Some reforestation projects result in little more than tree plantations. An ambitious project in Brazil's São Paulo state is trying to go further and create a real working ecosystem

Reconstructing Brazil's Atlantic Rainforest

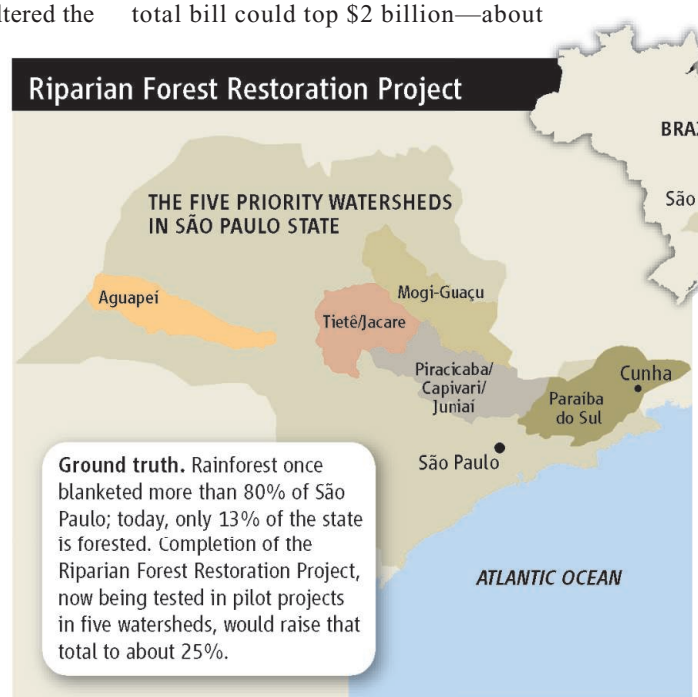
CUNHA, BRAZIL—Benedito de Carvalho Filho strides across his yard, through an empty cow pen and uphill. He clambers over rocks and searches, pushing aside shreds of barbed wire and vegetation, as his 12-year-old son shadows him. Finally, the farmer stops and points to the eye of a spring that barely percolates up from the earth. His water—or what's left of it.

Throughout this pastoral region that was once the heart of Brazil's Atlantic rainforest, extensive deforestation has not only changed land cover, it has also altered the hydrologic cycle. The forest once stretched over 1 million square kilometers along Brazil's coastal region with extensions inland. Today, only 7% of that original extent persists. And now, de Carvalho and other farmers are grappling with a growing realization: The fresh and abundant ground water they have relied on for decades is disappearing. For his family and his crops to have water, de Carvalho needs the rainforest back. He may be in luck.

With little fanfare, this past December, biologists and farmers planted the first seedlings of an ambitious project that ultimately aims to reforest 1 million hectares (2.47 million acres) of riparian rainforest across São Paulo, Brazil's most populous state. The goal is not just to recreate this globally unique ecosystem but also to reclaim the so-called services the rainforest once provided, from the maintenance of natural springs and soil fertility to the sequestration of carbon.

It's a tall order. Funded with seed money from the state and the Global Environment Facility (GEF), the Riparian Forest Restoration Project (RRP) will require an estimated 2 billion seedlings of hundreds of species of trees and take decades to complete. The total bill could top $2 billion—about $2000 per hectare—just a fraction of which has been raised.

"It is hard to think of a reforestation project undertaken anywhere that is quite this ambitious," says Thomas Lovejoy, formerly the World Bank's chief biodiversity advisor. Even if the RRP achieves only some of its ambitious goals, say conservation scientists, it appears set to test the limits of nature's resilience, the science of ecological restoration, and societal commitment.



Ground truth. Rainforest once blanketed more than 80% of São Paulo; today, only 13% of the state is forested. Completion of the Riparian Forest Restoration Project, now being tested in pilot projects in five watersheds, would raise that total to about 25%.

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Dimensions of diversity

The RRP will focus on restoring forest along the denuded margins of rivers and streams that establish migratory corridors for animals and plants and protect the ecological health of waterways. The eventual goal is to recover a significant portion of the staggering diversity of the rainforest's flora and fauna—its bromeliads, lianas, shrubs, grasses, birds, bats, butterflies, insects, microbes, mammals, and amphibians.

How exactly to do that is being tested in pilot projects in five watersheds across São Paulo state, with $19 million in start-up funds provided primarily by the state, GEF, and the World Bank. Each of the

Mother lode. Rainforest preserved in the Serra do Mar State Park is a source of trees and seeds needed to reforest riverbanks and streams. Benedito de Carvalho Filho (*above*), a farmer in Cunha, Brazil, points to his diminished natural springs on a deforested hillside overtaken by ferns.

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five watersheds is in turn divided into three "microwatersheds" that represent a range of ecological as well as social challenges. In Cunha, for instance, located within the larger Paraíba do Sul watershed, subsistence farmers work within a mosaic of forest fragments. It is a sharp contrast to the large northwest watershed, Aguapeí, where sugar cane is king and any remnant forest is hard to find.

In these pilot projects, the state Department of the Environment and its partners are experimenting with a variety of restoration methods. Some emphasize replanting trees alone; others aim to return a variety of plants and animals simultaneously. "We want to see how the forest can best develop on its own after a starting push," says project director Helena Carrascosa von Glehn.

At each site, the selection of trees and methods will depend on local conditions and the specific goals for the area, whether that be soil stabilization, water maintenance, or production of fruit and nuts from rainforest trees. "Our emphasis is on bringing people to this for 20 to 30 years and involving them in restoration," Carrascosa says.

Search for Mother Trees

At the heart of the effort is the Mother Tree project: a detailed plan for identifying the starting stock for the forest's regeneration. Conceived by Ricardo Rodrigues at the Laboratorio de Ecologia e Restauração Florestal in Piracicaba, Brazil, the Mother Tree project aims to find and mark the location of 15,000 trees of 800 different species to support seed collection programs and ensure adequate genetic diversity in the replanted forests. There is now a master list of 780 species appropriate for reforestation in designated watersheds.

To find the seeds, biologists are scouring remnants of the Atlantic forest across the state. So far, says Rodrigues, 20 biologists have recorded 10,200 mother trees.

One of those biologists is forest engineer Renato Lorza, who conducts his search for mother trees in the mountainous terrain of Cunha on foot, aided by a long-handled scissor. On a morning last December, a fine mist laces the air as he scoops up a handful of gleaming seeds from the forest floor. Most plentiful are the soft, marble-sized seeds of the Jussara palm (*Euterpe edulis*). Severely overharvested to extract heart of palm, the tree grows up to 25 meters to reach the light through the forest's dense canopy. The palm is but one of some 1300 tree species in the Serra do Mar State Park in Cunha that Lorza has come to know well during 2 years of collecting.

University researchers analyze and sometimes genetically sequence the material he collects. After the species is definitively identified, Lorza returns to nail a small metal label into the trunk of each mother tree. He has tagged 750 individual trees, representing 250 species in this remnant forest. Each one must be in a reproductive stage of life, but some species flower only every 20 years.

One giant, Number 2496, is *Sapium glandulatum*, a bird-dispersed pioneer tree. Number 2497 is a climax species, *Aspidosperma parvifolium*. Slow growing, the tree is a rare find, as it has been overharvested for use in construction. Both pioneer and climax species are essential to the reforestation effort. Fast-growing pioneer species are the first to establish in gaps that form when trees fall in the forest. They germinate and grow in light. The secondary species that follow germinate in light but grow in shadow; slow-growing and long-lived climax species germinate, establish, and grow in the shadows.

A state law—the most far-reaching of its kind in Brazil—mandates that each reforested hectare include a minimum of 80 tree species, with each represented by at least 12 mother trees from distinct populations to ensure good genetic variability. The law also mandates that the 80 trees reflect the different successional stages of the forest, which means a mix of both pioneer and nonpioneer species, in a ratio that is close to 1:1.

This basic approach grows out of the work of Paulo Kageyama, director of biodiversity conservation at the Brazilian Ministry of the Environment, who spent decades planting experimental forests for the hydroelectric industry to restore biodiversity around dams. Beginning in 1988, he began growing diverse plantations that included species representative of each major successional stage.

One such plantation, the state's Paraibuna forest, has stood as an emblem of success. Its 100 different tree species have thrived, and now that "other kinds of plants are arriving by wind or birds, the biodiversity is increasing," Kageyama says.

It took well over a decade, however, for the Paraibuna forest to cross that threshold and begin recruiting the other species needed to recycle nutrients, disperse seeds, and pollinate plants. It is now a functioning forest rather than a plantation that must be maintained, says Kageyama.

But many other reforested areas in Brazil have failed to make that transition. Of some 98 publicly funded reforested areas evaluated in 2000, only two did well, according to Luiz Mauro Barbosa, director of the São Paulo Botanical Institute and a co-director of the RRP. In most areas, after initially flourishing, the trees died, and weeds took over.

Barbosa says that diversity is a key ingredient of success: Forests with 30 tree species generally did better than those with only three or four. The premise is that if a sufficient and balanced diversity of trees is planted with species appropriate to the local conditions, the flourishing forest will recruit the other flora and fauna—essentially, build it and they will come.

Trees in context

Yet species diversity in and of itself has not always been sufficient. For instance, one reforestation effort in western São Paulo state began with 42 tree species, but after 10 years, just four pioneer species dominated the upper canopy, says Daniel Piotto, a forest engineer who has worked on industry-financed reforestation projects in São Paulo and is now a Ph.D. candidate at Yale University. Piotto thinks that the difficulty may lie in the limited availability of factors such as water, mineral nutrients, and suitable microclimate that put slow-growing climax species at a competitive disadvantage relative to faster growing pioneer tree species and grasses.

In addition, some biologists believe that the rainforest restoration will require more than a narrow focus on trees. Ademir Reis, now at the University of Santa Catarina, and Fernando Bechara, now at the Casa da Floresta Assessoria Ambiental in Piracicaba, have developed an experimental technique known as "nucleation."

It aims to jump-start the establishment of ecological relationships essential to plant and animal life through creating a wide variety of niches. In test plots, the biologists have combined a number of techniques: They erected perches to attract birds and bats, built shelters for small mammals, and planted herbs and shrubs (shunned as competitors to trees in traditional reforestation) to attract butterflies. They also transposed squares of topsoil from intact forest, delivering soil microbes, earthworms, and fungi. After just 1 year, Bechara has noted the return of 35 species of birds to one experimental area.

"Forest restoration is extremely expensive and labor-intensive. Anything that can mimic natural succession in depleted areas is worthwhile," says Gustavo Fonseca, chief conservation and science officer with Conservation International.

Building support

Equally important to testing restoration methods is ensuring the support of the local community: "We can do nothing without the involvement and support of the people," Lorza says. The RRP aims to build this support by convincing people that devoting some portion of their land to rainforest restoration would benefit them in the long run, even if it means giving up some hectares used for farming or pasture.

In Cunha, that means educating the community about the role of the rainforest in maintaining their natural springs, which have slowly disappeared over the past 40 years. Honario Eliane, a farmer who has lived in Cunha all of his 71 years, is convinced. "About two-thirds of the natural springs that once irrigated my land are gone. The river I used to swim in when I was a kid now barely covers my feet. We need this," he says. Honario's daughter is one of 19 teenage "environmental monitors" who work with a local nonprofit group known as Living in the Atlantic Forest, one of many partners in the state's reforestation effort.

Today, after some initial opposition, about 60 farmers in Cunha want to reforest some of their land, says Leila Pires, who directs the RRP in Cunha. Due to limited resources, reforestation has begun on just six farms.

To speed the project along and ensure its financial sustainability, São Paulo state is exploring the establishment of a fund for ecosystem services, says Carrascosa. The state has already implemented new environmental legislation in two watersheds, charging industry, large-scale farmers, and the government for water use. Other possibilities include GEF payment for carbon sequestration achieved through reforestation and the establishment of a private market for rainforest seedlings, Carrascosa says. She suggests that the RRP could prove to be a model for both the Amazon and the nation.

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House calls. Forest engineer Renato Lorza (*left*) and Ednei Marques of the nonprofit Living in the Atlantic Forest visit farmers in Cunha to enlist their support in the restoration project.

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