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Transcending the Locality of Grassroots Initiatives: Diffusion of Sustainability Knowledge and Practice through Transdisciplinary Research

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Abstract: Community-based approaches to natural resource management are being discussed and experienced as promising ways for pursuing ecological conservation and socio-economic development simultaneously. However, the multiplicity of levels, scales, objectives and actors that are involved in sustainability transformations tends to be challenging for such bottom-up approaches. Collaborative and polycentric governance schemes are proposed for dealing with those challenges. What has not been fully explored is how knowledge from local contexts of community-based initiatives can be diffused to influence practices on higher levels and/or in other local contexts. This study explores how theoretical advances in the diffusion of grassroots innovation can contribute to understanding and supporting the diffusion of knowledge and practices from community-based initiatives and proposes a transdisciplinary approach to diffusion. For that aim, we develop an analytical perspective on the diffusion of grassroots innovations that takes into consideration the multiplicity of actors, levels and scales, the different qualities/types of knowledge and practices, as well as their respective contributions. We focus on the multiplicity and situatedness of cognitive frames and conceptualize the diffusion of grassroots innovations as a transdisciplinary process. In this way three different diffusion pathways are derived in which the knowledge and practices of grassroots initiatives can be processed in order to promote their (re)interpretation and (re)application in situations and by actors that do not share the cognitive frame and the local context of the originating grassroots initiative. The application of the developed approach is illustrated through transdisciplinary research for the diffusion of sustainable family farming innovations in Colombia. This conceptualization accounts for the emergence of multiplicity as an outcome of diffusion by emphasizing difference as a core resource in building sustainable futures.

Keywords: grassroots innovation; strategic niche management; sustainability transitions; innovation diffusion; diffusion pathways; difference

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1. Introduction

Community-based approaches to natural resource management are being discussed and experienced for several decades as promising ways for pursuing both, the ecological conservation of ecosystems, as well as the well-being of the population that inhabits those territories [1,2]. They are often presented as alternatives to top-down conservation programs controlled by national governments—such as the establishment of protected areas—which were the most common responses to the depletion of ecosystems during the last century [3]. One central argument for community-based approaches is the observation that the livelihoods of millions of rural households and communities are intrinsically tied to and dependent upon local ecosystems [4]. A common feature of these approaches is the recognition of local communities' potentials as sources of knowledge and as the locus of actions that can significantly contribute to transformative processes [5]. In this way, local

communities become involved in processes for "alter[ing] institutions, technologies, policies, perceptions and behaviors" [6] (p. 17) with the aim of mobilizing diverse knowledge and experiences for inducing sustainability transformation in the complex socio-ecological systems they inhabit.

While the arguments for community-based approaches to natural resource management are compelling and relevant, their limitations have also become apparent with the increased number of studies of empirical experiences. A coherent synthesis of the limitations of community-based approaches is given by Berkes [7], who points at their difficulty to recognize and deal with the multiplicity of levels, scales, objectives and actors that are inextricably linked with the aim of managing natural resources for sustainability goals. Therefore, he postulates the importance of building vertical and horizontal interlinks. The vertical dimension refers to the hierarchical organization of both ecological as well as social systems and to their common feature as complex systems, which implies that "the levels are linked, but that each level requires diverse concepts and principles". The horizontal dimension refers to the importance of context in understanding and acting upon particular cases, because "each case is conditioned by the context in which it developed, meaning a solution package developed from one case cannot readily be transferred to others" [7] (p. 15188). Since then, a clear shift toward collaborative and polycentric governance schemes for natural resource management can be observed [8]. The focus has been mostly on the processes and arrangements for making decision. This can be seen as a result of the increased recognition of the multi-level feature of the challenge to manage natural resources. Less attention has been put on the processes by which the set of knowledge and practices that emerged in the specific local context of community-based natural resource management initiatives can flow and eventually influence management practices on higher levels (vertical interlinks) and/or in other local contexts (horizontal interlinks).

In order to deal with that gap, we propose to adopt an innovation perspective towards initiatives for natural resource management. Indeed, the notion of innovation resonates in the co-evolutionary perspective on natural resource management, in which "environmental changes will partly be related to adjustments and adaptations that emerge within the socio-economic systems in terms of altered institutions, technologies, policies, perceptions and behaviors" [6] (p. 17). In the same vein, an innovation perspective to sustainable natural resource management comprises the adoption of novel institutions, technologies, policies and behaviors, which aim at inducing changes in the unsustainable dynamics of the socio-ecological systems in which they are deployed. We propose to explore how theoretical advances in the diffusion of grassroots innovation can contribute to understanding and supporting the building of vertical and horizontal interlinks in community-based sustainability initiatives

The aim of this study is to develop an analytical perspective on the diffusion of grassroots innovations that takes into consideration the role of the multiplicity of actors, levels and scales, the different qualities/types of knowledge and practices and their respective contributions. The paper is conceptual and provides a brief description of a case study in which the authors engaged with grassroots innovation initiatives with the aim of studying *and* fostering diffusion through transdisciplinary research.

The paper is structured as follows. In the Section 2, we review scholarly work that builds and operationalizes the concept of grassroots innovations, based on theoretical insights from strategic niche management. Particular attention is paid to the cognitive frame concept, which is central in this literature in order to explain diffusion. The Section 3 highlights the importance of considering the multiplicity and situatedness of cognitive frames to understand the diffusion of grassroots innovations. In the Section 4, we reconsider and reconceptualize the diffusion pathways by emphasizing difference, in terms of different ways of knowing, acting and being. This leads us to the conceptualization of grassroots initiative-based transdisciplinary research spaces for fostering innovation and diffusion. In the Section 5, an empirical example of how the proposed perspective can be operationalized is briefly discussed. The discussion focuses on illustrating how the research process allowed

the recognition of the multiplicity of contributions that are being nurtured by grassroots initiatives and supported the wider diffusion of their lessons. The Section 6 summarizes the proposed conceptualization for transcending the locality of grassroots sustainability initiatives through transdisciplinary research.

2. Conceptualizing the Diffusion of Grassroots Innovation

Grassroots innovation initiatives are spaces for civil society reflection and action for advancing sustainability. They are conceptualized as "networks of activists and organizations generating novel bottom-up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved" [8] (p. 585). They provide space for articulating alternative understandings of sustainability and for crafting practical alternatives for its realization that are not aligned to the mainstream systems of consumption and production. Grassroots innovations are often described in contrast to mainstream "market-based" innovations. Table 1 summarizes the characteristics of grassroots innovation based on Seyfang et al. [9]: the guiding motivation (social and/or environmental concerns rather than profit and securing jobs); the context in which sustainability innovations are expected to be implemented (civil society rather than market economy); the organizational forms involved in the innovation process (associations rather than companies); the values underlying the search for innovation (solidarity and sustainability rather than efficiency and profit); and the resource base for advancing innovation (voluntary contributions, reciprocal relationships and grants rather than commercial loans and access to research and development infrastructure).

Table 1. Characterization of grassroots innovations in contrast to market-based innovations, based on Seyfang et al. [9].

	Grassroots	**Market-Based**
Motivation	Sustainability, social justice, environmental concerns	Profit, securing jobs
Context	Civil society	Market economy
Organisational forms	Cooperatives, associations, community initiatives, social movements	Companies
Resource base	Voluntary contributions, mutual learning, reciprocal relationships, grant funding	Business loans, commercial incomes, R&D infrastructure
Primary values	Solidarity, strong sustainability	Efficiency and profit

Over the last decade, scholars researching grassroots innovation have applied and expanded conceptualizations of sociotechnical niches to understand the role of these innovation initiatives in broader transitions towards sustainability. Several recent studies have focused on grassroots initiatives seeking innovative ways to tackle sustainability challenges in different fields, such as energy [9–11], food [12,13], communications [14], farming practices [15], complementary currencies [16,17] and eco-housing [18]. Most of them have taken theoretical insights from strategic niche management as the conceptual basis for their analysis. In the following section, we present theoretical developments from that strand of literature. Thereby the focus is set on those concepts and models that attempt to explain diffusion.

2.1. The Development of Sociotechnical Niches

The development of sociotechnical niches is conceptualized around four main aspects: protection, co-evolution, internal niche-building processes and two-level development. *Protection* is a fundamental property allowing for experimentation with novel approaches that do not meet the sociotechnical arrangements and assumptions of the conventional systems of production and consumption. Protection implies shielding the innovation from a broad set of societal selection processes, such as industry structure, infrastructure, dominant

practice, technological paradigms, policies, political power and cultural values [19]. The experiences gained by experimenting with novel approaches allow for testing, validating and—when needed—adjusting not only the technical qualities of the innovation, but also learning about the social realm in which they are embedded [20]. The *co-evolution* of non-technical aspects seems to be particularly important for the development of grassroots innovations. For instance, organizational practices and skills have been highlighted as crucial resources for the emergence and consolidation of single initiatives [9] and as a field of experimentation to strengthen and maintain long-lasting initiatives [15]. This co-evolution is promoted through three *internal niche-building processes*: (i) by consolidating lessons on both the technical and social dimensions of the innovation (learning); (ii) by maintaining and expanding the network of actors supporting the niche (networking); and (iii) by creating and communicating narratives about the future in which the niche innovations play a crucial role (articulating expectations). These niche-building processes lead to the aggregation of knowledge and experiences from different single initiatives and projects, and the consolidation of a "community that shares cognitive, formal and normative rules" [21] (p. 543). In this way "[l]ocal practices become part of a stabilized global technological regime, from which it is hard to deviate" [22] (p. 268). Thus, the progress of the niche community is conceptualized as *two-level development*: the local level, which represents the set of single projects in which niche actors engage in experimenting with innovations, and the global level, which represents the institutional infrastructure that facilitates and promotes the aggregation, storage and circulation of generalized knowledge.

2.2. Diffusion Pathways of Niches' Innovations

The formation of the global niche level is crucial for explaining the diffusion of niche innovations. The development of the global niche level is conceptualized as the process by which a shared cognitive frame evolves. Cognitive frames consist of "problem agendas, problem-solving strategies, search heuristics, theories, testing procedures, and design methods and criteria" [23] (p. 89). They serve as endogenous determinants for their own evolutionary process, i.e., how sociotechnical variation, selection and retention take place. Variation is guided by shared expectations about novel (better, more sustainable) solutions and these variations are tested through diverse local projects, the outcomes of which are collectively interpreted and codified. This implies a social process of selection (comparing locally achieved outcomes to shared expectations) and retention (embedding meaningful data from local experiences into the abstract cognitive frame). In the ideal development of niches, cognitive frames evolve and stabilize, providing a repertoire of de-contextualized knowledge that can guide action for a larger set of local contexts [22].

Based on this conceptualization, Seyfang and Longhurst [17] suggest three diffusion pathways through which innovative ideas and practices nurtured in the niche can diffuse:

(1) Growth in scale: de-contextualizing knowledge helps single local initiatives reframe themselves, enabling the expansion of their own coverage. Diffusion is linked to the successful growth of single initiatives that are likely to gain high shares of the corresponding niche markets.
(2) Replication: the process by which generalized knowledge is applied to establish initiatives in new locations where the (increasingly) stable cognitive frame is enacted and reproduced.
(3) Translation: the circulation of innovations (or some elements of them) beyond the niche where they have been nurtured. The focus is on the interactions between the niche and regime levels. Analytically this interaction implies the encounter of different—and potentially contradictory—cognitive frames.

In a similar vein, Naber et al. propose a typology that comprises four patterns by "which experiments can scale-up and diffuse innovative solutions" [24] (p. 344). Naber et al. complement growth in scale, replication and translation with accumulation, which "means that an experiment gets linked to other experiments". The lessons learned in different experiments and contexts can be compared and aggregated, which in turn "contribute[s]

to a more stable technological trajectory at the global niche level". The patterns proposed in the socio-technical niches literature focus on how projects (or experiments) can evolve, rather than on the transits of the multiple components of the innovations. Those pathways describe possible strategies for inducing diffusion through the re-configuration of single initiatives, i.e., by growing, replicating or accumulating them. However, they do not provide theoretical foundations for understanding how vertical and horizontal interlinks can happen. That is, they offer little explanation of how knowledge and practices of grassroots initiatives can eventually transcend the locality in which they are nurtured and become meaningful for other actors, at different levels and on different scales.

2.3. Revisiting the Diffusion Concept for Grassroots Innovation

At this point, it is reasonable to recall that innovation diffusion implies that the novel knowledge, practices and/or artifacts get deployed in meaningful ways by the new adopters. The case in focus here is that of innovations that emerged in grassroots sustainability initiatives. In such initiatives, alternatives to a sustainability problem (such as the provision of energy or food or the management of natural resources) are crafted and experimented with. This results in the circulation, application, selection and retention of new ideas, practices and/or artifacts among the participants of the initiatives. Diffusion is then a process by which all or some of those novel elements not only get known beyond the initial initiative but in which they are also deployed by and become meaningful for actors beyond that site of innovation. The cognitive frames concept is key in understanding this process, because—as described before—cognitive frames provide social actors with procedures of sense-making applicable to a specific range of situations and contexts. Thus, successful adoption of innovations might require adjustments in the cognitive structures of the adopting agents. Particularly when the new potential adopters do not share the same context as those who were involved in the crafting and/or validation of the innovation. In order to deal with this challenge, the literature on socio-technical niches foresees a process in which the multiplicity of cognitive frames is reduced and aligned towards an increasingly generalized and de-contextualized repertoire of knowledge.

This focus on streamlined processes and consensual decisions does not properly account for the plurality and emergent dynamics that characterize how grassroots initiatives evolve [25], nor the multiplicity of mainstream practices (incumbent regimes) that are often challenged by grassroots innovations [13]. Moreover, empirical studies have shown that—when diffusing towards mainstream regimes—only those elements of niche innovations that are more compatible with the cognitive frames and purposes of the incumbent regime are appropriated by regime actors [12,26]. Controversial elements from grassroots initiatives with greater transformative potential (such as critical knowledge or strong sustainability criteria) tend to be sorted out in the process. Here too, the mechanism of diffusion elaborated by the niche theory features a consensual orientation in which deviation is avoided or dismissed. The linkages between the different levels, scales and actors are then explained through a process, in which the differences get reduced. In order to advance a better understanding of the diffusion of grassroots innovations, we propose to take a closer look at the cognitive frame concept, highlight its multiplicity and situatedness, and analyze the implications of recognizing those features in detail.

3. The Multiplicity and Situatedness of Cognitive Frames

When tackling the diffusion of grassroots innovations, the multiplicity and situatedness of cognitive frames, as well as their dynamics and permeability, are relevant. This is because the way in which one's own and others' knowledge and experiences are interpreted, evaluated and appropriated is moderated by the cognitive frames that the actors bring to and incorporate into the process.

We propose shifting attention to the multiple cognitive frames that can operate in settings aiming for the diffusion of grassroots innovations and differentiate them by means of their level of generalization. To clarify what is meant by the level of generalization,

we recall the notion of rules as "generalizable procedures" and the situatedness of actors applying those rules. The rules of social life can be considered "generalizable procedures applied in the enactment/reproduction of social practices" [27] (p. 21). A rule is considered "generalizable because it applies over a range of contexts and occasions, [and] a procedure because it allows for the methodical continuation of an established sequence" [27] (p. 20). Thus, the level of generalization of social rules is determined by the range of situations in which they can be applied for building meaning and guiding action. Similarly, the usefulness of a rule for an actor is determined by the specific situation of that actor. At the global niche level, learning from the outcomes of local projects is "a process of collective and negotiated sense making" [23] (p. 89). The global niche's cognitive frame comprises elements such as problem agendas, shared expectations and criteria, by means of which single experiences and knowledge are interpreted and assessed. The resultant meanings and values are expected to be valid for the community of niche actors, i.e., for those who constitute the niche and share the niche's specific cognitive frame. However, a single niche actor can also be a member of a local initiative, which in turn comprises (or continuously produces and reproduces) its own cognitive frame. Situated in the local initiative, the same actor might adhere to other interpretations and valuations of the same concrete experience. For instance, an interpretation of a problem can be enriched with local specificities, which can lead to another set of valuation criteria. Therefore, cognitive frames can be characterized by the range of situations for which they provide useful procedures of interpretation. The larger that range, the higher the generalization level of the cognitive frame.

Having recognized the multiplicity and situatedness of cognitive frames involved in diffusion processes, we must consider in greater detail the settings in which the processing of knowledge and experiences of the different actors and local conditions take place. Such diffusion settings can be visualized by mapping the cognitive frames on two coordinates: the vertical illustrating variation in the level of generalization and the horizontal representing the multiplicity of cognitive frames that can feature similar levels of generalization. Figure 1 illustrates this and presents examples of the generalization levels previously described: local initiatives, global niche level, regimes and scientific theories.

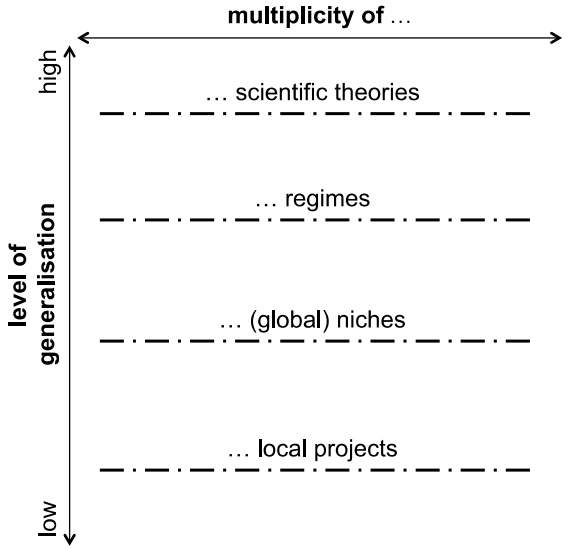

Figure 1. Mapping space for visualizing settings of knowledge articulation aiming for diffusion. The dashed lines represent different levels of generalization on which multiple cognitive frames can be found.

The mapping space in Figure 1 opens the possibility to emphasize difference and understand diffusion as a process that can be oriented in different directions (not only towards generalization) and promoted by settings in which multiple cognitive frames interact.

4. Diffusion as Transdisciplinary Knowledge Articulation

At this point, insights from discussions on transdisciplinarity can shed light on the implications of striving to generate and diffuse knowledge by involving different cognitive frames, i.e., producing knowledge that builds on differences and can be understood and applied by all involved parties to advance shared visions and actions in sustainability transition. Transdisciplinary research practices differ significantly in terms of how those aspirations are realized. While some propose and apply a science-centered approach, in which scientific knowledge production is complemented by participatory processes and contributions from so-called non-scientific actors [28,29], we call for a critical and culturally sensitive transdisciplinarity where analysis and activism, research and decision-making as well as knowledge production and societal transformation at large are no longer separated, but considered and articulated as constitutive components of the same process [30–33]. This can be seen in knowledge alliances [34] where different cognitive frames, motives and objectives are explored, articulated and debated to produce socially [35] and culturally [30] robust knowledge and action. Not only the multiplicity and situatedness of knowledge but also the dynamics generated in mutual learning processes [15,30] create a promising approach for the diffusion of sustainability innovations. In this way, the permeability of cognitive frames also becomes important for understanding and achieving diffusion. Spaces of knowledge articulation can emerge "[i]n which the own, the uncertain and the differences can perpetually be fathomed, interpreted and negotiated" [31] (p. 174); i.e., spaces that are constituted through different ways of approaching sustainability challenges.

Within the scholarly discussions on transdisciplinary research, some attention has been paid to the question of the transferability of knowledge among different cases [36,37]. The focus here is on assessing under which conditions and how the knowledge co-produced by researching one case can be applied to other cases. For that aim, Adler et al. conceptualize this type of knowledge transfer "as an analogical inference that is assessed regarding its strength or plausibility by investigating the relevant similarities and dissimilarities between the cases at hand and weighing them" [38] (p. 188). Thus, assessing the transferability of knowledge implies the explicit consideration of what factors are perceived as "necessary, sufficient or supporting" for the actual constitution of the cases. The aim of the present study (i.e., to understand and support the diffusion of knowledge and practices from grassroots initiatives) features some similarities with those discussions on the transferability of knowledge co-produced in transdisciplinary research. Two central issues can be highlighted here: (a) The spaces for knowledge articulation proposed here have the diffusion of innovations as their central subject. In this way, the question of transfer is internalized. The transit of knowledge (but also of practices and other elements of innovations) from one case to another is the main aim of the transdisciplinary process. Moreover, this transit is not restricted to a horizontal movement from case to case, which for the present study implies transits from one grassroots initiative to another. Transits to different levels of generalization (as conceptualized above) can be also pursued. (b) The importance of the actual constitution of the cases (their similarities and dissimilarities) for assessing the applicability of knowledge is resonating with our observation of the centrality of the cognitive frame when explaining the diffusion pathways of grassroots innovations. It is in this sense that the proposed spaces of knowledge articulation are conceived in order to allow for and foster the (re)interpretation of grassroots innovations through diverse cognitive frames.

Thus, taking a transdisciplinary perspective on diffusion, the focus shifts from stabilizing single cognitive frames to creating spaces of knowledge articulation where diverse cognitive frames engage. In applying the outlined perspective to the diffusion of grassroots innovations, we must consider in greater detail the settings in which the processing of knowledge and experiences of different actors and local conditions take place. In the following section, we derive conceptual elaborations of three generic types of transits and the knowledge articulation settings that can promote them.

4.1. Transits towards the Global Niche Level

To increase the certainty that the knowledge can be understood and applied by all actors supporting the shared vision of sustainability transformation, a diffusion process should involve the cognitive frames of those supportive actors. Figure 2 illustrates such a process, in which the experiences of one local initiative provide the basis for mutual learning about the sustainability issue of concern (schematically illustrated as a solid-line circle at the local project level). By interpreting the local experiences through different cognitive frames, the process promotes an in-depth understanding of the complexity and situationality of the local experiences, as well as the extraction of generic knowledge about the sustainability issue in question (schematically illustrated as a dotted-line circle at the global niche level). The robustness of this knowledge can be fostered by articulating interpretations from different cognitive frames; for instance, those embodied by: (a) representatives from other local initiatives and intermediary organizations actively engaged with the sustainability issue of concern; (b) regime actors with some interest in and/or relevant resources for advancing that issue; and (c) scientists with the disciplinary knowledge and expertise to better understand relevant aspects of the local initiative and its relation to more general sustainability discourses. The cognitive frames of such actors are schematically mapped in Figure 2 as reference points from which the local initiative is observed (dotted lines) and reflected on (solid-line arrows), towards the generation of a collective knowledge repertoire. The arrowheads pointing back at each cognitive frame indicate the self-reflection and learning that are a constitutive part of the knowledge articulation process.

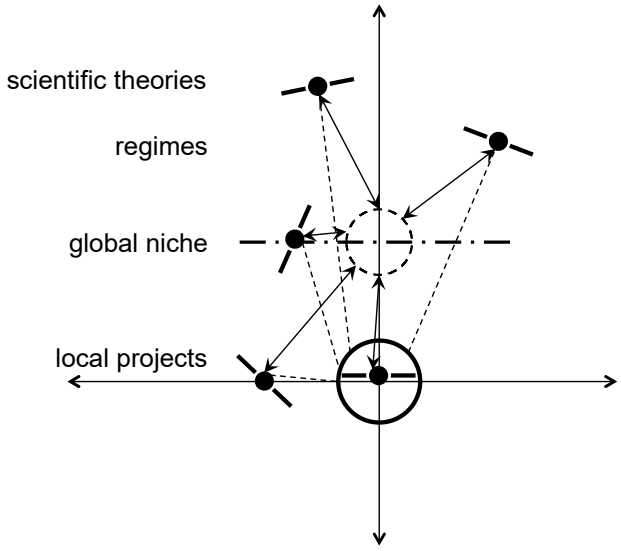

Figure 2. Knowledge articulation setting for extracting generic lessons from a single local initiative.

The actual composition of the setting illustrated in Figure 2 varies according to the subject and target of diffusion. For instance, if the focus were on the consolidation and mobilization of critical knowledge about deeper structural issues in society and politics, expertise on how to feed into the political debate, as well as knowledge about the structures and processes by which political decisions are made and implemented, would be the most relevant. Consequently, in this case, it would be meaningful to involve actors such as staff from state administration agencies, representatives from political parties and/or leaders of social movements. Contributions from scientific fields such as sociology, political sciences and public administration would also be appropriate. Taking opposing perspectives into account also contributes to the robustness of the results. Such a process should allow for the respectful recognition of contradictions and discrepancies. The aim is not necessarily to quash the opposing view or to integrate it into the generic knowledge generated but to make it explicit and consider it in relation to the more certain and consensual pieces of the collective knowledge repertoire.

4.2. Transits towards Local Contexts

A setting that aims to promote the re-contextualization and re-application of knowledge and practices of innovative grassroots initiatives in different local contexts is illustrated in Figure 3. Here, the re-contextualized knowledge and practices are schematically illustrated as a dotted-line circle. In the illustrated example, the basis for the process is obtained from the knowledge, experience and expertise gained from an exemplary case (illustrated as a solid-line circle). This could be a civil society initiative with advanced results in the sustainability issue of concern. Here too, the transit is conceived as a process involving diverse cognitive frames (illustrated as reference points at different levels of generalization) that can provide useful perspectives for the re-application of sustainability knowledge and practices in the context of the new local initiative.

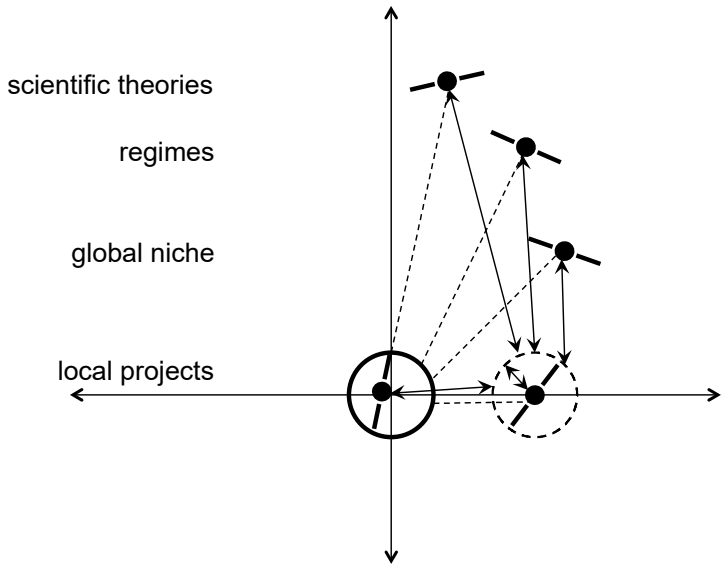

Figure 3. Knowledge articulation setting promoting re-contextualization of knowledge and practice from one local context to another.

As with transits towards global generic knowledge, the composition of the setting for promoting replication depends on the subject and target of diffusion. However, it appears in this case that the target is particularly pertinent, specifically in terms of the state of the initiative(s) expected to adapt and adopt innovative sustainability practices. If the new local initiatives are embedded in well-established networks, the process can directly promote mutual learning on the practical solutions or critical knowledge generated in the niche community. Expertise and knowledge that can contribute to that aim may include, for instance, officials from corresponding municipalities or from higher administration levels dealing with the sectors directly addressed (e.g., energy, food, health, education); entrepreneurs or representatives of companies active in the local context and in business sectors relevant to the sustainability practices of concern; and local political leaders. However, if the initiative is not already well established, the process must first tackle the challenges of initiating and consolidating the grassroots initiative at a local level. This, in turn, may require other or additional knowledge and expertise, such as leaders of existing initiatives, as well as local actors who might eventually lead the new one.

4.3. Transits beyond the Niche

In the standard literature of socio-technical niches, the translation pathway has been suggested in order to explain specific patterns of interaction between niche and regime levels. Based on empirical studies, Smith suggests two types of translation processes that vary "in the degree of involvement by actors from each context, and the degree of change being deliberated: is it about transferring practices or negotiating re-framings?" [18] (p. 440).

The transfer type of translation focuses on regime actors (re)interpreting practices nurtured in the niche according to the regime cognitive frame. The final outcome is the adaptation and integration of those practices most easily incorporated into the regime's cognitive frame. In this type of translation process, "a narrower sustainability is diffusing more broadly" [18] (p. 443) and a stronger sustainability understanding or more critical values constitutive of the niches resulted is sorted out. The second type of translation suggested by Smith "recognizes niche-regime differences more profoundly and seeks to understand the values, principles and activities that underpin each" [18] (p. 439). This re-framing type of translation is a learning process in which niche and mainstream actors jointly engage with the explicit aim of expanding the capacities of mainstream actors to adopt the sustainability practices nurtured in the niche. Such a translation can happen in so-called "intermediate projects" that are intended to provide a space in which both the niche actors and the regime actors experiment with niche practices. At this point, the importance of the permeability of cognitive frames for diffusion becomes clear. Establishing the setting of an intermediate project not only requires recognizing the multiplicity of cognitive frames (in this case niche and regime) but also requires acknowledging and—more importantly—explicitly exploring, (re)interpreting and negotiating precisely those differences between the cognitive frames themselves.

The analytical perspective developed in this study allows for conceptualizing a more generic form of transit, i.e., one in which the aim is to promote diffusion beyond the niche community. Figure 4 illustrates such a setting. Diffusion can target any socio-political arena for which the experiences of the niche are expected to offer a valuable contribution to addressing sustainability concerns. The illustrated case is one in which a certain repertoire of knowledge and practice in the niche community (schematically illustrated by a solid-line circle at the global niche level) is taken as the central subject for the mutual learning process. The specific focus might be to facilitate the uptake of the sustainable practices of the niche by the mainstream systems of production and consumption. Such a configuration would be close to the understanding of diffusion by closure: i.e., the search for practical solutions to the sustainability issue of concern ends when broad adherence to some components of the innovative practice is more likely to be achieved. However, by adopting a transdisciplinary perspective, it is possible to account for the multiple outcomes that can originate from the same diffusion process. The reflexivity that is central to the process and the permeability of the cognitive frames implies that changes in the participating cognitive frames are also possible outcomes. Therefore, besides accounting for socio-technical criteria (e.g., in the form of the standards and regulations of the relevant supply sectors), the proposed perspective also accounts for the dynamics that create multiple outcomes from the same process. Furthermore, the perspective allows for the consideration of alternative diffusion subjects (other than technical components) and targets (other than mainstream systems of production and consumption).

The mapping exercises presented in this section shows how the proposed perspective turns the attention towards the creation and maintenance of spaces in which the described transit can take place, rather than on the strategic management of resources (e.g., knowledge, finance, skills, political influence) from and for the niche as described by Seyfang and Longhurst [17]. The flow of resources is, of course, part of the overall picture. But framed this way, we are highlighting how the proposed conceptualization moves that flow as being the result of the internal debates and negotiations between the involved actors in the foreground. Moreover, creating and maintaining such a space where the necessary level of engagement can be achieved, requires the respectful acknowledgment and acceptance of epistemic differences between the actors, which become apparent in different cognitive frames. It could also be useful to consider the relevance of ontological differences as part of the conceptualization of diffusion as elaborated here, but this topic exceeds the aims and boundaries of the present study. To make the conceptualizations of diffusion through transdisciplinary research processes tangible the next section provides a brief illustration of how it can be operationalized in transdisciplinary research endeavors.

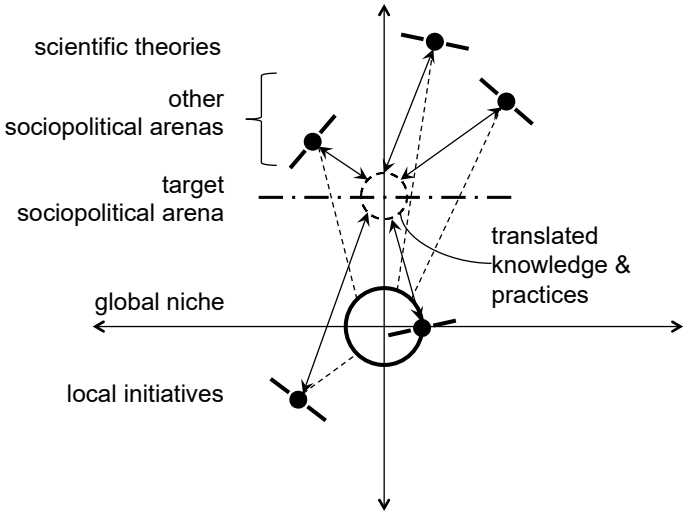

Figure 4. Schematic illustration of a generic set of knowledge articulation promoting the transit of sustainability practices and knowledge beyond the niche community.

5. Transdisciplinary Research for the Diffusion of Sustainable Family Farming Innovations in Colombia

This section presents the experience of the authors in a transdisciplinary research process that explicitly followed the twofold aim of: (a) improving the understanding of "the challenges and difficulties faced [by grassroots initiatives] in broadening the diffusion of sustainable family farming practices in Colombia" [15] (p. 830); and (b) supporting those initiatives in their transformative efforts. More specifically, the research included a diffusion setting promoting the transit of knowledge and practices toward the global niche level (as illustrated in Figure 2) and towards other local contexts (as illustrated in Figure 3). The design and results of that research have been reported and discussed in detail in previous publications [15,39,40]. Therefore, following a brief description of the diffusion setting in the study, the presentation focuses on illustrating how the research process (i) established a set of knowledge articulation that recognized and took advantage of a multiplicity of cognitive frames, (ii) facilitated the recognition of the diversity of novel contributions emerging from a grassroots initiative and their emergent, critical and contesting features; and (iii) supported efforts of existing national networks in promoting the wider diffusion of lessons and practices in the country.

5.1. The Diffusion Setting

The transdisciplinary research process was conceived and carried out through the cooperation of three parties: (i) RedBioCol—a network of practitioners promoting energy technologies for the treatment of organic residues in Colombia; (ii) the association of indigenous and peasant producers (ASPROINCA)—an association of family farmers with more than 20 years of experience in promoting agroecological practices among their members; and (iii) scientist from different disciplines, among them the authors of this study. The transdisciplinary research methodology called *case-based* Mutual Learning Sessions (*cb*MLS) was applied. In *cb*MLS, a case serves as a boundary object through which different perceptions and understandings of the phenomenon the case stands for are collaboratively analyzed and negotiated to learn from the case and for the case—for other cases, or other levels or scales [30].

The goal of this process was articulated in the central guiding question: By means of which instruments and strategies can farmers' associations effectively contribute to strengthening the Colombian family farming sector in economic, social, environmental and cultural domains? The longstanding experiences of ASPROINCA in promoting and supporting agroecological transformations in family farming were set as the case around which the learning process was organized. The setting involved 22 participants from

three different types of cognitive frames in the research process: representatives from five farmers' associations from five different departments of Colombia; representatives from seven civil society organizations working on different topics linked to rural development in Colombia; and researchers from different academic fields (i.e., sociology, agroecology, ecology, sustainability, geography, anthropology and cultural studies). In this way, the setting for knowledge articulation provided a diversity of cognitive frames along the two dimensions discussed in the previous sections: Different levels of generalization (local initiatives, NGOs with larger geographical scope of action, networks of initiatives and science) as well as multiplicity of cognitive frames in each of those generalization levels.

After a preparation phase, in which the problem of concern, central guiding questions and the set of participants were iteratively defined, the main space for mutual learning was conceived as a "case encounter". During the case encounter, the participants had the opportunity to visit family farmers supported by ASPROINCA and to interact with several of the association's staff. In different team constellations (plenary, group-work), participants collaboratively generated an in-depth understanding of the problem a family farming association is encountering in sustainability transformations, the strategies of success, barriers and failures, and through mutual learning derived lessons and recommendations for other cases and organizations on different regional scales and thematic foci. The design of the case encounter provided the possibility for the participants to get a deeper engagement with the specific situation in which the exemplary case has developed. And it promoted the (re)interpretation of the experiences and knowledge from the case through the different cognitive frames participating in the research. The final phase of the collaborative research involved processing, consolidating and publishing the results from the encounter for different target groups.

The group sessions promoted two types of action: (a) "to stimulate knowledge transfer between similar cases and to generate recommendations for ASPROINCA and for other farmers' associations" [15] (p. 837) (i.e., transits towards other local contexts); and (b) to promote the extrapolation of lessons to extract recommendations for the consolidation of the RedBioCol network (i.e., transits towards the global niche level). The results were processed to generate specific recommendations. These recommendations are normative assertions providing guidelines on how to tackle aspects deemed to be of general relevance for other cases and other scales; and what to consider in order to (re)apply the analyzed experiences of ASPROINCA.

This brief description of the setting illustrates how the transdisciplinary research process was conceived with the aim of bringing to fruition differences between the cognitive frames embodied by participants in a well-considered, purposeful team composition.

5.2. Contributions to Understanding and Supporting the Diffusion of Grassroots Innovations

In this section, we highlight specific aspects of the results and of the research process itself. It illustrates how the explicit and systematic valuation and articulation of differences allowed for recognizing the multiplicity of contributions that have been nurtured by the grassroots initiatives and supported the wider diffusion of lessons.

Multiple contributions to farmers' associations' capacity to promote sustainable practices:

The participants focused on and processed lessons from the ASPROINCA case, which were grouped into three main fields:

(a) Technical innovations, such as agroecology techniques, biodigesters, improved biomass stoves, and biological soil recovery and protection practices.
(b) Organizational innovations, such as self-managed revolving funds, training and retaining staff for technical support and the development of tools and methodologies for supporting the agroecological transformation of their members.
(c) Innovative ways of shaping commercialization channels, such as establishing processing capacities, registering and managing own brands and establishing regular markets exclusively dedicated to family farmers.

The research, therefore, was able to trace innovation processes not only in terms of technical solutions but also in terms of other aspects regarded as crucial by the grassroots initiatives for advancing sustainable family farming in Colombia.

Recognizing the emergent, critical and contesting features:

The research results indicate that the niche of grassroots initiatives studied can be better understood as responses to mainstream socio-political structures and dynamics, which are based on and reproduce a conception that equates peasant or rural with poor and backward [15]. The research resulted in three main findings to support this assertion:

(a) The lack of recognition of the socio-economic and socio-political significance of family farmers is acknowledged by most of the actors involved as one of the crucial challenges faced by family farmers. It represents a central aspect of the common problem for which the niche is developing alternatives.
(b) In the same vein, the diverse fields in which grassroots initiatives are fostering novel solutions can be seen as a search for alternatives to the provision of agricultural extension services for Colombian family farmers, i.e., training, technical innovation, finance and commercial channels. These are responses to the structural deficiencies of the regime, dealing with the techno-economic issues of small farmers.
(c) The results indicated that the grassroots innovation initiatives studied can be considered as a practical expression of the social movements of peasants aiming for socio-political recognition of their lifestyles. Such social movements have a well-documented trajectory in Colombia and Latin America.

Supporting diffusion process:

The example presented illustrates that operationalizing the introduced conceptualization implies that grassroots innovation researchers play an explicit and active role in the diffusion process. Three main aspects of this role appear particularly relevant:

(a) The transdisciplinary research space was created and maintained through the collaboration of representatives of grassroots initiatives and networks as well as the participating researchers from different academic fields.
(b) The design and realization of the research spaces comprised the systematic integration of conceptual frameworks (the proposed conceptualization of diffusion) and methodological tools (*cb*MLS, qualitative content analysis) from academic fields with knowledge generation and transfer practices commonly applied by the grassroots actors involved (e.g., knowledge exchange workshops, study visits to farms and peasant-to-peasant learning).
(c) The results were further processed by the two involved national networks and used as part of specific diffusion activities. For instance, the national network for family farming (which was represented in the *cb*MLS) in 2016 launched a program that aims at identifying and strengthening existing initiatives of "peasant markets" in the country [41]. In 2016, RedBioCol issued and distributed a brochure in which the organizational innovations of ASPROINCA were featured [42].

6. Summary and Conclusions

With this paper, we have addressed the limitations of community-based approaches to deal with the multiplicity of levels, scales, objectives and actors that characterize the complex socio-ecological systems in which the sustainable management of natural resources takes place. The allure of community-based approaches resides in the observation that the wellbeing of local communities is intrinsically tied to and dependent upon local ecosystems and that their knowledge and practices are rooted in long histories of relation with and use of those ecosystems. However, precisely this local character makes it difficult to recognize how the set of knowledge and practices that emerge in the specific locality of community-based natural resource management initiatives can influence (and become influenced by) management practices on higher levels (vertical interlinks) and/or in other local contexts (horizontal interlinks).

We adopted an innovation perspective and used theoretical advances in the diffusion of grassroots innovation in order to shed light on how those interlinks can be understood and strengthened. We departed from the conceptualization of grassroots innovations as emerging from civil society initiatives as networks of activists and organizations that reflect upon sustainability challenges and experiment with alternatives for dealing with those challenges from their local context. Applying theoretical advances from strategic niche management, the diffusion of such grassroots innovations presupposes the consolidation and growth of a niche level, in which a community of actors shares cognitive, formal and normative rules that guide both the understanding of the sustainability issues in focus and the local actions for dealing with them. Framed in this way, building interlinks implies a process in which all or some of the knowledge and practices nurtured in community-based initiatives get known and deployed by actors beyond that site of innovation. The cognitive frames concept is key in understanding this process because cognitive frames provide social actors with procedures of sense-making that are applicable to the specific range of situations, levels and scales in which they operate. Therefore, the diffusion might require adjustments in the cognitive frames of those agents that are expected to take advantage of the community-based knowledge and practices, and who are situated at different levels, scales and contexts. In order to deal with this challenge, the literature on socio-technical niches foresees a process in which the multiplicity of cognitive frames is reduced and aligned towards an increasingly generalized and de-contextualized repertoire of knowledge. This focus on streamlined processes and consensual decisions tends to overlook the plurality and emergent dynamics of grassroots initiatives, the multiplicity of mainstream practices that are often challenged by them and the controversial elements of grassroots innovation with greater transformative potential, such as critical knowledge or strong sustainability criteria.

In line with polycentric governance schemes that have emerged over the last 20 years and that recognize the multi-level feature of natural resource management, we propose a perspective on grassroots innovation that emphasizes the multiplicity of actors and levels, the different qualities/types of knowledge and actions and their respective contributions to the diffusion process. For that aim we introduced two main conceptual modifications:

Firstly, we conceptualized diffusion pathways of grassroots innovation as transdisciplinary processes. At this point, we call for a critical and culturally sensitive transdisciplinarity that departs from the awareness of the need to explicitly recognize and address differences as conditions for joint thinking and acting on sustainability issues of shared interest. In this way, the focus shifts from stabilizing single cognitive frames to creating spaces of knowledge articulation where diverse cognitive frames work jointly to: (i) process experiences from grassroots initiatives; (ii) create knowledge and promote practices that can be effectively applied for advancing the niche's shared vision; and (iii) facilitate the transit of such knowledge and practices across different local contexts, levels and scales.

Secondly, we focused on the multiplicity and situatedness of cognitive frames and the relevance of these characteristics for understanding and realizing the diffusion of grassroots innovations. Cognitive frames provide social actors with procedures of sense making applicable to a specific range of situations and contexts. To increase the certainty that the knowledge created and practices promoted can be understood and applied in a broad range of contexts, levels and scales, the involvement of multiple cognitive frames is crucial for achieving diffusion. Moreover, our analysis highlights the relevance of the dynamicity and permeability of cognitive frames and how they can be mutually adapted as a result of learning and reflection during the diffusion process.

To conceptualize the diffusion of grassroots innovations we consider the multiplicity and permeability of the cognitive frames (a central concept from strategic niche management) as a particular expression of epistemic difference, which in turn can be brought into fruition through processes of joint reflection and action (a central concern of a critical and culturally sensitive transdisciplinarity). In this way the diffusion process can be conceptualized as transdisciplinary knowledge articulations with the explicit aim to foster the transit

of knowledge and practices nurtured by grassroots initiatives towards other contexts, levels and scales. Based on this conceptualization we derive three generic types of transits that explain how grassroots innovation can diffuse beyond their locality. The conceptual elaborations also describe the knowledge articulation settings that can promote such diffusion processes. An empirical example of a transdisciplinary research process was presented in order to illustrate how the developed conceptualizations can be operationalized for both, understanding and supporting the diffusion of grassroots innovation.

The analytical perspective on the diffusion developed in this study recognizes the emergence of multiplicity as a potential outcome of the diffusion process—over and above the conventional expectation of achieving convergence and closure. This issue raises the need for the dynamicity of niches to be reconsidered. While sustainability transitions are, in principle, conceptualized as regime change without paying much attention to what happens at the niche level when the transition takes place, the proposed perspective pays greater attention to how niches reconfigure themselves as a response to—or consequence of—the successful transit of part of their knowledge and practices to the regime level.

By conceptualizing the diffusion of grassroots innovation as transdisciplinary research, the developed conceptualization can account for the work of grassroots innovation researchers as a constitutive element of the diffusion processes. These diffusion processes can be considered as a specific community-based type of "problem-solving transdisciplinarity" [43] where "solutions [. . .] respond to the local situation and the interests and values of the communities involved" [8].

In this study, we conceptualized transdisciplinary research alliances for transcending the locality of grassroots initiatives to promote the diffusion of sustainability knowledge and practice. We see great potential in a critical and culturally sensitive transdisciplinary approach where researchers investigate *about*, *with* and *for* grassroots initiatives focused on sustainability. Such alliances can contribute to conceiving and realizing research processes in which knowledge generation and practical experimentation are coherently and systematically interwoven and provide responses to the growing call for transformative sustainability research.

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