Prospects of the classic method of forest restoration by planting seedlings: a review

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Abstract. This paper aims to present a literature review highlighting the perspectives of classical method of forest restoration through planting seedlings, addressing advantages, disadvantages, and ecological implications of the technique, compared to nucleation techniques. When ecosystems are altered, restoration can be accomplished using forest restoration methods. The first initiatives used standard random planting of trees, without defined spacing. After, restoration plantings have become mixed with native species, combining different species according to their characteristics or role in succession, and may be performed in islands of diversity or lines. The first consists of planting seedlings in small nuclei with high diversity and density of individuals of different ecological groups. total area in-line planting can be done by direct seeding or planting seedlings. In this case, combinations of species from different ecological groups planted in rows can be performed. However, the classical method of planting seedlings, although widely disseminated and playing an important role in biodiversity conservation, does not include system processes as a whole, compromising the ecosystem ecological sustainability. On the other hand, the use of nucleation techniques enables the occurrence of primary and secondary processes of ecological succession by adding diversity of species and different life forms to the system, complicating relations with small energy input contrived.
Keywords: Native forest species, Classic Ecological Paradigm, Forest recomposition.

Introduction

Natural ecosystems, especially forests, have been under constant pressure and degradation from anthropic action, due to agriculture expansion, urban occupation and public utility works construction. Data from FAO (2011) indicate that South America and Africa are the regions losing their forests most rapidly, registering forest cover net annual losses equivalent to 4 and 3.4 million hectares in the 2000-2010 period, respectively. In these places, the intense anthropic action establishes the beginning of the environmental degradation process, causing ecological integrity loss, biodiversity reduction, soil structure degradation (Lamb & Gilmour, 2003), in addition to changes in the energy and structural balance of these environments (Morellato & Haddad, 2000; Souto, 2009), which requires interventions aimed at the biological stability of natural ecosystems.

To reduce the degradation levels, federal legislation predicts the creation of Permanent Preservation Areas (APP), in which the removal of original vegetation cover is not permitted, except under license from the competent environmental agency. Taking this legislation as a reference, recently, the State of Rio Grande do Sul, through State Decree No. 47,137 / 2010, instituted the State Program for the Recovery of Permanent Preservation Areas and Legal Reserves, thus demonstrating the government's concern in view of the environmental issue (Rio Grande Do Sul, 2010).

Thus, when certain locations are altered, ecosystem restoration can be carried out using different forest restoration techniques, which aim to recover, initially or concurrently, the structure and ecological functions of forests. Among these techniques, planting tree species is considered, according to Castro et al. (2012), the oldest method of restoring forests. The same can be done in different ways, through the random planting of trees (Kageyama & Castro, 1989), in islands of diversity (Reis et al., 1999), with the planting of seedlings in small nuclei (islands) with high diversity and high density of individuals of species from different

ecological groups as well as in total area, through direct sowing or planting of seedlings, aiming at a gradual replacement of species in the environment.

The conceptual support of the restoration technique by planting tree species is marked by the Classic Ecological Paradigm, which attempts to reproduce an idealized climax of preserved forests (Reis et al., 2006). From this perspective, the climax reached is unique and is obtained by a unidirectional trajectory. However, authors like Pickett & White (1985) started to consider the possibility of having several possible climaxes, produced from different trajectories followed by the ecosystem, which may occur due to the influence of natural disturbances, for example. Thus, the contemporary paradigm emerges. This allowed, according to Brancalion et al. (2009), that other restoration techniques besides the total planting of seedlings could be known and tested, such as isolation, conduction of natural regeneration, direct seeding, transplanting of seedlings, transposition of gallery, transposition of litter, artificial perches, nuclei of Anderson, among others.

Given this context, the present work aims to present a literature review highlighting the perspectives of the classic method of forest restoration through planting seedlings, addressing the main advantages, disadvantages, and ecological implications of the technique.

Contextualization and Analysis
Concepts in Ecological Restoration
Ecological restoration, a practical application of restoration ecology science, is a new and emerging area of knowledge that has evolved over the past few decades, consolidating itself in line with scientific research (Jakovac, 2007). In this sense, according to the Society for Ecological Restoration International (SER), ecological restoration is the process of helping to restore an ecosystem that has been degraded, damaged, or destroyed (Ser, 2004). Given the intensification of degradation and suppression of natural areas, ecological restoration has been widely used to reverse these processes and improve biodiversity conservation and the generation of ecosystem services and goods (Aronson et al., 2011). However, these authors stressed that, since it is a new science, it still needs consensus on definitions and concepts involved.

The terms rehabilitation, recovery, and restoration are generally used interchangeably. However, in terms of the processes to be developed and, mainly, the objectives to be achieved, these concepts differ from each other. It is understood by area rehabilitation, when it has an adequate function for human use and restoration of its main characteristics, leading it to an alternative and stable situation (MINTER / IBAMA, 1990). According to Ser (2004), rehabilitation emphasizes the repair of ecosystem processes and functions to increase the flow of services and benefits to people, without the need to re-establish the original composition and structure of the ecosystem.

Regarding recovering, Brazilian law defines, according to Law 9,985 of 2000, Article 2, item XIII, that the term refers to the restoration of an ecosystem, or a degraded wild population, to an undegraded condition, which can be different from its original condition. Thus, in recovery processes, we can have the return of the functions of a given environment, without the original ecosystem structure being reintroduced. This is the case, for example, with the recovery of certain resources or ecological factors, such as the soil, which, when recovered, promotes its life support services, not necessarily, for local biodiversity.

The restoration aims at restoring a degraded ecosystem to an undegraded condition, as close as possible to its original condition (Barbosa & Mantovani, 2000; Rodrigues & Gandolfi, 2001), in view of reestablishing the original ecosystem structure and ecological processes. According to Ser (2004), the plant community structure means the physiognomy or architecture of the vegetation, including the different forms of life of the organisms making up these communities (herbs, shrubs, lianas, epiphytes, among others) while the ecological processes (ecosystem functions) are dynamic attributes, such as interactions between organisms and between them and the environment. Rovedder et al. (2014), synthesizes that the intention of obtaining the identical configuration to the original can be a utopian goal, however, the attempt to restore the natural condition, as close as possible, is valid.

Classic method of forest restoration
When ecosystems are altered, their restoration can be carried out using forest restoration methods, such as planting tree species at random, on islands of diversity (Reis et al., 1999) as well as in total area, by sowing direct or planting seedlings.

The first initiatives to recover areas occurred in the late seventies, using the random planting model of trees, with no defined spacing (Nogueira, 1977; Kageyama & Castro, 1989). This method assumes that the propagules of different species fall, germinate, and grow at random in nature, giving no importance to the existing differences between the groups of species expressed in ecological succession (Kageyama & Gandara, 2000). Afterward, in the eighties, the restoration plantations started to be mixed with native species, combining different species according to their characteristics or role in the succession (Bellotto et al., 2009a).

In this case, planting can be carried out on islands of diversity or in rows. The first consists of planting seedlings in small nuclei with high diversity and density of individuals from different ecological groups (Castro et al., 2012). According to these authors, the islands formed simulates the form of forest expansion, as they expand until they cover the total area. According to Kageyama et al. (2003), the islands of diversity reduce the total cost of restoring the site due to the reduction in the number of

seedlings to be planted and the frequency of carrying out cultural treatments.

In-line planting, in total area, can be done by direct sowing or planting seedlings. In this case, combinations of species from different ecological groups planted in rows can be performed, as proposed by Piña-Rodrigues et al. (1997), in which a line with pioneer species and another line between pioneer and non-pioneer species is implemented. In addition to this combination, others can be established as suggested by Kageyama & Gandara (2000) with alternation of pioneer and non-pioneer species in the same line, and plants of different lines must be mismatched regarding ecological groups. Also, according to these authors, in-line planting should be prioritized for large-scale plantations, with operation automation.

The composition of species to be used is an important component of stability, due to the different characteristics of the species (Tilman, 1999). The use of native species provides the appearance of pollinators and natural dispersers, fundamental to the beginning of the natural regeneration process (Carpanezzi, 1994), promoting ecological succession through the attraction of dispersing fauna (Reis & Kageyama, 2003). Crestana et al. (2006) highlighted that the use of universal principles, such as species diversity, interaction between plants, secondary succession, and the use of native species of regional occurrence, should be considered when choosing the planting model.

In general, the choice of a planting model is based on the forest dynamics, in ecological and functional groups, aiming to simulate the conditions of the succession process (Piña-Rodrigues & Araujo, 2011). According to Rodrigues et al. (2009), the categorization of tree species into ecological groups (fill and diversity) is important for mixed forests implementation, considering phenological and growth characteristics, in addition to the shape and density of crowns, also considering the silviculture characteristics of these species and their behavior in plantations.

According to these authors, species belonging to the filling (covering) group have the function of quickly covering and shading the area, reducing the occupation by invasive grasses, and enabling environmental modification allowing the establishment of individuals in the diversity group. These species have as main characteristics: rapid growth, canopy cover with great leaf density, potential for nutrient cycling, being part of this group the early pioneer and secondary species from the beginning of natural succession. Regarding the diversity group, it is composed of species that present different successional performances (pioneers, secondary and climax).

After choosing the planting model, the spacing to be used is defined. Nascimento (2007) indicated that smaller spacing (1m x 1m; 1.5m x 1.5m; 1.5m x 2m) can provide faster soil coverage, inhibiting unwanted colonizing species such as brachiaria grass (*Brachiaria* spp). However, studies by Leles et al. (2011), suggest the use of 3.0 x 2.0 m spacing in forest replanting plantations, as this provided greater growth for pioneer species (initial phases of succession) and non-pioneer species (final phases of the succession), the growth was similar to the values achieved in denser spacing.

In operational terms, planting should be carried out, preferably, in rainy periods, where rainfall is higher and evaporation is lower, that is, during the winter months in southern Brazil, to favor the survival of seedlings (Castro et al., 2012). In regions with a subtropical or temperate climate, such as in the south of Brazil, the period of low temperatures and the frequency of frosts must also be observed.

The soil preparation can be carried out in total area or only in the planting lines. However, as the objective is to initiate the recovery of the environment, the soil preparation in total area is not the most recommended, since it provides an intensive mobilization of the soil combined with the high operational cost. Thus, it is recommended only to prepare the soil in rows, using appropriate machinery, which keeps residues from previous activities in addition to protecting the soil from erosion. Afterward, the holes are opened in the planting area, according to the established spacing.

Monitoring activities such as invasive plants eradication, control of leaf-cutting ants, crowning of planted seedlings, among others, must be continuous. Jesus & Rolim (2005), stated that this is one of the main problems of forest restoration projects, as it involves financial resources and labor. The monitoring after planting, besides allowing the control of problems and necessary practices, allows the observation of seedling survival and growth. Still regarding monitoring, Carvalho (2000) reported that the implementation of cultural treatments in plantations aims to reduce the competition imposed by invasive vegetation, light, moisture, and nutrients.

Also, the access of ruminants to planted areas should be prevented. The access of these animals in the area causes trampling, grazing, physical and mechanical damage, and plant consumption (Mariot et al., 2008). Moreover, Schneider et al. (1978), reported that cattle trampling leads to soil surface exposure and damages superficial roots responsible for nutritional absorption, which can compromise the survival of individuals. In this way, avoiding the entry of these animals in plantations, especially during the first years, favors the revegetation process, as it allows a full development of the seedlings as well as decreasing the need for replanting (Mariot et al., 2008).

The classic method of forest restoration through the planting of tree species can play an important role in biodiversity conservation, as long as one seeks to introduce species representative of the physiographic region of the plantation. According to Gomes (2006), the species composition of an ecosystem is the result of both processes that have

occurred and continue to occur on a large scale in time and space and local and short-lived processes. Thus, the species that were found in a given vegetation have evolved and adapted to the physical and biotic conditions of their environment and should be given priority in recovery plantations. Rovedder et al. (2014) point out that the introduction of alien genotypes can result in unsuccessful planting, due to not adapting the seedlings, or in ecological problems, such as local populations suppression and damage to interactions with other species, such as pollinators and dispersers, as a result of the phenological variations introduced.

The method offers the advantage of controlling the planting density (Almeida & Souza, 1997) and the rapid covering of the soil, provided by the treetops that, together with the root system expansion of the implanted forest, is a guarantee of protection against erosion. Also, the constant leaves deposition and other plant materials are important to restore soil fertility (Poggiani et al., 1981). In addition to these, other advantages can be seen in Table 1.

Table 1: Main advantages and disadvantages of the classical method of forest restoration through planting seedlings.

Classic Method	Benefits	Disadvantages	Recommendations
Planting seedlings in rows	Quick ground cover; less maintenance with grasses; reduction in maintenance costs; planting density control.	High implementation cost; difficulties in obtaining seedlings.	When there is proximity to a seedling nursery; different species availability; human and financial resources availability.
Planting seedlings on islands	Less seedlings; lower implementation costs.	Slow ground cover; operational difficulties; increased maintenance costs.	Indicated where regeneration already exists; places with low manpower availability; resource limitation.
Density	No need for species diversity; Fill the area with roof flaws.	-	Areas that have native forests, but that do not fill the entire area.
Enrichment	Populate the impoverished area with individuals of different species.	Conditional on monitoring.	Indicated for impoverished areas that do not have a source of propagules nearby.

Adapted from Cury & Carvalho Junior, 2011.

However, many difficulties are encountered when the restoration option is made via planting seedlings. Ferreira & Silva (2008) cited the lack of technical knowledge, the high implantation and maintenance costs, unavailability and / or low quantity of seedlings in the market, lack of manpower, in addition to the lack of specific incentives for the activity. Mariot et al. (2008) reported that this method is costly and tends to fix the composition in the succession process, without considering the other initial phases of the succession. This values the forest structure at the expense of natural dynamic processes (Reis et al., 2006).

Also, in classical plantations, individuals are basically the same age and marked growth in diameter and height (Mariot et al., 2008), but do not incorporate life forms diversity, which does not allow a mosaic formation, as occurs in natural forests.

The occurrence of different forms of life, including species of herbaceous size, lianas, vines, epiphytes, among others, in addition to the trees, is considered an extremely important challenge for restoration, since it allows the recovery of ecological processes and perpetuation of these ecosystems. In this sense, Bellotto et al. (2009b) reported the role of lianas as key species, due to resources supply to pollinators and dispersers, contributing to the maintenance of the associated fauna, in periods of scarcity of them, by tree species. Similarly, Cavalhães et al. (2007), highlighted the ability of bromeliads to create microsites and offer food to fauna.

Classic method in the face of ecological implications
The classic method, represented by the planting of seedlings, is characterized by the determined number of individuals that showed high growth in height and diameter (Bechara, 2006), seeking to reproduce a deterministic system (Reis et al., 2006). Thus, the planting of seedlings has a marked presence of the Classic Ecological Paradigm or Equilibrium Paradigm in the adopted methodologies, which always sought to reproduce an idealized climax of preserved forests, considered as an ideal model, as soon as possible. Martins (2012) reported that under the classic paradigm, the ecosystem is considered as a closed unit, self-regulating and not influenced by environmental and anthropogenic factors.

Classical models or deterministic successional models are restricted to the definition and interpretation of ecological groups, associating the plants of these groups in conventional plantations, inhibiting essential community interactions, implying low diversity, and few forms of life. As a result, there is a stagnation of natural succession (Tres, 2006), as it does not include the processes of the system as a whole, in addition to neglecting the complexity of the ecological system. This can be evidenced by the study carried out by Damasceno (2005), monitoring areas restored

through conventional planting of seedlings, in which the entry of new species into the system was not verified, which does not guarantee the system's self-sustainability or ecological viability.

The classic method of planting seedlings, especially in models that alternate lines of species from different ecological groups, represents a large part of forest restoration projects carried out in recent years, especially in the Atlantic Forest (Brancalion et al., 2009). However, Ferreti (2002) stated that the restoration has as reference the forest natural processes of recovery and regeneration. Thus, a restoration model does not necessarily imply planting seedlings. As an example, the author mentions that in certain situations the simple isolation of the area is already sufficient for it to recover naturally. The definition of a model or another implies knowledge of the area to be managed and the interpretation of the environment, making it possible to use and combine different models of restoration in the same place, reducing costs, time and labor.

Thus, a new paradigm (Contemporary Paradigm) starts to influence forest restoration techniques. This paradigm considers systems as a result of a variety of natural flows (energetic and biological), the sum of processes and contexts, encompassing biotic and abiotic elements (Parker & Pickett, 1999). Natural systems come to be considered as a complex web, involving interactions between plants, microorganisms, and animals, exchange of matter and energy, gene flow, among others (Reis & Kageyama, 2003).

In this way, the models developed under this paradigm start from the premise that restoration is a continuous dynamic process, and not the result of a single event, traditionally figured by conventional models. In addition, Martins (2012) reported that after recognizing the importance of factors such as disturbances, surrounding vegetation, initial floristic potential, resilience and diversity in succession, a series of methodologies can be adopted, highlighting those that aim to use the soil database seeds to start the regeneration process.

Nuclear techniques accelerate and qualify the natural regeneration processes due to stimulating interactions between species (Bechara, 2006), allowing the connection between areas previously separated by forest fragmentation, in addition to being characterized by the low implantation cost, as they use materials of easy access and obtaining (Mariot et al, 2008). In these techniques, only 5% of the area is effectively occupied, with the largest portion of the area destined for natural regeneration that will be facilitated and triggered by these techniques (Espindola et al., 2006).

Martins (2009) reported the possibility of taking advantage of the resilience potential that certain areas to be recovered have with the plant material availability, including propagules and plant remains, from areas whose environmental licensing allows vegetation to be suppressed. In this case,

nucleating techniques can be used such as gallon transposition, topsoil transposition (Nave, 2005; Bechara, 2006; Jakovac, 2007) and seedling transplantation (Nave, 2005; Viani & Rodrigues, 2007; Rodrigues et al., 2009; Turchetto et al., 2016). Also, the use of artificial perches, or plant species as natural perches (Reis et al. 2003), can accelerate the restoration process by attracting dispersers, and can be used concurrently with other nucleating techniques.

In this sense, both techniques, although still recent in the literature, have been showing good results, enabling the restoration of ecological functions in the areas under study, being indicated as a promising methodology for forest restoration. However, the continuity of long-term research is essential to ensure the effectiveness of these techniques as well as to allow them to be widely disseminated.

When comparing the results of conventional planting with those from nucleating techniques such as soil transposition, hydrosowing, transposition of galleries, artificial perches and planting of seedlings, in Anderson Groups, Mariot et al. (2008), stated that the use of nucleating techniques is bringing superior results from an ecological and economic point of view for the ecological restoration of the Serra do Facão Hydroelectric Plant construction site. These authors reported that the nucleating techniques used are attracting native fauna to degraded areas, which help in the seed's natural dispersion, thus increasing the probability of the environment to be occupied by other species.

The nucleation techniques represent an attempt to recreate the succession process due to the gradual increase in biodiversity radiated by the formed nuclei, obeying the natural successional stages of a native forest (Kageyama & Gandara, 2000), without worrying about a final climax to be achieved. Another trend in nucleation techniques under the contemporary paradigm, cited by Nave (2005), consists of recognizing the importance and need to consider, besides the technical aspects, the social, cultural, aesthetic, and political aspects of restoration.

Considering these premises, the restoration process of an area is gradual and continuous over time, with the interference of nature itself in this restoration trajectory.

Final considerations

The classic method of planting seedlings, despite being widely disseminated, used, and playing an important role in biodiversity conservation due to the introduction of regional species, does not include the processes of the system as a whole, which compromises the ecosystem ecological sustainability.

On the other hand, the use of nucleating techniques allows the occurrence of primary and secondary processes of ecological succession, adding diversity of species and different forms of life to the system, complexifying the relationships with

small artificial energy input. In this sense, the continuity of long-term research is extremely important, which will make it possible to prove the effectiveness of these techniques as well as to disseminate them.

It is noteworthy that the identification and choice of the most appropriate ecological restoration method to be used depends on an appropriate diagnosis of the site and its surroundings, which requires sensitivity and creativity from the restorer to interpret the signs and characteristics of the environment.

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