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Research Article

A Rational Model for Agroecology as a Science

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Agroecology was born as a competing theory to sciences derived from the Green Revolution like conventional agronomy or modernized animal husbandry. In recent years, several theoretical models or approaches have been developed in order to explain this science. However, any of them can explain its change or difference with its rival theories in a rational manner that allows assessment of its success. As a result, the aim of this study was to propose a rational model of scientific change based on main and auxiliary hypotheses. We found that seven basic principles have been formulated throughout theoretical books and papers as well as several auxiliary hypotheses that can be derived from them. These principles are as follows: (1) characteristic systemic principle of agroecology, (2) principle of biomimicry, (3) principle of biodiversity, (4) principle of specificity of agroecosystems, (5) principle of governance, (6) principle of socioecological resilience, and (7) principle of vulnerability. Also, three principles for food systems approach were retrieved. This model shows agroecology more like an organic theory that moves in different scales than a set of rival theories competing for success. However, a proper articulation and discussion of these basic principles is yet to be done.

1. Introduction

The Green Revolution can be defined as the production of goods from living beings following the principles of neoclassical economics [1]. Though it represented a steep growth in yields and animal production, it generated environmental and social negative externalities that lead to the raise of the environmental movement [2]. Agroecology was born as a response to such externalities and the disciplines that constitute its scientific base, conventional agronomy and modernized animal husbandry. Indeed, Gliessman [3] asserted that the sort of agriculture that stems from these disciplines tends to compromise productivity in the future and it has seriously damaged agrobiodiversity. Similarly, Norgaard and Sikor [4] pointed out that the negative externalities brought about by conventional agriculture are the results of the scientific premises conventional agronomy relies on. Although many agroecologists have gathered evidence to show that Green Revolution and conventional agronomical theories that derived from it have created both environmental and economic negative externalities, they have worked little to convince scholars and the scientific community that agroecology has succeeded where conventional agronomy has succeeded as well as where it has failed.

In recent years, several works that have focused in the theory of agroecology have been published. For instance, Francis et al. [5] marked a turning point when they defined it as the ecology of food systems. Indeed, one of the most prominent figures in theoretical agroecology, Gliessman [3] published a textbook that embraced this definition. However, Dalgaard et al. [6] kept a prior approach where agroecosystems are the object of study but pointed out that agroecology must move across different spatial and temporal scales. For these authors, agroecology studies agro-ecosystems that go from plot to a global scale that include agricultural systems such as fields, farms, watersheds, regions, and nations. Both approaches have been kept as Wezel and Soldat [7] found out in a systematic review even though they maintained that the plot/field approach was different from the agroecosystem as books later published in the food systems [3] and agroecosystem approach [8, 9] showed. Also, authors such as Sevilla [10] and González [11] have developed a different approach that Toledo [12] labeled the Spanish social approach of agroecology.

Furthermore, several authors have focused on the epistemological bases of agroecology. For instance, systems thinking has been considered by some researchers as fundamental to agroecological theory [4, 13]. For agro-ecosystems approach, Altieri [14] has written that agroecology does not study an isolated part of an agro-ecosystem, but it observes interactions between its components and the complex dynamics of different processes that emerge from it. Transdisciplinarity has also been regarded as one of the key epistemological bases of agroecology [6, 15]. For example, Gliessman [3] and León [9] have stressed that social, biological, and physical systems must be taken into account in agroecological research. Indeed, León [9] pointed out that an agroecosystem is a process where the cultural and ecological dimensions interweave in multiple interactions, so multiple disciplines and knowledge are needed.

However, these theoretical models do not present agroecology as a rational science, i.e., as a theory whose changes as well as its acceptance over competing theories can be rationally explained. From a scientific stance, negative externalities caused by applied agronomy do not refute conventional agronomy as a valid discipline, let alone confirm that agroecology is a sound science. Similarly, the existence of a new approach does not imply a previous one has been refuted. According to philosophy of science, a scientific field is an explanatory theory of a portion of the world. Such a theory has to be testable; i.e., it has to be enunciated in a way that can be contrasted with empirical phenomena or processes. Hypotheses are how such enunciation is carried out. When talking about competing theories—e.g., conventional agronomy and agroecology—both sets of hypotheses are compared before a given set of evidence [16]. It is said that a theory is better or more sound than other when it succeeds both where the other succeeds and where it fails [17]. As a result, a good way to present agroecology in a rational way is to present part of its theory as a set of hypotheses.

Unfortunately, hypotheses that make up a theory are not known by its practitioners, and sometimes they are not even explicit in consolidated fields [18]. For instance, the zeroth law of thermodynamics is considered to be the foundation of the first and second law, but it was formulated more than fifty years after them, hence its name [19]. Similarly, the theory of consumer's choice which is pivotal to neoclassical economics requires a necessary assumption that was formulated by Georgescu-Roegen [20] more than fifty years after the neoclassical revolution of the 1870s. Furthermore, a proposed set of hypotheses can always be contested. For example, even though the zeroth law has been accepted as one of the fundamental hypotheses or principles of thermodynamics to an extent that it is mentioned in popular textbooks of this field, it has been stated that it is redundant, i.e., what it asserts can be directly deduced from other fundamental principles without appealing to it [21].

As a result, basic hypotheses for a scientific field need to be explicitly stated, but they also need to be seen as tentative at least until they get widely accepted by the practitioners of it. The objective of this study was to propose a rational model of scientific change of agroecology that could be seen as the backbone of agroecology as a scientific field. It is important to bear in mind that the hypotheses that make its hard core are more of a starting point than a definite formulation of the basic principles of agroecology and the key hypotheses that guide or must guide empirical research.

2. Materials and Methods

2.1. Theory Model. To select and organize propositions that constitute the theory of agroecology, Lakatos' [22] model of scientific research program was followed. It comprises two parts. The first encompasses the abstract and general hypotheses, and it is called the hard core of the theory. According to this author, the hard core of a scientific program is the foundation for the development of empirical research and theoretical lucubration. The second part of a scientific research program is made up by those hypotheses that can be directly tested and which are rejected or modified in response to empirical and/or theoretical research. Thus, these hypotheses are particular affirmations that can be both directly derived from main hypotheses and observed in empirical research.

2.2. Data Extraction and Analysis. Two types of theoretical texts were collected. First, books with either the word agroecology or agroecological in its title were searched in local libraries in two cities in Colombia—Medellín and Bogotá—in http://www.amazon.com and in Springer and ScienceDirect databases. Then, perspective articles and review articles were searched in Springer, Jstor, Dialnet, and ScienceDirect databases, as well as Revista Brasileira de Agroecologia, Agroecología y Desarrollo, and Agroecologia (Journal of Murcia University). For this, articles with either the word agroecology or agroecological in its title were searched. Last, articles or books by the authors with more than three papers according to Wezel and Soldat [7] were searched in databases. Only texts in English, Spanish, and Portuguese were studied.

For the hard core, all the sentences that were labeled as principles were selected. These were selected as the basic hypotheses of agroecology since philosophy of science states that a science is ruled by its general principles [23]. Then, those sentences that were assessed as principles but were not written as indicative or declarative sentences were rewritten in this fashion in order to be grammatically presented in a way that can be confirmed or refuted. Last, all principles were given a name as it has been done in traditional sciences like thermodynamics or physics.

For the protective belt, certain assertions about particular phenomena in the texts and that are not presented as principles and do not have a great level of generalization or abstraction were selected. Then, it was determined if they could be directly derived from one of the core hypotheses found and arranged accordingly.

3. Results and Discussion

7 authored books, 7 edited books, 39 perspective articles, and 4 reviews were found. From the edited books, 10 chapters were studied, including one that was a review and was counted as such. Three types of principles were found. First, there were prescriptive principles, i.e., general rules or guides to be followed by agroecology practitioners. Leon's "agroecological principles in the cultural dimension" fall in this category, like "guarantee food security and sovereignty for both consumers and producers" [9]. Since they are rather moral or political than scientific principles, they were discarded. The second type of principles found in literature was those which were not expressed as statements or descriptions but as guidelines, similar to prescriptive principles, but they can be interpreted as hypotheses. Altieri's agroecological principles belong to this group. For instance, one of these principles is "provide the most favorable soil conditions for plant growth, particularly by managing organic matter and by enhancing soil biological activity" [24]. Finally, the third sort of principles was those which are properly written as declarative sentences.

3.1. Hard Core of Agroecology. Since there is not a consensus in agroecology on its object of study—field or plot, agroecosystem, and food system—the principles found were divided into two categories. The first comprises the principles that explicitly refer to agroecosystems. Since food systems approach includes production, these principles can be seen as the basic principles of agroecology. These basic principles are as follows.

3.1.1. Characteristic Systemic Principle of Agroecology. The organization of an agroecosystem is disturbed by ecological, technological, social, and economic processes from its environment [9, 10, 14].

This principle implies that social, ecological, technological, and economic disturbances must be considered when assessing sustainability of an agroecosystem. It also means that agroecosystems must be understood as a dynamic complex system, i.e., a process that emerges from the interaction of its components that changes in time, so attention must be set on functions and structure.

3.1.2. Principle of Biomimicry. The more an agroecosystem structurally and functionally resembles the natural ecosystems in its biogeographical area, the higher the possibility of such an agroecosystem being sustainable [3, 8, 25].

3.1.3. Principle of Biodiversity. The organization and sustainability of an agroecosystem are strengthened by its biodiversity and that of its environment [3, 9, 26].

3.1.4. Principle of Specificity of Agroecosystems. Every agroecosystem and its environment have their own characteristic features. Therefore, there is no technique suitable to all other agroecosystems and to ensure their sustainability [4, 8, 10, 14].

3.1.5. Principle of Governance. The dynamics of agroecosystems are governed by individual species when its biodiversity is low and by ecosystems dynamics when its biodiversity is high [27].

3.1.6. Principle of Socioecological Resilience. The ability of an agroecosystem to be resilient is function of both its ecological dynamics and sociocultural context of the social groups that set it up as well as the ability of the latter to react, organize, and adapt [28].

3.1.7. Principle of Vulnerability. Agroecosystems are prone to be more vulnerable in their spatial limits and when social groups that set them up lack social harmony and anomie [28].

3.1.8. Distinctive Hypotheses of Food Systems Approach. The food system approach is a complementary theory to the classical agroecological theory or agroecosystem approach that seeks to broaden the scale of agroecological research. Its basic hypothesis is "sustainability in agriculture can only come from understanding the interaction of all components of the food system" [3]. Moreover, this approach argues that a broader agroecology theory "offers powerful new means to improve the overall sustainability of agriculture. Substantially greater insights can be gained by ecological analyses of agriculture that go beyond narrow approaches focused on production and local environmental effects" [29]. Also, it alleges that "much agriculture takes place outside of production" [29]. These three assertions distinguish the food systems approach from the classical or agroecological approach of agroecology.

3.2. Protective Belt. As it was previously mentioned, the purpose of the present paper was not to bring to light all the auxiliary hypotheses mentioned in theoretical texts but to illustrate that they can be derived from the hard core of the research program if it was to be presented or built as a rational enterprise. Consequently, the particular hypotheses retrieved were arranged as concretions of the principles of agroecology.

3.2.1. Characteristic Systemic Principle of Agroecology

(i) "Every type of social operation (. . .) traces the historically precise boundaries of ecological efficiency of agroecosystems. This means that not only technological development, with its own dynamics and conceived as autonomous, conditions directly ecological efficiency levels" [30].

(ii) "The intensity and benefit, derived from [the interactions among the components of an agroecosystem] (. . .) depend on their proper organization and integration and on resources being managed to allow recirculation at farm level" [31].

(iii) Sustainability is only possible in a highly diverse agroecosystem where such a variety is well managed and used [32].

(iv) "Farm behavior is determined by the level of interactions among its diverse biotic and abiotic components" [31].

(v) Local agroecosystems that have been sustainable "share a series of functional and structural characteristics when combining high species diversity over time and space, substantial addition of organic matter, efficient nutrient recycling and a set of biological interdependencies which provide stability to pest populations and keep the soil fertile" [33].

(vi) "Regenerative organic techniques with low external inputs allow farmers to increase productivity" [34].

(vii) There is higher resilience in complex agroecosystems [35].

(viii) "There is greater productivity and lower susceptibility to environmental risk in complex and multi-species systems" [33].

3.2.2. Principle of Biomimicry

(i) The compliance of the following agroecological criteria ensures a sustainable agroecosystem: optimal spatiotemporal intra- and interspecific diversification; optimization of nutrient recycling; optimization of soil conditions through recycling of matter and preservation and use of its biodiversity; preservation of soil and water through maintenance of soil cover, erosion control, and microclimate management; minimization of crop loss through integrated pest and disease management (IPDM); and use of the dynamics of living organisms of the agroecosystem [33].

(ii) "Sustainable production originates in the adequate balance among soils, crops, nutrients, solar power, humidity and existing synergisms" [14].

(iii) González [30] raises a similar hypothesis when claiming that traditional sustainable systems "share a series of structural and functional characteristics: the promotion and use of a high species diversity; material and waste closed cycles through efficient recycling practices; systems of biological defense against pests; local dependence of energetic sources and low technological employment" among others.

3.2.3. Principle of Biodiversity

(i) "Varietal richness favors productivity and reduces risks" [26]

(ii) "There is greater production when two or more species are cultivated together than when they are cultivated apart" [26]

(iii) "Higher diversity in the farming system implies a higher diversity of associated biota" [33]

(iv) "Biodiversity boosts power and nutrient recycling" [33]

(v) "Polycultural designs (. . .) boost a series of positive effects over soil biology and productivity" [35]

(vi) "The diversification of agroecosystems carries with it pest regulation, as it brings about habitats and resources for a complex beneficial wildlife" [35]

(vii) "Integrating livestock and crop production carries with it a wide variety of benefits to farms" [3]

(viii) "Biodiversity ensures better pollination as well as more pest, disease and weed control" [33]

3.2.4. Principle of Specificity of Agroecosystems

(i) "Homogeneous technological packages cannot be adapted to the diversity of farmers and are only effective under similar conditions to those of industrial countries and experimental stations" [31].

3.2.5. Principle of Species Governance

(i) In an agroecosystem ruled by a species governance, after a selection carefully made, "it is possible [to] secure narrowly defined niche dynamics and direct these toward the economic objective(s)" [27].

3.2.6. Principle of Socioecological Resilience

(i) "Occasional alterations may be withstood with a robust, adaptable and diverse enough agroecosystem to recover once stressful situation is over" [25]

(ii) "Governance is relevant to resilience beyond the farm or the enterprise level" [36]

3.2.7. Principle of Vulnerability

(i) "Sustainability is not possible without preservation of cultural diversity" [25]

3.2.8. Some Auxiliary Hypotheses of the Food Systems Approach. There are some hypotheses that do not fit nicely into the aforementioned basic principles but rather refer to other aspects like management or politics. For instance, "technological change benefited mainly the production of agricultural and commercial products" [31] has to do with the former, whereas "large-scale commodity-oriented farming tends to wrest control of food production from rural community" [3] is related to power politics or macroeconomics.

3.3. A Rational Model of Scientific Change for Agroecology. Within the theory of agroecology, several principles have been proposed, so it can be said that a hard core have been roughly developing. However, they do not share the same level of acceptance or awareness, so a discussion about them needs to be done. When one or several of them do not suffice, they should be altered, discarded, or replaced by new ones, so a more sound or valid hard core can be reached. At this point, a consolidated theory can be reached if those final hypotheses become widely accepted and the basis of both theoretical and empirical work. This means that explanations on dynamics, sustainability, and productivity either of agroecosystems or food systems have to be based mainly on these principles.

Also, several auxiliary hypotheses that can be derived from the principles presented above have been proposed throughout books and theoretical papers. They show, on the one hand, that even though these principles might not be explicit in some authors, part of their theory can be derived from some of them. On the other hand, they highlight some elements that need to be empirically tested in order to further develop agroecology.

This model also gives a rational way to lead change within agroecology. If the underlying argument against the agroecosystem approach is that "sustainability in agriculture can only come from understanding the interaction of all components of the food system" [3], further empirical studies to validate this hypothesis should be at the center of the research program of the food system approach. Also, it calls attention to prior statements that should be tested within this approach. For instance, the principle of specificity of agroecosystems could be broaden into a principle of specificity of food systems where food produced, its distribution, consumption, and trade is highly dependent on their socioecological environment, so universal food industry models like those that can be seen nowadays are unsustainable. Similarly, the principle of biodiversity might be applied by stating that both sustainability and resilience of food systems are functions of the variety of food, trade strategies, consumption habits, and so on.

This approach also diverges from Wezel and Soldat's [7] or Toledo's [12] view in that it rather articulates the approaches instead of isolating them. Indeed, both the hard core and the protective belt integrate them in a way that shows independent prepositions that require further articulation. As it can be seen, authors from the agroecosystem approach—like Altieri or León—agree on the need to build a complex theory that comprises social, ecological, and economical elements. Regarding the agroecosystem/food system divide, the scientific research program model is closer to Dalgaard et al. [6] in that it shows different scales rather than epistemologically exclusive approaches. Nonetheless, further theoretical and empirical work is needed to confirm whether there is a quantitative range within agroecological theory or qualitative different approaches that behave like rival theories.

In addition, systems thinking and interdisciplinarity are central to both food systems and agroecosystems research programs, agreeing with the epistemological bases that have been proposed for agroecology by several authors. In food systems approach, understanding the interaction of all components of the food system means studying relations among components instead of isolating parts as is done in the analytic method. It also means examining food production, distribution, and consumption which requires at least theories and methods from ecology, economics, thermodynamics, and political science. In the characteristic systemic principle of agroecology, it is explicit that its application requires turning to different fields. Furthermore, agroecological principles do not belong to a single dimension. For example, the principle of biodiversity engages elements from ecology while the principle of vulnerability from sociology. Hence, the research program of agroecology as here presented is inherently systemic and transdisciplinary.

4. Conclusion

Although there is not a shared set of basic hypotheses within theorists of agroecology, several principles have been formulated. Also, several particular hypotheses that can be derived from these principles were found. This shows that a first rational model for scientific change for agroecology can be enunciated. Nonetheless, such principles have not been widely discussed yet. The consolidation of both agroecology as a rational science and a hard core requires such discussion.

Eight principles were found: characteristic systemic principle of agroecology, principle of biomimicry, principle of biodiversity, principle of specificity of agroecosystems, principle of species governance, principle of governance of ecosystems, principle of socioecological resilience, and principle of vulnerability. Some of these principles are more recurrent than others in theoretical texts, but all of them should be considered in a construction of rational model since they were labeled as fundamental by some theorists. A rational model implies a rational method to discard and accept the proposed principles. This can be achieved at least in two ways. First, they can be contrasted in empirical research. Second, a theoretical analysis of them could lead to a synthesis that explicitly states why some are to be discarded and some to be accepted.

Data Availability

The research articles and books used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors have no conflicts of interest to disclose.

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