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Agroecological transition: connecting theory to practice

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Abstract

Objective: Organize and systematize the basic principles for the agroecological transformation of agroecosystems and their interactions.

Methodology: The methodological support was an integrative literature review, compiling a primary bibliography with the latest developments in the area, encouraging the integration of the research field's path.

Originality/relevance: Its importance is given by being a support material for the academic area, finding gaps in further research, and supporting interested people in initiating transition processes. Furthermore, the study provides a multidimensional and systemic look at ecosystem processes and the practices that guide them in a simplified way.

Results: It was possible to observe the complexity of the various aspects that act synergistically in the agroecosystem. The main components of this relationship include planning, legislative justice for the protection and conservation of the environment, maintenance of soil health, agrobiodiversity, water management, waste management, animal integration, independence from external inputs, integrated policy management, diseases, and spontaneous plants.

Theoretical contributions: The theoretical foundations and practical principles that govern agroecology are inherent to the efficiency of transitions and consolidations of sustainable agroecosystems.

Social contributions / for management: The approach of this article is based on substantiating the agroecological transition process from a theoretical-practical aspect, seeking extension assistants, farmers, and farmers looking for steps to start the transformation procedure in their agroecosystems.

Keywords: sustainability, environment, ecosystem services and agroecology

Transição agroecológica: conectando teoria à prática

Resumo

Objetivo: Estruturar e sistematizar, com clareza, os princípios básicos para transformação agroecológica de agroecossistemas e suas relações.

Metodologia: O apoio metodológico foi de uma revisão de literatura integrativa, ou seja, compilando a bibliografia base com as novidades da área, fomentando a integração do percurso do campo de pesquisa.

Originalidade/relevância: A sua importância é dada por ser um material de suporte para o meio acadêmico encontrar lacunas em mais pesquisas, bem como um apoio os interessados em iniciar processos de transição. Além disso, o estudo fornece um olhar multidimensional e sistêmicos sobre os processos ecossistêmicos e das práticas que os norteiam, de forma simplificada.

Resultados: Foi possível observar a complexidade dos vários aspectos que atuam de forma sinérgica no agroecossistema. Cita-se como principais componentes dessa relação o planejamento, adequação legislativa de proteção e conservação do meio ambiente, manutenção da saúde do solo, agrobiodiversidade, manejo da água, gestão de resíduos, integração animal, independência de insumos externos, manejo integrado de pragas, doenças e plantas espontâneas.

Contribuições teóricas: A fundamentação teórica e os princípios práticos que regem a agroecologia são inerentes para eficiência de transições e consolidações de agroecossistemas sustentáveis.

Contribuições sociais / para a gestão: A abordagem desse artigo é pautada em fundamentar o processo de transição agroecológica sob o aspecto teórico-prático, buscando auxiliar extensionistas, agricultores e a agricultoras que buscam os passos de como iniciar o procedimento de transformação em seus agroecossistemas.

Palavras-Chave: sustentabilidade, meio ambiente; serviços ecossistêmicos e agroecologia

Transición agroecológica: conectar la teoría con la práctica

Resumen

Objetivo: Estructurar y sistematizar claramente los principios básicos para la transformación agroecológica de los agroecosistemas y sus relaciones.

Metodología: El soporte metodológico fue a partir de una revisión bibliográfica integradora, es decir, recopilando la bibliografía base con las novedades en el área, propiciando la integración del recorrido del campo de investigación.

Originalidad/relevancia: Su importancia está dada por ser un material de apoyo para el medio académico para encontrar vacíos en futuras investigaciones, así como un apoyo para los interesados en iniciar procesos de transición. Además, el estudio ofrece una visión multidimensional y sistémica de los procesos ecosistémicos y las prácticas que los guían, de forma simplificada.

Resultados: Se pudo observar la complejidad de los diversos aspectos que actúan sinérgicamente en el agroecosistema. La planificación, la adecuación legislativa de la protección y conservación del medio ambiente, el mantenimiento de la salud del suelo, la agrobiodiversidad, la gestión del agua, la gestión de residuos, la integración de los animales, la independencia de los insumos externos, la gestión integrada de plagas, enfermedades y plantas espontáneas se citan como los principales componentes de esta relación.

Aportaciones teóricas: Los fundamentos teóricos y los principios prácticos que rigen la agroecología son inherentes a la eficacia de las transiciones y las consolidaciones de los agroecosistemas sostenibles.

Contribuciones sociales: El enfoque de este artículo se basa en fundamentar el proceso de transición agroecológica bajo el aspecto teórico-práctico, buscando ayudar a extensionistas,

agricultores y agricultoras que buscan los pasos de cómo iniciar el procedimiento de transformación en sus agroecosistemas.

Palabras clave: sostenibilidad, medio ambiente, servicios ecosistémicos y agroecología

Introduction

The world population growth is projected to reach 9.7 billion people by 2050 (*United Nations Organization*, 2019). This population increase generates concerns and reflections in different spheres, directly or indirectly influencing people's quality of life. One of them of extreme relevance is food production, as there are doubts about whether current systems can meet this demand with quality and nutritional diversity and respect for environmental resilience.

Agroecological Systems, for example, in addition to giving an ecological character to agriculture through a systemic transformation, also provide greater nutritional diversity for those who consume, which is a demand from multiple interested parties (farmers, supply chains, or natural resource managers) (Magrini et al., 2019; Gonçalves et al., 2021). These systems are based on the search for sustainability and are supported by the social, environmental, and economic triads.

The *Food And Agriculture Organization Of The United Nations* (2019) defines the sustainability of agri-food systems with the following criteria: (1) the biodiversity of the ecosystem must be protected; (2) to respect cultures; (3) be economically fair and accessible; (4) nutritionally adequate and healthy; and (5) to optimize the use of natural and human resources, respecting their resilience. The principles of Agroecology compile concepts of ecosystems, energy flow, nutrient cycling, population regulation mechanisms, structural properties of communities, social awareness, cultural diversity, and others (Wesel et al., 2020; Sokol et al., 2022).

Even though the theme of agroecological systems is very relevant, despite the vast number of existing articles, there is a lack of systematic materials that help in the operational use of agroecological characteristics in production and ways of making a transition. In this sense, explaining the multidimensional nature of the agroecological transition at a biophysical level becomes essential for debates to become practical, as its implementation requires the coherence of changes, and this factor demands expressive action from science (Magrini et al., 2019).

Therefore, this study seeks to answer the following question: What are the main stages of an agroecological transition? The main objective is to structure the basic principles for transforming agroecosystems and their relationships. This is an integrative review of the state of the art, in which it addresses the theoretical literature compared to what is updated on a subject in practical terms (Botelho et al., 2011).

Thus, a conceptual and methodological structure is proposed to provide support that links theory to practice. The second session brings the theoretical focus on Agroecology, adding points about its emergence and conceptual bases. Next, the possibilities of how to plan and the practical process are outlined. In the fourth session, considerations are made based on the analysis of critical issues on the topic to provide researchers and interested parties, such as extensionists and farming families, with complete material to serve as a contribution to transition their systems towards balanced environmental, social equity, and economic improvements.

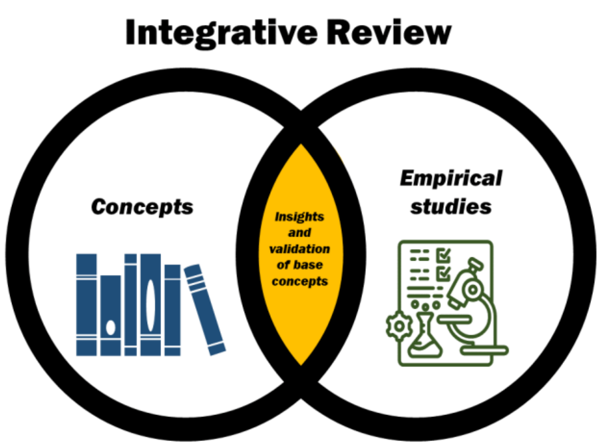
Methodological Procedures

This work is essential, in which, although there is no physical application of the research, a compilation of knowledge and information plays a crucial role in obtaining academic or applied results of great relevance. This type of research has a broad vision. Generally, it provides valuable insights into the field of focus, thus enriching the research environment, influencing the quest to identify gaps in current knowledge, and pointing to areas needing additional research and future developments. This research adopts a qualitative approach, moving away from the search for numerical support for variables that require statistical analysis. This methodological option is justified by the study's primary purpose, which aims for deep contextualization and a comprehensive understanding of the nuances inherent to the focused topic (Schwartzman, 1979; Flick, 2009).

The integrative review (Figure 1) plays a crucial role in defining the current state of knowledge on a specific topic. This happens because it is conducted in a way that identifies, analyzes, and synthesizes the results of independent studies on the same subject, intertwining them with a primary conceptual contribution. In this way, it contributes to a potential improvement in the quality of new research, identifying knowledge gaps, or strengthening existing theories. This review methodology stands out as a comprehensive tool in the context of reviews, as it allows the inclusion of experimental and non-experimental studies, aiming to provide an in-depth understanding of the phenomenon under examination. (Souza, Silva and Carvalho, 2010).

Figure 1

Illustration of the integrative review



Source: Authors (2024).

The foundational literature was based on a connection with renowned authors who specialized in the topic at hand, as referenced in articles that address agroecology and systems in agroecological transition. The survey of recent empirical studies was conducted on the *Science Direct*, *Scopus,* and *Google Scholar* platforms, covering the period from March 2018 to March 2023. These were read and interpreted to understand whether they would support the transition phases found in the theoretical base. This analysis involved interpreting the results of these studies and establishing connections with the underlying theoretical principles. In this way, the presentation of data in the structure of the integrative review was carefully constructed, joining the empirical evidence to the underlying theory. This approach allowed for a cohesive and informed synthesis, providing a comprehensive and contextualized understanding of the transition stages in the context of the literature reviewed. Furthermore, from the primary sources, priority was given to analyzing articles in periodicals, aiming to obtain updated studies linked to the basic concepts. At the same time, book consultation was conducted to establish a solid conceptual basis. As for secondary sources, the reference to FAO stands out.

Development

Agroecology: substantiating its conceptual roots

Agroecology is a dynamic concept that has recently gained prominence in scientific, agricultural, and political circles. It was developed from the 1970s onwards due to the search for theoretical support for the different currents of unconventional agriculture, called Alternative Agriculture (AA) (Costa et al., 2015). In broad terms, the interpretations and understandings currently existing around the concepts and principles of this constantly improving science are, in fact, the result of the evolution of conceptions linked to AA, especially with the development of studies that allowed the advancement of science in approaches with a more global understanding of the phenomena, that is, beyond the reductionist/Cartesian view, predominant in agricultural sciences (Aquino and Assis, 2012).

Alternative agriculture movements emerged at the beginning of the 20th century in reaction to the conventional (or industrial) agriculture model that was spreading intensely in developed countries. In short, the traditional agricultural system is based on the "artificialization"[1] of production systems and dependence on external inputs. It is essential to clarify that in Brazil, a large part of the consumers/population interprets and characterizes sustainable-based productions as organic; however, there are differences (Lima et al., 2020).

In this context, movements opposing this agricultural paradigm were generically called alternative agriculture. The most important are organic agriculture, biodynamic agriculture, organic agriculture, natural agriculture, and permaculture. Despite their limitations in theoretical terms, these schools were fundamental to the development of agroecology, as they expanded debates about the need for a new paradigm in agriculture that incorporates the ecological dimension into agricultural production (Oliveira et al., 2010; Santos et al., 2013).

Throughout the history of Science, a series of theoretical contributions departed from and challenged the dominant scientific approach. These studies opened new perspectives; above all, they pointed to the need for a new scientific stance, which gives technological science a more humanistic, integrative, and pluralistic character, recognizing popular and traditional knowledge (Caporal et al., 2009). Epistemological advancement was fundamental to developing agroecology as a science (Gonçalves et al., 2020).

Thus, agroecology is a field of transdisciplinary knowledge that receives influences from social, agricultural, and natural sciences, mainly applied ecology (Barros and Araújo, 2016). Ecology provides the methodological basis for integrating this knowledge, allowing a global understanding of phenomena (Feiden, 2005). Therefore, to understand the principles of agroecology, it is essential first to know the concepts of ecosystems, mainly agroecosystems, energy flow, nutrient cycling, population regulation mechanisms, and structural properties of communities (Wesel et al., 2020; Gonçalves et al., 2021).

In this context, agroecology is a science of integration, emerging as a new approach that integrates agronomic, ecological, and socioeconomic principles to understand and evaluate the

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[1] Act or effect of artificializing or becoming artificial.

effect of technologies on agricultural systems and society as a whole (Abreu et al., 2012). Thus, it is a science and a set of practices. It provides methodological working structures for a deeper understanding of the nature of agroecosystems and the principles according to which they function (Altieri, 2012; Gliessman, 2014).

The definition of agroecology can be summarized as a) the ecological integrative study of the food system, b) the application of ecological concepts and principles to the design and management of sustainable food systems, and c) the integration of research, education, action and change that brings sustainability to all parts of the food system: ecological, economic and social (Gliessman, 2018; Gliessman et al., 2019; Wesel et al., 2020).

In this way, it shows alternative paths to conventional and aggressive agriculture, as it provides principles on how to design and manage agricultural systems that are better able to withstand future crises - whether pest outbreaks, pandemics, climate disruptions, or financial collapses (Altieri and Nichols, 2020).

In general terms, agroecology has the potential to form the basis of a new paradigm of sustainable rural development. Due to a social process in rural Brazil, the adopted industrialization model has been gradually deconstructed, aimed at creating alternatives to predatory environmental standards. During this change, new possibilities have emerged in constructing a new paradigm for the sustainable use of rural space, providing better life prospects.

Agroecology does not propose to solve or be the solution to the problems generated by human actions arising from the current production model. Instead, it aims to guide a more sustainable rural development strategy and transition to agricultural styles. These guidelines allow for driving substantial changes in rural areas, with perspectives that ensure greater socio-environmental and economic sustainability for different agroecosystems (Aquino and Assis, 2012).

Furthermore, this Science is in constant construction, given its complexity, as it presents a transdisciplinary characteristic, requiring the effective participation of several Sciences and disciplines, such as Agronomy, Biology, Economics, Sociology, and Anthropology. Also, it incorporates and re-elaborates the traditional knowledge of the populations. As an integrative science, Agroecology provides the basis for integrating this knowledge (Tosetto et al., 2013).

It should be noted that Agroecology and its various technological propositions should not be understood as a set of recipes to be applied at any time and in any place; this implication is on purpose since, from an agroecological perspective, no agroecosystem is the same as another, each one has peculiar dynamics among its components. “Agroecology promotes principles and not rules or recipes to develop an agroecological production system” (Nicholls et al., 2016, p. 3).

Agroecology works on the interrelationships of all components of the agroecosystem and the dynamics of ecological processes, given the complexity of the entire process. Thus, it can be said that it focuses on principles that go beyond using alternative inputs to develop integrated agroecosystems with minimal dependence on inputs external to the property (Altieri et al., 2017). The transition and redesign of a given system must be based on the establishment of an ecological infrastructure, based on the diversification of landscape scale and the encouragement of environmental interactions that generate benefits (soil fertility, nutrient cycling, water retention, and storage, the regulation of pests/diseases, pollination and other essential ecosystem services) (Nicholls et al., 2016). The design of agroecosystems in transition must follow some objectives that summarize the contextualization described above, which are explained in Tables 1 and 2.

Table 1

Agroecological Principles for designing biodiversity, efficient, resource-conserving, and resilient agricultural systems

1	Enhancement of organic matter (OM) decomposition and nutrient cycling
2	Strengthening the agroecosystem's "immune system"
3	Provision of more favorable soil conditions
4	Minimization of essential resource losses
5	Diversification of genetic resources
6	Improvement of beneficial biological interactions

Source: Adapted from Nicholls et al. (2016)

Table 2

The relative contribution of various management practices to one or more agroecological principles

Practices	Principles to which they contribute *					
	1	2	3	4	5	6
Application of organic compounds	X		X			
Cover crops and green manures	X	X	X	X	X	X
Green cover	X		X	X		
Crop rotation	X		X	X	X	
Alternative controls - Extracts/biologicals		X				
Use of insectary plants / attractive plants		X			X	X
Hedges/windbreaks		X	X		X	X
Consortium/polycultures	X	X	X	X	X	X
Agroforestry	X	X	X	X	X	X
Animal integration	X		X	X	X	X
* Each number refers to an agroecological principle listed in Table 1						

Source: Adapted from Nicholls et al. (2016).

Strengthening agroecological research is essential, especially those that aim to validate agricultural multifunctionality related to the preservation of biodiversity, helping to increase understanding of the interactions between local and landscape processes that affect biodiversity and ecosystem function and the mechanisms that interfere in these interactions. In light of this statement, in the following section, the means of guiding actions aimed at agroecological redesign and transition are contextualized, mediating from scientific practices and experiences.

Agroecological transition: what are the main stages and processes?

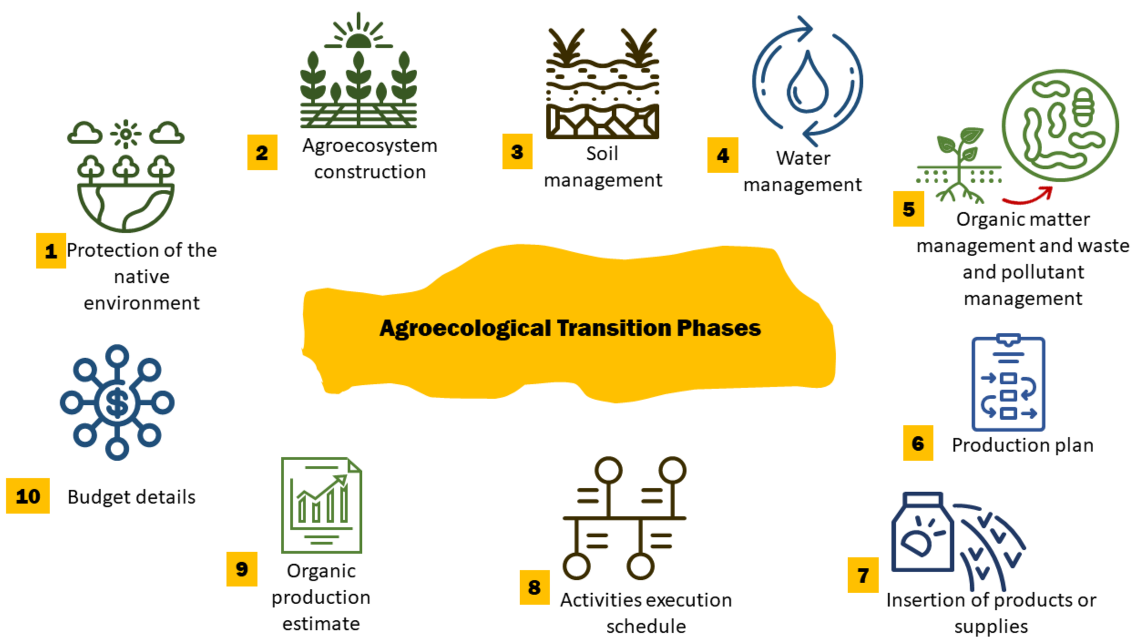
Agroecological transitions are based on modifying the agroecosystem by restoring its structures and processes to redefine the landscape and ensure Ecosystem Services (ES). Some of these services play a crucial role in the long-term performance of agriculture, as highlighted by Boeraeve et al. (2020a) and Deguine et al. (2023). Brazilian legislation also contributes to this perspective, establishing clear definitions through Federal Decree No. 7,794, dated August 20, 2012, demonstrating the National Policy for Agroecology and Organic Production. In article 2, paragraph IV, the legislation defines the agroecological transition as follows: "A gradual process of changing practices and management of traditional or conventional agroecosystems through transforming the productive and social bases of land use and natural resources leads to agricultural systems that incorporate ecologically based principles and technologies" (Brazil, 2012).

In rural establishments, products must be cultivated and seen as a complex living system where multiple plants, microorganisms, animals, and minerals cohabit and interact. The transition process requires adopting practices that value traditional genetic resources, promoting the recovery and improvement of materials that can be used in ecologically based production systems. This path involves the application of innovative methodologies and strengthens the joint participation of farmers and technicians in the assessment of systems. Subsequently, it is essential to implement actions to adequately manage soil, biodiversity, water, and all components of the agroecosystem, as Deguine et al. (2023) recommended.

The results of the integrative review linked the phases that address the agroecological transition as a gradual process of change in agroecosystems (Figure 2), as discussed by Souza and Resende (2014), relating them to research that explores their interconnections, highlighting the importance and role. It is important to note that these phases may occur simultaneously or not, depending on the internal dynamism of the agroecosystem. This material was considered a reference, as no others were found that indicate, in detail, the various processes that occur in the conversion to the agroecological system. Although Micheleff Filho et al. (2013) describe that in the transitions from conventional systems to ecologically based systems, four general and different phases are presented, namely: the progressive removal of synthetic inputs; the rationalization of the use of agrochemicals, the application of integrated pest and disease management (IMPD) and integrated nutrient management (MIN); use of alternative and low energy cost materials; remodeling of diversified production systems, seeking a balance between crops and animal husbandry, there is a generalization of the phases. Souza and Resende (2014) have an approach that is more focused on the practicality of the process, covering the four phases of Michereff Filho et al. (2013).

Figure 2

General roadmap for starting the agroecological transition process



Source: Authors, adapted from Souza and Resende (2014).

In this sense, the first stage consists of protecting the natural ecosystem and defining environmental preservation actions so that a significant part of the establishment promotes the stability of biodiversity and conservation of the environment. Another point, still emphasized in the first stage, is the exclusion of genetic engineering in the organic production and processing process (Yu et al., 2018; Solodovnik et al., 2023), which serves as a means of conserving the natural ecosystem and biodiversity (Sousa and Resende, 2014).

Since GMOs can offer resistance to pesticides and antibiotics in people and animals, the food chain is unbalanced (increasing some groups and decreasing others). For example, the development of very resistant weeds can lead to new diseases or even the suppression of populations of earthworms, bees, and other animals, as well as plant species considered beneficial to the system; in addition, they can favor the emergence of new viruses (Winckler and Munarini, 2019).

Managing biodiversity and local vegetation complexity increases the abundance and diversity of natural enemies (Trincher and Warren Raffa, 2023). Species richness is consistently and positively related to vegetation diversity in the agroecosystem. This phenomenon is exceptionally beneficial because it is called biodiversity works.

A study in the Province of Hainaut, Belgium, sought to study the ecological processes and interactions on farms that underwent agroecological and conventional transition through some indicators of ecosystem services. The results obtained demonstrated a multiple performance of agroecological agricultural systems, as the aggregate and soil respiration rates were stable, as well as a lower abundance of pests (due to the balance in the trophic chain), pointing out that conventional systems do not have autonomy and good performance compared to agroecological systems (Boeraeve et al., 2020b). Another study sought to understand the impacts of agroecological management on plant diversity and soil-based ecosystem services in pasture (agroecological and conventional) and coffee (agroecological and conventional) systems in the Brazilian Atlantic forest. In the case of pastures, where there was an increase in plant diversity due to agroecological management, it resulted in higher soil quality due to more excellent litter cover and structural heterogeneity of the plant, as well as symbiotic organisms that increased organic matter (OM) content, demonstrating superiority in functionality concerning conventional systems. In the case of traditional coffee, despite the greater intensity of weeding and greater use of external inputs, these practices do not promote improvements in soil quality or coffee productivity compared to agroecological systems. In contrast, the agroecological management of coffee was associated with increased plant diversity and was positively associated with soil microbial biomass carbon (Teixeira et al., 2020).

Ecosystem services are affected by agricultural intensification, and increasing data demonstrates the loss of biodiversity on the planet due to agriculture carried out in a simple and fragmented way, threatening approximately 62% of animal and plant species. Although halting the loss of protected and intact nature is essential to reducing species extinction, bending the biodiversity curve will require sustainable agriculture (Deguine et al., 2023).

The second stage, entitled “construction of the agroecosystem”, requires planning and designing the environment so that activities can be planned and interact. Consider the possibility of maintaining/inserting animals in the system so that they contribute to the climate economically and environmentally. Thus, it establishes diversity so that the PU is more stable, as this factor prevents the intense multiplication of pests and diseases and strengthens a more balanced food chain. Furthermore, they promote the management of spontaneous vegetation through processes that help with nutrient cycling, maintaining the physical conditions of the soil (Sousa and Resende, 2014).

A rotation or succession plan for crops and green manure using windbreaks or buffer zones is recommended. These recommendations are because these elements benefit the microclimate, increase productivity, and minimize wind erosion in the same way that they prevent contamination by drift from conventional areas and are also active in the interception of insects, fungi, and bacteria that are dispersed by the wind (Sousa and Resende, 2014; Lopes et al., 2016; Quandahor et al., 2023).

In this context, as Nikolić et al. (2019) highlighted, the application of technologies such as spatial mapping and habitat monitoring of endangered species plays a crucial role in effectively understanding the functionality to be implemented. It is imperative to identify priority areas to improve green networks, which include semi-natural and natural areas, and enhance habitat management. This involves distinguishing between different levels of fragmentation and assessing the risk of extinction.

In the context of agroecosystem redesign, it is essential to understand agrobiodiversity and potential conflicts between agriculture and nature before the transition. Climate risk assessments must support spatial planning and conservation projects (Adams et al. 2017; Nikolić et al. 2019) to ensure a comprehensive and sustainable approach.

The third stage provides indications regarding soil management. Therefore, it is necessary to determine measures to minimize the loss of the top layer of the soil, determining minimum cultivation, maintenance of coverage, and plowing, among other elements. The systems need to replace nutrients in the soil with OM and other elements disturbed by harvesting, stimulating nutrient cycling (Sousa and Resende, 2014). Brito et al. (2017) corroborate this information, describing:

> The plant remains of these crops on the soil promote a considerable increase in the supply of phytomass and the cycling of nutrients – since these plants absorb them from subsurface layers and release them on the surface after decomposition. In addition to providing the soil with direct protection against the action of erosive agents, they also improve the physical structure and optimize the diversification of the soil's biological community (Brito et al., 2017, p.35).

Likewise, regarding the soil management stage, attention must be paid to using methods that transform its structure. Given this, it is recommended to practice direct planting, equipment such as a knife-roller, disc-roller, crusher, and brush cutter, use the traditional preparation system and use a rotary hoe only in cases of extreme necessity (limited to crops that require planting). Attention should be paid to rotating crops that need different soil preparation, interspersing intensively tilled species with direct planting species, and avoiding fires (Sousa and Resende, 2014).

These managements can list a variety of advantages, with current research demonstrating that the use of OM in soils rebalanced natural enemy densities to increase uniformity, enhanced the ability to increase productivity, as well as improved the soil's aggregation structure and chemical components. (Aldebron et al., 2020; Gmach et al., 2020; Pampuro et al., 2020).

A study carried out in Malawi, in Southeast Africa, demonstrated that the diversification of crops and incorporation of OM into the soil, mainly legume residues, brought ecosystem and socioeconomic benefits. These are independence from synthetic inputs, soil health, functional biodiversity, food and nutritional security through direct consumption, agricultural income, and changes in underlying production relations (Madsen et al., 2020; De Fraga et al., 2022). Still, more experimental studies are needed to understand the complexity of OM's performance in the soil (Gmach et al., 2020), so that gaps can be filled and thus, technical and scientific subsidies can be obtained to strengthen ecologically based practices in soil management.

The fourth stage is conducted by water management, in which water conservation techniques are adopted. Notably, this stage is vital because there is a need to produce more food by improving water use efficiency and providing ecological security at the regional level (Liu and Song, 2020).

The use of inputs correctly, without the risk of contamination of sources, that is, the adoption of systems that allow the responsible use and recycling of water, the processing and handling of organic products, planning and design of systems that adapt to the use of water in a way that is compatible with the local climate and geography; whenever possible, recycle rainwater and monitor the extraction of this available on site (Sousa and Resende, 2014; Álvarez-Vázquez et al., 2020; Nogueira, 2023).

The importance of water management consists of "controlling erosion, delaying the runoff of rainwater, preventing the silting of river and lake beds, reintroducing water into the water table, and making this water available to maintain springs throughout the year, providing stability in the vessel" (Sousa and Resende, 2014, p.125).

A study on different types of soil and crops that evaluated water and soil conservation practices for systems undergoing agroecological transition in Europe resulted in positive impacts, such as increased soil OM and slow mineralization that directly improves physical properties. From soil, the advantages were seen, mainly in rainfed agricultural systems, where water availability depends exclusively on the amount of rainfall and its distribution (García-Tejero et al., 2020). In this way, it is clear that such practices must have integrated applications, as there is a direct relationship between them, thus providing a more excellent balance in the processes contained in the agroecosystem.

The fifth stage is "Organic matter cycling system and waste and pollutant management". There must be a description of where the MO is produced/acquired and how it is managed. It is necessary to characterize the fertilizers and conditions, where they will be used, and on which crops, and detail the quantities, times, and equipment. It is essential to point out how to apply excrement and organic fertilizers and how to control their waste. The material used must be of biological origin, based on the regional soil fertility program, and be careful with the risks of contamination from heavy metals and other harmful elements (Krzywoszynska, 2012; Sousa and Resende, 2014; Krebs and Bach, 2018).

To such an extent, it is necessary to describe the management of all waste resulting from the family property, such as garbage, sewage, vinasse, and cassava wastewater. Finally, synthetic roof structures, plastic soil coverings, or other possible pollutants are suggested, which need to be removed from the area, cannot be burned, and are sent to recycling units (Sousa and Resende, 2014).

Notably, research relating to the destination of waste and effluents helps improve guidance for the academic community and farming families and is extremely important. In agroecological zones in South Asia, there was an analysis of the alternative use of plant residues to increase soil organic carbon, soil moisture, soil nutrients, and soil biological activity by applying biochar and raw agricultural waste generated in the field. The results demonstrated that mulch and *biochar*[2] improved the production of agroecosystems by up to 64%, and around 1,625 farmers in the region adopted waste management practices in the field, promoting circular agriculture (Dey et al., 2020).

For Koppelmäki et al. (2019), the transition must imply and encourage independence, including from commercial organic fertilizers, as is often seen in large-scale organic agriculture. For this, without a doubt, waste management is essential. Faced with this problem, the authors researched nutrient recycling in an integrated agroecological food production and processing system based on substance flow analysis. The results were promising, indicating the potential of surpluses for recycling nutrients and increasing crop productivity in sustainable agricultural and food systems.

The sixth stage describes the entire production, from seeds acquired to sale. Souza and Resende (2014, p.126) state that a production plan must be created based on a step-by-step process, being: “seeds, seedlings, planting, control of herbs, diseases, insects, fertility management, harvesting, storage, cleaning, sorting, processing, storage, export or sales”.

Undoubtedly, this issue also requires external support, with the involvement of multiple actors considering territorial interests regarding sustainable development, the capacities of existing organizations within communities, and the role of local governments, NGOs, and the scientific academy. The integrated and multifaceted approach boosts the implementation and planning of agroecology, ensuring the acceleration of the dynamics present in the transition (Rojas et al., 2019). Encouraging methodologies that align biophysical and landscape

[2] In Brazil, the term “biocarvão” is used. There is no exact translation.

modifications with management experiences in UP can provide opportunities for creating integrated territorial planning models at local and regional levels (Kiryushin, 2020).

In the seventh stage, there is the analysis of products or inputs obtained in rural establishments, where the products to be purchased outside the units must be described, detailing their origin and ways of managing them. It is necessary to present the products' physical, chemical and biological composition, prioritizing those based on analyses of the sources invested in the project and detailing when non-organic procedures will be eliminated (Sousa and Resende, 2014).

It should be noted that increasing input efficiency or replacing agrochemicals with biological-based ones alone will not transform the agroecosystem into an agroecological one. Instead, what is needed is the compilation of a whole, meaning that to incorporate an ecological logic, modern agroecosystems require systemic change (Altieri et al., 2017; Van Der Ploeg et al., 2022). Enhancing biodiversity, landscape redesign, and systemic functions contribute to the functional fortification of all interactions within an agroecosystem, improving its stability.

To gradually free ourselves from dependence on external inputs, it is necessary to understand the intricate behavioral mechanisms of the different food chains of microbes, insects, predators, and associated crop plants, as the further strengthening of this integration stimulates a series of ecological services (Altieri et al., 2017). In this sense, using elements that can be managed within the UP, such as MIPD, contributes to minimizing external dependence.

Along this path, attention must be paid to the association: (i) use of cultivars resistant to pests and adapted to the organic system, (ii) optimization of applications of alternative and bioactive controls (for example, pheromones, semiochemicals), (iii) improvement of biological control using natural enemies, and (v) ecological engineering of habitats and landscapes to optimize pest and disease suppression (Mitchell et al., 2018; Bolanle et al., 2022; Singh et al., 2023).

The eighth stage determines the importance of the activity execution schedule. The ninth addresses how essential estimating organic production in the UP is. Finally, the tenth highlights the budget details in the transition process (Sousa and Resende, 2014; Van Der Ploeg et al., 2022). These three phases, described by the authors, are fundamental to the decision to carry out the agroecological transition and are directly linked to detailed and essential planning. In this regard, it is important to highlight that there must be efforts by government and rural assistance entities to support farming families so that they can carry out this process in a complete and organized way.

Generally, the dimension underlying agroecology-based design operates at the scale of plots or fields, guided by the principle that agroecosystems should bear a more remarkable resemblance to natural ecosystems. It is essential to highlight that the practice of agriculture based on biodiversity and native environmental processes increases efficiency in the use of resources and energy recycling (Duru et al., 2015; Bellamy, 2021; Van Der Ploeg et al., 2022).

It is worth noting that agricultural systems in transition can be adapted to soil and climate changes by adopting agricultural varieties, sustainable soil management practices, the application of irrigation technologies, and the training of farmers, all of which help to reduce the use of external inputs. The agroecological transition is fundamental on a global scale, as, in underdeveloped countries, it enables independence from external inputs, enabling production using ecological processes, guaranteeing food availability, and mitigating food and nutritional insecurity (Mockshellma and Villarino, 2019).

In this context, there are examples of agroecological transition that have obtained favorable results and can be found in recent studies, such as Koppelmäki et al. (2019), Morales et al. (2019), Boeraeve et al. (2020b), El Bilali (2020), Dey et al. (2020), Schiller et al. (2020), Osorio et al. (2020), Madsen et al., (2020), Kiryushin (2020), among others.

Furthermore, these studies must detach themselves from traditional research approaches, engaging in multi-stakeholder networks to define options that work in practice and at all scales; build on 'theories of change' and indicators to develop viable strategies and quantify change; support policymakers through easily accessible consultancy services to drive change across the broader socio-ecological landscape; encourage local innovation systems and increase budget allocations for the agroecological transition; and enable public and private financing of long-term research programs more appropriate to the time in which agroecological interventions operate.

Final Considerations

From the compiled information, the theoretical basis of the practical principles governing agroecology is considered inseparable from the efficient functioning of transactions and consolidations of sustainable practices. The different concepts and definitions of agroecology presented do not diverge but complement each other. Furthermore, this research exposed traces of the complexity that guides the topic.

The objective of the work was achieved, as it managed to provide a detailed and structured approach to the stages and principles involved in the agroecological transition. Once there was a description of the phases of the process, from the protection of the natural ecosystem to the analysis of products obtained in rural establishments, going through stages such as the construction of the agroecosystem, soil management, water management, and organic matter cycling, among others.

The study faced the challenge of finding articles that holistically addressed the agroecological transition, highlighting the complexity inherent in the conversion of agroecosystems. The difficulty reflects the gap in the scientific literature and highlights the need for research that adopts a holistic approach using the principle of complexity. It is suggested that future studies explore this methodology to analyze the dynamic interactions between elements of the agroecosystem, considering agronomic, socioeconomic, cultural, and environmental aspects. This more comprehensive approach will allow for a scientifically based understanding of the challenges and opportunities associated with the agroecological transition, thus contributing to advancing knowledge in this area.

Furthermore, it is highlighted that the most significant difficulties faced by the agroecological transition are resistance to changing conventional agricultural practices, the need for awareness and education, scarcity of financial resources, competition with cheaper products, sensitivity to climate change, challenges in the integration of traditional and scientific knowledge, bureaucratic obstacles in certification, cultural resistance and lack of investment in research and development.

The redesign to implement the agroecological-based agroecosystem must be developed considering the edaphoclimatic peculiarities and the adaptive aspects that come together to favor the environment. These actions can only be accomplished through the collective mobilization of all parties involved, collaborating in a participatory and integrated manner. This support should bring together farming families, the academic community, researchers, rural extension agents, government officials at all levels, NGOs, and other stakeholders.

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