Direct Sowing: An Alternative to the Restoration of Ecosystems of Tropical Forests

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1. Introduction

In tropical regions, under certain situations, we can employ a nature-oriented regeneration, as opposed to the artificial one. This is possible when there still is some resilience in the environment which can enable its own regeneration. The nature-oriented regeneration is a simple method of low cost, which may promote the formation of productive forests in the areas previously degraded (Shono et al., 2007). However, for the areas that have been very fragmented and with a more severe environmental degradation promoted by human disturbances, there are physical, chemical and biological barriers that reduce the resilience of these areas and prevent natural regeneration processes (Shono et al., 2007).

In these situations, it is necessary that humans (foresters, ecologists and farmers) intervene, through artificial means (seedlings plantation or direct sowing) to start processes of soil covering and vegetation restoration. The use of direct sowing to restore degraded ecosystems has become a viable alternative for this purpose in the tropical forest regions, as opposed to the conventional method of planting seedlings (Ferreira et al., 2007).

In this context, this chapter aims to analyze ecological, technical, socio-economic and forestry aspects involved in this process. It also highlights that several experiments conducted in the tropical regions around the world may contribute to broaden the perspectives and enhance methodologies, so that the ecological restoration can be used more widely.

Herein some already undertaken research findings will be reported which will bring to light some experiences that may contribute to the decision making on the choice of direct sowing for restoration of degraded ecosystems.

2. Importance of restoration of tropical forest ecosystems

In the tropical regions, natural resources are of great economic importance to the countries therein, especially to communities that depend exclusively on these resources for their livelihood and survival (Lamb & Gilmour, 2003).

Among natural resources, exploitation of native forests, either for obtaining direct or indirect benefits, has always been associated with the development of human communities. However, as an immediate consequence of continuous exploitation, the environment degradation has become increasingly apparent. This is resulting from the use of development models based on super-exploitation, and in most of cases the latter is done without adequate planning and without any commitment to the future generations. Thus, it is globally observed in a significant reduction framework of forested areas.

The highest rates of change in relation to the use of soil are recorded in the tropics. According to Lamb & Gilmour (2003), it is estimated that approximately 17 million of hectares of forests are annually changed from their natural conditions to other forms of use. It is also estimated that half of this area is in the range of wet tropical forest.

Even if we consider all the richness of biodiversity of the plants, animals, and microorganisms of the tropical forests, besides the high rates of rainfalls, high incidence of sunlight, large amount of biomass, and intense recycling of organic matter, these are still considered as fragile environments (Ambasht, 1993). One should also consider that as a result of poor edaphic conditions in most of the areas, forests may be easily converted and degraded, leading to savannization and desertification (Ambasht, 1993).

In an attempt to reverse the accelerated environmental degradation condition, practices of recovering degraded ecosystems are very old, and can find examples of its use in the history of different peoples, times and regions (Rodrigues & Gandolfi, 2004). Nevertheless, until recently, recovery processes of degraded zones were more characterized as silvicultural practices without close ties to the theory, and usually performed as a practice of seedlings plantation with specific purposes, such as erosion control, slope stabilization, and landscape improvement (Rodrigues & Gandolfi, 2004).

Knowledge broadening concerning processes related to the dynamics of natural vegetation formations has promoted meaningful changes in the orientation of environmental recovery programs (Rodrigues & Gandolfi, 2004). In this case, the actions of recovery no longer have the connotation of sheer application of silvicultrural practices that aim only at the restoration of forest species in a given environment in order to fulfill the difficult task of trying to recover the ecological processes. As result, it implies in the attempt to restore the complex interactions of vegetal communities having intrinsic characteristics to assure the perpetuation and evolution of the natural ecosystems (Rodrigues & Gandolfi, 2004).

Overall, it is possible to note that most of the experiences in restoration of degraded areas in tropical forests involve large investments. However, according to Jesus & Rolim (2005), the main and most current trends to recover degraded areas are related to an appropriate species selection, implementation of more effective plantation models, and researches are always focusing on the reduction of implementation costs. As stated by Ferreira (2002), the development of technologies aiming at the recovery of degraded areas at lower costs is indispensable, since in tropical forests most areas are in possession of small owners, who have limited or no available resource to be employed in the recovery process. In this context, despite very effective experiences and already consolidated by means of seedlings plantation, the employment of direct sowing in the field, similar to agricultural areas, may also be feasible in silvicultural, ecological, social, and mainly economic aspects promoting restoration of ecosystems at lower costs.

It is observed that the existing imbalance between the use and maintenance of forest resources is caused principally by their excessive exploitation, when in most situations it even happens without the awareness of required mechanisms in order to have an efficient regeneration of these environments (Maury-Lechon, 1993).

In the tropics, to recover degraded areas, it is necessary that the socio-economic conditions of the local communities are taken into consideration, since in many areas, these factors may be more important to select suitable methods to be employed for this purpose than the ecological and silvicultural factors themselves (Lamb & Lawrence, 1993). In this case, according to the aforesaid authors, human communities that exploit forests directly for their own survival are of great importance in the ecological processes and their restoration.

According to Ketler (2001), this interdependence may be observed in different countries where their economy is strongly related to efficient use of the land. For instance, some experiments conducted in New Zealand, Mexico, and Philippines show that when restoration is planned, besides the ecological processes, the social and cultural values of the communities also need to be observed and taken into consideration (Ketler, 2001).

3. Systemic approach to the restoration of forest ecosystems

Environmental systems are complex and dynamic, consisting of a large number of interconnected elements, capable of exchanging information with their surroundings, and able to adapt their inner structure as a result of interactions among their elements (Cristofoletti, 2004). Although they are organizationally closed, but open in terms of flows of matter and energy, environmental systems receive inputs, transforming them and generating products. In view of their model, it is necessary to evaluate the flow and transformation of some inputs, such as water, sediments, light, raw matter, nourishment, and others (Cristofoletti, 2004).

In the case of forest ecosystems, organisms and their communities (flora and fauna) reproduce hierarchically complex levels of structural organizations that function in closed form, and where each group fulfills its own ecological purpose. That is, plants absorb light energy and conduct photosynthesis, herbivores eat plants, carnivores eat other animals, fungi recycle nutrients, and so forth, with the whole system working and self-producing within the limits of thermodynamics laws (Odum, 1988; Ricklefs, 2003).

According to Aumond (2003), this model assumes irreversibility of the process, in which matter and environment energy flow continuously considering the whole structure of the ecosystem, and keeping it beyond the state of equilibrium. The instability of this process, associated with the mechanisms and techniques of restoration that allow the internalization of part of the matter and energy flow, leads to a self-organization resulting from the emergence of new structures that work as attractions of a growing complexity.

In degraded systems, the absence of some ecological variables hinders the development and improvement of biodiversity, and the organization model will be open, with high entropy, resulting in progressively greater and irreversible losses (Aumond & Comin, 2008). The water seeps out of the system, consequently dragging particles, such as organic matter, macro and micronutrients, further impoverishing the soil of the degraded area. In areas lacking vegetation, water retention will always be lower than in areas with vegetation cover. Direct sunlight on the soil surface leads to extreme temperature fluctuations. Solar heat transfer to the environment by means of conduction, radiation, and convection, produces considerable temperature fluctuations in the soil followed by great losses to the atmosphere. Therefore, in open systems, there are appreciable losses of matter and energy, and hence it is necessary to internalize the ecological processes; that is, to enable the organizational closing of the degraded zone, inducting into the introspection of environmental variables, aiming at the increase of flow of matter and internal energy in the system (Aumond & Comin, 2008).

The sustainability of ecological systems is supported by three pillars: biodiversity, nutrient cycling, and energy flow (Franco & Campelo, 2005). Also, in the opinion of these authors, to maintain the soil any system need to include as many vegetal species as possible, sustain high levels of organic matter in conjunction with the soil microbiota, besides being most effective in the use of water, light, and nutrients.

Several authors consider the soil, vegetation, water, fauna (invertebrates), microclimate, and relief rugosity as being the main components to be taken into account when recovering a degraded area (Odum, 1988; Ricklefs, 2003; Aumond, 2007). Considering the environment and degraded system, with the main components, by means of an influence diagram, one may observe that the presence of water flow in the surface may indicate an increase of erosion in the soil; the presence of a vegetal layer corresponds to greater microclimatic softening due to the decrease of solar radiation, which results in lower environment temperatures and higher relative humidity of air; roughness such as relief changes may indicate more water, sediments, and propagules retained in the degraded system; water affects the microclimate through the mitigation of its variables, and so on.

Upon studying an integrative model to recover areas degraded by mining activities, Aumond (2007) developed an ecological model, considering the area as a complex and dynamic system, sensitive to initial conditions for the site preparation, with the application of rugosity techniques to trigger over time emergent properties that accelerate the recovery process. Over a period of time of 26 months, the author assessed the evolution of the components (soil, vegetation, fauna, water, microclimate, and rugosities), concluding terrain variations helped retaining and minimizing the volume and flowing coefficient of the water in the terrain, with an impressive decrease of erosive processes. The author also confirmed the development of the *Mimosa scabrela* species (through the use of seedlings plantation) and the height of spontaneous vegetation had better growth in irregular areas, contributing to the changes of solar radiation, temperature and relative humidity of air which resulted in the death of herbaceous plants and shrubs, standing out the trees, confirming an advanced stage of succession in irregular areas.

Thus, the restoration process for degraded zones starts from its reforestation by using methods that make ecological succession feasible, covering the exposed soil and stimulating the development of new vegetal species. When this process is successful, not only the development of new species in the environment occurs, it also resumes the condition of self-sustaining, and the reconduction of ecological relations enables the integration of the area recovered with areas preserved in its surroundings (Van den Berg et al., 2008).

When it comes to the restoration of permanent preservation zones, programs will only be successful if the land owners consider the actions attractive and think that they can bring benefits or payments in the form of ecological goods and services, such as: improvement of quality and increase in the quantity of water produced by the hydro resources, carbon sequestration and conservation of biodiversity (Lamb et al., 2005). However, according to

Miller & Hobbs (2007), defining programs and priority actions to restore landscapes based only on types of characteristic habitats or forms of vegetal cover, from metric standards, such as the index of fragmentation of a specific zone or yet, considering very broad objectives like conservation of biodiversity, may constitute large setbacks to reach more effective and well succeeded restoration.

In several countries, it is observed that the most widely employed method for such purpose is by means of seedlings plantation of different ecological groups with mixed populations. Nevertheless, the use of direct sowing presents satisfactory results both from the ecological and economic-silvicultural points of view by using native species, making it feasible to recover the degraded zones.

4. Direct sowing system for tropical forests restoration

Upon starting a forest restoration program by using native tree species, it is essential to be aware of some aspects of the seed technology of the species to be used, mainly related to germination. As stated by Figliolia et al. (1993), awareness of favorable conditions for seed germination, principally temperature and lighting, is a determining factor in the germination process, since both the factors are directly interconnected with ecological characteristics of the species.

Seeds of pioneer species need to have conditions of high luminosity and temperature to germinate, and seedlings are intolerant to shade, besides having dormancy and forming a seed bank in the soil. On the other hand, seeds of climax species are not demanding of lighting to germinate and present little or no dormancy, constituting a seedling bank in the soil (Budowski, 1965).

Direct sowing consists of introduction of specific forest seeds directly into the soil of the zone to be forested. In principle, it is a technique recommended only for some initial pioneer and secondary species in areas lacking vegetation, and also for late secondary and climax species, for the enrichment of secondary forests (Kageyama & Gandara, 2004).

It is an inexpensive and versatile reforestation technique, which can be used on most sites, with a greater focus on situations where natural regeneration or seedlings plantation cannot be performed (Mattei, 1995a). Besides that, it shows favorable results in degraded areas of difficult access and steep terrain slopes (Barnett and Baker, 1991).

The methods most commonly employed to perform direct sowing with the purpose of restoring degraded zones are: spread of seeds throughout the area, sowing through grooves or plantation lines, and sowing through ditches (Barnett & Baker, 1991). According to Groot & Adams (1994), this method is very efficient whenever one desires to regenerate areas at very low costs, where clear cutting operations are conducted (Groot & Adams, 1994).

In Figure 1, one may find the steps required for the forest restoration process by using direct sowing. At first, one shall make a diagnosis of the area to be restored by means of a climatic and soil analysis to check whether there is or not the possibility to use this technique; followed by selection of vegetal species aiming at making the environment as close as possible to the original condition with the intent to facilitate the adaptation of the species.

Primarily, it is recommended to employ the species that naturally occurs in the region, or native species that may be associated with different ecological groups, and also the socio-economic importance of the species to the human communities within the areas to be restored. However, as claimed by Maury-Lechon (1993), the employment of species of the genus *Pinus, Eucalyptus,* and *Acacia* may be recommended for many countries where they do not occur naturally, since they are associated with their use with positive socio-economic impacts, are well adapted to the climatic conditions, and that do not compromise the local ecological balance. One must bear in mind that it is necessary to do careful planning to bring in their gradual replacement and assure the development of native species. In this case, from report of Durigan (1996), the exotic species may be initially recommended, playing the role of pioneer species. According to the author, this is desired in areas where the degradation degree is high and that may require a long-term recovery because they may provide a better environment to the native species of later successional stages.

It is also important to know the basics of germination, since the seeds of some species need to have pre-germination treatments to increase the percentage and standardize the germination. By means of tests originally carried out in the laboratories (Figure 2), it is possible to assess the physiological quality of the batches of seeds and establish the amount that will be used to perform the direct sowing, without wasting them.

The use of direct sowing is related to show some advantages, such as reduction of deformations of root system of field plants. It may also stimulate better development of seedlings, and yet, eliminates the cost of seedlings production during the nursery phase. On the other hand, it is observed that one of the major difficulties related to its use, to a large extent, is that it is still necessary to do a good analysis, because in most cases the results are inconsistent concerning emergence, survival, and growth of plants (Winsa & Bergsten, 1994).

Thus, some factors may be associated with the difficulty in applying this method to large areas because of high diversity of vegetal species in the tropical forests. Little is known of the species demands in the environment as to the essential factors to the emergence and development of seedlings, such as: lighting, temperature, and required humidity. These factors are associated directly with the features of the areas where the seeds are sown. In addition, another difficulty is related to the definition of the relation between the survival of seedlings and quantity of seeds that should be sown in order to assure a good recovery and good development of species.

When it comes to sowing density there is little information in literature. But, considering an immense diversity of vegetal species in the tropical forests, it is practically impossible to define the one that could be considered as ideal. However, Burton et al. (2006) recommend that a density that should be considered desirable shall be that one representing at least 50% of the soil cover; minimum density shall be related to maximum production, without observing an increment even with an increase of density and when it achieves a balance in demography, without a decrease or failure in the final stand.

One observes that for the restoration of degraded zones in the tropical forest ecosystems, the success of the use of direct sowing is related to the degree of degradation in the zone, that is to say, the possibility of success of the development of plants decreases with the increase in the degree of degradation. In wet tropic forest areas of Australia, the employment of direct sowing is recommended only before verifying a state of more intensive degradation (Sun et al., 1995).

Fig. 1. Illustration of steps required for the implementation of direct sowing in the process of restoration of degraded and riparian zones (Pictures of Santos, 2010).

Fig. 2. Analysis of viability of seeds lots in the laboratory by testing them in a germination camera (BOD), at constant temperature and under continuous lighting, before the implementation of direct sowing in the field (A); Germination of the seed lots of *Erythrina velutina* Wild (B) and *Sapindus saponaria* L (C).

In Brazil, some experiments were carried out in an attempt to make the direct sowing technique viable in the ecological and silvicultural terms, both in restoration of ecosystems and implantation of populations for economic purposes (Ferreira et al., 2007). Several experiments presented good results in the implementation of the species *Pinus sp.* (Mattei, 1997; Brum et al., 1999; Mattei et al., 2001; Finger et al., 2003), recovery of degraded slopes (Pompéia et al., 1989), and in the implementation of riparian forests (Santos Jr et al., 2004; Almeida, 2004; Klein, 2005; Ferreira et al, 2007, 2009 and Santos, 2010).

As claimed by Kageyama & Gandara (2004), the direct plantation of forest seeds may be used both for implementation of pioneer species in areas without forest covering, and for the implementation of slow-growing species (late secondary and climax species) in the enrichment of secondary forests.

However, in both direct sowing and work with seed banks, the emergence of seedlings of native species is irregular with predominance of few species, and pioneer ones prevailing, requiring the replacement of seeds in places where there were failures in germination. This way, the need for selected species for this purpose to present rapid emergence of seedlings in order to quickly obtain an effective soil recovery rate was observed. In order to have the acceleration of the germination process of the seeds and promotion of rapid development of seedlings, the use of treatments to break seed dormancy may be required, since the intent is to promote the fast soil covering (Winsa & Bergstein, 1994; Aerts et al., 2006; Ferreira et al., 2007; 2009; Santos, 2010).

The quality of the seeds, as assessed by the germination and vigor of each lot, is indispensable to ensure the germination in the field. Seeds with low vigor are unable to germinate in adverse conditions, and when they germinate, in most cases, they do not generate vigorous seedlings (Botelho & Davide, 2002).

Many authors identify the preparation of the site as an essential factor in the development of the seeds in the field (Smith, 1986, Winsa & Bergstein, 1994; Fleming & Mossa, 1994; Falck, 2005; Andrade, 2008; Santos, 2010), since in degraded areas, the exposure of soil to weathering results in the change of its physical, chemical and biological characteristics, retarding or making the development of any species impossible. Therefore, it is necessary to prepare the soil, prior to sowing, minimizing the physical difficulties to be found by the seedlings, and increasing the absorption of water by the soil and providing nutrients located in the lower layers of soil, besides other factors (Santos Jr, 2000).

In an experiment carried out by Santos (2010), with direct sowing, in the municipality of São Cristovão, Sergipe, Brazil, in two subsystems with different types of soil occupation (agriculture and pasture), it was found that the soil slips by means of plowing and harrowing may have contributed to the loss of seeds, mainly in the portions without a physical protector, due to the soil movement, leading to a landfill or seed dragging. This fact was evidenced in the pasture area, where the seeds of the species *Guazuma ulmifolia*, *Machaerium aculeatum*, *Lonchocarpus sericeus* and *Bowdichia virgilioides* presented low emergence in comparison to the portions with physical protectors. In an agricultural area, this fact was evidenced for the seeds of the species *B. virgilioides* and *M. aculeatum* (Table 1).

Species	Seedling Emergence (%)			
	Subsystem 1 – Pasture		Subsystem 2 – Agriculture	
	WP	WOP	WP	WOP
Erythrina velutina	57.14 aA	78.09 aA	99.05 aA	84.76 aA
Bowdichia virgilioides	16.19 bA	0.00 cA	96.19 aA	39.05 bB
Sapindus saponaria	40.00 aA	42.86 bA	79.04 aA	64.76 aA
Guazuma ulmifolia	26.67 bA	7.14 cA	52.38 bA	26.19 bA
Lonchocarpus sericeus	50.00 aA	6.19 cB	44.76 bA	44.28 bA
Machaerium aculeatum	7.14 bA	0.95 cA	14.76 cA	1.91 cA
Average	32.86A	22.54A	64.37A	43.49B

Averages followed by the same letter do not differ between them as per the Scott-Knott test at 5% probability (Ferreira, 2006).
Small letters in columns compare species for each protector (WP/WOP) in subsystem 1 and 2.
Capital letters in lines compare protectors, for each species, in subsystem 1 and 2.

Table 1. Seedling emergence of forest species (%), until 90 days after sowing in the absence and presence of physical protectors in two subsystems placed in the Rural Campus of Federal University of Sergipe, municipality of São Cristóvão, Sergipe. WP – with physical protectors; WOP – without physical protectors. (Source: Santos, 2010).

Sun et al. (1995) stated that the competition with grasses and the lack of soil fertility are the factors that also affect the seedling survival, once weeds have certain aggressiveness in the field. This characteristic makes them exceptional competitors, since in few months they colonize the area, interfering with the forest species, mainly in the development of climax species.

Weeds also present effective mechanisms for survival in the environment, as strategies to withstand adverse conditions, for instance: high reproductive capacity, effective dispersion mechanisms, and large seed longevity. These mechanisms are of great importance to ensure their success and win the competition with other species. The strategies of development in the environment noticed in weeds are similar to those mentioned by Budowski (1965) and Swaine & Whitmore (1988) for the pioneer or colonizing tree species.

The dry season, burial of seeds by torrential rains, and the severe cold are considered as the main climatic factors that cause damage to direct sowing (Mattei 1995b). It is also mentioned as a failure in direct sowing due to lack of contact of the seed with the mineral soil, displacement of the seed after sowing, flooding or excessive moisture close to the seed, and losses resulting from the attack of birds and ants.

Santos (2010) states that the presence of laminar erosion in the soil during the rainy season may affect the emergence of species due to dragging and burial of seeds that are planted without any physical protectors. And yet, even the portions with physical protectors may be affected by burial, and the presence of water in some places (Figure 3). Therefore, there is clear need to evaluate and monitor the area where the seeds will be directly sown.

Fig. 3. Presence of water in the physical protector (A) and burial through laminar erosion (B) after rainy season in a pasture area located in the municipality of São Cristovão, Sergipe, Brazil, after the implementation of direct sowing (Source: Santos, 2010).

One of the first experiments performed by using direct sowing in Brazil is mentioned by Silva Filho (1988) where tests were conducted in an attempt to recover zones in severe conditions of degradation located in Serra do Mar (Hill), São Paulo. Considering the high slope steepness, *Brachiaria* seeds were sown, but due to the rains, they were dragged to the bottom of the hill, promoting great emergence of seedlings in this area.

Upon evaluating the direct sowing of *Pinua taeda* and *Cedrela fissilis* through the use of two techniques of soil preparation (without preparation and plowing and harrowing), Mattei (1995b) concluded that the sandy soil proved to be inappropriate for the direct plantation of seeds in the rainy season because of the movement of its particle and rapid infiltration.

With the intent to make the direct sowing process possible, several authors tested the use of physical protectors aiming at the reduction of herbivory rate and at increasing the temperature and moisture of the superficial layer of soil (Mattei, 1997; Santos Jr. et al., 2004; Falck, 2005; Klein, 2005; Ferreira et al., 2007; Andrade, 2008; Santos, 2010).

According to Mattei (1997), the objective of use of physical protectors is to promote the improvement of germination of seeds and survival of seedlings in the field, creating a microenvironment for the development of young plants (Figure 4). Besides, it prevents the soil slips in conjunction with the seeds in different times of heavy rains, preserving the depth of sowing, and facilitating the emergence and hindering the attack of natural enemies (Mattei, 1995b).

Predation by ants and birds, considered as one of the major problems in the implementation of direct sowing, has been reduced by using physical protectors, which showed a significant decrease in predation (Schneider et al., 1999; Mattei & Rosenthal, 2002). As claimed by Serpa & Mattei (1999), the use of physical protectors may help in retaining moisture at the sowing point, as the presence of water is one of the essential factors in emergence, survival and development of plants.

The use of physical protectors in direct sowing cannot be recommended as a standard methodology for all species and situations, since its effectiveness cannot always be proven.

According to Ferreira et al. (2007), the use of plastic protectors was not effective either for the emergence or for the survival of seedlings, for the pioneer species: *Senna multijuga*, *Senna macranthera*, *Solanum granuloso-leprosum* and *Trema micrantha* (Table 2). On the other hand, the use of physical protectors, similar to those employed by Ferreira et al. (2007), was effective for the survival of the seedlings of the climax species such as *Cedrella fissilis, Copaifera langsdorffii, Enterolobium contortisiliquum, Piptadenia gonoacantha* and *Tabebuia serratifolia*, mainly preventing the attack of ants as observed by Santos Jr et al. (2004).

Fig. 4. Direct sowing of the species *Erythrina velutina* Wild (A) and *Bowdichia virgilioides* Kunth (B) through the use of physical protectors for germination (Source: Santos, 2010).

	Seedlings emergence (%)		Seedlings survival (%)	
Species	**WP**	**WOP**	**WP**	**WOP**
Senna multijuga	38.24 a	40.81 a	86.75 a	87.40 a
Senna macranthera	15.55 a	15.71 a	91.25 a	90.91 a
Solanum granuolo-leprosum	22.72 a	18.26 a	52.50 a	33.67 a
Trema micrantha	15.29 a	17.58 a	94.72 a	95.36 a

Tukey Test conducted at level 5% of probability
Comparisons of averages between treatments – same letters in lines do not differ between them.

Table 2. Seedling emergence and tree species survival 3 months after sowing under field conditions (WP – with physical protectors; WOP – without physical protectors). Adapted from Ferreira et al. (2007).

Physical protectors to improve emergence and/or survival of seedlings may be fabricated by using different materials like wood laminates, plastic cups, cardboard and plastic bottles. However, the latest trend is to use biodegradable materials to reduce the costs of implementation and which do not jeopardize the environment. It should be emphasized that whenever plastic containers are used it is necessary to remove them after accomplishing their purpose.

To Smith (1986), the success of direct sowing is to create a microenvironment with favorable conditions for rapid seedling emergence, with enough moisture during the period of emergence of seedlings and in the following phase, since the plants that germinate and grow in the field have restrictive protection in relation to the numerous lethal agents, which may be controlled in nurseries. Consequently, there are more risks of survival to be lower by using direct sowing than with seedling plantation. However, it is one of the most promising techniques in the recovery process for the degraded areas, especially when one of the objectives is to reduce the implementation costs (Santos Jr, 2000).

In tropical regions, with great environmental heterogeneity, it is possible to observe a significant variation of temperature moisture. In most studies, this range is from 20° to 30° C (Longman & Jenik, 1974). One of the ways mentioned to make the environment more appropriate for emergence is through the use of physical protectors, once they foster a more suitable microenvironment (Santos, 2010). On the other hand, in other studies the use of physical protectors for this purpose would be unnecessary in this phase (Santos Jr et al., 2004; Ferreira et al., 2007).

Another relevant factor in the use of direct sowing, is related to the size of the seed, as this characteristic may significantly influence both emergence and development of the seedlings in the degraded zones (Doust et al., 2006).

In this context, some information about tropical forest species were provided by Sautu et al (2006) for a group of 100 species that compose the Panama Canal Basin, which can be useful in coping with direct sowing.

Ferreira et al (2009) observed that both emergence and development of seedlings have been influenced by the seed density in the study carried out by using *Caesalpinia leiostachya* (0.154g), *Schinus terebinthifolius* (0.013g), *Cassia grandis* (0.753g), *Himenea courbaril* (4.994g), and *Enterolobium contortisiliquum* (0.664g). As claimed by the authors, the species that had bigger seeds, with higher density, tended to show faster and higher seedling emergence.

This fact was also verified by Doust et al. (2006) in a study conducted in Queensland, Australia, with 16 species for restoration of tropical forests. The authors noted that species with bigger seeds (>5.0g) presented better development in relation to small seeds (0.01g – 0.099g), and those considered as intermediate (0.1g – 4.99g).

This technique has a high potential to recover degraded areas provided that in the forest formation the main form of regeneration, both in gaps and in the expansion of the remaining, takes place by means of natural sowing (Botelho & Davide, 2002) which, under favorable conditions, fosters good germination of seeds.

5. Final considerations

Direct sowing, in view of experiments conducted and results obtained by several researchers, offers itself as a feasible alternative to restoration of degraded ecosystems in the tropical forests (Santos Jr et al., 2004; Ferreira et al., 2007; Ferreira et al., 2009; Santos 2010).

For its employment, some essential factors need to be taken into consideration: the degradation state of the area, selection of species with best capability for this purpose, site characteristics (terrain steepness, fertility, temperature, moisture, etc.), presence of weed, a thorough analysis of the need for physical protectors as they can foster a more favorable microenvironment to the emergence of seedlings, and protection against agents that predate seeds and seedlings, mainly ants and birds. On the other hand, it is necessary to understand that the use of physical protectors cannot be recommended as a standard method as a result of great interaction observed between them, the environment conditions, and the species employed. The results are not always favorable and, in many cases, their use is unnecessary.

One of the main favorable factors in the use of direct sowing to restore degraded forest ecosystems is the possibility to reduce implementation costs. Nevertheless, one needs to understand that, in addition to the ecological and silvicultural aspects of the selected species, it is also necessary to observe the socio-economic conditions of the local communities where the restoration will be carried out. In many regions, communities are dependent on natural resources for their living, and they need to be involved in the process.

From broader knowledge of ecology of ecosystems, searching understanding about the diverse interactions and its functioning may stimulate better uses of direct sowing, as it may represent an alternative to recreate or restore degraded environments in the tropical regions with characteristics more similar to the original natural environments.

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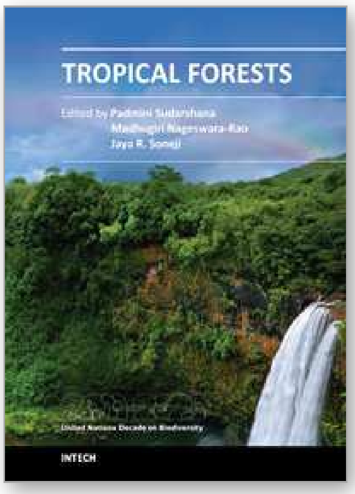

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The astounding richness and biodiversity of tropical forests is rapidly dwindling. This has severely altered the vital biogeochemical cycles of carbon, phosphorus, nitrogen etc. and has led to the change in global climate and pristine natural ecosystems. In this elegant book, we have defined "Tropical Forests" broadly, into five different themes: (1) tropical forest structure, synergy, synthesis, (2) tropical forest fragmentation, (3) impact of anthropogenic pressure, (4) Geographic Information System and remote sensing, and (5) tropical forest protection and process. The cutting-edge synthesis, detailed current reviews, several original data-rich case studies, recent experiments/experiences from leading scientists across the world are presented as unique chapters. Though, the chapters differ noticeably in the geographic focus, diverse ecosystems, time and approach, they share these five important themes and help in understanding, educating, and creating awareness on the role of "Tropical Forests" for the very survival of mankind, climate change, and the diversity of biota across the globe. This book will be of great use to the students, scientists, ecologists, population and conservation biologists, and forest managers across the globe.