chapter twenty-seven

Restoration practices in Brazil's Atlantic Rain Forest

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27.1 Introduction

The Atlantic Rain Forest (Mâta Atlantica) extends along the southern coast of Brazil and inland into Argentina and Paraguay. Originally covering 15% of the land area of Brazil, it was a region of an estimated 1.3 million km^2 (MMA 2000). Today, remnants of the Atlantic Forest represent about 8% of the original area, or some 94,000 km^2 in Brazil

(Desmatamentozero 2001). Isolated from other major forest ecosystems in South America, the Atlantic Forest is a diverse mix of vegetation and forest types with a high rate of endemism. The two main ecoregions of the Atlantic Forest include the coastal forest, extending in a narrow strip only 50 to 100 km wide in northern Brazil. The interior Atlantic Forest stretches across the foothills of the Serra do Mar and related mountain ranges. These inland forests reach as far as 600 km from the coast and range in elevation as high as 2,000 m. The coastal forest has been the most disturbed, with only about 3% of its original forest cover remaining. The best-preserved areas of the Atlantic Forest in Brazil survive in relatively inaccessible areas of the states of São Paulo, Paraná, and central Rio de Janeiro. The largest contiguous stretch of Atlantic Forest, from Serra da Juréia in Iguape/SP to Ilha do Mel in Paranaguá/PR, was declared a Biosphere Reserve by UNESCO in 1991 and a World Heritage Site in 1999. This stretch covers an area of about 1.7 million ha with elevations ranging from sea level to 1,400 m. Half of Misiones Province in Argentina remains in forest, and 13% of the original interior Atlantic Forest survives in Paraguay.

The Atlantic Forest has been disturbed for 500 years; it has been logged and cleared for sugarcane and coffee cultivation, livestock breeding, and to provide industrial fuel. The development of sugarcane, coffee, and cacao for export was key to Brazil's economic and population growth from early colonial times until the mid-20th century. Early in the 19th century, large areas of the forest were burned and converted to coffee plantations. A steel industry developed early in the 20th century, expanding the demand for charcoal. Half the forests of Minas Gerais state were destroyed between 1920 and 1940, replaced today by extensive plantations of exotic *Eucalyptus* spp. Expanding human population and conversion to urban areas has been most intensive since 1960. Most timber production in the Atlantic Forest is exploitive and has fragmented and degraded the remaining forest (Dean 1995). Nevertheless, some forest remnants retain great diversity with as many as 450 different tree species per ha.

Despite legal protection aimed at conserving the forest, anthropogenic pressure continues to impact the Atlantic Forest. The relevant legislation (Decree 750/93) allows tree felling and the suppression and exploitation of Atlantic vegetation only under certain circumstances. Nevertheless, the most pressing need is to protect the remaining areas of forest from human encroachment. Restoration goals are to restore and expand the area of remnant forests and provide ecological corridors between blocks of remnant forest. Most restoration activity in Brazil is small, associated with remediation of construction projects or as partnerships on private land between conservation NGOs, government agencies, and private foundations. In the 1980s, hydroelectric companies attempted small-scale restoration to compensate for natural vegetation destroyed by construction of dams and reservoirs (Souza and Batista 2004). In general, restoration relies on natural regeneration and successional processes, augmented by planting. Small nurseries are often developed to provide planting material from local seed sources.

27.1.1   Ecological summary

The Atlantic Forest is located in the escarpment of the Serra do Mar spanning over 23° of latitude along the coast of South America. Over the years, there has been no common definition of the Atlantic Forest. A broad definition of the Atlantic Forest Domain in Brazil was developed in the early 1990s and approved by the National Council of the Environment in 1992, based on botanical and geological considerations together with environmental conservation issues (Pinto et al. 1996). Codified through Federal Decree 750/93, the Atlantic Forest Domain includes coastal forest, araucarian forest, deciduous forest and semideciduous inland forest, together with associated ecosystems, such as restinga, mangrove swamps, high plateaus, grassland enclaves, high-altitude swamps,

and cerrado (MMA 2000). Climate in the region is bimodal, with two seasons characterized by the amount of rainfall. In the northeast, temperatures average 24°C. Temperatures in the south and southeast are lower and occasionally dip to −6°C. Brief ecological descriptions follow. In this chapter, however, we limit our consideration to the highly disturbed coastal forest.

- Dense ombrophilous forest, or hydrophilous evergreen coastal forest, of dense, tall stands with a typically tropical character, with many vines, epiphytes, tree-sized ferns, and palms. Composition and structure vary with elevation. Soils are sandy and infertile, with a superficial layer of humus in the southern coastal belt, and developed on tertiary or pre-Cambrian rocks in the north.
- Semideciduous seasonal, or subcadocifolia forest, occurring mainly on the high plateaus and inland mountains of São Paulo, Paraná, and Minas Gerais states, and characterized by a dry season. Soils vary from the relatively fertile *terra roxa* (red soils derived from limestone parent materials) to low-fertility sands. Characteristic vegetation is semideciduous arboreal and scrub. In the northeast, a transition from humid marshy forests to the caatinga vegetation includes forest enclaves in subcoastal and high arid regions.
- Mixed ombrophilous or subtropical subcadocifolia forest with Araucarias has a composition similar to the hydrophilous evergreen coastal forest but occurs on deeper, more fertile soils. It has an upper tree stratum of Brazilian pine (*Araucaria angustifolia*), which grows to an average height of 30 m. Below the pine is another arboreal stratum, about 20 m tall, formed of *Lauraceae*. This forest is distributed continuously, or in isolated clumps in the midst of natural grassland.
- High-altitude grassland (Campos de Altitude) occurs above 1,800 m elevation with characteristic communities of tall mesophylous grasses, in some places xerophilous, interrupted by small heathland areas.
- High-elevation swamps are dense ombrophilous forests, with two arboreal strata and one scrub stratum found on the upper half of eastern slopes in the northeast, where rainfall is high due to orographic effects.
- Restinga is a vegetation formation typical of sandy coastal areas, comprised of widely varying vegetation communities such as sparse grasses, dense forests up to 12 m tall, or swamps with a dense aquatic vegetation.
- Mangrove swamps are located in brackish waters along estuaries and are an important source of nutrients to marine food chains.

27.1.2 *Environmental and economic importance*

The Atlantic Forest is the third most extensive biome in Brazil, after Amazonia and the Cerrado. It makes up 13% of the land base and even though the forest is restricted in area, it has great biodiversity. High rates of endemism remain; the Atlantic Forest has twice the diversity of Amazonia and 45 times the diversity of the North American hemlock forests (Lowe 1993). More than 6,000 of the estimated 20,000 plant species are endemic, 72 of 620 birds, 60 of 2,000 reptiles, and 253 of 280 amphibians (Paglia 2000). The rate of endemism rises to over 70% among palm trees, bromeliads, and other epiphytes. Some 60% of mammals are endemic (160 of 261). For comparison, there are 353 mammal species in the Amazon with five times the area. There are 250 known species of freshwater fish, of which about 56% are endemic (Paglia 2000). Brazil has greater primate diversity than any other country, and 6 of 16 genera and 25 of 77 species are found in the Atlantic Forest. Indeed, international conservation interest in the Atlantic Forest grew out of concern for primates. The black lion tamarin (*Leopardus pardalis*) is one of the most endangered primates in the world.

About 80% of the Brazilian population, distributed over four of the country's five regions, depend in some way on the Atlantic Forest for their livelihood, including ecological services such as maintenance of soil fertility and provision of clean water. The Atlantic Forest contains water sources that supply the large cities and inland communities; it also regulates the climate and provides shelter to hundreds of traditional communities, including indigenous peoples. As much as 70% of Brazil's GDP comes from the area of Atlantic Forest domain (MMA 2000). About 40% of the population relies on medicines derived from forest plants and 20% still use firewood for cooking and heating. The expansion of large cities such as São Paulo is a major cause of deforestation. Nevertheless, there are still relatively large stretches of forest remnant even in the area between São Paulo and Rio de Janeiro (Figure 27.1). The most affected areas are of most concern to conservation groups, the states of South Bahia and Espirito Santo.

Protected areas of Atlantic Forest are limited in scope, encompassing only 2.5% of the original forest, but approximately 35% of the remaining area. There are 14 national parks, 14 federal biological reserves, and 6 federal ecological stations. In combination with state and municipal parks, the area of protected forest is over 28,000 km². These areas are in danger of encroachment by landowners who aim to enlarge their areas, by landless peasants who see them as some of the last land in the region not privately owned, and by urban expansion.

27.2 Restoration practices

The Atlantic Forest in several regions of Brazil was reduced to isolated fragments incapable of accommodating fauna that require large territories. Such fragments are often

Figure 27.1 Forest enrichment in the Prainha Ecological Park, Rio de Janeiro, using *Ficus clusiaefolia* (Miq) Schott ex Spreng,

unable to maintain basic ecological processes. Although the top priority should be to halt the processes of deforestation and degradation in forest remnants, it is also important to restore forest landscapes by expanding and rehabilitating remnants, connecting them, and restoring degraded areas. Constraints on restoration include fragmentation of the remaining forest, high costs for restoration, and the need for long-term tending (Ferreira and Bechara 2000).

Until 1989, restoration in Brazil followed two mutually exclusive restoration strategies. The more popular strategy was to establish a "green carpet" of aggressive rapidly growing species, such as the herbaceous plants *Melinis multiflora* and *Brachiaria decumbens*, or trees such as *Eucalyptus* sp. (Griffith et al. 2000). This strategy provided rapid coverage and soil protection and was attractive to government environmental bodies (São Paulo 2000). Not surprisingly, problems arose, such as the need for frequent fertilizer applications, the vulnerability to pests and fire, erosion caused by lack of vegetation coverage, and visual impoverishment (Millar and Libby 1989; Einloft 1997). The second strategy was based on ecological succession or natural invasion (Klein 1994; Willians et al. 1999). This process culminates in vegetation assemblages that are more structured, diverse, and complex than the green carpet of exotic plants (Macedo 1993). This strategy, however, is slow and can leave the surface exposed to erosion for a time.

The current model has two steps: first, a degraded site or area is treated to create conditions favorable to rapid growth and, second, create conditions that enable ecological succession to proceed and attain equilibrium conditions in harmony with the regional landscape in order to guarantee self-sustainability with less need for future interventions. Brazilian legislation imposes conditions on the techniques and species that can be used to restore degraded areas. Permanent Preservation Areas are defined in the Brazilian Forestry Code (Law 4771/65) and only native species can be used for restoration in these areas. They include a 50 m strip around the margins of rivers, lakes, lagoons, reservoirs, and springs; the summits of hills, mountains, and mountain ranges; hill slopes; and restinga (Brasil 1965). Other degraded areas can be restored using exotic or native species. Multiple restoration systems can be used in a given area, depending on the presence and characteristics of existing vegetation. Where forests are present but degraded, combinations of natural and artificial regeneration can be used to rehabilitate the forest. If absent or highly degraded, several systems of planting can be used to restore the Atlantic Forest (Almeida 2000). Restoration designs that incorporate natural regeneration, such as in islands (e.g., discrete patches or clumps of pioneer trees and shrubs scattered across a pasture area), may be more cost-effective than conventional approaches where whole areas are planted (Kolb 1993).

27.2.1 Natural regeneration

Secondary forests result from natural succession following total or partial suppression of primary vegetation. The secondary forest may retain some of the structure and species found in the primary forest (IBGE 1992). Spontaneous natural regeneration of areas near remnant forests is an important part of the restoration of degraded areas. Remnant forest is an invaluable source of germ plasma, indispensable for genetic improvement (Simoes and Lino 2002). The efficiency of spontaneous regeneration depends on the availability of seeds, effective dispersal by wind, birds, and rodents, and the environmental conditions in which the new plant develops. Every plant species has its own optimum niche, which needs to be identified to ensure success (Kageyama et al. 1990). The process can be accelerated by practices to induce natural regeneration and is most useful in areas of slight to moderate disturbance that retain the biotic and abiotic characteristics of the natural forest formations. Areas to be regenerated are isolated from continuing disturbances (Kageyama

et al. 1994). Additional practices include control of liana populations (climbing vines) and aggressive species such as *Graminea* spp. (Rodrigues and Gandolfi 1996).

27.2.1.1   *Measures to support natural regeneration*

Often, the main effort to prevent continuing degradation of a forest remnant is simply to isolate it. The main degradation factor of forest remnants today is fire; repeated fires destroy forest remnants. Surrounding the forest area with pastureland, or building and maintaining firebreaks, are relatively simple but very important measures (Moraes 1998). Clearly, these have a cost that needs to be considered when planning a forest restoration program. Cattle are another factor (Armour et al. 1991) and must be kept out of forest remnants by fencing.

Isolated forest remnants are frequently invaded by mostly exotic *Graminea* spp. The persistence of these plants along the border further encourages wildfires, especially in dry periods. Large masses of woody creepers are common, spreading over and suffocating border trees (Rodrigues and Gandolfi 1996). Controlling or eliminating the *Graminea* by periodic spraying not only prevents fire but also prevents them from competing with new seedlings. Simply attempting to eliminate creepers from disturbed forest fragments could mean a loss of local biodiversity (Morellato 1991). A specific management program can be introduced for excessive growth of some species of creeper (Williams et al. 1999).

Before planting begins, the potential of the seed bank to restore an area needs to be assessed (Seitz and Corvello 1984). Sometimes, plowing or disking can bring viable seeds to the surface from depths of 15 to 20 cm, which, after germinating, will provide partial recovery of the area (Leck et al. 1989). Another possibility is to transfer seed-laden soil from a recently deforested area to the restoration site (Skoglund 1992; Rodrigues and Gandolfi 1996). This method is used in mining areas where the seed bank is removed from an area about to be mined and this soil is used to recover stabilized areas that need to be restored (Campelo 1998; Pederson and Van Der Valk 1989; Seitz 1996).

Seed dispersal by animals is commonplace in tropical forests and an inexpensive way to accelerate restoration is to introduce food sources that attract birds and bats from neighboring forest remnants. This can be achieved by a correct choice of pioneer species, including those that provide a varied diet of fruit and areas for roosting (Guevara et al. 1986; Uhl et al. 1991). Plants known as *bagueiras*, which have berries that are extremely palatable to animals, play a key role in maintaining the dynamic equilibrium of forests and also in restoring degraded areas. Use of such plants can rapidly increase the number of species in a recovery area. Many birds characteristic of open spaces, such as the streaked flycatcher (*Myiodinastes maculatus*, Tyrannidae), the tropical kingbird (*Tyrannus melancholicus*, Tyrannidae), and thrushes (*Turdus* sp., Turdidae), prefer to roost in dry branches that are very common in the region. Distributing dry sticks over degraded areas provides birds with artificial roosting sites, and they drop the seeds ingested during feeding onto the soil (Guedes et al. 1997).

27.2.2   Enrichment

Forests that have been slightly disturbed can be rehabilitated using enrichment plantings. The technique is used in areas currently occupied by short vegetation dominated by early successional species (Rodrigues and Gandolfi 1996). Enrichment is intended to enhance the floristic composition of an area by introducing species of floristic or commercial importance through seeding or planting (Souza and Jardim 1993). Enrichment can increase the density of existing species or introduce new species. Secondary or climax species are usually planted under the canopy of pioneer species (Figure 27.2). To undertake enrichment planting in degraded forests, it is important to understand the ecophysiological demands of the species, particularly with regard to their tolerance of shade. Natural regeneration
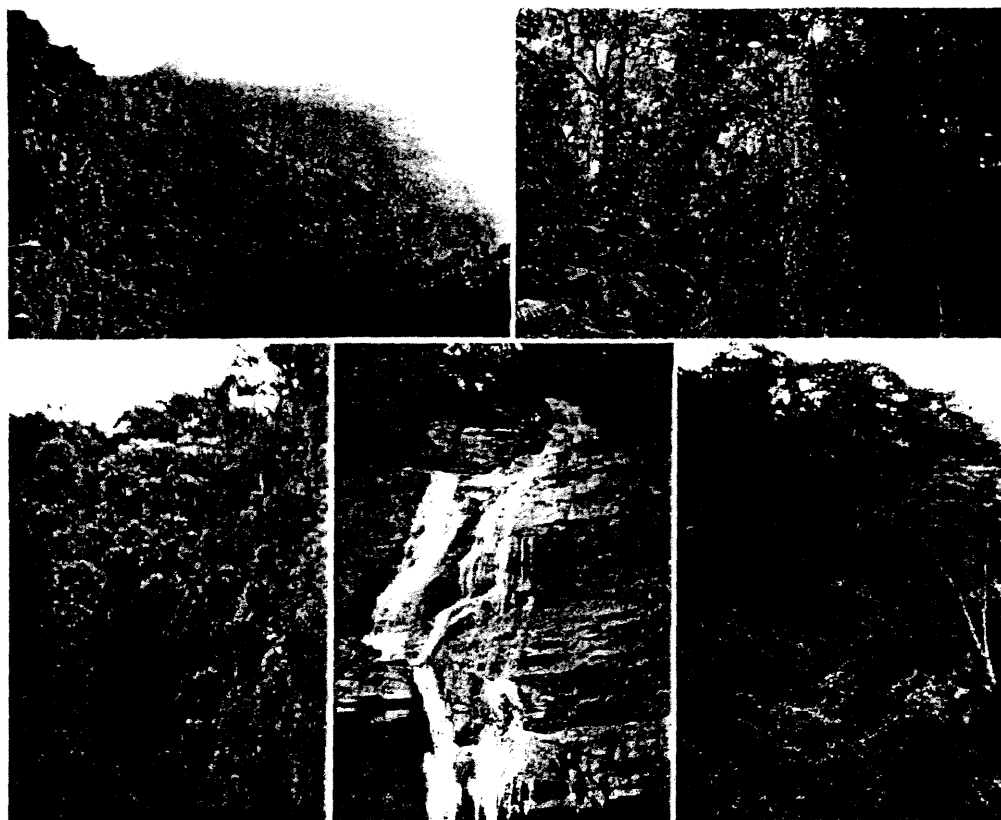
Figure 27.2 Tijuca National Park, Rio de Janeiro, is the largest (34.5 km^2) urban park in the world and a reserve of Atlantic forest. In 1861, Pedro II, Emperor of Brazil, expropriated farmland for the park. Created mainly by artificial regeneration using direct seeding, in the beginning there were only 16,075 trees in the park. Manoel Gomes Archer, a major in the National Guard, planted more than 80,000 seeds of species from remnant Atlantic forest with the help of six slaves and paid workers.

can be combined with enrichment plantings where late successional species are introduced into previously disturbed zones, or throughout an area if desirable species are absent as a result of anthropogenic disturbance (Gandolfi and Rodrigues 1996).

27.2.3 Ecological corridors

Ecological corridors are strips of vegetation between forest remnants formed either through natural regeneration or through afforestation. Remnants may be of primary vegetation or secondary vegetation sufficiently advanced in development and height, capable of providing habitat or serving as a transit area for fauna living in the forest fragments (CONAMA 1993). Studies of biodiversity in forest islands reveal a correlation between the fragment size and the number of species that survive. The relationship varies from one locality to another; but, in a 100 ha forest island, reducing the area by 10% will cause 13% of the species to be lost in 50 years, while a 15% loss of area causes 40% loss of species (Iracambi 2001). Iracambi Recursos Naturais Ltda undertook one example of an ecological corridor project. They set up the Iracambi Atlantic Rainforest Research and Conservation Center, situated on a working farm near the village of Rosario da Limeira (lat. 21°00'S, long. 42°30'W) in the southeast of the state of Minas Gerais. The main

objective is to link the farm's forest island with neighboring islands to create a continuous stretch of forest. To reduce the effect of fragmentation, corridors of about 20 m wide were established on either side of farm boundaries to connect neighboring fragments. These contain a variety of species known to have flowers and fruits that attract insects and seed dispersal agents (Iracambi 2001).

27.2.4   Artificial regeneration

Afforestation is used in highly disturbed areas that do not preserve any of the biotic char-acteristics of the original forest formations, typically where the original forest was replaced by agriculture and livestock grazing. Species are introduced in the following chronological sequence: pioneer species, secondary species, and climax species. In most cases, species are planted as seedlings in accordance with several restoration models that are variations on the plantation model (Gandolfi and Rodrigues 1996; Jesus 1997; Barbosa et al. 1999), depending on which species are planted, their spatial arrangement, and density.

27.2.4.1   Species selection

The choice of species for planting depends greatly on the purpose of the plantation. Apart from adaptation to the ecological conditions of the site, the selection should be based on the objective of the restoration activity: that is, whether the forest is intended to reconsti-tute permanent protection areas (APPs), or merely for the restoration of degraded areas (ADs), or even restoration associated with the production of timber and other forest prod-ucts (Kageyama et al. 1990). The appropriate goal for disturbed or degraded APPs is a mixed-species planting with the maximum possible diversity of native species. Plantations intended to restore ADs that are not located in APPs can be made with less diversity, even including monoculture of an exotic species (Jesus 1997).

Priority should be given to species typical of the specific environments being recov-ered (Almeida 2000). This requires a knowledge of the successional process in the region and the autecology of the species to be planted. Certain species can catalyze the second-ary succession process more efficiently than others, creating conditions that favor the emergence of spontaneously regenerated species (Parrota and Engel 2001). The availabil-ity of silviculture technology for native species is important, including seed production and preparation, production of seedlings, and planting of the forest (CESP 2000). Interaction between basic silvics, characteristics of the area to be restored, and available technology are factors that will decide which restoration models are suitable (Kageyama and Gandara 2000). Restoration costs vary significantly, depending on the method used.

27.2.4.2   Random planting model

The random planting model, or mixed planting of species with no predetermined order or arrangement for the different species in the plantation, is premised on the observation that the propagules of different species fall, germinate, and grow randomly in nature (Nogueira 1977). The key characteristic of this model is that it does not give importance to pioneer or climax species, concentrating more on the so-called "noble" forest species, which are basically the intermediate ones in succession (Kageyama and Gandara 2000). It is therefore a model that ignores differences between the groups of species in ecological succession; it considers all species to be equal when competing with each other, and that there are no differential demands between the species in terms of shade tolerance. One advantage of random planting is that it can proceed even when knowledge and technol-ogy are lacking, by planting many species and accepting that the survivors are the best-adapted species (Balistieri and Aumond 1997). One disadvantage of the random planting model is delay in achieving canopy closure. This delay may necessitate tending and

further treatments to remove invasive vegetation (Barbosa et al. 1999; Kageyama and Gandara 2000).

27.2.4.3   Succession model

Use of ecological succession principles in mixed-forest plantations is an attempt to simulate natural regeneration (Piña-Rodrigues et al. 1990; Kageyama et al. 1990). The succession model separates species into ecological groups and places them in proximity such that the earliest species in the succession provide enough shade for species in the later stages (Kageyama et al. 1994). The basic concept is that pioneer species give more closed-shade conditions to climax species, while initial secondary species provide partial shade to the later secondaries (Kageyama et al. 1990). Plants in plantations can be arranged in modules or lines. In modules, a central plant of a late-successional species is surrounded and shaded by four or more plants of early-successional species. Line planting can be in alternating lines, with a line of early-successional species next to a line of late successional or climax species. Line planting is recommended for large-scale plantations (tens or hundreds of ha); module planting (which is more precise) is better in small-scale and experimental plantations (Rodrigues et al. 1992; Santarelli 1996). The original recommendations were for pioneer and nonpioneer trees (secondary and late-climax) to be planted in a ratio of 1:1 (Kageyama et al. 1994). Actual practice, however, has been to plant more pioneer trees (de Souza and Batista 2004).

27.2.4.4   Dense plantation

A system of very dense plantations used in the restoration of degraded areas in Japan was introduced to Brazil to restore degraded hillsides in the state of Rio de Janeiro (Piña-Rodrigues et al. 1997). The spacing used is 1 m × 1 m, which is equivalent to 10,000 seedlings per ha. Continuous lines of pioneer species are planted, together with lines containing mixed pioneer and nonpioneer species. As a result, pioneer plants, whose function is to provide shade, surround each nonpioneer. It is also important to ensure homogeneous distribution of species dispersed by biotic and abiotic means. Pinã-Rodrigues et al. (1997) maintained a proportion of 1:6 between nonpioneer and pioneer species, thereby simulating conditions existing in secondary areas, where colonizing species from more open areas predominate.

27.2.4.5   Direct seeding

Direct seeding is an alternative to planting seedlings and can be used when seeds are available in large quantities. It is advantageous when planting seedlings is difficult, such as limited access or lack of nurseries. This method is preferred in mountainous areas subject to soil erosion (Pompéia et al. 1990; Pompéia et al. 1992). Direct seeding can be used to introduce pioneer species into areas with no forest cover, and to introduce nonpioneer species to enrich secondary forests (Kageyama and Gandara 2000). Aerial sowing or broadcast seeding gives good results in areas with abundant and well-distributed rainfall and loosely compacted topsoil (Almeida 2000). In one project on 70 ha of the Serra do Mar, in Cubatão, São Paulo, the operating cost was approximately US$ 386 ha^{-1}. Most of the cost (74%) was labor to collect and prepare the seeds. The total cost per ha was about US$ 451, which included an investment in infrastructure for seed preparation and pelletizing. Other research has shown the need to test the suitability of a species for direct seeding and, most important, the need to use high-quality seed (Parrota and Engel 2001).

27.2.4.6   Cuttings

Cuttings of some forest tree and shrub species can be planted successfully. Several native Atlantic Forest species have given good results from this type of planting, for example, the

cedars (*Cedrella fissilis* and *Cedrella odorata*), and various species of gameleira (*Ficus* spp.) (Almeida 2000). Limitations include the need for constant rainfall in the initial stage and irrigation after planting until the cutting produces buds and becomes established (Teixeira 1983).

27.2.5   *Restoration in vegetation islands*

The implantation of seedlings produced in forest nurseries is a way to generate nuclei capable of attracting greater biological diversity to damaged areas (Reis et al. 2003). The planting of an entire damaged area is especially difficult. One way to reduce the costs of restoration activities is to plant in restricted patches or islands. Such vegetation islands are areas with a few tree species surrounded by bare soil or nonforest vegetation (Eletronorte 1998). Small forest fragments or even isolated trees attract fauna that disperse seeds, thereby accelerating succession in the surrounding area (Guevara et al. 1986). These islands are centers of high diversity and sources of propagules for dispersion to the surrounding area (Willians et al. 1999). Vegetation islands should contain plant species from various stages of succession and include adaptations to pollinating and dispersion processes distributed throughout the year. Vegetation islands can be established by planting pioneer and nonpioneer species together in the islands or by planting nonpioneer species in the islands and pioneer species in the area as a whole (Kageyama and Gandara 2000). The first method is less costly, but the expansion of the island to occupy the entire area will be slower. The second method is more expensive but spreads faster and costs less than completely planting the area, because large numbers of seedlings of pioneer species are used, which costs less to produce.

27.3   *Restoration projects*

Restoration projects in the Atlantic Forest are small and fragmented, localized efforts. For example, a project by the Instituto Terra near Baixo Guandu is restoring native forest cover to 630 ha of private property (Instituto Terra 2003). The area was recognized as a Private Reserve of Natural Heritage in 1998. Activities are appropriate to the four main vegetation types on the property. In peppertree plantations (*Schinus terebinthifolius* Raddi), trees were thinned and seedlings of native species were planted in the understory. Removing cattle, which allowed herbaceous species to establish and eventually tree seedlings to invade from forest remnants, restored heavily grazed pasture. Secondary forests and shrubs were managed to promote natural regeneration and some native species were planted. A nursery was constructed as part of the project, producing 55,000 seedlings annually. Seeds are collected from forest fragments on the property. Excess seedlings are grown and provided to local landowners and other restoration projects. Since 1998, 309,000 seedlings have been planted on 125 ha (2,472 seedlings ha^{-1}) of abandoned pastureland. Twenty-two ha of secondary forest were cleared of liana and 20 ha of gallery forest have been enrichment planted with 22,000 seedlings (1,100 seedlings ha^{-1}).

Few projects provide details about the cost of the work. Public agencies provide total project costs, with few disaggregating costs by activity. Enrichment planting restored an Atlantic Forest fragment of approximately 50 ha, located in Mata do Convento, in Vila Velha, Espírito Santo, in the southeast of Brazil. The initial planting cost US$1,890 ha^{-1} and an additional US$1,503 ha^{-1} was spent on maintenance. Further tending cost US$990 ha^{-1} on secondary maintenance and US$660 ha^{-1} on further maintenance (Jesus 1997). Restoration of 10.81 ha following construction of the port of Sepetiba in Rio de Janeiro involved both physical stabilization and vegetation establishment. The total cost over the 13-year period was US$103,594 or US$737 ha^{-1} $year^{-1}$ (Valcarcel 1994). The Companhia

Energética de São Paulo (CESP) reported estimated costs of reclaiming areas of soil extraction used in the construction of hydroelectric plants. Costs for physical stabilization and revegetation were estimated to be US$4,000 ha^{-1}, assuming 5 to 7 years for establishment of the plantation (CESP 2000). Research by the Escola Superior de Agricultura Luiz de Queiroz, under contract to CESP, enabled them to reduce to 2 years the time required for the plantations to become effectively established without the need for subsequent interventions. Costs were reduced to US$1,500 ha^{-1} using the successional model (Kageyama and Gandara 2000).

27.4   *Socioeconomic and policy factors*

The importance of restoring and conserving Atlantic Forest remnants is not exclusively a question of maintaining biodiversity. Public support is more likely to come from the awareness of the environmental services indirectly and directly provided by natural systems. Among other things, these relate to the production of water and the maintenance of regularity in the supply, cycling and replacement of nutrients, moderation of climate and regulation of rainfall regimes, containment of erosion processes, and equilibrium in food chains. Nevertheless, there is immense political pressure to maintain the current status quo, especially from large landowners. Further, development, landuse, and natural resource policies are fragmented by sector and Brazil lacks an environmental policy that integrates these policies with urban policies. Agriculture, grazing, urbanization, industrialization, and transportation sectors are viewed and managed in mutual isolation.

Brazilian legislation is very complete on the removal of vegetation and related issues. On the other hand, the responsible are ill-equipped to carry out their functions because of inadequate funding and staffing. Inspection and control of environmental issues was decentralized because of the size of the country and the need for greater flexibility. Although this yields benefits by allowing greater agility and specificity of action, many environmental bodies on subnational levels are not structured to carry out these functions. Political pressures are often more intense at the local level. Still, restoration may generate employment and income from the production of seedlings, planting and tending, and products such as firewood, palmetto, and herbal medicines. Even in urban areas, such as on the hill slopes of the city of Rio de Janeiro, activities to restore these areas to prevent landslips at times of heavy rainfall employ labor from the same deprived communities that inhabit those hillsides and are the first to be affected by environmental imbalance.

27.5   *Research needs*

Actions to protect and restore the Atlantic Forest can be considered some of the most urgent conservation needs in Brazil. Experience and research show that natural regeneration strategies have much to contribute to the success of restoration activities. Often, there is a need to combine these with physical or physical–biological measures in an attempt to slow down intensive degradation processes and to physically stabilize an area before restoration measures are successful. Knowledge is lacking on the autecology of native species, as well as information about their economic potential in areas where sustainable forest management is not legally restricted.

Little is known about the true costs of restoration activities. Too often, the experiments that underpin recommendations made by technical experts do not consider cost effectiveness such that accurate economic analysis can be carried out and decisions taken with an understanding of cost–benefit ratios. One exception is a study comparing natural invasion (do nothing), direct seeding pioneer species, mixed-species line-planting, multipurpose commercial species, and planting native species (Parrota and Engel 2001). Establishment

and maintenance costs for direct seeding compared favorably with planting seedlings, ranging from $747 to $912 ha^{-1} for direct seeding and $1,200 to $2,500 ha^{-1} for planting seedlings (Parrota and Engel 2001). The dissemination of information on restoration methods and techniques also leaves much to be desired. Many public bodies working with rural extension processes do not have access to these procedures, which makes it difficult to popularize them.

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