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OPINION ARTICLE

Unraveling the concept of local seeds in restoration ecology

Alice Dupré la Tour[1,2], Julie Labatut[3], Thomas Spiegelberger[4]

Scientific works converge toward the importance of using seeds of local origin in restoration to limit biodiversity loss and increase ecosystem resilience. Efforts are made to define what should be considered as local seeds. However, the concept of local seeds remains complex to delimit both scientifically and operationally, and carries non-neutral assumptions that impact restoration activities. This article aims to unravel the concept by examining its construction using a social science approach crossed with ecology. The interest for the genetic origin of plant material has developed since the 1990–2000s, in a context of international debates on biodiversity conservation. The delimitation of the local seeds concept necessarily integrates paradoxical assumptions: one of the major ones is that the local character of a plant is relative to both the reference ecosystem and the species considered. Moreover, it also depends on the objectives of restoration, the feasibility of the chosen method for restoration and the regulations. To overcome these paradoxes, compromises and translations are made to delineate collectively and operationally what is local. By adding a cross perspective between social sciences and restoration ecology to the debate, we highlight that the constructions of the local seeds concept integrate a diversity of ecological, sociotechnical, and economic assumptions that are not neutral for restoration. This perspective on the concept, its ambiguities, and its contingencies leads us to to underline the importance of reflexive and integrative approaches to work at different scales on standards for the use of local seeds in restoration.

Key words: concept construction, genetic origin, local seeds, restoration ecology, social sciences, translation

Conceptual Implications

- While scientists generally agree to recommend the use of local seeds in restoration, what should be considered as local seeds remains complex to delimit both scientifically and operationally.
- The concept of local seeds is relative and results from a collective construction to meet a need.
- To meet the operational needs of ecological restoration, the constructions of the concept of local seeds integrate a diversity of ecological, sociotechnical, and economic considerations.
- To understand how the concept is constructed, what compromises and translations it contains and on which paradigms it is based, social science approaches are complementary to those of ecology.
- To stabilize common operational definitions at different scales, integrative standards are necessary.

Opening the "Black Box" of the Local Seeds Concept

In restoration ecology, scientific papers and recommendations converge on the importance of using plant material of local origin (Sackville Hamilton 2001; Bischoff et al. 2010; Vander Mijnsbrugge et al. 2010). However, reaching consensus on what can be considered as local seeds remains complex, both scientifically and operationally. Here we revisit the local seeds concept by adding a social science approach crossed with ecology to the debate. To do so, we take up the concept of translation, which designates the processes of linking natural, technical, and social elements leading to the production of new scientific or technical statements (Latour 1987). These translations link heterogeneous issues and proceeds to different alliances to arrive at a new statement intelligible to others actors. For instance, operational guidelines for restoration stakeholder result from translations that transform theoretical statements by integrating sociotechnical assumptions, economic configurations, restoration networks, regulations, strategies, and management philosophies. These

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translations operate within particular contexts that guide research work. They involve interactions and negotiations between various rationalities and interests, those of restoration stakeholders and symmetrically of scientists. Latour (1987) showed the limits of the model of diffusion that consists in focusing on the way scientific statements spread in society and leaving the scientific complexity in "black boxes" of made science. The model of translation he elaborated consists in considering the construction of scientific statements in its social interactions, before these statements stabilize in black boxes that are then closed. In this perspective, we open the "black box" of the "local seeds" concept to trace back its construction processes and focus on how scientific production on local seeds is being co-constructed in interaction with society. Considering local seeds in this perspective is to hypothesize that (1) there is not a proper local character of which scientists should gradually reveal the features, that (2) the concept of local seeds is not neutral but collectively co-constructed, integrating various issues to answer a need in a given context, and that (3) examining the process of this construction allows to better understand it and to help improving these processes by making them more reflexive and integrative.

To develop operational knowledge, the construction process should include not only dedicated exchanges including the various scientific and operational stakeholders in a co-construction approach, but also an identification of assumptions and "rational myths" (Hatchuel et al. 1987) at stake. Indeed, scientific and operational concepts such as "local seeds" can be seen as "a nexus of assumptions, rational myths, belief systems, hypotheses and material constraints which stem from broader institutional forces, intervene in the building of patterns of actions, and open new performance possibilities and inventions" (Labatut et al. 2012). In many cases of local seed delimitation, operational stakeholders are already taken into account or associated in the knowledge construction. In contrast, the "local seed" concept is often "naturalized" and the identification of its underlying assumptions is little implemented and discussed.

Therefore, we want to emphasize that scientific knowledge about local seeds in ecological restoration has developed in historical contexts, is based on different scientific positions, and integrates feasibility issues encountered in the field. From there, we develop several items that help explain the difficulties in agreeing on a common definition of local origin of seeds. Finally, we focus on the compromises to overcome the paradoxes of restoration with local seeds. The challenge is to agree collectively on the contours of the concept in order to delineate operational common standards at different scales.

Emergences of the Local Seeds Concept

First Emergence in the 1990–2000s

The topic of the genetic origin of plant material used in restoration projects emerged in the 1990–2000s in research (Fig. 1), in parallel to international debates on biodiversity issues. The Convention on Biological Diversity (CBD) in 1992 marks an institutionalization of biodiversity as a political and a societal issue. Its definition of biodiversity includes genetic diversity, establishing diversity within species itself as a conservation issue (Sackville Hamilton 2001). The idea of genetic erosion, developed since the late 1950s, has gradually led to the awareness of the loss of local crop varieties. As a reaction, in situ conservation projects of "crop diversity" have been implemented since the 1990s (Fenzi & Bonneuil 2016). In the notion of agricultural "genetic resources," the gene is conceived as "the proper unit of biodiversity" (Fenzi & Bonneuil 2016). This focus shift toward the genetic level in conservation also occurs in restoration ecology, redirecting its research agenda. The idea of favoring plant material of local origin for ecological restoration has developed (Fig. 1) in this context of institutionalization of the conservation of genetic diversity, to give birth to the "local-is-best" paradigm (Broadhurst et al. 2008; Jones 2013; Breed et al. 2018).

A Need Arising From Identified Ecological Hazards

Scientists in the field of restoration ecology have promoted the use of local seeds to avoid various risks linked to the introduction of nonlocal plants (Vander Mijnsbrugge et al. 2010). Nonlocal plants may have lower fitness than local flora, can be maladapted to the environment (Moore 2000; Bischoff et al. 2006; Breed et al. 2018), and may hybridize with local flora leading to outbreeding depression (Moore 2000; Sackville Hamilton 2001). Moreover, nonlocal plants with high phenotypic plasticity may outcompete local flora (McKay et al. 2005; Bischoff et al. 2006) or negatively interact with other organisms as their reproductive cycles differ from local plants (Sackville Hamilton 2001; Bucharova et al. 2019). In addition, the choice of local seeds can be justified by the precautionary principle (Moore 2000; Jones 2013).

A Developing Concept With Variable Boundaries and Names

However, the concept of local seeds remains ambiguous (Breed et al. 2018), giving room for various interpretations or even misunderstandings. Recent works strive toward precise general principles and standards, but they underline the multiplicity of elements to take into account and the need for local guidelines (Gann et al. 2019; Pedrini & Dixon 2020). Moreover, a variety of terms is used to qualify these seeds (Fig. 1). The term "local" can refer to a "previously existing genotype at a site" (Hufford & Mazer 2003), or in a broader sense "to mean that the populations originate where found, and by extension, are adapted to local environmental conditions" (Vander Mijnsbrugge et al. 2010). "Native" and "indigenous" among others are considered as synonyms (Hufford & Mazer 2003), despite the fact that each of them has its own history and connotations before being used to qualify restoration seeds.

The Scientific and Technical Foundations of the Concept: Revegetation Goals and Paradigms

The criteria for supplying restorative seeds depend on the operation's goals, which may differ and confront each other. Couix and Hazard (2013) have shown that these goals rely on different paradigms (i.e. theoretical conceptions) of conservation and ecological restoration. Within biodiversity studies, there are different scientific positionings that associate both research approaches and general visions of ecological issues, which Granjou and Arpin (2015) call epistemic commitments. These commitments impact knowledge produced for restoration (Rodriguez et al. 2018) and orient in particular the choices of priority goals.

Indeed, depending on whether one seeks to restore a gene pool, a set of taxa, a dynamic, or service, the seed supply requirements vary. According to the Society for Ecological Restoration (SER) standards, ecological restoration aims to “achieve ecosystem recovery, insofar as possible and relative to an appropriate local native model (termed here a reference ecosystem),” while rehabilitation focuses on the restoration of ecosystem functionalities, “without seeking to also recover a substantial proportion of the native biota” (McDonald et al. 2016). The positioning in these different types of environmental repair efforts and their goals is decisive in the seed supply criteria.

Relativity of the Local Seeds Concept

Drawing Boundaries on a Continuum of Nativity

The local or nonlocal character of a plant is relative in relation to an environment to be restored or a reference ecosystem. In the survey of Smith and Winslow (2001) on perceptions of native status, a respondent answered: “Nativity is a continuum and we humans want to categorize. So there is inherent conflict. The truth is that there are shades of nativity. But practically we do have to draw lines sometimes.” A binary separation between local and nonlocal does not reflect the gradient of local origin inherent to the continuum of the living. Therefore no systematic criterion delineates the desirable plant material for revegetation.

Reference Ecosystems and Arbitration Between Restoration Goals, Decisive Choices for Seed-Sourcing Strategies

The choice of seeds depends on the restoration goals and subsequently on the reference ecosystem chosen for the restoration project, which can be historical or contemporary (McDonald et al. 2016). A contemporary reference ecosystem aims at reconstitution of a flora similar in terms of composition of a nearby site, whereas targeting a historical reference ecosystem leads to taking into account further elements such as the management of the site during the reference time. There is an evolutionary normativity in the choice of the reference: Moreau et al. (2019) have thus shown that the landscape reference of open rather than forest environments resulted from a historical construction, dating from the 1990s in the case of the French Causses. In many cases, the sites to be restored already have known uses that have strongly deviated them from their previous states (Broadhurst et al. 2008; Jones 2013; Breed et al. 2018) and local seeds may not be the better option (Broadhurst et al. 2008; Jones 2013). In this perspective, Jones (2013) states that the widespread “local-is-best” assumption should be nuanced: local *stricto* sensu may be better and should be preferred when no data supports the opposite. Broadhurst et al. (2008) even argue that “failure by scientists to recognize that many of the assumptions underlying the *local is best* paradigm are without a strong scientific basis serves to maintain misconceptions among practitioners.”

The restoration goals, determining the selection of plant material, can interact and require arbitration (Table 1). This is

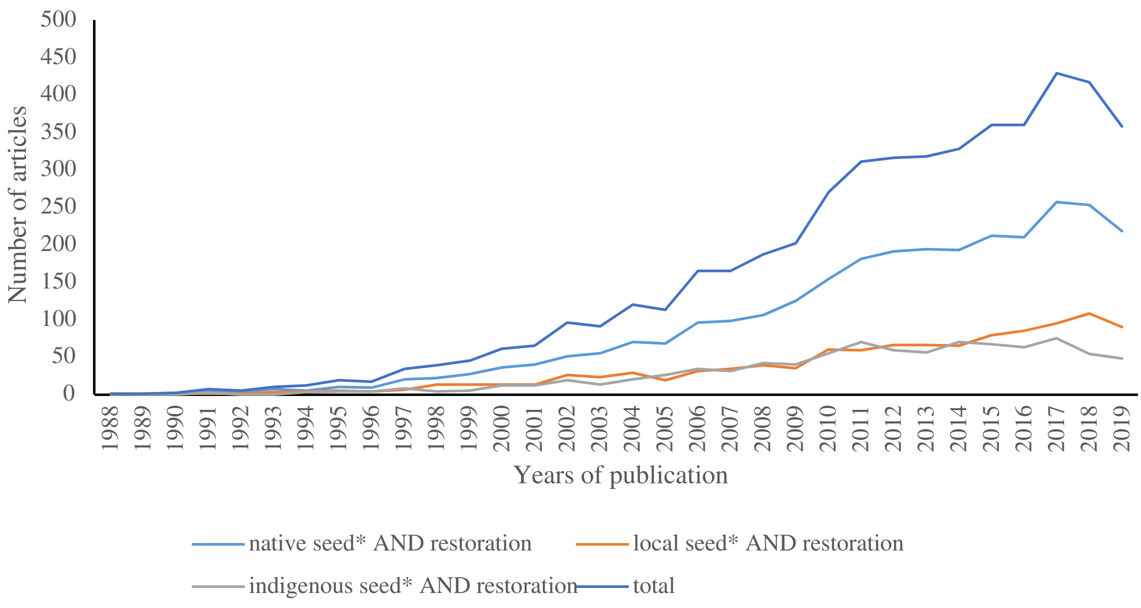

Figure 1. Evolution of the number of articles on the Web of Science (accessed on 17 January 2020) including three query terms (native seed* AND restoration, local seed* AND restoration, indigenous seed* AND restoration) for the period 1988–2019 (1988 being the year of foundation of the Society for Ecological Restoration).

[Correction added on 13 November 2020 after first online publication: the word ‘deviated’ was inserted in between ‘strongly’ and ‘them’ in the fourth sentence of the subsection ‘Reference Ecosystems and Arbitration Between Restoration Goals, Decisive Choices for Seed-Sourcing Strategies’).]

Table 1. Paradigms, goals, and principles of seed provenancing strategies, adapted from Breed et al. (2018), Bucharova et al. (2019), and Jørgensen et al. (2016).

Paradigmatic Gradient	*Main Goal*	*Provenancing Strategy*	*Strategy's Principle*
Logic of conservation of specific and genetic heritage	Preserving original integrity of local flora	Local provenancing	Sourcing seeds from an area close to the target site
↕		Genetic provenancing	Defining seed transfer zones from gene flow patterns
	Enhancing the adaptive potential by increasing the overall genetic diversity of seeds	Regional admixture provenancing	Collecting seeds from multiple population within a seed transfer zone
		Composite provenancing	Supplementing local sourcing with seeds from multiple distant sources to mimic natural gene flow
		Admixture provenancing	Sourcing seeds from multiple areas across species' natural distribution
	Matching populations to the expected future environmental conditions at target sites	Predictive provenancing	Collecting seeds from areas that have similar climates as the one predicted for the target site
		Climate-adjusted provenancing	Supplementing local sourcing with seeds from multiple distant areas along a climate gradient in line with climate change projections.
Logic of adaptation to evolutionary and anthropic issues			

particularly the case when favoring the genetic identity of the original flora or the adaptability of the reconstituted flora. While genetic identity involves reimplanting genotypes as close as possible to the original ones, adaptability implies favoring the physiological ability to tolerate environmental conditions. The adaptive potential depends on the genetic heritage but also on phenotypic plasticity and variation between genetic and environmental influences on selective traits (Gonzalo-Turpin & Hazard 2009). Although generally the original flora is better adapted (Sackville Hamilton 2001; Basey et al. 2015; Bucharova et al. 2019), local flora is not always optimally adapted (Sackville Hamilton 2001; Wilkinson 2001; Jones 2013; Bucharova et al. 2019), contrary to the "Panglossian paradigm" in evolutionary thinking (Gould & Lewontin 1979), for which natural selection leads to optimization. Jones (2013) argues that exceptions to the "local-is-best paradigm" are reported more and more often, in particular because of the strong alterations of the environments to restore. Seed-sourcing strategies like "composite provenancing" and "admixture provenancing" (Table 1) recommend using seeds from various sources to increase genetic diversity, enhance adaptability, and limit both risks of inbreeding and of outbreeding (Broadhurst et al. 2008;Breed et al. 2018; Bucharova et al. 2019). Jones (2013) regrets that this type of initiatives is discouraged by what he calls a "belief in the merit of local plant material," as well as an emphasis on the risk of outbreeding depression. Finally, "predictive provenancing" and "climate adjusted provenancing" (Breed et al. 2018; Bucharova et al. 2019), other seed-sourcing strategies, even recommend to use nonlocal seeds from areas ecologically similar to the future target area, given predicted climate change. Global changes indeed upset the concept of local environment with stable conditions (Broadhurst et al. 2008).

Such provenancing strategies are forms of organizational intervention that involves accepting risks, uncertainty, and partial knowledge (Hatchuel et al. 1987). To propose the solutions expected from them, scientists must therefore unfold chosen logics that combine ecological foundations with management philosophies and representations of relational organizations in restoration (Hatchuel & Weil 1992). These strategies result from the linking and translation of these different issues into unified statements (Table 1; Fig. 2). They rely on what Hatchuel et al. (1987) calls "rational myths," both rational and limited by the empirical constraints and assumptions, but allowing to mobilize around a representation: in our case, the representation of conservative, adaptive, or interventionist paradigms in what we call paradigmatic gradient (Table 1).

Geographic, Ecological, or Genetic Proximity: Compromises Directed by the Requirement of Feasibility

Sourcing local seeds brings up another question related to that of goals: should preference be given to the geographical proximity of the seed sampling area, to its ecological similarity to the area to restore, or to its genetic or phylogenetic proximity to reference vegetation? Plants from adjoining areas may be less adapted than others from more distant but ecologically close to the habitat to be restored (Vander Mijnsbrugge et al. 2010). The geographical proximity allows defining pragmatically supply areas in plant material.

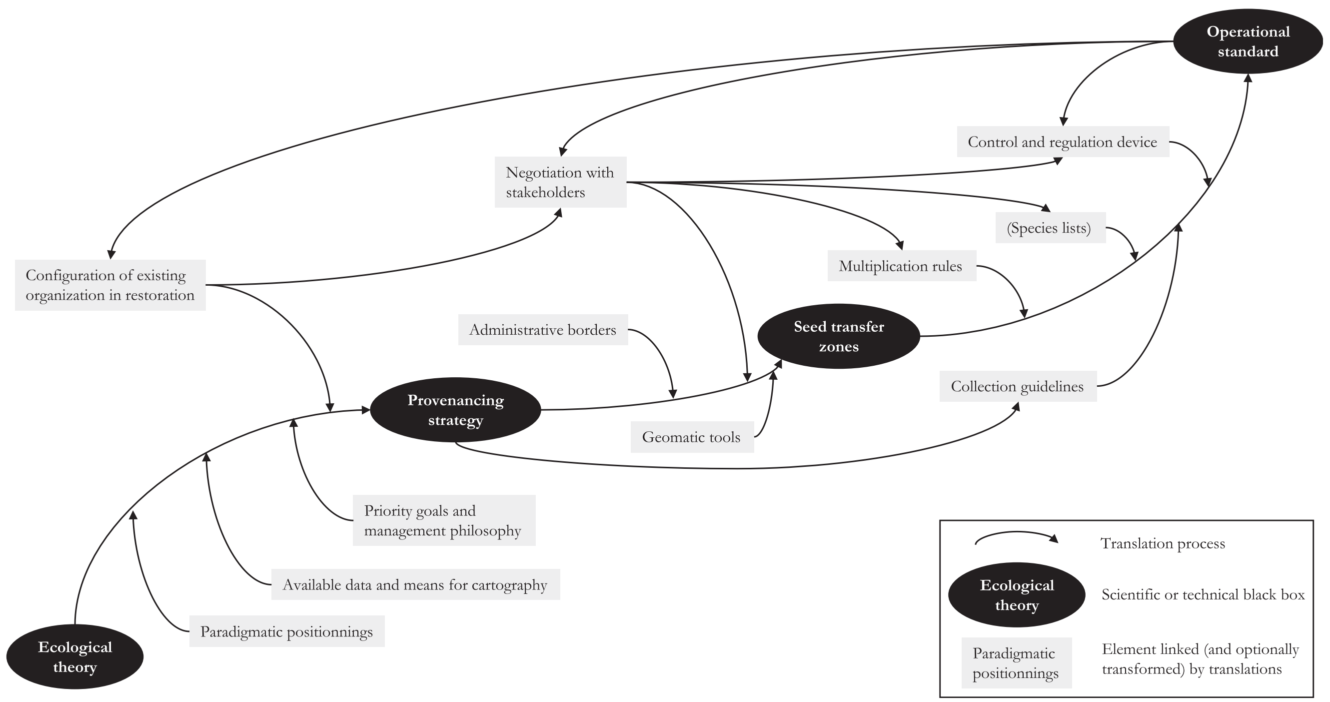

Figure 2. Construction of an operational standard for production and use of local seeds in ecological restoration: a translation network.

However, it does not guarantee the genetic connection between the sites, nor their ecological similarity. Even if plants from the same metapopulation come from genetically connected sites, these can be ecologically distinct (Jones 2003). Though gene flows limit local adaptations (Sackville Hamilton 2001; Bower et al. 2014), these may occur, for example, along altitudinal gradients (Gonzalo-Turpin & Hazard 2009). Many species have strong differentiations by habitat, even on small geographical scales (McKay et al. 2005; Vander Mijnsbrugge et al. 2010). For these reasons, it would be relevant to think in terms of environmental or ecogeographical distance (Sackville Hamilton 2001) to assess genetic distance, which would be only partially correlated with geographic distance (Moore 2000; Wilkinson 2001; McKay et al. 2005; Bischoff et al. 2010; Bower et al. 2014). In order to evaluate the genetic identity between the plant material of restoration and the target flora, it is also possible to carry out genetic studies using molecular markers. However, these studies feasible for research purposes in the field of restoration genetics (Hufford & Mazer 2003) are not carried out systematically for restoration operation on each species. Such studies are therefore more useful to refine the definition of source zones criteria and can serve to delineate seed zones.

The Seed Transfer Zones, Operational Translations of Scientific Compromises

The delimitation of seed transfer zones allows to a certain extent combining criteria of geographical proximity and ecological proximity. The idea is to map regions within which plant material can be collected for use in restoration operations in the same region. However, belonging to the same seed transfer zone does not guarantee, beyond a very small scale, neither the genetic connection nor the habitat similarity. This is especially true in mountain areas, where topographic and climatic barriers can hinder gene flow (Schönswetter et al. 2005), and where a same-seed transfer zone includes a wide range of altitudes and climates.

Moreover, genetic diversity and adaptation patterns vary by species (Basey et al. 2015), depending on their dispersion, their pollination modes, and their longevity (Wilkinson 2001; Jones 2003; Broadhurst et al. 2008; Malaval et al. 2010; Vander Mijnsbrugge et al. 2010). Thus, for Jones (2003), the choice of the gene pool to be used for revegetation depends on the species' pattern of genetic variation, which can be more or less continuous or discrete along a spatial gradient. Plant fitness decreases with their degree of heterozygosity, which is lower in inbred, small, and isolated populations (Vander Mijnsbrugge et al. 2010). The delimitation of seed transfer zones should therefore ideally be defined for each species (Bower et al. 2014; Bucharova et al. 2019), which seems unfeasible from an operational point of view.

Despite all these theoretical complications to delineate an acceptable origin for plant restoration material, there is a need for guidelines for seed supply (Bower et al. 2014). New translations (Fig. 2) are then necessary to overcome paradoxes and reach operational compromises.

Overcoming Paradoxes Through Compromises

From Ecological Knowledge to Operational Guidelines: a Series of Translations That Integrate Sociotechnical and Economic Issues

The paradoxes of local seeds stem from a fundamental paradox in ecological restoration: seeking to "'assist recovery' of a natural or semi-natural ecosystem" (McDonald et al. 2016) through anthropic intervention, although the difficulty of this enterprise is widely recognized (Palmer et al. 2006). Anthropic intervention involves taking into account the technical feasibility, the temporality of the intervention, and monitoring, as well as its financing. For seed supply, this translates into a selection that may include ecological criteria, but must necessarily include operational criteria such as seeds' availability, production costs (Broadhurst et al. 2008), or even the possibility to produce seeds of the targeted species. If local seeds are identified by scientists as generally the best solution (Sackville Hamilton 2001; Bucharova et al. 2019), its practical translation is very variable, as scientists condense their knowledge to make operational guidelines, and can be too restrictive to reach an operational level (Broadhurst et al. 2008). Practical guidelines require agreeing collectively on a common delimitation of what is considered as local seeds, even if that implies enlarging the definition to the point of integrating paradoxes. Such conception work integrates stakeholders at different levels: conservation and regulation actors, seed harvesters, producers, restoration practitioners, insofar as each brings a knowledge in terms of feasibility. Such participatory approaches already apply to define guidelines, and we state that they should be implemented as early as possible in the translation chain.

Delimitation of Seed Transfer Zones and Species Lists Building for Regulation Through Negotiations With Stakeholders

In terms of recommendation, the first criterion that needs to be clarified is the definition of seed transfer zones (Breed et al. 2018). This results in the delimitation of operational seed zones, applicable for all species, and which limit the risk of maladaptation of the seeds used. In different countries, seed transfer zones have thus been delimited, giving rise to guidelines, regulations, or collective marks (Tischew et al. 2011; Bower et al. 2014; Shaw & Jensen 2014; Basey et al. 2015; Jørgensen et al. 2016; Abbandonato et al. 2018; Bucharova et al. 2019; De Vitis et al. 2019).

These zones, which can be delineated on geoclimatic, biological or genetic criteria according to the provenancing strategies (Table 1), result from several arbitrations. Their definition implies creating the same artificial boundaries for all species. To provide sufficient economic opportunities for seed companies, their area may be large. In most of the countries where zones were delineated, these were designed according to the strategies of relaxed "local provenancing" or "regional admixture provenancing" strategies (Table 1), except for Norway where genetic patterns were used (Jørgensen et al. 2016; De Vitis et al. 2019). The delimitation is also subject to compromises between different stakeholders, as shown by the example of the "Alpes" zone delimited in France for the collective mark Végétal Local. While scientists had a preference for separating the northern Alps from the southern Alps, the seed companies argued that the potential market for such limited areas could not sustain a sector. The stakeholders have therefore agreed to delimit a single Alpes zone. Comparable arbitrations took place in Germany to ensure the practical implementation of the mapping (Bucharova et al. 2019). The delimitation in discrete zones induces paradoxes well noticed by the stakeholders of the restoration. In particular, the rule assumes that if a restoration project is located near a border, it is acceptable to source from another end of the seed transfer zone, but not just across the border (De Vitis et al. 2019). Within these zones, all species can theoretically be collected to restore any type of environment. Finally, the collection site has to have never been seeded, which is difficult to verify. These paradoxes can lead to abuse or mistakes.

Despite these paradoxes, scientists (Bower et al. 2014; Jørgensen et al. 2016; Bucharova et al. 2019) underline that the solution of seed transfer zones is the most desirable and feasible. In Europe, the Directive 2010/60 has instituted the possibility of producing local seeds for restoration, as long as collection and production take place in limited seed transfer zones. To avoid the exaggerated use of plants within the same zone, in Germany, for nonwoody plants the mapping of the zones is completed by lists of species for each zone (Bucharova et al. 2019). The combination of seed transfer zone and species lists has also been initiated, in connection with seed harvesters and producers, in France for the Alpes zone (Huc et al. 2018). In addition to species selection based on ecological criteria, agronomic criteria to allow their collection and multiplication, and regulatory ones to enable their commercialization have to be taken into consideration (Leger & Baughman 2014). However, proposing standard seed mixtures for all the restoration projects in a seed transfer zone can lead to introducing new species in an area.

Multiplication and Its Paradoxes, One More Compromise With Nativity

The possibilities of direct harvesting being limited and not sufficient to meet the demand, seed production by multiplication is required (Tischew et al. 2011; Abbandonato et al. 2018). The devices of seed transfer zones must therefore be associated with multiplication rules that guarantee the genetic origin and the diversity of the seed produced. Multiplication of local seeds is in itself paradoxical since it consists in cultivating plants intended to initiate dynamics for the reconstitution of environments that tend toward natural ones. The implementation of multiplication rules implies once again translating a conception of the nativity into operational guidelines. In fact, genetic selection happens at all stages: during collection on the local sites, growing at the multiplication site, harvesting, drying and cleaning of harvested seeds, transport, and seeding/germination/establishment on the restoration site (Basey et al. 2015). The risk of reducing genetic variability can be limited by requirements but cannot be avoided. Moreover, multiplication excludes some species, due to absence of knowledge on how to germinate or to harvest them, or because their breeding is more expensive than their harvest in the wild.

All stages of multiplication require compromised frameworks between limiting the risk of genetic impoverishment and not making production too difficult.

Prioritization of Criteria Between Availability and Nativity

In prioritizing different criteria, a decisive criterion for the choice of seeds is their availability in sufficient quantities at the desired moment. This is why several authors (Jones 2003; Breed et al. 2018; Bucharova et al. 2019) defend the interest of sowing nonlocal seeds of local species—for instance what Bucharova et al. (2019) call "native cultivars"—if it is not possible to source local seeds. In order to avoid giving way to invasive plants, the criterion of local genetic origin takes second place. A large part of revegetation operations are carried out indeed with seed mixtures composed of agricultural and horticultural cultivars, and wildflowers of unknown or nonlocal origin (Tischew et al. 2011; Ladouceur et al. 2018; Bucharova et al. 2019) which are available in large quantities. However, these are selected and bred for fodder production for domestic livestock and not for ecological restoration purposes. Their selection must meet the standards of seed regulation and consequently suffer low phenotypic plasticity and genetic variability. Considering nonlocal seeds as a lesser evil is an argument for the status quo of cultivar use. The guidelines for restoration practice must therefore be formulated strategically to avoid the misappropriation of nuanced scientific conclusions.

Constructing Standards Collectively for a Collective Recognition

To be collectively recognized by both actors of restoration and scientists, the local seeds delimitation must be feasible with the means of practitioners and consistent with the research results. Different complementary scales are relevant to collectively define the modalities required for local seeds. The SER standards provide global recommendations that can guide the local requirements. International and national standards are also set up on the basis of regulations, as with European Directive 2010/60 (Tischew et al. 2011; Abbandonato et al. 2018). At national and local levels, operational translations of the concept of local seeds are formalized in standards, rather than on the tripartite model of certification or collective mark (Fouilleux & Loconto 2017; Bucharova et al. 2019; De Vitis et al. 2019). In all cases, the standards are negotiated in order to delimit an operational definition of local seeds.

Conclusions

The concept of local seeds results from a construction process, which links and integrates natural, technical, and social elements. It is collectively designed to meet the needs and criteria of ecological restoration, and can be defined in different ways, none of which is neutral. The approach in social science crossed with that of ecology allowed us to open the black box of the concept and shed light on its origins, networks of translations, and paradoxes. This helps to better understand the dynamics between science and restoration practices and to better support the development of local seeds.

The different scientific and technical conceptions of restoration seeds and the underlying assumptions are so far little stated and discussed. We believe that the diversity of restoration conceptions, and objectives should be more explicit in an ecological debate that should integrate the operational stakeholders from the knowledge construction. Unraveling the underlying conceptions and assumptions invites a more reflexive and integrative construction of the concept of local seeds.

By making explicit non-neutral elements in the construction of scientific knowledge through the model of translation, we wish to open a dialogue between social sciences and ecology allowing access to the social processes of scientific construction. To our knowledge, there is no social science work on local seeds, although ecologists deal with organizational issues in position or policy articles (Tischew et al. 2011; De Vitis et al. 2017, 2019; Abbandonato et al. 2018; Ladouceur et al. 2018). By shedding light on the sociotechnical mechanisms involved, the social sciences can provide a reflexivity on scientific work in perpetual progress. Conversely, the investigation of ecological theories allows social scientists to better understand the principles underlying the actions to develop local seeds in restoration.

The diversity of paradigms and objectives for restoration invites us to integrate the stakeholders not only in the operationalization of knowledge but also in its scientific construction, by opening the paradigmatic debate, beyond the scientific sphere, to all stakeholders. The paradoxes inherent in the definition of local seeds are already raised by different stakeholders involved in the revegetation and can even be used to discredit the work on local seeds. The challenge is to avoid the relativism that all seeds are equal regardless of their origin. For all these reasons, it is necessary to support the development of robust common standards to frame the use of local seeds. Meanwhile, climate change is upsetting the restoration issues and is likely to bring about changes in knowledge and practices (Temperton 2007). Thus, there is a need both for a formalization of the definition of local seeds to promote the operational transition, and for a continuing research on restoration that includes social sciences and interdisciplinary approaches as well as ecology.

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