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Point of view

Are we ready to restore South Brazilian grasslands? Plant material and legal requirements for restoration and plant production

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ABSTRACT

The need for grassland restoration in the State of Rio Grande do Sul (RS), Brazil, has become evident in the last two decades, when more than 1 million hectares were converted to other uses only in the Pampa region. Since then, studies have started to verify the most suitable ways to restore subtropical grasslands. Around the world, species introduction is one of the principal restoration techniques. We investigated the availability of seedlings and seeds of native grassland species in the local market and the legal framework regarding the restoration of grassland vegetation in RS. We found, in total, only seven companies that sold seedlings or seeds of nine native species from grasslands, a very limited number given the great biodiversity of South Brazilian grasslands. In addition to that, we found no criteria and procedures for grassland conversion or obligatory replacement established in legal norms for grasslands to Pampa region, as there are for forest vegetation. Without legal requirement, a market for seeds and seedlings likely will not develop and, without a market, there will be no producers, and restoration will remain limited. Our results support the need to create initiates and legislation with basic guidelines for the grassland conversion and restoration in RS.

Keywords: grassland restoration, seedlings, seeds, Brazilian law, Pampa, Atlantic Forest

Introduction

In Brazil, the study and implementation of ecological restoration in non-forest ecosystems is only at the beginning (Overbeck *et al*. 2013; Pilon *et al*. 2017), as in other tropical and subtropical countries (Buisson *et al*. 2019). However, the need for grassland restoration has become evident in recent decades. Savanna formations in the Cerrado decreased 8 million hectares between 2008 and 2018 (Projeto MapBiomas 2020). In the same period, more than 1 million hectares of Pampa grassland were converted to other uses (Projeto MapBiomas 2020). Data from 2002 show that about 45 % of the grassland vegetation located in the highland region, in the Atlantic Forest biome, in the State of Rio Grande do Sul (RS) had already been converted (Andrade *et al*. 2015). As regional-scale mapping is based on remote sensing data, it is not always possible to distinguish areas

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previously used for agriculture but today used as pastures (Pillar *et al*. 2006), or grasslands that suffer from invasion by exotic species (Guido & Pillar 2017): due to these types of degradation, loss of well-conserved grassland likely is even higher. Importantly, losses of native grassland in RS - focus region of this study - have not been uniform in space. Region with soil properties and topographic conditions more favorable for agriculture, for instance, have suffered higher transformation (Andrade *et al*. 2015).

Although grasslands and savannas have been much neglected in conservation and restoration in Brazil (Overbeck *et al*. 2015), their conservation had actually been required in legislation since 1934, by Decree nº 23.793/1934 (Brasil 1934 - Art. 2) which mentioned "forests and other types of vegetation". The current law for the protection of native vegetation, Law nº 12.651/2012 (Brasil 2012a), which replaced Law nº 4.771/1965 (Brasil 1965) demands the conservation and restoration of all types of vegetation. It also ensures that rural properties must have at least 20 % of their area (in case of the Pampa and Atlantic Forest biomes) designated as Legal Reserve, intended to "assist [...] and promote the conservation of biodiversity [...]". Degraded areas in the Legal Reserve also need to be restored (Art. 2, VIII, Decree n° 7.830/2012 – Brasil 2012b), just as after native vegetation that has been converted to other uses without appropriate authorization, *i.e*., illegally, and after the development of a licensed activity, such as mining (Brazilian constitution, Art. 225, VII, § 3º – Brasil 1988). Clearly, a legal requirement for restoration of open ecosystems exists in Brazil, just as it does for forests.

Decree n° 8.972/2017 (Brasil 2017b), in response to legal norms and international agreements signed by the Brazilian government (MMA 2017), instituted the National Policy for the Recovery of Native Vegetation (Portuguese acronym, Proveg), and the National Plan for the Recovery of Native Vegetation (Planaveg) (MMA 2017). Among its main objectives, this plan includes the recovery of native vegetation of at least 12 million hectares by 2030 in Brazil. For the Brazilian Pampa biome (IBGE 2019), for example, the plan establishes the goal to restore 300,000 hectares by 2030. However, the document also draws attention to the fact that restoration of Pampa grasslands still is at its very beginning and that success factors for restoration in the region are mostly absent (see also Overbeck *et al*. 2007; Andrade *et al*. 2019).

Recovery of the vegetation is a key process in restoration of degraded land, and in many restoration projects, species introduction is an important technique to achieve successful restoration. In South Brazilian grasslands, the regeneration of species from the soil seed bank has been shown to have a limited role for the recovery of plant populations after land use change (Vieira & Overbeck 2020). Research has also shown that species introduction via hay transfer might not be effective in these grasslands (Thomas *et al*. 2019). Sowing and planting seedlings from native species are common techniques in grassland restoration around the world (*e.g.* Kiehl *et al*. (2010) for Central European grasslands) that more recently are also being applied in the Brazilian Cerrado (Sampaio *et al*. 2015; Pellizzaro *et al*. 2017), but that still are very little used for restoration of South Brazilian grasslands. The main constraint is where to obtain seeds and plants from.

Here, we ask if current market conditions and existing legal framework support the restoration of South Brazilian grasslands. Specifically, we aim to identify (1) if plant material, that is, seeds and seedlings from native grassland species (grasses, herbs and shrubs), are available in local nurseries and on the commercial seed market for use in restoration; and (2) if current legislation gives clear criteria as to when grasslands can be converted to other uses, or not, and if it requires and supports compensation of suppressed grassland and ecological restoration of grassland in RS.

Data collection

The basis for our analysis of commercially available plant material were a list of nurseries that produce tree species provided in Instituto de Pesquisa Econômica Aplicada (IPEA 2015) (in English: Institute of Applied Economic Research) and the list of producers and sellers that work with flowers and ornamental plants from Associação Riograndense de Floricultura (AFLORI 2018) (Riograndense Floriculture Association). Although the IPEA list is mostly focused on trees, we considered it to be a potentially promising source, as producers or shops working with trees may also provide shrubs and herbaceous species. Each establishment was contacted by phone, inquiring (1) if they sold native species that naturally occur in grassland ecosystems (grasses, herbs and shrubs) in RS and, if so, (2) which native grassland species they sold. This contact was conducted between August and October 2018. Additionally, in early 2020, we searched on the internet for large companies that sell seeds (Sementes Feltrin 2020 and Isla 2020) and browsed the availability of grassland species that are native to RS. This search provided a good extent of places that might be selling native species that could be used in restoration in RS.

In order to identify the legal requirements for grassland conversion and for compensation and restoration, we searched Federal and State norms in force during the second half of 2018 associated with conservation, restoration, nurseries and the use or production of native species, including seeds and seedlings. This search included norms and protocols for both non-forest and forest ecosystems in order to conduct a comparative evaluation.

Results and discussion

Availability of seeds, plants and legal norms for grasslands

Our initial list included a total of 74 nurseries and commercial garden centers, from which we were able to contact 34. From these, only five (15 %) informed that they produced or commercialized some native grassland species, and an additional five facilities did not know if they produced/commercialized native grassland species. A few facilities worked exclusively with native trees (three contacts) and 26 contacts informed that they worked mostly with exotic species: ornamental species for gardens, grasses for lawn, tree seedlings for wood production or fruit trees (*e.g.* fig, vine and citrus).

Overall, we found only seven native species available in nurseries (Tab. 1, Fig. 1). The available species included four grasses (*Aristida jubata*, *Coleataenia prionitis*, *Cortaderia selloana* and *Paspalum notatum*), two species with colorful flowers (*Evolvulus glomeratus* and *Glandularia peruviana*) and one medicinal species (*Achyrocline satureioides*). We found seeds of two native species available on the visited internet pages of seed sellers (*Axonopus affinis* and *Axonopus compressus*), besides hybrids of two other native species (*Glandularia* sp. and *Petunia* sp.) that, as hybrids, will not be accounted for as they cannot be considered as natural species. None of the species found is restricted to the Brazilian Pampa.

Our search for legal norms that address grassland conversion, compensation of converted areas, obligatory replacement, and restoration, identified five legal norms directly related to the topic: four Federal and one State norms (Tab. 2). They cover the definition of successional stages of the vegetation and implications of this for management and conservation, criteria for conversion of natural vegetation to other uses and mandatory vegetation restoration/replacement of vegetation. Most of them refer to forest vegetation and to the Atlantic Forest biome. For the Pampa region, no specific regulations for grassland, the dominant vegetation type, exist (Tab. 2).

Availability of native seeds and plants: sufficient for restoration?

Our results clearly demonstrate that the market for seedlings and seeds is absolutely insufficient for restoration of grassland vegetation in RS, and this lack of available plant material can be considered a severe barrier to restoration. In total, only nine species were found available on the market – a tiny fraction of the grassland flora of the state which is composed of over 2.600 species (Boldrini *et al.* 2015). Natural grasslands in the region usually present an average of 20 to 35 species/m^2, with a record of 56 species/m^2 (Menezes *et al.* 2018). Even in areas of poorly conserved native grasslands, more than nine species are easily found per square meter (*e.g.* Bonilha *et al.* 2017). If we extrapolate to a few hectares, this diversity can reach one or two hundred species on a site level (Boldrini *et al.* 2008;

Table 1. List of native grassland species currently commercially, as seeds or seedlings, available in Rio Grande do Sul State in the facilities contacted for this study.

	Family	Species name	Common name (in Portuguese)	Number of establishments	Available as
1	**Asteraceae**	*Achyrocline satureioides* (Lam.) DC.	macela, marcela, macela-do-campo	1	Seedling
2	**Convolvulaceae**	*Evolvulus glomeratus* Nees & Mart.	azulzinha, evólvulo	2	Seedling
3	**Poaceae**	*Aristida jubata* (Arechav.) Herter	barba-de-bode	1	Seedling
4	**Poaceae**	*Axonopus affinis* Chase	grama-tapete	1	Seed
5	**Poaceae**	*Axonopus compressus* (Sw.) P. Beauv.	grama-são-carlos, grama-missioneira	2	Seed
6	**Poaceae**	*Coleataenia prionitis* (Nees) Soreng	capim-santa-fé	1	Seedling
7	**Poaceae**	*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.	capim-dos-pampas	3	Seedling
8	**Poaceae**	*Paspalum notatum* Flüggé	grama-forquilha, capim-forquilha	1	Seedling
9	**Verbenaceae**	*Glandularia peruviana* (L.) Small	melindre	1	Seedling

Table 2. Legal norms to Pampa and Atlantic Forest biomes for grasslands and forests in Rio Grande do Sul State.

	GRASSLANDS		FORESTS	
LEGAL NORMS	Pampa biome	Atlantic Forest biome	Pampa biome	Atlantic Forest biome
Defines successional stages	-	CONAMA Resolution n° 423/2010	-	CONAMA Resolution nº 33/1994
Criteria for conversion	-	Law nº 11.428/ 2006; Decree nº 6.660/2008	-	Law nº 11.428/ 2006; Decree nº 6.660/2008
Criteria for restoration/ replacement	-	-	Normative Instruction SEMA n° 01/2018	Normative Instruction SEMA n° 01/2018

Freitas *et al*. 2009; Ferreira *et al*. 2010; Dresseno & Overbeck 2013): such diversity obviously cannot be reached if depending on the purchase of native plants currently commercialized. Given the fact that restoration in South Brazilian grasslands in many cases appears to be seed-limited, clearly the development of production chains of plants and seeds for restoration is necessary.

One important aspect when introducing plant species in restoration is genetic diversity. We are not aware of any detailed information on the region of origin and genetic diversity of the species already commercially available but can assume that they most likely are cultivars that do not necessarily stem from material native to the region. Cultivars are plants that usually have the advantage of good establishment and growth, but concerns have been raised on uncritical use, as cultivars might be superior competitors than native genotypes and as use of locally adapted genotypes and introduction of genetic diversity

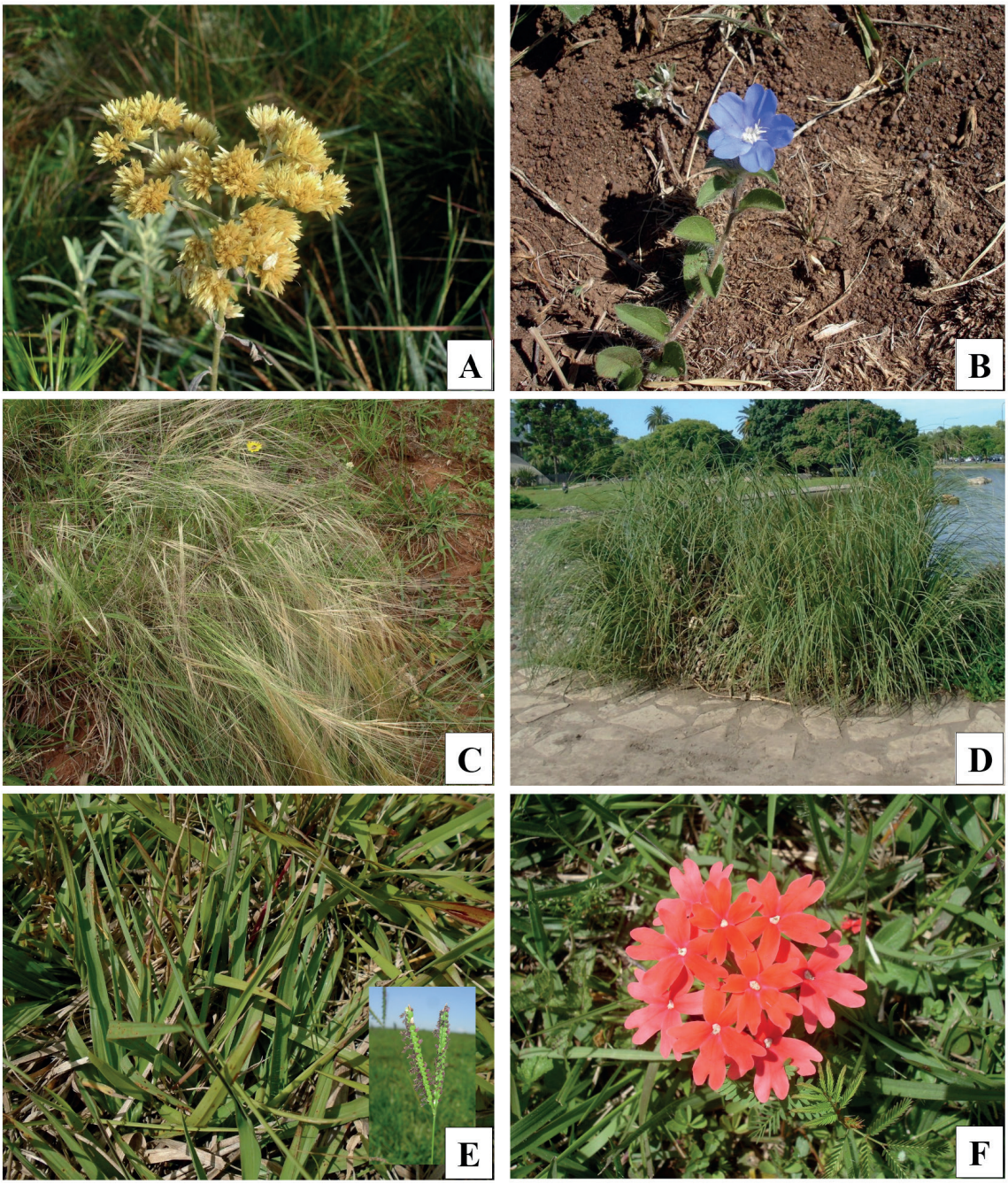

Figure 1. Examples of native grassland species currently commercially available, as seeds or seedlings, in Rio Grande do Sul State in the facilities contacted for this study: **A)** *Achyrocline satureioides*; **B)** *Evolvulus glomeratus*; **C)** *Aristida jubata*; **D)** *Coleataenia prionitis*; **E)** *Paspalum notatum*; **F)** *Glandularia peruviana*.

are considered to enhance restoration success in the long run (Kettenring *et al*. 2014). For our study region, a study on *Paspalum notatum* has evidenced high genetic diversity across native populations of the species (Fachinetto *et al*. 2017), with implications not only for plant breeding, but also for ecological restoration. However, we are unaware of any studies on the other plants that are commercially available, at least concerning our study region. According to Stumpf *et al*. (2009), the insertion of Brazilian plants into the national market generally is a result of research carried out abroad. For the use as ornamental plants in urban gardens, the question of genetic identity or diversity may not be so relevant, but it is for ecological restoration (see below).

Unavailability of grassland seeds and seedlings appears to be a consequence of the long-time bias on forest in conservation policy, evidenced until today in the region by the inexistence of any legal criteria for the grassland conversion, and specially for restoration/replacement for Pampa biome. For example, in restoration projects in grasslands ecosystems of RS submitted to the SEMA (Secretariat for the Environment and Infrastructure of RS state) between 2013 and 2014 and analyzed by Bateman (2016), 20 of the 25 had as method of restoration projects the planting of seedlings of native trees, and only one used mainly grasses (there is no information whether native or exotic species). As the Pampa is the only Brazilian biome contained in only one federative unit, RS, it is especially sensitive to the policy of this state (Bateman 2016). For the Pampa region, there is no recognition/identification and analysis of the degree of conservation of grasslands in a legal norm, as there are for Highland grasslands of the Atlantic Forest (CONAMA Resolution n° 423/2010 - Brasil 2010). Therefore, highly or poorly conserved grasslands in the Pampa biome are treated similarly by environmental agencies, since the conversion can be authorized regardless of its conservation status. In contrast, for forests in Atlantic Forest biome in RS, conversion will be authorized or not depending on the successional stages, defined by CONAMA Resolution nº 33/1994 (Brasil 1994). Additionally, Normative Instruction SEMA n° 01/2018 (Rio Grande do Sul 2018 - that revoked the Normative Instruction SEMA/DEFAP n° 01/2006) establishes the procedures to be observed for obligatory forest replacement in RS, such as planting 15 seedlings for each native tree cut in when native vegetation is suppressed. Therefore, for forests, with criteria and procedures for conversion and, specially, obligatory replacement established in legal norms, there is already a consolidated seedling market, while for grassland vegetation both are missing. Without clear legal requirements and criteria for grassland restoration, such a market for seeds and seedlings obviously will not develop and, without a market, there will be no producers, and restoration will remain limited. This can lead to a negative feedback process: without successful projects, grassland restoration will not be stimulated.

Current legal requirements for native plant production: simplification necessary?

Economic use of native species is allowed in Brazil, provided it has been authorized by the competent state agency (Law nº 12.651/2012, Art. 37 - Brasil 2012a). The Normative Instruction nº 17/2017 of the Ministry of Agriculture, Livestock and Food Supply (Brasil 2017a) is the most important legal norm for production of native species. It "regulates the production, commercialization and use of seeds and seedlings of forest species or species of environmental or medical interest, native and exotic [...]". According to this Normative Instruction, the entire seed production chain, from seed collector to the merchant, must be registered with the National Registry of Seeds and Seedlings (Portuguese acronym, RENASEM). Only nursery production of up to 10,000 seedlings per year does not require registration with RENASEM, but other requirements are still necessary (see, *e.g.*, Normative Instruction nº 06/2013 - Brasil 2013). However, when there is no commercial purpose, governmental or non-governmental institutions that produce, distribute or use seeds and seedlings with the purpose of recomposing or recovering areas of environmental interest, are exempted from registration with RENASEM (Art. 175, Decree nº 5.153/2004 - Brasil 2014). According to Normative Instruction nº 17/2017 (Brasil 2017a), collection and production of seeds and seedlings need to be thoroughly documented. With the exception of the trader, the other agents in the production chain need technical responsibility to control, issue declarations and other requested documents.

The legal framework for seed collection and commercialization is complex, and many authors (Miura *et al*. 2016, Freire *et al*. 2017 and Schmidt *et al*. 2018) suggest that restoration in Brazil should be legally facilitated in terms of legal requirements, given the current need for numerous procedures for the production of native seedlings and seeds for restoration. The strong normative formalization contrasts with the current production of native seeds in Brazil, which is an essentially family and community activity (Schmidt *et al*. 2018). Excessive rules increase costs and make it difficult to regularize small nurseries and seed collectors (Freire *et al*. 2017), many of which already existed before legislation on the topic (see Schmidt *et al*. 2018). There is a need to "obey the norms and standards established for each species or group of species [...]" (Normative Instruction nº 17/2017 - Brasil 2017a), which makes restoration in Brazil difficult, since numerous studies are needed to complete each of these parameters for a single species, requiring a lot of time with research (Miura *et al*. 2016). While Freire *et al*. (2017) and Schmidt *et al*. (2018) recognize recent positive changes (for example, excluding the need for a responsible technician

for small seedling nurseries at Normative Instruction nº 17/2017) they conclude that simplifications are necessary. For example, they suggest that native and exotic species should be treated in separate legal norms, as the latter usually are used on a larger scale (Freire *et al*. 2017) and primarily for production or commercial interests (*e.g*., forage species). They also suggest regulations for fast seed quality tests, such as the tetrazolium test for seed viability, techniques for seed dormancy breaking and simplified storage methods (Schmidt *et al*. 2018).

A stark contrast exists regarding the quantity and complexity of criteria demanded in activities that will support restoration actions and those required for requests to convert native vegetation to other land uses. While restoration is highly demanding regarding seed and seedling production, the conversion of Pampa native grassland to other uses, for example, is very simple, often requiring just a single request from one environmental agency (Rolim *et al*. 2021). It is urgent to revert this, as ultimately conservation is a much better strategy to maintain biodiversity and ecosystem services, when compared to restoration with its technical difficulties and often high costs.

Genetic conservation: main item to be included in restoration legal norms

While on the one hand, complex legal procedures complicate production and commercialization of plant materials for restoration, it is of course necessary to have rules that guarantee that the used plant materials are, in fact, adequate. Conservation of genetic diversity is a fundamental aspect in restoration (see above), but it still needs to be ensured by legal norms in Brazil. For the plants currently commercialized, no information on genetic integrity is available, as previously discussed. The use of local or regional seeds and seedlings ensuring the use of material adapted to climatic, edaphic and biotic conditions (Keller *et al*. 2000; Millar *et al*. 2008; Biernaski *et al*. 2012) has been shown to result in higher restoration success, especially in the long term. Therefore, for ecological restoration that is to rely on native plant material, it is necessary to define collection zones, which are geographic areas in which plant materials can be moved freely with little interruption in genetic patterns or loss of local adaptation (Miller *et al*. 2010). Genetic studies for each species are the most appropriate way to define seed collection zones because, depending on the species' reproductive system, the genetic structure of the populations will be different, and the variability distributed in a different way among the individuals that compose the population (Biernaski *et al*. 2012). As it obviously is not possible to conduct detailed studies on genetic diversity for all species, at least given the currently available resources, ecoregions may be appropriate limits for defining seed collection zones, especially in regions with little topographic or climatic variation (Miller *et al*. 2010).

In Brazil, this debate is still very much at the beginning (*e.g.* Biernaski *et al*. 2012) and no information was found in legal regulations about the use of local plants to vegetation recovery. European Union countries have already moved forward, ensuring that restoration takes place only with seeds and plant seedlings from the target region (*e.g.* Commission Directive 2010/60/EU 2010; Mainz & Wieden 2018). This is a necessary measure not only for grassland vegetation, but also for forest restoration in Brazil, as it is known that the control over the provenance of the plants used for restoration is practically non-existent. Grasslands in the Pampa and Atlantic Forest biomes in RS share the same dominant grass species (*e.g. Andropogon lateralis*; Andrade *et al*. 2019), but they can be genetically very different due to major climatic and soil differences. Even within the same biome, such as the Pampa, there is great environmental heterogeneity. It would not be advisable to use seedlings or seeds from one region to restore another. In this context, seedling nurseries and seed propagation areas should also remain within the collection zones, in order to avoid genetic crossing between different populations.

The need of minimum criteria for grassland restoration and the need of research

Only in 1981 a legal norm (Law nº 6.938/1981 - Brasil 1981) introduced the idea of vegetation recovery and established the need for restoration of degraded lands (Pinto *et al*. 2014; Castelo 2015). This norm also introduces "preservation and restoration of environmental resources", that is, any kind of natural environment. Although RS originally presented grassland vegetation in 62 % of its area (Cordeiro & Hasenack 2009), minimum criteria have not yet been established for the recovery of grassland areas by environmental agencies in RS. The question of regulations that set criteria for restoration or measurement of restoration success has been critically debated in Brazil, specifically for São Paulo state (*e.g.* Durigan *et al*. 2010; Aronson *et al*. 2011; Chaves *et al*. 2015). In this context, Aronson *et al*. (2011) state that public regulation is required as far as it can effectively improve the quality, and increase the scale, of restoration projects and programs. At the same time, the legislation cannot be so restrictive as to make activities, such as restoration, impracticable (see Durigan *et al*. 2010).

Licensing and inspection agencies need parameters to assess whether the requirements have been met (Durigan *et al*. 2010). In the absence of legal norms, and despite the few documented restoration works carried out in Brazilian subtropical grasslands, some aspects initially relevant in restoration and monitoring projects in this region need to be considered for the elaboration of a legal standard, such as the necessity to define ecological zones for seed collection for RS, as discussed above. Laws also need to include criteria to evaluate restoration success based on a comparison with more than one reference site (Ruiz-Jaen & Aide 2005) or a

set of general objectives to be achieved in the course of the restoration process (Aronson *et al*. 2011).

Many aspects still need to be studied to develop efficient ways to restore South Brazilian grasslands, such as understanding the potential and behavior of native species (type of management that favors seed production, phenology, storage, breaking dormancy, vegetative development, etc.) and the best ways of introducing these species in grasslands. This is the role of science. However, public agencies and legislators also need to play their part, adapting the legislation based on the best scientific knowledge available and pushing actively to advance technical knowledge. It is the dialogue that needs to be strengthened in Brazil to advance in restoration of grasslands and other ecosystems.

Here, we show that both the provision of plant material and the legal framework for restoration is insufficient for restoration of South Brazilian grasslands. Importantly, an intrinsic relationship exists between the legislation and the effective development of the seedling and seed chain. The basic parameters for the restoration of grasslands in the RS should, ideally, be regulated by the competent agencies in a way that restoration will be facilitated, or better, even stimulated.

The insufficiency of seedlings and seeds available in the market impede, at the moment, grassland restoration at a larger scale. For now, restoration will depend almost exclusively on direct seed/hay collection around the target area, techniques that have not yet been fully evaluated in terms of their efficiency. Additionally, the difficulty of finding areas with native grasslands in some regions can make this even more challenging.

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