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Review

Emerging Agro-Rural Complexities in Occident México: Approach from Sustainability Science and Transdisciplinarity

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Abstract: Rural and agricultural modernization and industrialization (RAMI) increased in recent decades in a multiscalar way. RAMI has implied the rural landscape transformation through the arrival of industrial models. These processes have not been linear or unidirectional; heterogeneities, opposites, mosaics, hybridizations, new interactions, problems, and tensions, between traditional and industrial agriculture and other agriculture types, have emerged. We tackle and problematized the RAMI processes, which is a complex and a real-world problem, from Sustainability Science (SS) and transdisciplinarity. Thus, considering studies and experiences in different rural areas in the world, an epistemological positioning is presented, which allows overcoming scientific frontiers and relating it to rural sustainability. We delve into the Lake Pátzcuaro Basin (LPB), Mexico, an area with a strong agricultural tradition ("milpa" systems). Recently, the presence of industrial agriculture (mainly avocado monoculture and berry greenhouses) has increased, occurring the coexistence between peasant-entrepreneurs, indigenous–non-indigenous, and new-rural. The article aims to understand comprehensively the emerging complexities from the RAMI, deepening LPB's real case. The epistemological approach developed allow us to conceive the interaction and possible complementation between traditional agriculture, industrial agriculture and other agriculture types, and the emergence of an included middle that corresponds to an "emerging complexity". Finally, relevant topics and questions are highlighted.

Keywords: rural and agricultural modernization and industrialization; peasant agriculture; industrial agriculture; rurality; traditional knowledge; epistemology; complexity; Lake Pátzcuaro Basin; Michoacán; Purépecha people

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1. Introduction

In recent decades, industrial civilization has reached a global dimension, which affects all aspects of life [1]. The current environmental degradation derives mainly from the values and practices of this civilization [2]. We have transgressed four of the nine planetary boundaries, the critical processes that regulate the Earth System's functioning (climate change, biosphere integrity, biogeochemical cycles, and land-system change) being able to trigger abrupt and non-linear environmental changes on continental to planetary scale [3,4]. Sustainability Science (SS) has emerged as academic response to this challenge. SS recognize the limitations of conventional scientific knowledge to address the complex relationships between social and natural systems [5–9], seeking to link scientific and non-scientific knowledge with action to address the current persistent socio-ecological crisis and promote paths for the continuity of life [9].

Globalization and neoliberal policies have promoted agricultural production for international markets at the expense of local needs, marginalizing rural activities for self-sufficiency, typical of traditional agriculture [10]. Small farmers are affected by the local impacts of these international market dynamics [11,12]. There has been a trend towards the industrialization of agriculture [1,13,14] and expansion of agricultural territories [15]. Monocultures landscape dominate some areas previously management with diversified traditional agriculture [16,17]. Industrial agriculture causes environmental deterioration, reducing ecological, and biocultural diversity, influencing the people's relationships with environments, impacting the ways of life and well-being of local communities and the multifunctionality of landscape [10,18].

Currently in the world there are millions of small traditional farmers [19]; family farming produces more than 80% of food [20]. The main authors in fields such as agroecology and agroforestry recognize in traditional systems the principles that they postulate for sustainability [13,21–23]. The prevailing vision in industrial civilization rejects the traditional knowledge and practices generated during most human history [1]. This vision, simplistic and not very adaptive to local contexts [24,25], conceives rural development as a transformation, sudden or gradual, from traditional to industrial modalities [26]. However, in practice, such a modernization process has not been so simple or merely one-way, and new heterogeneities, problems, and complexities have emerged at different scales. From SS is possible addressing this comprehensively.

For this kind of problems, a fundamental approach from SS is transdisciplinarity [8,27]. It addresses the complexity and challenges the fragmentation of knowledge [28–30], characterized by its hybrid nature, non-linearity and transcending academic disciplinarity [31], adapting to local contexts [5,28,29] and frequently oriented to real-world problems [9,32,33]. Transdisciplinarity implies intercommunicative action, with transdisciplinary knowledge because of intersubjectivity, emphasizing the importance of incorporating different perspectives and perceptions, which are key characteristics of complex systems [28,34]. People who inhabit a place tend to have different views and perceive different elements, problems, or priorities [35] on multiple nested scales [36]. These points are relevant for defining the problem, what constitutes a solution, and legitimate knowledge [35].

This paper addresses the real case of the Lake Pátzcuaro Basin (LPB), Michoacán, Mexico. This area, with a strong agricultural tradition, is inserted in the context of the globalization and economic liberalization, being exposed to the reorientation of land use towards industrial agriculture [37,38]. The article aims to understand comprehensively the emerging complexities from the rural and agricultural modernization and industrialization (RAMI), concerning traditional agriculture and sustainability, proposing an epistemological positioning for that and deepening LPB's real case. Research questions: (1) What epistemological approach, positioning, and elements, allow to comprehensively address RAMI and emerging complexities? (2) What implications do RAMI, and such emerging complexities, have for sustainability and traditional agriculture? (3) How has RAMI happened in the LPB's real case, and which complexities, implications and concrete effects have emerged? Thus, this study contributes mainly to (1) an epistemological approach which, incorporating elements of transdisciplinarity and the paradigm of complexity (axioms of levels of reality and perception and of the included middle, and dialectics), and thus integrating different knowledge, visions, and actions, allows to perceive and incorporate the coexistences and interactions between opposites (as traditional and industrial agricultures) and hybridizations (incorporations of industrial agriculture' traits in traditional productive units (PUs)), possible complementations and tensions between different types of agriculture, and finally the emerging complexities, thus addressing RAMI in an comprehensive way; (2) a synthesis of studies and experiences in different rural areas in the world related to RAMI; and (3) the application of the epistemological approach and the synthesis of studies and experiences in the real-world case of LPB, considering its cultural, social, political, and environmental particularities and complexities.

2. Methods

A central element and challenge of transdisciplinary research is knowledge articulation and integration [27] (see Section 3), so in this study we have sought to complement different knowledge and information sources, from different sectors and actors (local community authorities and peasants, academic researchers' experts, and local consultants) related to the research topic and problem, and different cases and experiences. Research, works and experiences from different fields of knowledge and scientific disciplines were considered, mainly SS, Inter and Transdisciplinarity, Complexity Paradigm, Philosophy of Science and Epistemology, Agroecology, Agroforestry, Peasant Studies, Rural Sociology, Rural Geography, Ethnoecology and Ethnobiology, and Land Use Studies.

(1) A bibliographic search was conducted, in order to collect antecedents on the research topic and problem. This documentary research provides inputs to achieve a vision on the state of that topic. The ScienceDirect database was used, and the following search terms: "modernization of rurality" (10); "modernization of rural areas" (35); "modernization of agriculture" (46); "industrialization of rurality" (8); "modernization of rural areas" (71); "industrialization of agriculture" (55); "modernization of rurality +/AND sustainability" (0); "modernization of agriculture +/AND sustainability" (10); "industrialization of rurality +/AND sustainability" (0/0); "industrialization of agriculture +/AND sustainability" (10); "industrial agriculture +/AND traditional agriculture" (3); "industrial agriculture +/AND peasant agriculture" (0); "industrial agriculture +/AND Patzcuaro" (0); "; "Patzcuaro +/AND sustainability" (3); Patzcuaro" (34). The search was conducted in both English and Spanish. The search terms were related to both traditional agriculture and industrial agriculture, in order to include both positions regarding the research topic and problem.

(2) Field work and meetings were carried out that consisted of: (a) field trips in LPB, peasant communities and PUs; (b) meetings with academic researchers' experts on the topics of the article and LPB, local consultants, and local community authorities and peasants, specifically of the communities San Francisco Uricho y San Miguel Nocutzepo; (c) semi-structured interviews with peasants. The purpose of those different meetings was incorporate and articulate essential knowledge from all relevant actors related to the problem, which is key to complex sustainability problems: expert opinion (academic researchers'), local experience from the study area (local consultants), and local perception and traditional knowledge (local communities authorities and peasants). The field trips were made for direct observation of the phenomenon and the study area. The interviews were carried out to acquire knowledge about the social reality in the study area based on information that only a person (subject) can provide us, in addition to learning about events that cannot be observed directly. This information was used in the section about LPB.

In addition, other activities contributed to developing the research and the reflections and proposals that are presented here., including congresses, meetings and discussions, and other studies. These instances include: Congress "The Transdiscipline Made Practice" (Valdivia, Chile, 2016), Course "Tools for Transdisciplinary Research" (Morelia, Mexico, 2018), Course "Sustainability assessment in rural and urban environments" (Morelia, Mexico, 2019), "III World Congress of Transdisciplinary" (online/Mexico City, 2020–2021); Project "Family and social agriculture and agroforestry in contexts of local and global changes" (Morelia, Mexico, 2020). In addition, various studies related to the topic of this article carried out in the LPB and different rural areas of Mexico and Chile. All these activities have allowed enriching the epistemological approach and positioning and the reflections and conclusions that are developed in this article.

3. Epistemological Approach and Positioning: Sustainability Science, Transdisciplinarity, and Rural and Agricultural Modernization and Industrialization

3.1. RAMI from SS and Transdisciplinarity

According to Kuhn [39], scientific progress operates by changing our perspective and perception rather than accumulating knowledge. One of the great scientific revolutions of the 20th century was the emergence of approaches and posits that involve multidisciplinary restructuring [40]. Moving from fragmentation towards integration and complementarity of the parts [41,42], recognizing the need for a comprehensive and contextual vision and the articulation of uncertainties [41,43,44]. Correspondence between our thinking and the world's and nature complexity is necessary [30].

The SS is recognized as a consolidated field of research to address global societies' complex problems [5,8,45–47]. The SS encourages the integration of different fields and disciplines and their approaches [27], connecting the scientific world with the world of citizenship and the political–administrative world [9]. There is an agreement that sustainability challenges require new knowledge production and decision-making [8]. Among what SS will need to do is the following: (1) span the range of spatial scales between such diverse phenomena as economic globalization and local farming practice; (2) deal with functional complexity of environmental degradation resulting from multiple stresses; (3) recognize the wide range of outlooks regarding with knowledge usable within both science and society [5].

Since the 1990s, there has been a growing call for transdisciplinary approaches to address crucial societal challenges, especially those related to sustainability [8,48,49]. SS is considered a transdisciplinary science rather than a discipline for sustainability [27]; indeed, transdisciplinary research is a key attribute in SS. SS is a problem-driven and solution-oriented field, so transdisciplinary research is a promising option. One of its goals is to bridge the gap between solving real-world or societal problems and scientific innovation [8]. A conceptual and methodological framework in transdisciplinarity facilitates integrating different knowledge bodies that participate in the research process [8]. Integration is the main cognitive challenge of transdisciplinary [49].

The 2000 conference "Transdisciplinarity: joint problem solving between science, technology, and society" [50] referred to the approach to real-world problems as an epistemic goal of transdisciplinary research [49]. The complexity of a societal problem requires to go beyond the exclusive domain of scientific experience [49]. Therefore, research practices that focus on collaborations between scientific of different disciplines and actors from outside academia, are crucial [8,27]. Some critical arguments for this type of research are: (1) Research on complex sustainability problems requires the constructive input of various knowledge communities to incorporate essential knowledge from all relevant disciplines and actors related to the situation, as well as to reconcile values and preferences; (2) Collaboration between researchers and other actors promises to increase legitimacy and accountability regarding the problem and the solution options [8,27,51,52]. It is necessary to establish mutual learning processes between the different scientific researchers and non-academic actors [8,49]. Mutual learning is a fundamental principle of transdisciplinarity [53].

In addition to being oriented to real-world problems, transdisciplinary research is appropriate both for the requirements associated with such problems as well as SS goals as a scientific field [8]. Therefore, transdisciplinary research in general and SS in particular, can be considered an "interface practice" since they integrate two ways to approach their problems: the exploration of new options to solve societal issues and the development of approaches, methods, and knowledge related to the scientific question [8]. So then, in transdisciplinary sustainability research addresses social or real-world problems which also are of interest to that scientific field.

RAMI and its social, environmental, and regarding with sustainability implications correspond to a complex situation, requiring integrating and the contribution of knowledge from different scientific fields and other perspectives and experiences, including traditional knowledge. A complex and transdisciplinary approach requires incorporating traditional perception and experience, in this case of peasant communities, to foster collaboration between researchers and local actors and mutual learning processes. Furthermore, it is a real-world or societal problem and at the same time one of scientific interest, which as has been said, is one of the distinctive characteristics of addressing problems in transdisciplinary sustainability research [8,9,32,33,49]. This problem includes strictly social aspects, such as local insecurity and resource hoarding by actors external to the communities [54]. RAMI and its impacts on sustainability are for the interests of various social sectors such as environmentalists, agrarian policymakers, social leaders, extension workers, and agricultural workers [55]. A complex and transdisciplinary approach allows addressing this societal problem and contributing to the development of scientific knowledge. In addition, the scientific literature has identified the evaluation of the sustainability of different development pathways as a central theme for the SS [46], and the study of RAMI and its effects on local sustainability are relevant on this regard.

3.2. Axioms of Transdisciplinarity and Dialectics

Transdisciplinarity is aimed to building bridges and articulating different fields of knowledge [28,40]. There are several schools of Transdisciplinarity; Klein [56] has referred to the discourse of transcendence, the problem-solving discourse, and the discourse of transgression. Nicolescu [57] has differentiated between the phenomenological Transdisciplinarity of Gibbons and Nowotny, the theoretical one of Nicolescu, Piaget, and Morin, and the experimental one; and schools such as Mode 2 Science [52], Post-normal Science [51], and the proposal of the Zurich International Conference on Transdisciplinarity [50] can be recognized. Below, we presented elements of transdisciplinarity and the paradigm of complexity [42,57,58], which allow us an epistemological positioning in the face of the problems of RAMI, for its comprehensive approach.

Nicolescu [57,59] posit three axioms of transdisciplinarity: the ontological, the logical, and the one of complexity. The first is related to the levels of reality and perception. By "level of reality" is designated a set of systems that are invariable under specific general laws (in natural systems) and general rules and norms (in social networks). Transdisciplinarity extends its action through various levels of reality [30]. According to Nicolescu, these different reality levels are accessible to our knowledge due to the different levels of perception that are potentially present in our being. These, in turn, allow a unifying and encompassing vision of reality, requiring a correspondence between the levels of perception of the observing subject and the levels of reality of the observed object [57,59].

The logical axiom: the included middle. Quantum physics has led us, in theory and scientific experiment, to verify the coexistence of pairs of opposites, such as wave and corpuscle, local and global causality [57,59]. However, our mental habits, scientific or not, still tend to be governed by classical Aristotelian logic that does not tolerate contradictions [57,59]. Morin [42,60] has emphasized that at the heart of the paradigm of complexity is the dialectical confrontation of contradiction. It is necessary to move to a logic of the included middle that allows coherently unifying different levels of reality and perception, and elements that initially may seem merely antagonistic [30]. *Contraria sunt complementa* was the motto of the Nobel Prize in Physics Niels Bohr: opposites as complements that converge without losing their identities [30].

The axioms of transdisciplinarity presented, and the dialectic, permit a comprehensive vision, allowing the integration of different knowledge fields and overcoming disciplinary and scientific boundaries. This approach also allows conceiving and proposing the coexistence and unification of elements that initially may seem merely antagonistic, such as industrial and traditional agriculture. The latter is the result of a historical coevolutionary process between humans and their environments, which results in complex traditional environmental knowledge [1,61,62] and highly diverse agriculture [1,19,21,63,64]. With modernization, new heterogeneities and interactions arise between traditional and industrial agriculture and other types of agriculture, which through this approach can be viewed and approached as opposite and at the same time complementary.

4. Traditional Agricultures: Particularities, Their Knowledge and Contrasts with Industrial Agriculture

In Mesoamerica, complex and millenary agriculture emerged based on manual labor, with little few animal domestication, which resulted in a set of management techniques and strategies, such as the domestication of plants, construction of terraces to conserve humidity and expand the surface of cultivation, irrigation, annual polycultures, plant rotation, among others [65]. Another interesting strategy is that each PU cultivated scattered lands, located in areas with different characteristics of soil, humidity, or topography, which can be interpreted to manage risks and take advantage of microenvironmental differences [65], and as a sample of socio-environmental complexity.

Agriculture arises based on a gradual accumulation of ecological knowledge about local diversity, with the management of ecosystems and domestication [66,67], developing through the generation and transmission of said knowledge and with the adoption and adaptation of technical innovations in various areas of the world, including Mexico. Thus, arises the so-called "traditional agriculture" [66]. Every culture is related to nature and the local environment, establishing a mutual and complex adaptation relationship [68,69]. This relationship is diverse in cultures that inhabit a territory for extended periods (tens, hundreds, or thousands of years) since they generally develop knowledge and sophisticated management strategies to avoid the rapid decline of natural resources and optimize their renewability [25,63,65,70]. Modernization and industrialization have modified the relationship between peasant communities and their environments [69].

To carry out the diverse environmental interactions, traditional peoples and peasants have required an appropriate cognitive system, since a corpus of knowledge always corresponds to each praxis. Traditional knowledge is comprehensive and holistic, encompassing various thematic fields [71–73]. It is valuable to explore this repertoire of perceptions, symbols, and concepts of traditional peoples and peasant's cognitive structure since such knowledge systems have been necessary for human survival, are adaptive and built based on local realities and experiences in the real-world [1,61,62]. That correspond to a legacy of the historical process of humanization of nature and the human's naturalization [64]. The product of this process is currently in the minds and hands of traditional peoples, especially in indigenous communities [1,74]. This knowledge is threatened by industrial civilization, which rejects traditional life forms [1].

Traditional agriculture contributes substantially to food security at the local, regional, and national levels [1,19,21] and its agroecosystems present a high diversity and adaptive capacity to changes social, economic, and environmental [19,21,63,75], achieving the above under marginal conditions and with a low use of external inputs of industrial origin [76]. Peasant rationality presents a "multiple use strategy", which has been widely documented [64,77,78].

Traditional and industrial agriculture have different objectives and contrasting traits: (1) type of energy used during production; (2) scale of productive activities; (3) degree of self-sufficiency of the PU; (4) level of the labor force; (5) level of diversity (ecological, productive, and biological) maintained during production; (6) level of environmental (energy) productivity; (7) level of labor productivity; (8) type of knowledge used during production; (9) worldview associated with productive rationality [26,79]; and (10) consumption and commercialization. As one progresses from traditional agriculture to industrial agriculture, in general the following transition occurs with respect to each one of the ten contrasting traits: (1) energy, from solar and biological energy to fossil; (2) scale, from a scale manageable by the members of a peasant family, to larger PU sizes, in ha. or in animal heads; (3) self-sufficiency, reduces self-sufficiency, considering food, productive, genetic, and financial self-sufficiency; (4) labor force, from family and occasionally community labor force, to the use and need of external and paid wages; (5) diversity, decrease in diversity, considering ecological or ecogeographic, productive, and biological diversity; (6) energy productivity, decreases considerably with agricultural industrialization; that is, energy efficiency is lost in the total process [80–82]; (7) labor productivity, increases with agricultural industrialization, that is, efficiency is gained, increasing the yield for each hour or day of work of each day; (8) commercialization and consumption, it goes from self-consumption and commercialization in the community itself or in nearby communities, to commercialization on a regional, national and/or international scale [16]; (9) knowledge, from a knowledge that the peasant has regarding nature and the local environment, holistic and experiential, to a specialized, exogenous and standardized, usually requiring external technical advice; (10) worldview, it is passed from a vision in which nature, and its elements and processes, appear as living entities with which or within which human beings interact and with whom it is necessary to dialogue during the production process, to a materialistic, productivist, and pragmatic vision that conceives of nature as an entity separate from society to be manipulated by modern technology and scientific research. This differentiation concerning worldview is clearer in those peasant communities that belong to original people's culture, and it tends to weaken in those communities acculturated by modernity [26]. This can be applied at the PU scale or regional or other territorial unit scale.

Between the types of traditional and industrial agriculture, there is a range of intermediate states that are the result of the different combinations between typically traditional or peasant traits and industrial ones at PU scale, mixed traditional/industrial farming systems, hybridizations. In other words, different moments in the process by which modernizing mechanisms transform the traditional way into one industrial, and at regional or basin scale mosaics with different degrees of "peasantinity" or "agro-industriality" can be observed [26]. Different types of agriculture emerge that coexist and interact, making it necessary to consider such complexity to understand the future of rural and agriculture. From these multiscale hybridizations, mosaics, and interactions, emerge tensions, and different types implications, and thus a complex whole is formed. With RAMI an equilibrium or static state or situation does not emerge in rural areas, but one dynamic and far-from-equilibrium, result of processes that are not linear, as will be seen with the development of this article.

5. Rural and Agricultural Modernization and Industrialization

5.1. Modernization and Industrialization Processes

The modernization of agriculture is part of industrial civilization [83]. In developing countries, such a process began mainly from the 1950s [13]. Previously in Mexico, a program began in 1941 between the Ministry of Agriculture and Livestock and the Rockefeller Foundation, which later was called the Green Revolution and whose starting points were [66]: (1) experimentation and application of innovations of American agricultural sciences; (2) generation of knowledge for the specific situation in Mexico; (3) preparation of Mexican professionals; and (4) analysis of the agricultural economic situation in Mexico.

Agricultural intensification has spread widely in developing countries in recent decades [13,84]. The modernization of agriculture in such countries consists mainly in the incorporation of agricultural technology and in agricultural/rural development strategies and projects [55]. This complex process is influenced by internal forces in each country and by external mega-forces. Among the internal forces are demographic pressure, political system, research and extension policies and programs, agroclimatic conditions, and historical experience. Among the external mega-forces are international trade, international agricultural research centers, international organizations for the development of agriculture, and bilateral aid from developed countries [55]. In Mexico, the introduction and adoption of the agro-industrial model was a complex process in which various actors participated, teaching and experimentation institutions, and extension and financing programs were founded [63].

A central idea was that the modernization of traditional agriculture, including production, processing, storage, and marketing, was considered a sine qua non of the prosperity of developing countries [85]. Modernization is associated with the notion that traditional agriculture and peasants were backward, not very productive, that multifunctional PUs were something of the past, and modern agriculture was perceived as the only way to feed the world [66,85]. This modernization implied depeasantization [86] and was perceived as part of the natural order of "progress" [85]. The PUs had to specialize in the production of a single product [13], and peasant agriculture had to give way to another type of agriculture much less autonomous, based, and dependent on external resources (technology, seeds, agrochemicals, and capital), instead of being based mainly on resources produced and reproduced in the PU itself [13,21].

Agricultural modernization was a manifestation of changes that had been germinating for some decades in the agricultural sciences, and it was outlined by intellectuals who helped design it [85], it was an externally devised and gestated process. European agricultural modernization was the laboratory that shaped the Green Revolutions and Programs for Integrated Rural Development in most of the Global South. In Latin American countries, in recent decades, globalization and neoliberal policies have fostered agricultural production for international markets at the expense of local needs [10], and small farmer communities are increasingly seen more and more affected by the local impacts of the dynamics of such a market [11,12]. In Mexico, since the 1980s, the State's agricultural policy has focused on farmers with larger properties and more market potential [87], impacting the viability of small producers, who have frequently been forced to seek other means of life [86,88].

The initial methodologies in agricultural modernization presented a series of shortcomings and biases, such as a top-down approach, without any sociological basis or understanding of the community structure, of small farmers [25] or land tenure. Research was conducted in irrigated crops and high-potential regions that were already endowed with infrastructure, and research and extension on dryland crops was neglected, as was research on polycultures [25]. Soil and water conservation studies were conducted only after degradation was a serious problem; indigenous knowledge about biological control and other management was not thoroughly examined; there was no integrated rural development approach, with little coordination between different areas, such as agriculture, animal production, irrigation, or education; little NGO participation in agricultural projects; in some countries large projects were emphasized, which accelerated environmental deterioration and human displacement [55].

The modernization of agriculture has intrinsic and self-generated limits, which has led to new agricultural crises [85]. For a long-term reduction of rural poverty, the modernization of traditional agriculture can contribute, but is insufficient in itself [89]. Furthermore, entrepreneurship within the framework of agricultural modernization was far from a "free" praxis. The agricultural "entrepreneur" is obliged to implement practices prescribed by scientists, policy makers, bankers, and the agro-industrial complex. New technologies create dependency: they solve specific problems, but also create new ones that, in turn, require additional technologies, repeating the same cycle. These new technologies, to be economically viable, must be applied at scales that frequently involve investment in agricultural expansion and credit [85]. The use of the best farmland in agricultural modernization gave great results in the short term with respect to agricultural yields, but in the long term the reality was different, and some yields decreased [13]. Although the results of the green revolution initially produced some euphoria [66], the modernization of agriculture through technological intensification has been severely criticized since the 1970s [25,55]. In Mexico, the modernization process implied controversies and oppositions on the part of various actors, motivating interesting debates about the convenience or not of the agro-industrial model in the country and its foreseeable consequences [63].

Gradually, it became clear that the focus on intensive food production had failed to deliver the expected benefits for the development of rural areas. Only when the green revolution produced significant social and environmental impacts did agricultural policymakers, researchers, extensionists, administrators, and people in the environmental movement question total reliance on agricultural technology and demanded that human well-being and environmental protection should be at the fore central to sustainable agricultural development [55].

5.2. Industrialization Process and Implications

Industrial agriculture, gradually replacing or transforming traditional agriculture and rural landscape in different ways and degrees, has unleashed profound social, economic, cultural, and ecological impacts, for example, on soil, atmosphere, water, genetic resources, wildlife, ecosystems at different scales, impacts on humans at level of people, communities, and societies, on traditional knowledge and world views, and on sustainability, since all the dimensions and scales of such impacts are constitutive of the sustainability problem. These impacts have been described and analyzed by numerous researchers (see [1,13,14,21,90–92]). According to González [16], the modern specialization of agricultural production in the industrial model entails: (1) adopting a mode of agriculture that degrades regional and local natural and human resources; (2) subordinate local producers to the intervention of transnational companies and foreign government agencies that cooperate with national governments, increasing the dependence of these local producers; and (3) harm to domestic consumers regarding access to a diet that is sufficient, healthy, and culturally acceptable.

The new scenario created to optimize crop quality and agricultural and economic productivity is characterized by extensive monocultural fields in which most natural patterns, such as geomorphology, drainage network, forest mosaic, buffer zones, and ecosystem processes have been simplified [70]. Regarding traditional agriculture, there is a loss of multiple use of resources and ecological and biological diversity [13], observing a low adaptive capacity and resilience of industrial agroecosystems [75], of buffering, and self-regulation in agro-industrial food systems [92] and threatened food security [21].

The degrading effect on peasant communities includes the breakdown of the form of social and ecological coevolution that the peasantry had maintained through their historical ways of managing natural resources [13,93]. A subjugation occurs, not only of agriculture models, but also of life styles and conditions, with land grabbing by entrepreneurs and/or agricultural investors and the exclusion of peasants and indigenous people from their lands and key resources for their traditions, worldview, lifestyles, and well-being, thus becoming precarious their living conditions [54]. On the other hand, several authors have highlighted that with agricultural modernization, the development of PUs does not imply the prosperity of rural regions [83,94,95], that is, a disconnect has been generated between development at the PU level and rural development at the regional level.

6. New Pathways for Sustainable Rural Development and Emerging Complexities

The predominance of industrial agriculture and its scientific base is not functional in the face of hunger and sustainability problems [21,96,97]. The conventional approach to increasing the food supply, given the perception of “successful” in the recent past, suggests a rejuvenation of the agribusiness model of the last century [98]. The above would result in agricultural intensification and expansion (“new productivism”), especially in Mexico (exporting country) [97]. In contrast, prosperity in rural contexts is increasingly understood as multidimensional, and people seek to reconcile economic parameters with social and environmental well-being [95]. Implies that economic efficiency at the PU level and economic growth at the regional level is not adequate indicators of farmers well-being. Large specialized and capital-intensive PUs are less and less the ideal agricultural model [95].

In contrast to agricultural modernization, there is evidence of alternative farming and rural developments, often leading to more sustainable farm production and rural areas [83]. The literature describes practices that seek greater sustainability, labeled as low-input agriculture, agroforestry systems, polyculture agriculture, natural agriculture, permaculture, regenerative agriculture, agroecology [96,97]. On different continents, there are examples of culturally, socio-economically, and ecologically integrated agricultural systems in communities, more resistant to external threats and globalization, which contribute to environmental care and improve productivity [97]. The agricultural matrix at the landscape level is key to addressing, simultaneously, the food crisis and the biodiversity crisis; there is a growing consensus among ecologists that metapopulations, metacommunities, and landscape processes are determinants for biodiversity [96]. Likewise, emerging agri-food networks are platforms where farmers and consumers innovate and seek alternative development models, which be laboratories for social change and prosperity in rural areas [95]. Diversity and multifunctional are crucial. The latter allows PUs to contribute to rural areas' social and environmental sustainability [83,99]. The most diverse PUs in many regions is connected with cultural landscapes and mosaics that have an emotional and aesthetic value for the local residents [100].

Horlings and Marsden [97] emphasize that for the other rural and agricultural developments and initiatives to be a real alternative to the prevailing industrial model, it is required that sustainable agri-food networks be expanded, integrated, and supported through new and innovative institutional and market arrangements, with the participation of farmers and consumers, and with a regionally integrated and place-based eco-economy. These authors highlight elements corresponding to the dimensions: (1) economic: agri-food network, comprehensive approach to food production, added value at PU level; (2) technological: technological generation as a demand-driven and spatially sensitive process; (3) ecological: agroecological principles, flexible and adaptable to local ecosystems; (4) socio-cultural: autonomy, human-nature synergy, demand-driven research; (5) spatial: locally integrated into the community, use of local resources; (6) politics: participatory approaches, influence of communities in agri-food networks, local institutional actors) [97]. These findings are frequently not reflected in rural policy, which often remains oriented towards an entirely commercial PU ideal, treating other PU types as obstacles to productivist agriculture [95].

The transition and transformation from traditional agriculture to industrial agriculture is complex and multidimensional. With the modernization process, a series of supposed dichotomies were generated, such as the dichotomy between peasants and new entrepreneurs, between the laggards and the first to modernize, between traditionalism and modern culture, between small and large PUs, to mention only some [85]. Furthermore, this modernization has implied depeasantization [85,86,101] and in some regions repeasantization, the emergence of "new peasants," "peasants of the 21st century," and neo-ruralities [83,85,101]. Such depeasantization and repeasantization are quantitative (decrease or increase in peasant farmers and peasant PUs) and qualitative (change in the type of agriculture, becoming more or less peasant or industrial) [85]. The repeasantization process includes agriculture based on local natural resources, with soil fertility as a crucial element; a return to mixed PU (polyculture and animal husbandry), and participation in newly built local markets [83,101]. In Mesoamerica, the "Peasant to Peasant" movement (PTPM) works for sustainable agriculture led by peasants, based on the transmission of traditional agriculture knowledge and techniques from, by, and to the peasants themselves [102].

These processes of depeasantization and repeasantization, and different types of agriculture, apparently dichotomous and contrary, can coexist and even feed each other. Although in the modernization project there was the notion that history could only move in the direction of the traditional to the modern, from the peasants to the entrepreneurs [85], in practice, it has not been unidirectional. Instead, coexistences and mosaics have been generated between traditional and industrial agriculture and different types of agriculture [21,26], in the context of dynamic situations and non-linear processes. Farmers who base their production on local resources and agroecological techniques, that is, they continue to operate in a traditional form of agriculture, others with a commercial orientation that use and depend on external inputs and links with international markets, other cases of intermediate states, and different types of agriculture, coexist in a same region [21].

Jacobia et al. [92] analyzed the interaction between agro-industrial food systems and local and agroecological food systems in Bolivia and Kenya. This interaction can increase the buffering capacity against disturbances, for example, by sharing inputs and by-products in periods of drought. On the other hand, such interaction and its intensification can decrease resilience, exacerbate externalities, and impact food sustainability. The spatial and economic expansion of agro-industrial food systems can cause productive and livelihood exclusion of small farmers, and local and regional effects such as deforestation, competition for water resources, concentration of land ownership, low generation of employment, health impacts, increased carbon footprint, decreased energy efficiency and increased non-reusable waste [92]. Hogeland [103] studied the response of agricultural cooperatives to the industrialization of agriculture in the United States in the 20th century, which challenged the primacy of family farming by disseminating a competitive production model based on vertical integration. Decisions commonly made by family farmers, such as what to produce, where, when, and for what market, were co-opted by the corporate hierarchy. He showed that with cooperatives as a facilitating or connecting actor between both, family agriculture can be better linked to industrial agriculture.

In Latin America, an interesting case is the PTPM. The strength of the PTPM is its ability to generate agroecological knowledge in a horizontal and decentralized way. The PTPM continues to achieve success in developing and extending sustainable agricultural practices in the field, among other achievements, thus consolidating itself, mainly in Mesoamerica [102]. However, the joint work of the PTPM and the NGOs' has achieved little impact in the political context. The Green Revolution transformed Mesoamerica's fields in a couple of decades, precisely because it linked governments, research institutions, banks, development agencies, and producer associations in a joint effort at agricultural modernization. The PTPM works with NGOs, government development projects, research institutions, farmers' unions, also with local churches and religious groups, parent–teacher associations, and local governments, but has not played a coordinating role, and all that has been done has certainly not penetrated policies or other institutional spheres [102]. Multi-actor interaction and coordination, knowledge complementation, and mutual learning processes, are essential. For rural and agricultural sustainability, the articulated action of different sectors and social actors is required: the purposely adoption of technologies, managements and practices by farmers, the support of the government, and also NGOs, universities and research centers, consumers, among others.

Koopmans et al. [94] explored multi-actor approaches to rural and environmental governance. Based on empirical evidence from eleven case studies in a variety of national and regional contexts, they distinguished five governance strategies faced with the challenge of reconnecting agricultural modernization and sustainable rural development: (1) integrating diverse land-use interests; (2) sustainable farmers reconnecting with consumers; (3) cooperation between farmers in quality production and along the food chain; (4) resource-efficient agriculture; and (5) self-governance for smaller PUs. Some difficulties in developing these new forms of governance have been that certain local actors accept responsibilities that traditionally belonged to the government, the peer pressure that participating farmers may experience, incoherent policies, poorly directed or coordinated from different government departments, and levels of bureaucracy. New governance approaches must be developed with vertical and horizontal coordination to foster synergies between PUs modernization and sustainable rural development, strengthening multi-sector and multi-actor links [94].

To overcome the supposed dichotomies that arose with modernization, it is necessary to integrate the different types of development and agriculture. The interconnections between these different types of agriculture, actors, and PUs are critical. In some cases, adapting to local particularities and with the necessary participatory and dialogue processes, combine and integrate some aspects of both traditional and industrial PUs, it may be convenient for rural and agricultural sustainability. For example, traditional PUs can benefit from industrial elements in storage, processing, and distribution. Huttunen [83] studied different processes of agricultural modernization and rural development in the Nordic context, observing connections between PUs of different types of agriculture at regional scale, which are produced through various exchange practices, such as buying, contracting, hiring, sharing, bartering, co-ownership, and exchange of work, with intertwining of elements such as materials and skills associated with agricultural practices at PU scale. PUs creates marketing and exchange opportunities with each other, which tend to be, at least partially, not market-based; for example, product and job exchanges related to animal feeding, cultivation, and the use of machinery [83]. In the Finnish case, for example, current rural development is characterized by the co-production of food and other rural products and services in PU of different types of agriculture. All types of PU play different roles in cooperation and reciprocal relationships, generating a complex network of interconnected agricultural practices at the regional scale. In these types of situations, it is appropriate to characterize rural development as a co-production resulting from the interconnection between different types of agriculture [83]. The process of modernization at regional scale relates to the agricultural practices at PU scale and the processes there, such as the incorporation of elements of industrial agriculture in previously traditional systems and the resulting hybridization of the PU. The interactions and certain exchanges between PUs can promote hybridizations at that scale, for example, exchanges of machinery, technologies, practices, knowledge, and skills. This is how the arrival and operation of industrial models in rural areas affects in regard with RAMI, triggering, promoting, and materializing such modernizing processes.

Through the interconnections between PUs and actors that practice different types of agriculture, the supposed dichotomy is no longer such. Instead, these different PUs and actors are part of the same total system and the same process of regional rural development. This allows conceiving certain alignment between the agricultural modernization project with a more sustainable rural development [83]. Good examples along these lines include the role of cooperative approaches and agricultural cooperatives in the transition to a more sustainable agri-food system and opportunities for diversification [104], the role of agricultural modernization in agreements of environmental and rural governance that contribute to regional sustainable rural development [94], and the contribution of multi-actor governance in aligning agricultural modernization at the PU level with sustainable rural development, fostering synergies between both [94]. The total process is multiscale, connecting and interacting processes at PU scale (such as hybridizations) and at regional scale (such as mosaics and interconnections between PUs from different types of agriculture). To visualize this possibility of sustainable rural development and possible complementarities more than mere dichotomies, a holistic, transdisciplinary, and complex approach is fundamental. Thus, it is a reconceptualization of rural and agricultural modernization.

7. Lake Pátzcuaro Basin Case

7.1. Characterization of the LPB, Its People and Agriculture

The LPB is in the State of Michoacán, in western Mexico. Approximately 81% of its surface corresponds to the municipalities of Pátzcuaro, Tzintzuntzan, Quiroga, and Erongarícuaro (Figure 1). The basin has an area of around 100,000 ha [37]. Geographically it is located between 19°25′–19°45′ N and 101°25′–101°54′ W [105], and its altitude ranges from 2040 to 3400 masl [37]. It is an endorheic basin [106]. The climate is temperate subhumid, with most of the rainfall in summer and an annual rainfall of 1010 mm. The average yearly temperature is 16.9 °C, with a minimum of 8.0 °C and a maximum of 25.7 °C [107]. There are eight soil types: andosol, luvisol, lithosol, acrisol, gleysol, rankers, vertisol, and feozem. Most of them are young soils, highly susceptible to erosion [108].

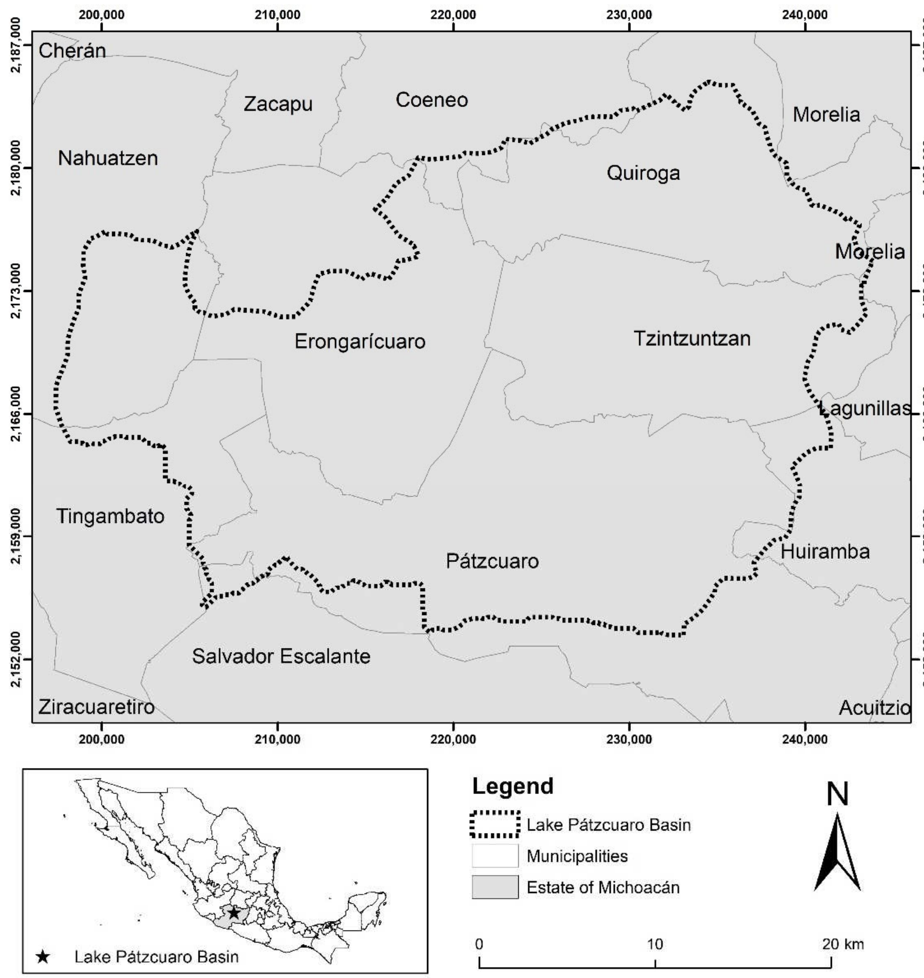

Figure 1. Lake Pátzcuaro Basin (LPB) in the State of Michoacán, Mexico, its delimitation, and the corresponding municipalities.

The LPB population is mainly peasant, distributed in more than 100 human settlements that include small *rancherías*, communities of 500–3000 inhabitants, intermediate settlements, and colonial origin cities [109,110]. LPB is part of the Purépecha region, the demographic and territorial majority ethnic group in Michoacán [37,109]. Original people represent 20% of the total population of the region [111]. Basin population includes migrants from other areas of Mexico, including large urban centers.

The main economic activities are agriculture, livestock, forestry, crafts, and fishing [37], with agriculture as the most usual way of transforming the landscape from natural to cultural [112]. The communities in the LPB have a strong agricultural tradition, especially in the production of maize. Peasants had practice agriculture for approximately 5000 years [113], commonly maintain small and diversified PUs (usually < 5 ha) [37]. They employ family labor and produce goods for self-sufficiency, such as crops, livestock, forest products, and commercialization [38]. In recent decades, most farmers use pesticides, chemical fertilizers, and machinery [114]. Maize is the most important crop [17,37]. Most of the peasants obtain their seeds from growing or from local neighbors for growing maize. Peasants cultivate "milpa", a system typical of Mexican traditional agriculture, combining maize with beans, squash, and chilacayote [38].

LPB is highly heterogeneous (Figure 2). Six maize races exist in the basin: conical, purépecha, western maize, chalqueño, tabloncillo, cacahuacintle, and four other less frequent races [37,38]. This high variability is the product of the interaction between biophysical and cultural heterogeneity [115]. Toledo and Barrera-Bassols [109] reported ten types of vegetation, high soil heterogeneity (9 major types, 13 subtypes, and more than 20 edaphic associations), and 12 types of agricultural systems [109]. Considering temporality, water, topography, and geographical distribution, Mapes et al. [112] distinguished 14 agricultural landscapes in LPB: temporary humidity agriculture; temporary rain agriculture without modification of the terrain; seasonal rain agriculture with terraces; uncontrolled spring irrigation agriculture; controlled spring irrigation agriculture; manual lake watering agriculture with bucket; manual lake flooding agriculture with a scoop; agriculture irrigation of the lake or wells mechanized with pumps; mechanized lake irrigation agriculture with waterwheel; juice agriculture; mountain arboriculture; riverbank arboriculture; solar or backyard in high areas; solar or backyard on the shore. In the LPB, irrigation, moisture, juice or riverine, and seasonal (rain-fed), agriculture is practiced, each associated with specific edaphoclimatic conditions present in different basin areas (Figure 3). The latter, which uses rainwater, is currently the most important, with the milpa being the most frequent agricultural and agroforestry system [17].

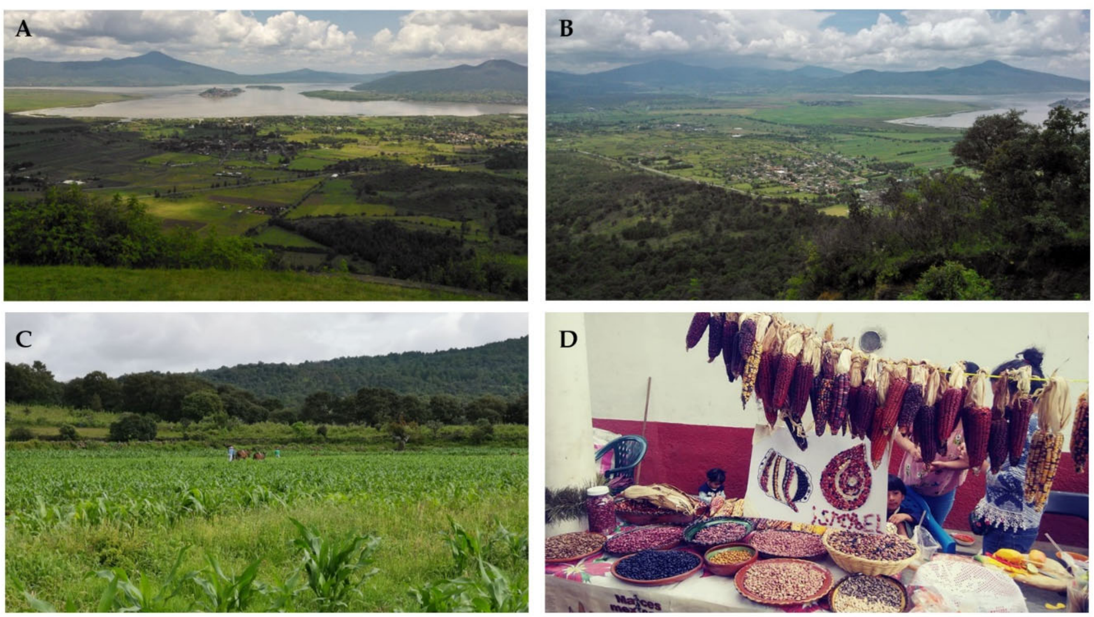

Figure 2. The LPB is highly heterogeneous, considering its variety of human settlements, landscape forms, historical sites, and types of agriculture, with their corresponding management and products. (**A**) A part of the CLP, seen from its south side, with some of the 9 islands present in the lake. In the foreground is Janitzio Island, where several pre-Hispanic traditions of the Purépecha culture are maintained. (**B**) The town of the peasant community of Arocutin, with approximately 572 inhabitants, in the municipality of Erongaricuaro. (**C**) Milpa, an agricultural system typical of traditional Mexican agriculture, which in this region usually combining maize with beans, squash, and chilacayote. In the image there are peasants in the San Andrés Tziróndaro community working the land with a yoke of oxen or horses, a typical tool of traditional agriculture. (**D**) Products from the milpa in the San Francisco Uricho peasant community.

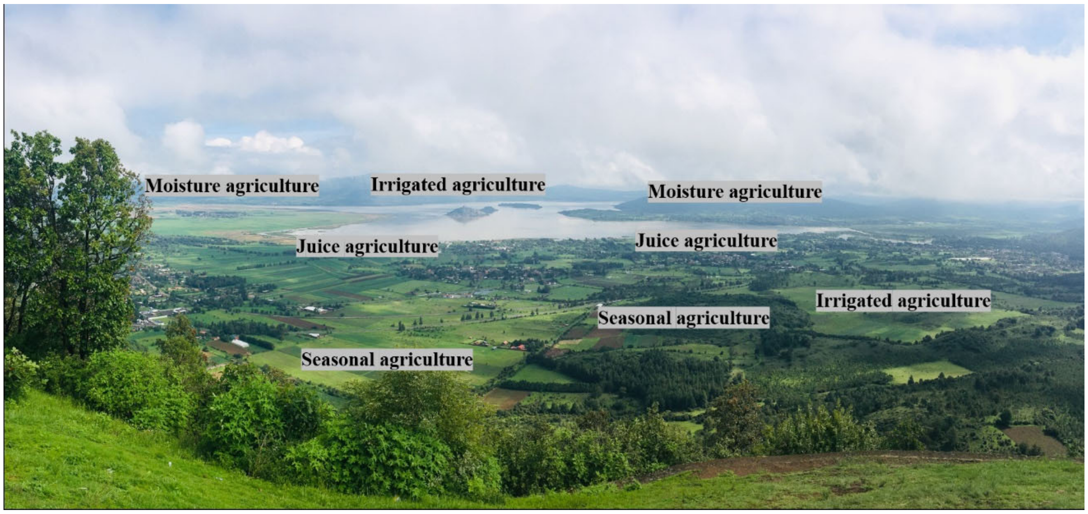

Figure 3. Agriculture, frequently as agriculture–cattle–forest systems, is the main activity transforming the landscape in LPB. The figure shows the four types of agriculture in the basin: irrigation, juice or riverine, moisture, and seasonal (rain-fed), and the locations in the basin: irrigated agriculture in different parts of the altitude gradient of the basin, in luvisol soils; juice agriculture in always humid lands on the shore of the lake (2040–2060 masl), in vertisol soils; moisture agriculture on slopes mainly in the upper part of the basin (2040–2800 masl), in andosol soils; and seasonal or rain-fed agriculture mainly at the piedmont and in the plain (2040–2800 masl), in acrisol and litosol soils [17,38,112]. The latter is currently the main one; it takes advantage of rainwater, and it is carried out mainly for self-subsistence. The milpa is the most frequent agricultural and agroforestry system [17]. Each of these types of agriculture is associated with specific edaphoclimatic conditions, taking advantage of the geoform, the availability of humidity, and the properties of the different soil types present in the LPB. There are eight soil types: andosol, luvisol, lithosol, acrisol, gleysol, rankers, vertisol, and feozem.

7.2. Traditional Agriculture and Neoliberal Reform: the Context of RAMI in Mexico, Michoacán, and the LPB

Since 1970, and especially since the second half of the 1980s, Mexico has undergone a series of changes in its agricultural sector because of trade liberalization and policies oriented to the international market, within the frame of the so-called neoliberal reform, with TLCAN and domestic agricultural reforms [16,116–118]. One of the main drivers of agricultural land use in Mexico is the international market [88]. These policies have created favorable conditions for developing extractive industries with transnational capital in territories rich in natural resources, which coincide with areas historically occupied by indigenous peoples [54]. Neoliberal policies have affected mestizo and indigenous communities, modifying not only environments but also social actors and customs, traditional social dynamics disappearing and new ones emerging [119].

Mexican policy for more than three decades has promoted an agro-export specialization in the Mexican countryside, at the cost of the weakening of traditional agriculture and causing a high food dependency of the country, concentration of wealth, and social and environmental impacts [119]. Before the 1980s, Mexican agricultural policy was oriented towards the production of food for the local market; later, the economic policy adopted by the State sought to promote the competitiveness of agricultural products, focusing on farmers with larger properties and greater commercial potential [87]. The idea of subsidized peasants was abandoned by public policy [120]. These policies led to a crisis in the traditional farmers sector [117,118], having impacts on their livelihoods, traditional economics, land use, and Mexican rural ecosystems [10,54], leaving the viability of this sector in question [88,117]. This process of industrialization of agriculture and its effects occurs at different scales, manifesting itself in different ways in the PU, in the communities and on a regional scale. Faced with these impacts, traditional farmers have responded in different ways, either by expanding their lands, diversifying their activities off the farm, migrating, or incorporating new technologies [117,118].

In the State of Michoacán, the Federal Government has promoted the agro-export model [54], increasing the areas planted with fruit trees for exports and advancing land grabbing and accumulation due to dispossession by actors external to the communities [54,119]. Some areas that had traditional polyculture landscapes are now dominated by fruit monocultures. This expansion of export agriculture implies a loss of food security for national and local consumers as well as of agrobiodiversity [17].

Michoacán is the main avocado producer and exporter at the national level [119,121], the expansion of this crop being linked to the modernization projects of the State, and measures have been applied that have promoted it in recent decades, such as preferential credits, low-cost inputs, among others [54]. Avocado production in Michoacán usually implies high use of external inputs, cutting-edge technologies, high income, concentration of capital, and various socio-environmental impacts [119,122]. The expansion of avocado implies a productive reconversion of the field to the detriment of the production of basic grains, displacing or subordinating peasant production [119]. The avocado area increased from 13,045 ha in 1974 to 153,018 ha in 2011, showing exponential growth in that period [123]. This growth has occurred on the lands of Purépecha communities [119], developing an agro-export enclave economy in the Purépecha Plateau [54].

In the LPB, within the context of the modernizing project of the State and the Mexican neoliberal reform, and the associated agricultural reforms, also the industrialization of agriculture has been promoted [37]. Since the 1970s, traditional agriculture has been incorporating traits of industrial agriculture. Many of the peasants have incorporated into their PU elements such as the use of mechanized machinery with fossil energy, agrochemicals, industrial feed for livestock, improved seeds and/or livestock, financial support from the government, and some have planted non-creole avocados on peasant lands replacing milpa. These incorporations and the resultant hybridizations have implications on the operation of the PU, and finally on its sustainability. Table 1 shows the traits and the variables corresponding to each trait that have been industrialized, the specific hybridization that has occurred, and its implication on PU's functioning.

Table 1. Traits and variables that have been industrialized at the productive units (PUs) scale in the LPB within the context of the Mexican State's modernization Project, the specific incorporations and hybridizations that have occurred, and its implication on the PU's operation.

Traits and Variables	Incorporations and Hybridizations	Implications
Energy Variables: Productive energy Domestic energy	Incorporation of tractors, heavy machinery, agrochemicals, industrial feed for livestock. Use of gas in domestic work.	Increase the use of fossil (non-renewable) energy and other inputs external to the system.
Self-sufficiency Variables: Productive self-sufficiency Genetic self-sufficiency Financial self-sufficiency	Incorporation of agrochemicals, industrial feed for livestock, improved seeds and/or livestock, dependence on financial support (credit and insurance).	Decreases the self-sufficiency of the system.
Diversity Variables: Productive diversity	Avocado plantation on peasant lands, replacing milpa and forest.	Decreases the diversity of the system.
Energy productivity	Incorporation of tractors, agrochemicals, improved seeds.	Decreases the productivity or energy efficiency of the system.
Work productivity	Incorporation of tractors and heavy machinery.	Increases the productivity or efficiency of work of the system.

The arrival of PUs of industrial agriculture to the LPB begins in this century; indeed, Toledo et al. [26] do not mention this region among the industrial agriculture poles of the State of Michoacán. Like other regions of Mexico, the LPB is exposed to the land use change from milpa to commercial crops [38]. In recent years, through the purchase and lease of land, there has been an increase in the area with industrial agriculture in the basin, with avocado (*Persea americana*) [37] and other intensively produced crops, such as blackberries (*Rubus* sp.), strawberries (*Fragaria x ananassa*), blueberries (*Vaccinium* sp.), tomato (*Solanum lycopersicum*) and potatoes (Solanum tuberosum), also producing hybrid maize from other regions. According to a study carried out by Cumana [106] about the land-use change in the LPB in the period 2004–2014, the agricultural area increased 7.14%, with forest being one of the lands uses partially replaced by agriculture. Considering the climatic requirements of avocado [124], it can be assumed that this crop replaced the forest area in the LPB [106]. Land-use change for avocado production has taken place at the expense of mainly native pine and oak forests, and also milpa [122], and berries greenhouses are located mainly in the basin plain, so they directly use land suitable for milpa. Table 2 shows the avocado surfaces in the municipalities of Pátzcuaro, Erongarícuaro, Quiroga and Tzintzuntzan between the years 2003 and 2018. In these four municipalities, which cover 81% of the total surface of LPB, there was a considerable increase in the avocado area, increasing 133 times in the case of Pátzcuaro, 42 in Erongarícuaro, 43 in Quiroga, and 11 times in Tzintzuntzan; additionally, in the four municipalities the total of the avocado area in 2018 was conventional production (non-organic), and the total was Hass variety, which is usually destined for export or to large urban centers [121].

Table 2. Avocado surfaces in Pátzcuaro, Erongarícuaro, Quiroga, and Tzintzuntzan, in the LPB, between the years 2003 and 2018 (Source: [121]).

Municipality	Area Planted with Avocado (ha)															
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Pátzcuaro	8	40	50	40	60	140	180	128	305	197	197	211	228	256	786	1063
Erongarícuaro	16	0	42	71	79	82	250	255	540	455	477	485	514	590	632	670
Quiroga	5	5	0	0	0	20	0	20	105	65	65	73	90	150	193	213
Tzintzuntzan	5	5	5	5	6.5	10.5	10.5	10	12	14	14	17	25	45	48	54

7.3. Traditional Agriculture—Industrial Agriculture and Emerging Complexities in the LPB

Based on the contrasting traits between traditional and industrial agriculture presented above, Toledo et al. [26] applied an index that estimates the degree of peasant-agro-industriality, corresponding 0 to high peasantness and 1 to high agro-industriality. After analyzing the 113 municipalities of the state, Michoacán obtained a value of 0.43, placing itself in a position towards the peasant. This inclination towards the traditional is related in part to enclaves of original people in the Las Cañadas area, the Nahua portion of the Michoacán coast, the Purépecha Plateau and the LPB. The three municipalities that the index revealed as the most traditional are precisely those of the Purépecha Plateau and the LPB: Charapan, Nahuatzen, and Tzintzuntzan [26]. Eighteen years after this work, the current state of the situation is not exactly known.

The LPB is culturally and environmentally complex. It is heterogeneous in population and economic activities; peasant communities share the same space with cities with population speaking and non-speaking Purépecha language, and different economic activities and land uses coexist in the landscape [37,112]. Different types of agriculture are practiced associated with different environmental conditions. There are communities more agricultural and others more forest, there are some with a larger population of native peoples than others, there are some with larger environmental heterogeneity. The arrival of a new type of agriculture, industrial agriculture, with new actors, technologies, and management, implies new heterogeneity in the LPB. Different degrees of presence and incidence of industrial agriculture are observed in the basin. While in some communities its presence is already noticeable in the landscape, such as in San Miguel Nocutzepo, Santa

María Huiramangaro, Erongarícuaro, San Juan Tumbio, or Estacion Ajuno, in other communities it is practically absent, as in San Francisco Uricho, San Andrés Tziróndaro, San Jerónimo or Santa Fe de la Laguna.

The particularities of the LPB, especially its heterogeneity, its rural and agricultural character, and the way in which industrial agriculture has arrived and expanded, coexisting with traditional agriculture [122], is leading to the emergence of various interactions, mosaics, and hybridizations. The region still shows a predominantly traditional character, with agriculture being carried out mainly by peasants in small PUs [17,37], with a tendency to increase industrial agriculture. Different types of agriculture coexist in the basin, and in the same community. Large and industrial growers imply technologies and managements as greater amount and the latest technologies for fertilization, irrigation, pest and disease control, higher frequency of cutting herbaceous plants, large greenhouses, post-harvest management, and a strong cooling and packing industry [122,125], all this coexisting with more traditional PUs and managements. Different actors also coexist, such as peasant-entrepreneurs, indigenous–non-indigenous, with their cultural contrasts. Quantitative and qualitative depeasantization has occurred in the basin. For some decades, peasants have been incorporating characteristic elements of industrial agriculture, such as the use of agrochemicals, tractors, and fossil energy, resulting in hybridizations, which corresponds to qualitative depeasantization, and more recently, industrial farmers have arrived in the basin [37,38], which corresponds to quantitative depeasantization.

Industrial agriculture is causing impacts: (1) deforestation due to the replacement of forest by avocado orchards; (2) water pollution and competition for water resources; (3) eutrophication; (4) soil erosion and possible contamination by agrochemicals; (5) replacement of crops of cultural and nutritional importance; (6) increased greenhouse gas emissions [38,122]; (7) exclusion of spaces that were of free movement in the peasant communities; and (8) feeling of local insecurity in the face of new, external and unknown actors. In addition to such impacts, certain connections occur between industrial PUs and traditional PUs: (1) employment of labor. Some members of peasant families who worked in their own traditional PU, now go on to work as wage earners in industrial agriculture, usually as seasonal workers in avocado orchards or berry greenhouses, or combining work in both types of agriculture, occurring some work hybridization; (2) purchase of peasant land by industrial farmers or investors. For now, there are no connections between both that imply the exchange of materials or equipment, knowledge and skills, or co-ownership. On the other hand, in the basin there is little organizational innovation by local actors to strengthen traditional agricultural production, innovating in commercialization and exchange opportunities, including some not-market based. Examples of this would be self-managed local fairs, coordination and agreements between organized farmers and consumers, new forms of diffusion using new technologies to attract other buyers and tourists, cooperation between farmers from different communities, combine crop production with offering traditional dishes at fairs or local kitchens, selling product baskets, among others. A planning and management culture of local authorities that seeks to establish dialogues and partnerships with local communities, and develop new forms of coordination, is key [83]. Table 3 shows a synthesis of the emerging effects with the arrival and increase of industrial agriculture in the LPB and the respective expressions and concretions.

Table 3. Emerging effects with rural and agricultural modernization and industrialization (RAMI) and the arrival and increase of industrial agriculture in the LPB, and their expressions and concretions.

Effect	Expressions and Concretions in LPB
New heterogeneity	➢ New actors ➢ New technologies ➢ New management and practices
New coexistences	➢ Between different types of agriculture, and their technologies and management ➢ Between different actor, as

	✓ peasant-entrepreneurs ✓ original–non-original people
Qualitative and quantitative and depeasantization	➢ Peasants have been incorporating elements characteristic of industrial agriculture (qualitative) ➢ Industrial farmers and PUs have arrived to the basin (quantitative)
Main impacts of industrial agriculture	➢ Deforestation ➢ Water pollution and competition for water resources ➢ Eutrophication ➢ Soil erosion and possible contamination by agrochemicals ➢ Replacement of crops of cultural and nutritional importance ➢ Increased greenhouse gas emissions ➢ Exclusion of spaces that were of free movement in the peasant communities. ➢ Feeling of local insecurity in the face of new and unknown actors
Interactions and connections between industrial PUs and other more traditional PUs	➢ Employment of labor. Members of peasant families who worked in their own traditional PU, now go on to work as wage earners in industrial agriculture, usually as seasonal workers in avocado orchards or berry greenhouses. ➢ Purchase of peasant land by industrial farmers or investors. ➢ There are no connections that imply the exchange of materials or equipment, knowledge and skills, or co-ownership.

The context conditions associated with the Mexican neoliberal reform, and the arrival and increase of industrial agriculture in the LPB with its emergent effects and their expressions and concretions (Table 3), have influenced some peasants to have incorporated elements into their PUs such as mechanized machinery, agrochemicals, industrial feed for livestock, improved seeds and/or livestock, financial support, and occasionally non-creole avocados (Table 1). The implications on the functioning of the PUs of such incorporations and the consequent hybridizations that have occurred with agricultural industrialization in the LPB, that is, the increased use of energy fossil (non-renewable) external to the system, and the decreases of the system's energy efficiency, system's self-sufficiency, and occasionally system's diversity (Table 1), negatively affect sustainability. Along the same lines, industrial PUs also are negative for sustainability in LPB, mainly the impacts mentioned in Table 3. In this way, we can relate the contextual conditions associated with the Mexican neoliberal reform with the arrival and increase of industrial agriculture in the LPB (industrial PUs) and with the incorporation of industrial traits in the PUs (hybridizations), thus addressing RAMI processes and phenomenon in a comprehensive way. In general, all these different effects and impacts at different levels and scales, be they political, socials, land-use change, agricultural practices, or others, tend to result detrimental to sustainability (Figure 4). They are also detrimental to sustainability the scarce development of complementary connections between traditional and industrial PUs, and little organizational innovation and in commercialization by part of local actors such as farmers, communities, NGOs, among others. In addition, as peasants lose their land, there will also be a decrease in food self-sufficiency at rural household level and regional level. Finally, we can visualize RAMI in the LPB real case comprehensively, interrelating all multiscalar different processes posited in this article, that is, mosaics, interactions, hybridizations, tensions, and the consequent different types derivations, as subjugation, grabbing and dispossession, complementation possibilities, and different agriculture types, forming a complex whole. This approach and vision differs from a linear and unidirectional one, as RAMI has sometimes been visualized and posited, without more options than just the combination of traits or aspects of traditional and industrial agricultures (Figure 5).

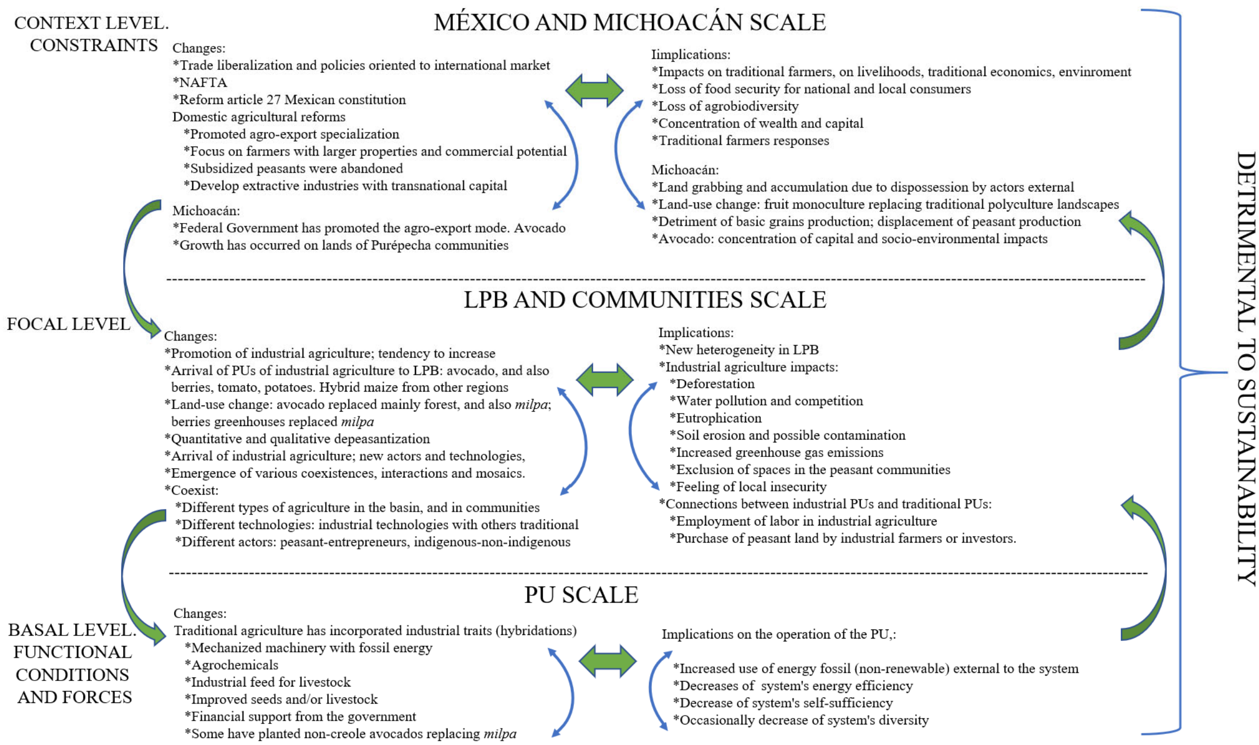

Figure 4. RAMI-related change processes at different levels and scales, from Mexico to the PUs of LPB, represented in a nested multi-scale complex hierarchy. While the changes at the level of Mexico and Michoacán began in the 1970s, the arrival of industrial PUs to the LPB began at the beginning of the present century. In general, the effects and impacts presented here, at different levels and scales, be they political, socials, land-use change, agricultural practices, resource management (such as forest and land), or others, tend to result detrimental to sustainability. The changes at the contextual level, that is, in Mexico and Michoacán, political, economic, sectoral, and social changes, establish constraints conditions to the operation of the LPB (top-down), and changes at the basal level; that is, in the PUs, corresponding to the hybridizations associated with the incorporation of industrial traits, provide the conditions and functional forces to the LPB (bottom-up). All these levels are nested interrelatedly as parts of a complex whole, from a comprehensive approach.

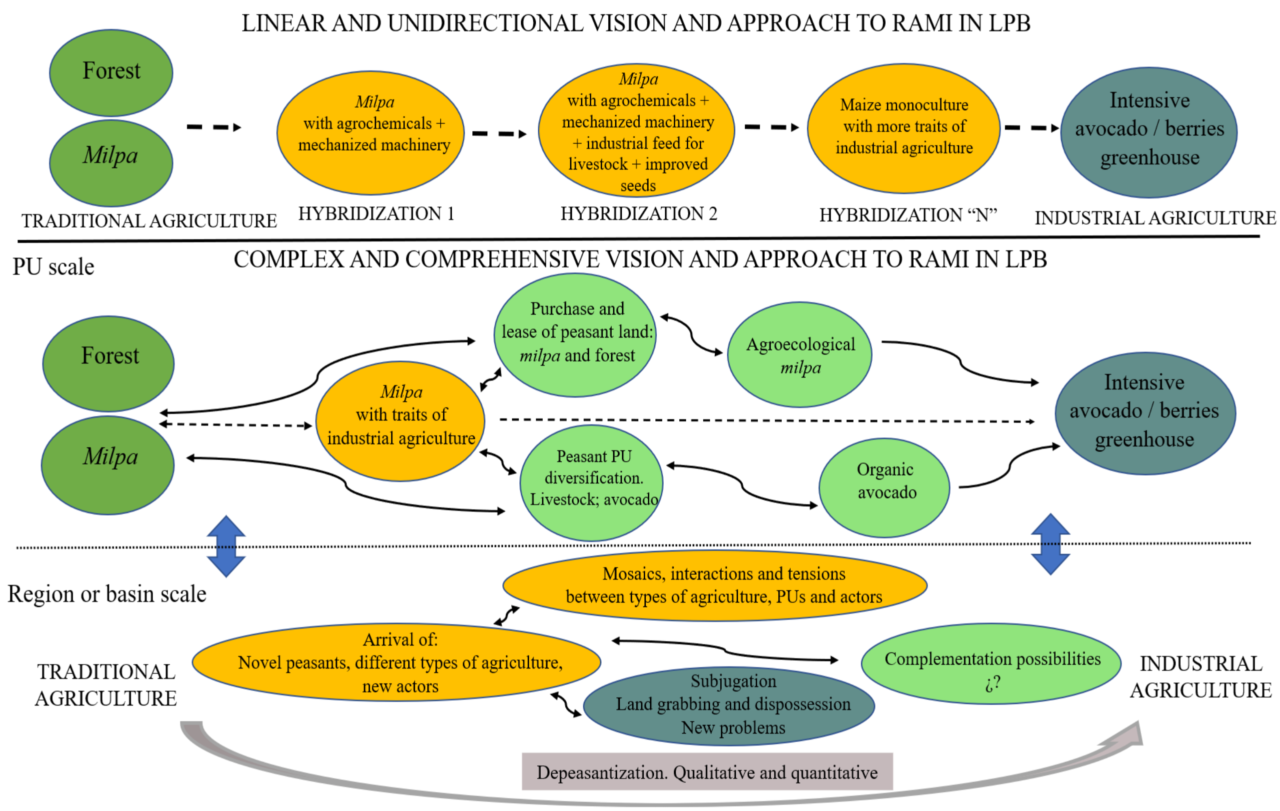

Figure 5. Model of RAMI in LPB real case, contrasting a linear vision and approach with respect to a complex and comprehensive one, as was developed and applied in this study. While in the first one RAMI is conceived as unidirectional, just going from the traditional to the industrial, in the second approach it is conceived as the integration of different interrelated, multidirectional and multiscalar processes, forming a complex whole. With RAMI, the region is declining in peasantinity, that is, is increasing in agro-industriality, in a process of depeasantization. While from the linear and unidirectional vision and approach such process is seen like just the transformation from milpa and forest to berries greenhouses and intensive avocado orchards, from the complex and comprehensive vision and approach that looks different. Be able to be perceived peasant PUs diversifying with the incorporation of livestock and/or avocado, milpas with traits of industrial agriculture in different degrees (hybridizations), peasants renting or selling their lands of milpa or forest in different parts of the basin, organic avocado orchards, all these processes in a network of multidirectional interrelations, including also at the basin or regional scale the emergence of new peasants, the arrival of new actors and types of agriculture, the generation of mosaics, interactions, and tensions between such actors and types of agriculture, and different derivations both cultural, social, economic, environmental, well-being, and quality and lifestyle. New possibilities (as possible complementations between different types of agriculture, which in LPB are scarce and uncertain) and also new problems (as subjugation, grabbing and dispossession, and exclusion and insecurity) emerge for rural development and sustainability; that is, new complexities emerge.

8. Conclusions

Like the evolution of science, rather than accumulating information on traditional and industrial agriculture, and the effects of RAMI, it is crucial to address the problem from an adequate approach. This modernizing process is multiscale, with different processes of change and variables at each scale. While at the PU scale there is a transition from traditional agriculture to industrial agriculture through the incorporation of traits of the latter, and also the interaction and combination of different types of agriculture, at higher scales, such as basin, region, or other territorial unit, larger industrial PUs arrive that transform the rural landscape and emerge tensions and problems such as subjugation, land grabbing and dispossession by actors external to communities, concentration of capital, exclusion and insecurity, and loss of autonomy and food security.

RAMI processes have not been linear or unidirectional, but hybridizations and mosaics have been generated between traditional and industrial agriculture and different types of agriculture. More than one type of agriculture that replaces another in a uniquely homogenizing process, it has been processes of transition, multidimensional transformation, and interactions with new emerging heterogeneities. Regional rural development can benefit from different interconnected types of agriculture, and thus move towards a possible convergence between modernization and co-constructed sustainable rural development. We must approach the processes of world construction as a collective construction, considering the interaction between different actors and their perspectives and perceptions, and not imposing visions and interests or modernizing processes.

Transdisciplinarity and the paradigm of complexity provide elements to approach modernization in a comprehensive manner, integrating knowledge from different scientific fields and disciplines as well as traditional non-scientific knowledge. It is key to properly perceive a phenomenon to deal with it. Perceiving different interacting levels of reality and from the dialectical confrontation between opposites, the coexistence and interaction between traditional agriculture and industrial agriculture can be approached not as merely dichotomous and antagonistic but at the same time as complementary. Thus, depeasantization and repeasantization, industrial agriculture and traditional agriculture, traditional knowledge and scientific knowledge, actors with different cultures and perceptions, among others, be complementary. For this, an integrative approach is required and not a dichotomous one, which allows us to re-understand modernization and emerging complexities. The levels of reality, the included middle logic, and the dialectic, allow us to perceive and address the coexistence, interaction, tension, and possible complementation between industrial agriculture and traditional agriculture, and the emergence of an included middle that does not correspond to traditional agriculture or to industrial agriculture. However, what arises is not only an intermediate state, but an "emerging complexity", which corresponds to the hybridizations resulting from the different combinations of traits typical of traditional agriculture and others of industrial agriculture and the coexistence and interaction of those hybridizations and different types of agriculture in the LPB and other regions of the world. Thus, it is possible to go beyond the Aristotelian logic (traditional agriculture or industrial agriculture) and the included middle logic (traditional agriculture and industrial agriculture, and a third that emerge from the coexistence and complementation between both), being able to be perceived with a look closer and finer, not three situations but a greater variety of situations tending to interrelate with each other, that is, an emerging complexity. In short, the epistemological approach and positioning developed and presented in this article allow us to perceive, and thus consider and incorporate in the analysis and reflections, the emerging complexities from the RAMI processes, corresponding to an own approach and positioning of transdisciplinary sustainability research.

Such as approach allow us moving from one level to another, from the perspective and perception of some actor to another and integrating opposites. In this way, allows to perceive heterogeneities, differences, and at the same time link them, and to conceive the complementary coexistence of antagonistic elements and processes as part of the identity constitution of a territory, landscape, or region. This approach allows perceiving new possibilities and research lines for rural sustainability.

The history and rural, agricultural and peasant character of the LPB, and its environmental and cultural heterogeneity, are adequate to address RAMI in all its multidimensionality and complexity. The rural landscape transformation associated with RAMI implies new heterogeneity. The region still shows a predominantly traditional character, but with different degrees of modernization and increase of industrial agriculture. There has been quantitative and qualitative depeasantization, hybridizations between traditional and industrial agriculture, and different coexistence has emerged: between different types of agriculture; between different actors, such as peasant-entrepreneurs, original–non-original people, with their cultural contrasts. Although there is some interaction between industrial PUs and more traditional PUs, the connections that can be observed between both for now are scarce, and its development is uncertain. For complementary connections between traditional and industrial agriculture or other agricultures types can be developed, an effective dialogue is required between the corresponding actors, a participatory land use planning and design adjusted to local skills and needs, and a governance with multi-sector and multi-actor interaction, knowledge complementation, and mutual learning processes. In this way, synergies between the PU-scale modernization process and regional development can be fostered and thus achieve a co-construction of regional sustainable rural development.

Among the relevant topics and questions regarding the problem that is addressed in this article, the following stand out: (1) governance and alignment of modernization with rural sustainability, What is the role and how can industrial agricultural models and PUs contribute to construct connections and synergies with other more traditional types of agriculture, conducive to more sustainable rural development? How can such connections and synergies be fostered and realized, in order to align modernization with rural sustainability?; (2) peasant communities and their perception, How do the peasants of the communities perceive industrial agriculture and associated actors, and their arrival in the territories they inhabit?; (3) social justice, what is the role and how can industrial agricultural models and PUs contribute, coexisting and interacting with other more traditional types of agriculture, in reducing the poverty gap and construct more equitable life conditions?; (4) institutions and public policies, What is the role of the State in relation to the coexistence and interaction between different types of agriculture and rural actors? What incentives, supports, norms and regulations are required?; (5) food sovereignty and security, What is the role and how can industrial agricultural models and PUs contribute to these objectives, coexisting and interacting with other more traditional types of agriculture?; (6) academia and science, How do we generate an research according and sensitive to the concerns of the peasant communities that inhabit the territories where industrial agriculture and associated actors have arrived, addressing it comprehensively?; and (7) sustainability, How does RAMI and the arrival and increase of industrial agriculture affect rural sustainability, considering the perception of the local peasantry, the local environmental, cultural and socio-economic particularities, and the inherent multidimensionality and multiscalarity of that phenomenon?, How can systems of monitoring and assessment to report on the socio-environmental conditions in complex rural systems with coexistence and interaction of different types of agriculture and actors and with new emerging complexities (as those shown in this article), in order to co-construct a more sustainable rural development? All the above, especially in the context of Latin America and Mexico.

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