PHOTO ESSAY

Restoration of a Tropical Forest: The Orchid and Botanical Garden of Puyo, Ecuador

Matthew Bare and Omar Tello

Ecuador stretches from the Pacific coast up and across the Andes Mountains and back down to the headwaters of the Amazon. The country contains roughly 5% of the world's biodiversity in just 0.17% of its land area (Pearson and Beletsky 2005). Clearing of tropical forests is driven by a multitude of geopolitical factors, but the leading causes in the Amazon are harvest of valuable timber species and subsequent development of cattle pasture. Owing to low soil fertility, tropical regions often support only two head of cattle per year on one hectare, and grazing productivity begins to drop significantly after only five to ten years (Nebel and Wright 1993).

In a seven-hectare plot of land located at 950 meters elevation in the Andes at the headwaters of the Amazon, a restoration effort was undertaken in 1980 to create a fully functioning secondary forest with a diversity of plants, insects, and birds comparable to that in a primary forest. The land had previously been used for cattle grazing and was in a much degraded condition, with little or no topsoil and primarily a monoculture of gramalote pasture grass or carpetgrass (*Axonopus scoparius*). From local accounts, we estimated that the land was first cleared between 1920 and 1930 for sugar cane cultivation, and later shifted to cattle ranching. By 1980, all neighboring lands were occupied by pasture, and the closest secondary forest was located two to three kilometers away.

In 1980 the restoration area and surrounding lands were being used for low-intensity cattle grazing. Cattle ranching has since actually decreased in the region as yields have decreased, frequently making ranching unprofitable. Photo by Omar Tello

This restoration was the inspiration of Omar Tello, an Ecuadorian accountant who chose to follow a dream and create a tropical forest out of an abandoned pasture. For the first ten years, Sr. Tello pursued most of the restoration work by himself, by trial and error (often with what seemed like more errors than successes), and without support from universities, NGOs, or the government. We are not attempting a scientific report here; most of our observations are general, and very little specific data exists. However, we wish to present the experience as a lesson in the practice of ecological restoration to be shared with all.

The Restoration Process

Tropical rainforests, despite their biodiversity, are naturally poor in soil quality and quantity. Average depths of topsoil range from only 30 to 60 centimeters; moreover, soils are traditionally acidic and low in nutrients (Jordan 1985, Kauffman et al. 1998). Because of the much depleted condition of the soil, we conducted soil rehabilitation and fertilization over the entire restoration area. Beginning in 1980, soil amendments were created from locally acquired materials, mostly sawdust and sugar cane husks. Wood scraps were added to increase organic matter and prevent erosion, and manures from chicken and guinea pigs were added to raise

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Restorationist Omar Tello collects plants for his project from a nearby logged forest. Ecuador suffers from one of the highest rates of deforestation in the entire Amazon basin, and the majority of deforested land is converted to cattle ranching. Photo by Angela Tello

Omar Tello quit his job as an accountant in 1980 in order to follow his dream of creating a forest out of an abandoned pasture. Locals called him crazy for fertilizing his land with sawdust instead of grazing cows. Today, 30 years later, the reserve is self-sustainable from tourist entrance fees, has received enough private donations to build an interpretative museum and classroom, and receives students from Ecuador and abroad to conduct research. Photo by Matt Bare

Compost was prepared by mixing chicken manure, sawdust, and sugar cane husks. This compost was crucial to the success of almost all trees planted in the restoration. Photo by Matt Bare

The reserve works with volunteers and students from Ecuador and around the world. Omar Tello (*right*) surveys the forest with a botanist from Germany who has helped classify plants in the reserve. While the reserve has no formal agreements with Ecuadorian universities, student internships and theses have created a foundation for future research in the reserve. Photo by Matt Bare

nitrogen content. For plantings, we collected seeds from nurseries and surrounding forests, cultivated them in seed beds, and then transplanted the seedlings. New individuals and species were added several times a month for 20 years following the beginning of the restoration; for the last ten years, new species and individuals have been added less frequently. Similarly, active soil rehabilitation was carried out between 1980 and 2000; subsequently fertilization has been performed only on selected species.

In the first years of restoration, almost all species we planted were consumed by insect pests, specifically grasshoppers, ladybugs, and various butterfly larvae. Planted species especially vulnerable to pests included jacaranda (*Jacaranda copaia*), Brazilian fire tree (*Schizolobium* spp.), and cedrela (*Cedrela* spp.). Other common trees of the region, mahogany (*Swietenia macrophylla*), and a tree known locally as guayacán (*Tabebuia* spp.), successfully germinated in seed beds but failed to survive on-site because of soil infertility.

After five to ten years, we saw plants begin to grow with higher rates of success as topsoil noticeably increased;

(Top Left): Jacaranda (*Jacaranda copaia*) and stilt palm (*Iriartea deltoidea*) are visible in this photo from 2005. The restored canopy reached 10 to 15 meters after 25 years. A particular emphasis in the reserve is placed on orchids, as it is located in one of the regions of highest orchid endemism in the world. We use orchids as a vehicle to educate visitors about the importance of biodiversity and ecological restoration. Photo by Omar Tello

(Bottom Left): Lupe Tello, Omar Tello's wife, teaches local students about the importance of insects and the food chain. She is in a newly built interpretive center, made possible by private donations of visitors to the reserve. The museum is filled with photos taken every year of the restoration, beginning in 1980. Visitors can see the progression of the forest colonization, beginning with grasshoppers and increasing to include the current diversity of spiders, amphibians, snakes, and small mammals. Photo by Matt Bare

topsoil was measured to a greater depth, and a greater quantity of organic matter was observed. The first tree species to grow successfully were uva del monte (*Pourouma bicolor*), guarumo (*Cecropia sciadophylla*), and pigue (*Piptocoma discolor*). The first species observed to produce seeds were sweetwood (*Ocotea* spp.) and jacaranda, after approximately ten years.

After about 16 to 20 years, we saw a sharp increase in insect diversity, including a variety of pollinating and predatory species including spiders. In addition, as springs began to flow in areas that had previously been dry, we observed a greater abundance of reptiles and amphibians. Twenty years after the inception of the reserve, we ceased rehabilitation and fertilization of the soil. An adequate layer of topsoil existed, enough trees were present to anchor the soil, and leaf litter was providing appropriate levels of nutrients to the soil. Additionally, insect diversity and trophic levels were regulating plant herbivory by insects. Today, almost 30 years since the creation of the reserve, the majority of plant species are reproducing without assistance, and the topsoil layer is comparable to that of primary forests (30–60 cm). Hand fertilization is still necessary with certain tree species, namely the slower growing hardwoods such as mahogany and ceibo (*Ceiba* spp.)

Omar Tello takes local students on a tour of the reserve, pointing out medicinal plants used by the indigenous cultures of the Amazon, edible plants, orchids, and more. The reserve is working to begin collaborations with local NGOs to expand their work in schools in order to have a greater impact in the field of environmental education in Ecuador. Photo by Matt Bare

Reflections

Our efforts indicate that rehabilitation of degraded rainforest may require significant manual labor to build soil in areas where soil degradation is high. Two key elements were necessary for our restoration: a sufficient quantity of healthy topsoil and control of insect pests. Certain tree species, especially uva del monte and guarumo, played a significant role in regenerating topsoil because of their copious leaf litter, a fact corroborated in other studies (Malmer et al. 1998). A diversity of plant and insect species was also crucial in order to control pest outbreaks, and this was possible only after the forest began to grow and build up defense mechanisms. The same insect pests from 1980 exist today but are regulated by spiders, amphibians, and reptiles. The reemergence of freshwater springs was crucial for creating new habitats for different trophic levels. This experience is backed by other studies showing that greater diversity leads to greater overall ecosystem stability and pest control (for example, Kricher 1998).

Distance from surrounding forests was a major factor influencing the presence of insect species in the reserve. Almost all insect species colonized the reserve from adjacent secondary forest and more distant primary forest. A closer proximity to secondary and especially primary forest might have provided a greater stability of insect diversity in the first years of the reserve, aiding in the control of insect plagues. Today, owing to the abandonment of certain cattle ranches, there are actually more forest patches in the area surrounding the restoration than there were in 1980. Connecting the restoration area to an ecological corridor is one priority that we would like to pursue in the future. Currently, we are working with the local authorities to acquire neighboring land (see www.orchidconservationcoalition.org).

Another important factor in restoration was the selection of a diversity of tree species to include those that grow easily in degraded soils and others that aid in nutrient cycling and provide bird and animal habitat. In addition, soil rehabilitation, an invaluable component of our restoration, was accomplished with locally acquired materials, such as chicken manure and

sawdust, but required careful monitoring. If we had abandoned our soil restoration efforts after even ten years, planted trees would have mostly been replaced by invasive pasture and pioneer species. Currently, in 2009, little hand management is conducted in the restoration, and we assume that the forest can maintain, if not increase, its current diversity as it has for the last 29 years.

Ecuador, in addition to many other tropical countries, is paying more attention to the field of reforestation. Worldwide, climate change treaties are beginning to include more incentives for carbon sequestration through reforestation and tropical forest conservation, and we hope that our restoration effort can serve as a model for future restoration activities in the Amazon region.

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