
**OPPORTUNITY FOR THE STUDY OF CRITICAL SUCCESSIONAL
PROCESSES FOR THE RESTORATION AND CONSERVATION OF
MOUNTAIN FOREST: THE CASE OF MEXICAN PINE PLANTATIONS**

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SUMMARY

It has become clear that native species are incorporated naturally under the canopy of many tree plantations. This process of incorporation (facilitation) can be used as an opportunity to create successional models in restoration and species reintroduction projects. The need to incorporate basic ecological information is a critical issue in the process of ecosystem restoration. Pinus is a genus widely used in plantations worldwide. In Mexico, 199 790.4ha are planted with pine each year. Many of these plantations have been established with rehabilitation and conservation goals, and provide an opportunity for restoration through the reintroduction of native species of plants and ani-

mals. Because pine species are considered as pioneers in forest successional stages, pine plantations represent natural laboratories that can be used to test scientific hypothesis to strengthen the restoration and reintroduction programs. These plantations also represent an opportunity to apply scientific knowledge in practical field conservation and address the science-policy interface. In this essay, we presented arguments focused on the importance of plantations as areas for experimentation, given the diversity of environments in which they are found, from sea level to high altitudes, as well as the diversity in their structure and composition.

Introduction

Succession refers to the changes in plant associations, groups of animals or organ-

isms in general, through time and space (Drury and Nisbet, 1973). The classical succession theory states that succession is predictable, and points out

the presence of the species facilitation processes, that is, one plant species is capable of facilitating the establishment of another plant species

(Clements, 1928). The first plants to arrive after a disturbance are called 'pioneer' (earlier) species and the characteristic species of advanced

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OPORTUNIDAD PARA EL ESTUDIO DE PROCESOS CRÍTICOS SUCESIONALES PARA LA RESTAURACIÓN Y CONSERVACIÓN DE BOSQUES DE MONTAÑA: EL CASO DE LAS PLANTACIONES DE PINO EN MÉXICO

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RESUMEN

Se ha evidenciado que bajo el dosel de muchas plantaciones forestales se incorporan, de manera natural, especies nativas. Este proceso de incorporación (facilitación), puede ser usado como una oportunidad para crear modelos sucesionales en proyectos de restauración y reintroducción de especies. La necesidad de incorporar información ecológica básica es una cuestión crítica en el proceso de restauración de ecosistemas. Pinus es un género ampliamente usado en plantaciones a nivel mundial. En México, las plantaciones de pino representan 199 790,4ha al año. Muchas de éstas se han establecido con objetivos de rehabilitación y conservación, y constituyen una oportunidad para la restauración a partir de la reintroducción de especies de plantas y

animales nativos. Debido a que los pinos son considerados como especies pioneras de la sucesión, las plantaciones de pino representan laboratorios naturales que nos permiten invalidar hipótesis científicas para fortalecer programas de restauración o reintroducción de especies. Estas plantaciones también representan una oportunidad para aplicar el conocimiento científico en la práctica de la conservación de campo y atender la interfase política-sociedad. En el presente ensayo presentamos argumentos enfocados hacia la importancia que las plantaciones tienen como áreas de experimentación dada la diversidad de ambientes en las que se encuentran, desde el nivel del mar hasta las grandes altitudes, así como de estructura y composición de las mismas.

OPORTUNIDADE PARA O ESTUDO DE PROCESSOS CRÍTICOS SUCESIONAIS PARA A RESTAURAÇÃO E CONSERVAÇÃO DE BOSQUES DE MONTANHA: O CASO DAS PLANTAÇÕES DE PINHEIROS NO MÉXICO

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RESUMO

Tem-se evidenciado que sob o dossel de muitas plantações florestais se incorporam, de maneira natural, espécies nativas. Este processo de incorporação (facilitação), pode ser usado como uma oportunidade para criar modelos sucessionais em projetos de restauração e reintrodução de espécies. A necessidade de incorporar informação ecológica básica é uma questão crítica no processo de restauração de ecossistemas. Pinus é um gênero amplamente usado em plantações a nível mundial. No México, as plantações de pinheiros representam 199.790,4 ha ao ano. Muitas destas foram estabelecidas com objetivos de reabilitação e conservação, e constituem uma oportunidade para a restauração a partir da reintrodução de espécies de plantas e

animais nativos. Devido a que os pinheiros são considerados como espécies pioneiras da sucessão, as plantações de pinheiros representam laboratórios naturais que nos permitem invalidar hipóteses científicas para fortalecer programas de restauração ou reintrodução de espécies. Estas plantações também representam uma oportunidade para aplicar o conhecimento científico na prática da conservação de campo e atender a interfase política-sociedade. No presente ensaio apresentamos argumentos focados para a importância que as plantações têm como áreas de experimentação devido à diversidade de ambientes em que se encontram, do nível do mar até as grandes altitudes, assim como de estrutura e composição das mesmas.

successional stages are called 'later' successional species. There are several interaction patterns between pioneer and later species during succession, where pioneer species are eventually substituted by later species (Connell and Slatyer, 1977; Pickett *et al.*, 1987; Sánchez-Velásquez, 2003). Botkin (2005) describes these patterns as: 1) Facilitation. One species is capable of setting the way for another species, and the latter can in turn prepare the way for the next one. 2) Interference. The earlier successional species can restrain the establishment of later successional species for a while. 3) Life-history differences. One

species cannot affect the entry timing of another one; two species may appear at different times during succession due to differences in dispersion, germination, growth and seed longevity. 4) Chronic patchiness. Succession never takes place, those species established in the first place remain until the next disturbance.

Pines are characterized by their rapid growth, being shade-intolerant pioneer successional species that are adapted to disturbances like fire (Heywart, 1939; Curtis, 1959; Daubenmire, 1968; Ahlgren and Ahlgren, 1960; Peet and Christensen, 1980; Sánchez-Velásquez, 1986; Pineda-López

and Sánchez-Velásquez, 1992; Rodríguez-Trejo and Fulé, 2003) and to cleared areas larger than 1000m² (White, 1979; Jardel *et al.*, 2004). Therefore, pine species are considered, throughout the world, excellent species for the establishment of forest plantations as well as for the ecological restoration of cleared areas. Since pine species are considered as pioneers in natural forest successional stages (Henry and Swan, 1974; Peet and Christensen, 1980) and are used in several reforestation programs, they offer unsurpassable opportunities to study succession and restoration processes. Pine plantations could be used as a facilitation

mechanism to reintroduce, under its cover, a great variety of threatened or endangered species (Ramírez-Bamonde *et al.*, 2005).

In some countries, the natural recruitment of native species under the canopy of pine and foliage leaf plantations has been observed (Arrieta and Suárez, 2006; Pérez-Salicrup *et al.*, 2006). Since many plantations are used for ecosystem rehabilitation (functional recovery), the selection of species for these plantations is essential in order to incorporate natural native species and to accelerate the succession process towards the rehabilitation or restoration (Menninger and Palmer, 2006).

Mexican Pine and Pine Plantations

In Mexico, pine trees are one of the most important genetic resources for forestry, since resins, timber (80% of the national production), paper pulp, firewood and industrial products, among others, are obtained from pines. Pine trees are widely distributed in Mexico, because they grow naturally (Eguiluz-Piedra, 1988) at altitudes ranging from 100m (e.g. *Pinus caribaea*) up to more than 4000m (e.g. *P. hartwegii*), under an annual precipitation ranging from 200mm (e.g. *P. lambertiana*) to 2500mm (e.g. *P. patula*). Seeds of Mexican pines have been sown in many countries, such as South Africa, Argentina, Chile, New Zealand and Australia, with a remarkable success (Sánchez and Huguet, 1959; Rogers *et al.*, 2003). To offset the effects of deforestation in Mexico, the federal government's National Plan for Development applies special policies for the reforestation and restoration of degraded areas, and pine trees are the main source of reforestation.

Actions at a countrywide scale, well-known as a top priority, include the detention and reversal of degradation and deforestation processes, through the recovery of degraded forest land for reforestation or commercial plantations. Reforestation is proposed as a restoration and conservation mechanism, with three objectives: 1) Restoration of the largest possible area of degraded land, focusing on the quality of the site related to tree production and reforestation; 2) Conversion of degraded and unproductive areas into plantations of wood, non-wood, endemic and cover species to improve the environment and increase the presence of groundwater reservoirs; and 3) Increase plant biomass to contribute to carbon uptake. The strategies established to attain the above objectives include: a) Set an integrated reforestation plan for basins, assigning priority to high altitude areas, to guarantee the

recharge of groundwater reservoirs; b) Use native species in plantations for conservation and restoration, to contribute to the biodiversity preservation in forest ecosystems; c) Promote the development of agroforestry plantations in order to encourage landowner participation.

Currently, there is no available information on the total reforested area, but an estimated 571 000ha has been reported for 1999, and 998 952ha have been planted since 2001 under a variety of environmental conditions using different species. Pine trees are the most widely used species because of their adaptation features, which will be discussed below. Reforestation in Mexico covers 199 790.4ha established per year, with an estimated investment of USD 31 951 831.9. Since 2003, CONAFOR (National Forest Commission) offers economic support to forest landowners as a compensation for supplying environmental services (OCDE, 2003). Mexico has very large surface areas reforested in a wide variety of environmental conditions and, therefore, opportunities to develop strategies to reintroduce native species in degraded areas are wide and diverse.

Pine Plantations: Conservation Opportunities

At a global scale, plantations comprise 147×10^6 ha, and $\sim 2,8 \times 10^6$ ha are incorporated to plantations each year, 22% of them established for soil and water conservation (FAO, 2005). Pine trees account for 20% of plantations worldwide (FAO, 2000). In North and Central America, pine trees are the tree type most widely used in reforestation programs (>80%). In South America, Asia and Africa, pine trees are included among the four most important tree genera used for reforestation, while in Oceania they are not important (FAO, 2000). Plantations may be established for a number of purposes (commercial, restoration, rehabilitation, CO₂ uptake, industrial timber products and firewood, among others). Pine tree plantations have interesting attributes from the standpoint of restoration and reintroduction of endangered species and communities (see Figure 1). It has been demonstrated that *Pinus caribaea* plantations are suitable for the establishment of species characterized from late successional stages in rainforests, at Sri Lanka, for

example *Shorea disticha* and *S. trapezifolia* (Ashton *et al.*, 1997). *Pinus maximinoi* and *P. patula* plantations can be used for growing endangered species of advanced successional stage plants in mountain cloud forests, such as *Magnolia dealbata* and *Quercus germana* at Mexico and Colombia (Cavalier and Tobler, 1998; Ramírez-Bamonde *et al.*, 2005). It has also been demonstrated that pine plantations favor (nurse) the incorporation of native flora (Lust *et al.*, 1998; Vallauri *et al.*, 2002; Pausas *et al.*, 2004). For example, *Pinus sylvestris* favors the regeneration of *Ilex aquifolium*, a flag species of plant conservation in Spain (Arrieta and Suárez, 2006), and *Pinus radiata* favors the regeneration of *Pseudopanax arboreos*, *Hedycarya arborea* and *Alectryon excelsus*, among others at New Zealand (Moles y Drake, 1999).

Despite the fact that Mexico is considered as the pine species diversification site (Styles, 1998) and has a large amount of pine plantations, the paradox is that there are 22 (out of 49) species included in the Mexican Standard NOM-Ecol-059-94 under a protection category. Some Mexican pine species are consid-

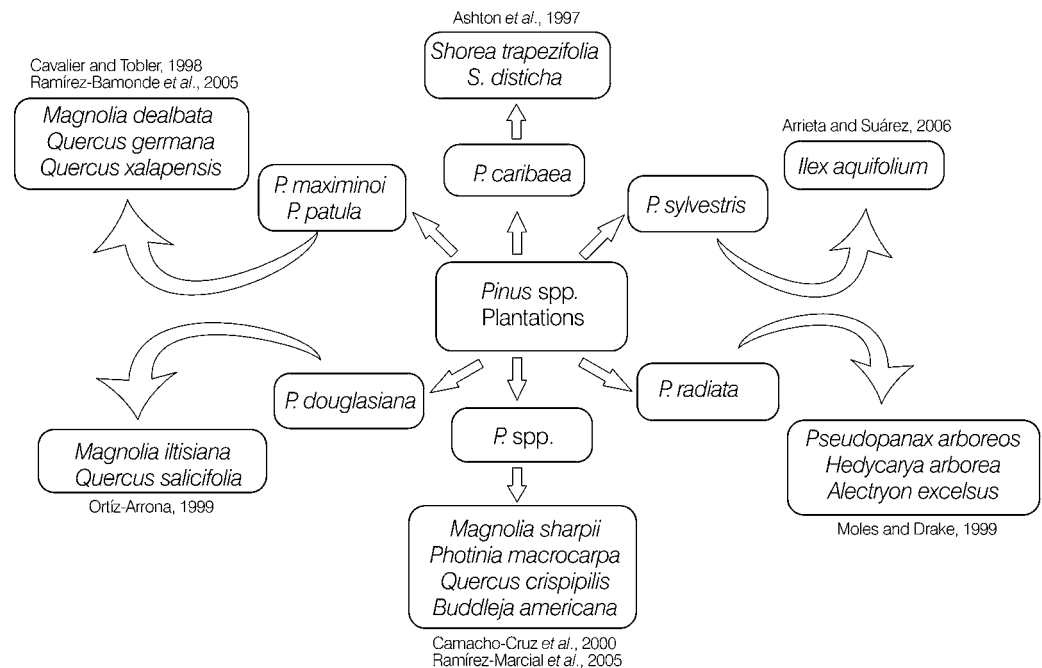


Figure 1. Outcome of pine plantations of different species at different localities, demonstrating the facilitation recruitment of endangered plant species. See text for more details.

ered as endangered (e.g. *Pinus maximartinezii*), threatened (e.g. *Pinus caribaea hondurensis*), subjected to special protection (e.g. *Pinus pinceana*) and rare (e.g. *Pinus jaliscana*). Some groups of pine species can be used throughout the environmental gradient for restoration and conservation programs.

Pine plantations are not the only useful option for restoration and reintroduction, as the native pine forests can also be useful for introducing endangered species or for preserving diversity (Sánchez-Velásquez *et al.*, 2008). For example, *Magnolia iltisiana* and *Quercus salicifolia*, species characteristic of the cloud forest, can be reintroduced under the cover of natural *Pinus douglasiana* forests (Ortiz-Arrona, 1999); whereas in Chiapas, Mexico, *Magnolia sharpii*, *Photinia macrocarpa*, *Quercus crispipilis* and *Buddleja americana*, among others, were successfully established under the *Pinus* spp. canopy (Camacho-Cruz *et al.*, 2000; Ramírez-Marcial *et al.*, 2005). (Figure 1). In addition, pine plantations can be replaced by late-planted species during the forest succession (Carnus *et al.*, 2006; Meiners, 2007).

Plantations are also suitable for managing and improving the quality site related with conservation and restoration for wildlife objectives (Clout, 1984; Hansen *et al.*, 1991; Hanowski *et al.*, 1997; Lindenmayer, 2002). For instance, when comparing bird communities in a grassland, 13-year old *P. patula* plantations and a natural oak forest in central Veracruz, Mexico, a higher diversity in pine plantations relative to the adjacent oak forests and grasslands was found; furthermore, 25 bird species (29%) occurred exclusively in pine plantations (Mendoza-Ortiz, 2006). Plantations can also favor different species of wildlife through the connectivity between landscape fragments, which today represent the prevailing type of landscape throughout the world, hence promoting the flow of individuals at a metapopulation level.

Natural pine forests are important since they function as

nursing areas for plants used as food source, shelter and habitat by a great diversity of wildlife groups, including arthropods, resident and migratory birds, mammals, etc. (Wunderle and Latta, 1996; Young *et al.*, 1997; Zanne *et al.*, 2001). However, the study of the wildlife values of extensive monocultures is surprisingly scant, and existing knowledge is insufficient to envisage whether these habitats will help conserve most forest species in the future (Brook *et al.*, 2006). Among those animals that inhabit forest plantations, arthropods require a special mention since they represent 80-90% of the diversity of animal species in forests and can radically influence forest structure and function in ways that can either stabilize primary production or interfere with management goals (Mattson and Addy, 1975; Holden, 1989; Wheeler, 1990; Schowalter, 2000). By selectively affecting tree growth and mortality rates, insects can alter forest composition, structure and succession (Schowalter *et al.*, 1986; Franklin *et al.*, 1987; Haack and Byler, 1993; Schowalter, 2000). For example, the mountain pine beetle (*Dendroctonus ponderosae*) prefers to attack older trees, and the damage produces uneven-age stands of lodgepole pine that, in the absence of fire or other dramatic disturbances, tend to perpetuate on a particular site (Cole and Amman, 1969; Amman, 1977). However, this selective killing of weak trees tends to enhance overall stand fitness and resistance (Schowalter, 2000; Logan and Powell, 2001). Additionally, through this natural selection process, most native phytophagous insects reach a dynamic state of equilibrium with their hosts and natural enemies (Schowalter *et al.*, 1986; Schowalter, 2000). Therefore, pine plantations offer an extraordinary opportunity to study those successional interactions that can help improve forest management and biodiversity conservation and may be crucial for obtaining a better perspective of the role of stands in biological conservation (Jef-

fries *et al.*, 2006; Barlow *et al.*, 2007).

Concluding Remarks

In Mexico, more than 15 million hectares of plantations involving different development stages, along with several species and environments, represent an opportunity for ecologists concerned about biodiversity restoration and conservation. Plantations in general, and specifically pine ones, constitute natural laboratories, where scientific questions and hypotheses can be tested to promote restoration and conservation programs. Some questions that can be addressed in pine plantations include: Which threatened, endangered or economically important species, from advanced successional stages, can use pine plantations as nursing or facilitating habitats? What time (plantation development or age) is right for the introduction of desirable species for conservation or production? What plant species useful for wildlife can be established under the pine canopy? What bird species may reappear or recolonize an area of pine plantation? What pine species (in plantations) are the most useful for restoration? What is the environmental gradient in which different Mexican forest types can be restored using pine plantations? How can the environmental services be improved using pine plantations as facilitators for other species belonging to more advanced successional stages? When is the equilibrium reestablished in the insect-plant interrelations in pine plantations? How quickly is the arthropod species richness reestablished in pine plantations? Our hypothesis is that pine plantations can play a central role in conservation through the reintroduction of threatened or endangered species, as well as in the preservation of biodiversity in general. This is the opportunity to translate conservation science (or scientific knowledge) to conservation on the ground (the conservation in practice) and address the science-politics interface. The above questions

may also be explored in other countries where pine plantations are abundant and grown for ecological restoration purposes.

Today, nearly all the Earth's ecosystems are severely disturbed and fragmented. In order to warrant the preservation of biodiversity and of biological and evolutionary processes, it is our responsibility to study and understand these ecosystems (i.e. fragmented, plantations, disturbed, etc.) in their current state. This knowledge will set the basis for the right decision-making with respect to management and conservation of biodiversity resources and of the processes that sustain them.

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