23–131.
34. Altieri MA, Nicholls CI. Agroecology and genetic diversity in peasant agriculture. *LEISA Revista de Agroecología.* 2019;35(2) 22–25.
35. Vázquez LL. Agroecological seeds: Recovery of the bioecological and sociocultural functions of seeds. *J Appl Biotechnol Bioeng.* 2025a;12(3):108–112.
36. Global alliance for the future of food. The politics of knowledge: understanding the evidence for agroecology, regenerative agricultural practices, and Indigenous foodways. 2021. p: 1–114.
37. Bas E, Guilló M. Foresight and culture of innovation. *Ekonomiaz*. 2011; Nº 76:18–37.
38. Bezner R, Sidney Madsen, Moritz Stüber, et al. Can agroecology improve food security and nutrition? A review. *Glob Food Sec*. 2021;29:100540.
39. 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.
40. Bezner R. In Sustainable diets: linking nutrition and food systems, In: Burlingame B & Dernini S, editors. 2019. 53–63.
41. Zutphen van KG, van den Berg S, Gavin–Smith B, et al. Nutrition as a driver and outcome of agroecology. Nature Food. 2022.
42. FAO. Biodiversity and sustainable diets. United against hunger. 2010.
43. Chambers R. Shortcut and participatory methods for gaining social information for projects. En putting people first sociological variables in rural development, In: MM Cernea, editor. Oxford University Press; Washington, D.C ; 1991. p. 515–537.

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