Feliciano Sevillano, expert on the sustainable production of Dragons Blood, inspecting the flow of latex from tree that may be selected as a "mother' tree to produce seedlings for reforestation in the lower Napo River region. Photo ©2020 Steven King

Sustainable Harvesting of Dragon's Blood (*Croton lechleri*) in Peru

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Summary

This article describes the sustainable management practices and use of sangre of drago *Croton lechleri*), a medicinal plant native to tropical forests, which has been used in traditional medicine by many Amazonian indigenous peoples and cultures for centuries. This plant is also used as a phytomedicine in Latin America, North America, and Europe. The authors, who are experts in the sustainable management of dragon's blood, describe how they are working to create strategic alliances with families, communities, and regional nonprofit agencies to promote an ecologically sound production network focusing on triple bottom line benefits for a diverse array of stakeholders, including local forest-dwelling people, patients, communities and the tropical forest biocultural diversity. The authors and have been working with plants, people and communities for more than 30 years in the Peruvian Amazon.

Introduction

The increased global focus on managing human health with plant-based medicines is enhancing the wellbeing of many people but continuing to put pressure on wild medicinal plant populations. Cultivation of medicinal plants, along with sustainable wild harvesting, can ensure the long-term survival of medicinal plant species around the world for the benefit of local producers, patients, ecosystems, and developers of plant-based products. A number of initiatives, nonprofits, companies, communities, and individuals are working to implement and document sustainable harvesting and management practices worldwide.

This article is a follow-up to the article "Blood of the Dragon: The Sustainable Harvest and Replanting of the *Croton lechleri* Tree," which was published in *HerbalGram* issue 84 in 2009.[1] In this report, we provide an update on the sustainable harvesting and management of *C. lechleri* (Euphorbiaceae) in the Peruvian Amazon with multiple partners over the past decade.

In 2012, the US Food and Drug Administration (FDA) approved Fulyzaq® (now called Mytesi®; San Francisco, CA; Napo Pharmaceuticals) as the first oral botanical drug which is a chemically complex new molecular entity (NME) for the symptomatic relief of non-infectious diarrhea in patients with HIV/AIDS on antiretroviral therapy.[2] The active ingredient in Mytesi is crofelemer, which is isolated and purified from the latex of *C. lechleri.* Crofelemer is a complex proanthocyanidin that currently cannot be produced by a synthetic method. Because of this, the producers of Mytesi (including the authors of this article) have been focusing on the long-term sustainable management and harvesting of *C. lechleri* during the development and commercialization of Mytesi and other indications for

the active ingredient of this botanical drug. The development and regulatory approval of Mytesi has been a long-term process that allowed for investments in studies on basic biology and ecology and the implementation of reforestation programs over many years. (See Table 1 for a list of products currently sold or under development that are extracted and purified from the latex of *C. lechleri*.)

Croton lechleri: Botany, Benefits, and Regeneration

Croton lechleri is a fast-growing tropical tree in the spurge family of plants, many of which produce milky, usually white, sap. *Sangre de drago*, meaning "dragon's blood," is the common name of both the tree and the characteristic deep red latex produced by this species. *Croton lechleri* is the most well-known and widespread of the red latex-bearing *Croton* species in the northwest Amazon basin, and it is found throughout parts of Colombia, Ecuador, Peru, Bolivia, and Brazil.

The small-to-emergent canopy tree has white or gray bark that exudes clear red latex when lacerated. This tree is monecious (it contains female and male reproductive organs in the same individual) and is a pioneer species that often is found in disturbed sites and in riparian habitats (adjacent to rivers). It tolerates both sun and light shade and its seedlings typically grow 1-2 m per year. *Croton lechleri* is not listed as endangered or threatened under the US Endangered Species Act or the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and is not entitled to special protection under other US federal laws or via any international treaty to which the United States is a party.

C. lechleri has been shown to help optimize soil conditions in secondary forests, which facilitates ecological succession and restores soils that have been degraded as a result of clear-cutting. In secondary forests, *C. lechleri* provides shade for understory growth and improves soil biology through aeration and the addition of organic matter to the soil, which

Mr. Enemias Jumanga Villar, from the Ashaninka indigenous community of El Milagro, near the town of Lorencillo with seedlings of Croton delivered to him for planting in his food and medicinal plant agroforestry garden near his home. Photo ©2020 Richard Pariona

Ricardo Pariona Fonseca, general manager of CORFA SAC, preparing Croton seedlings for transport to local family for planting in agroforestry system in Lorencilo, Central Rainforest area of Peru.
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Florencia Cuno Pishagua, from the Ashaninka indigenous community of Puerto Porvenir, in her field with Croton trees planted as part of her agroforestry food production system, who has received plants, technical and financial support as part of the reforestation activities in the Pichis River Valley.
Photo ©2020 Steven King

not only returns important nutrients to the soil (e.g., nitrogen, phosphorus, calcium, potassium, and magnesium), but also balances soil pH and catalyzes microbial activity.

Dragon's blood is used in traditional medicine by local and indigenous people for a number of conditions, including, diarrhea, ulcers, wound healing, skin infections, and respiratory problems.[3-8] Because of its effectiveness at healing cuts and treating various gastrointestinal issues, and the wide distribution of *C. lechleri* trees, dragon's blood is one of the most common traditional medicines in all of Latin America. Commercial products based on *C. lechleri* extract are found widely in the Peruvian Amazon, in the capital city of Lima, as well as in many places in North America and Europe. Throughout its natural range, *C. lechleri* trees are considered part of the standard natural pharmacopeia and frequently are observed growing in local gardens where the latex can be extracted as needed, typically by cutting a small incision in the trunk with a machete, a process known as the tapping method.

Preliminary studies have found that the tapping method of latex extraction (wherein crude plant latex is extracted without initially harming the tree) is less successful for large-scale production than the traditionally used felling method (cutting the tree down to extract latex from the felled tree).[5] The average volume of latex obtained differed significantly between the two methods of harvesting (50 mL using the tapping method versus 3,000-3,800 mL using the felling method), and within 10-12 months following tapping, the tapped trees suffered a high mortality rate.[1]

Boat transporting latex on Huallaga River near the city of Yuirnaguas, Peru. In this region of tropical forest in the department of Loreto the primary mode transport is on rivers and streams. Photo ©2020 Steven King

Natural Regeneration and Seedling Reproduction

Experts assert that successful natural regeneration is key to the sustainable management of tropical forests. Assuring the replacement of harvested specimens is a constant concern for forest ecologists and specialists to maintain the forest structure and composition.[9] The critical period of the regeneration process is the seedling stage. There may be higher seed production and a higher germination capacity, but if the species does not have the capacity to overcome the external factors, such as lack of adequate sunlight, that reduce its abundance, the regeneration of a species will fail.[10,11]

Croton lechleri reproduces early and profusely. It does not require a specific pollinator and at about four years of age it can produce approximately 600,000 seeds per tree per season. On average, one kilogram of seeds (dry weight) corresponds to roughly 70,000 seeds. Seed germination is quite successful, especially under the disturbed conditions of a forest clearing. As a result, natural regeneration is widespread, and dozens of seedlings compete for light and nutrients at the base of mother trees.

Croton lechleri has large clusters of terminal inflorescences, which grow up to 30 cm in length. Flowering occurs every year, between June and October, during the dry season. Fruits are capsular, trilocular, grouped in spikes, have one seed per monocle, and mature in two to three months. Seed dispersion occurs by the violent explosion of fruits between October and November, at the beginning of the rainy season.[12] This dispersion method creates a viable seed bank in the understory soil, associated with leaf litter. These seeds can remain dormant for long periods at the base of the mother tree, waiting for environmental conditions that are conducive to germination.

Due to these characteristics, the natural regeneration of this species can be seen in areas altered by forest exploitation (e.g., for roads, yards, trails), areas used for agriculture and grazing, and places where the competing vegetation largely is eliminated. This allows the development and unrestricted growth of *C. lechleri* seedlings. By thinning forests and exposing soil to additional sunlight, fire can lead to increased germination and a greater number of seedlings. The fires that destroyed large areas of the Brazilian and Bolivian Amazon in late 2019 likely did not affect this species, because *C. lechleri* does not generally occur in the affected regions.

Studies of the dragon's blood tree's natural regeneration have been undertaken by multiple authors. Ravelo (1994) reported six to 72 specimens per hectare in Ecuadorian rainforest, with an average diameter at breast height (DBH) of 26.3 cm per plot.[13] Gaviria (1995) reported densities of natural populations of five trees per hectare in Palcazu and 88.6 trees per hectare in Oxapampa. In Madre de Dios, Gaviria reported 149 trees per hectare in areas

Production areas for sustainable harvest and reforestation of Dragons Blood latex in Peru. Map image courtesy of Geology.com

without human intervention, 42 trees per hectare in areas with light intervention, and 57 trees per hectare in areas with substantial intervention.[14] On the other hand, Ríos (2006) reported 10-33 trees per hectare in the Alexander von Humboldt National Forest.[15,16] Densities have been recorded at 8.4 trees per hectare on the Napo River in Pona and 6.4 trees per hectare in Cuyana near Iquitos, with stem growth rates of between seven to 12 inches per month for the first two to three years.[17]

Central Rainforest Region of Peru: Pichis River Valley

The Puerto Bermúdez and Constitución districts of the Oxapampa province in central Peru are covered by tropical rainforest. With altitudes ranging from 210 to 290 meters above sea level, this area is considered a transition zone between the Andes and low Amazon. It has a humid and warm tropical climate with an annual average temperature of 22.5°C (72.5°F), a minimum temperature of 15°C (59°F), and a maximum temperature of 32°C (89.6°F).

The Pichis River valley is the ancestral territory of the Asháninka, Yánesha, and Cacataibo indigenous peoples. Since 1980, the cultural environment has changed due to migration by people from other regions. The recent immigrants have introduced new knowledge and land use practices that are different from the traditional methods used by indigenous peoples. These immigrants also have implemented trade mechanisms and created dependence on commercial goods. One of the negative agricultural practices introduced that continues to generate social conflicts and environmental damage is the production of coca (*Erythroxylum coca*, Erythroxylaceae) leaves to make illicit drugs. Government institutions and non-governmental organizations (NGOs) such as the National Commission for Development and Life without Drugs (DEVIDA) are working to improve the agricultural and social conditions in the valley.

From a conservation perspective, the Oxapampa-Asháninka-Yánesha Biosphere Reserve, recognized by UNESCO, protects the Yanachaga-Chemillén National Park, the Yánesha and El Sira Communal Reserves, and the San Matías-San Carlos Protection Forest. The objective of the biosphere reserve is to create a biological corridor of protected natural areas to ensure biodiversity in perpetuity, guarantee the permanence of indigenous peoples' cultures through the sustainable use of wild resources, reduce external pressure on titled land territories, and empower the active participation of civil society to strengthen the sustainable management of forest resources and improve their quality of life.

Relationships with Indigenous Peoples and Local Institutions

The development of initiatives with indigenous communities and rural settlers cannot be separated from their identity and culture. The experiences of the last few decades have shown us that successful projects arise from locally identified needs. We have ensured this through the involvement of the indigenous and local communities from the

Families of the Awahun community of Yamakay where reforestation and latex collection work is being done, saying goodbye after a series of meeting, field observations and discussions on current and future reforestation work. Photo ©2020 Steven King

early design stages of these projects through the later stages of implementation. The inclusion of the population in decision-making not only guarantees the protection of their rights, but also contributes to community-based sustainable management of plant resources. Therefore, this approach is not only morally correct but economically wise.

In the territories where we interact with indigenous and rural communities, our philosophy is to maintain a relationship of collaboration and coexistence. This consists of establishing effective communication mechanisms, holding working meetings with leaders and executives, and actively participating in communal meetings. Our participation in these events allows us to collaborate in a climate of trust with the indigenous peoples. This collaboration also helps to prevent or resolve social and environmental conflicts that may arise when working with forest resources and with the collection and reforestation of *C. lechleri* latex.

In the Pichis valley, there are two indigenous organizations: the Asociación de Nacionalidades Asháninka del Valle Pichis (Association of Asháninka Nationalities of the Pichis Valley; ANAP) and Unión de Nacionalidades Asháninkas y Yáneshas (Union of Asháninkas and Yáneshas Nationalities; UNAY). We have built alliances and strategic collaborations with these nonprofit federations to promote the ecological production of latex and carry out the reforestation of *C. lechleri,* mainly in native communities in the Pichis valley. We also have beneficial collaborative relationships with DEVIDA, Instituto del Bien Común (Institute for the Common Good; IBC), Fondo Verde (Green Fund), Servicio Forestal y de Fauna Silvestre (Forest and Wildlife Service; SERFOR), and Programa de Bosques del Ministerio del Ambiente y Servicio Nacional de Sanidad Agraria (Forest Program of the Ministry of the Environment and National Service of Agrarian Health; SENASA). The objective with these institutions is to promote the reforestation of *C. lechleri* in the Pichis valley.

Sustainable Management of Croton lechleri *Latex*

Historically, the Pichis valley has served as a source of high-quality *C. lechleri* latex. In the 1970s, the Asháninka marketed latex through intermediaries in the markets of Lima, other major cities in Peru, and internationally. We started the first latex collections and reforestation work in this region in 1998 on behalf of the now-defunct Shaman Pharmaceuticals, and later, Jaguar Health Inc. Since that time, we have developed positive and mutually beneficial working relationships. Admittedly, there have been challenges, but the goal always has been to ensure the sustainable production and fair trade of latex in the Pichis valley.

This production activity has become an important economic resource for many families in indigenous communities. In this area, approximately 95% of latex collectors are from indigenous communities. We have trained 32 two-person teams on the most effective methods for latex collection to ensure quality. Each group is provided a complete set of materials and tools to collect latex. They also receive

Table 1: Product Portfolio

		DEVELOPMENT STAGE				
PRODUCT	INDICATION	PRECLINICAL	PHASE 1	PHASE 2	PHASE 3	MARKET
Mytesi	Noninfectious diarrhea in adults with HIV/AIDS antiretroviral therapy					
Mytesi	Cancer therapy-related diarrhea (CTD)				Study report expected late 2020	
Mytesi	Supportive care for IBD					
Formulation of crofelemer	Rare Disease Short Bowel Syndrome (SBS) & Congenital Diarrheal Disease (CDD			Orphan-drug status previously received for SBS; applying for orphan-drug status for CDD		
Mytesi	IBS - Diarrhea Predominant (IBS-D)				Paper published December 2019	
Mytesi	Idiopathic/functional diarrhea			Study initiated and sponsored by the University of Texas Health Science Center at Houston		
Lechlemer	Cholera and other GI indications (second generation anti-secretory agent)		Received preclinical services funded by the National Institute of Allergy and Infectious Diseases for pre clinical toxicity studies			

basic medicines, and training occurs at frequent intervals.

We estimate that approximately 75% of the latex from the Pichis valley is collected in secondary forests, 15% from reforestation sites, and 10% from primary forests where timber species have been harvested. As indicated above, the natural regeneration of this species is rapid and widespread, but goal is to shift the harvesting ratio to 25%-30% from secondary forests, 65%-70% from reforested areas and

Our collectors in this region indicate that they obtain an average of one gallon of latex from one to five trees with an average DBH of 28-35 cm. Larger trees (DBH > 60 cm) can yield up to two gallons of latex. When harvesting trees from reforested areas, we recommend harvesting trees that are 9-10 years of age. In most locations, it is ideal to collect latex from trees with DBHs of 35 cm or larger.

Recently, in the Pichis valley, *C. lechleri* wood has entered the market. The main customers are the manufacturers of containers for the transport of fruits, most often for the packaging of papaya (*Carica papaya*, Caricaceae) to ship to Lima. Therefore, the latex producer gains additional income from the sale of the wood.

Reforestation on Indigenous and Local Communities' Lands

The success of reforestation depends on the quality of seedlings. Once we locate the mother trees, we remove weeds from the base of the tree in a roughly 15-meter radius. Then, about 20 to 30 days later, we select the seedlings or saplings that have sprouted. We dig them up, place them in plastic bags with organic material, and transport them with great care to the forest nursery. The seedlings remain in the forest nursery for a maximum of three months until they have acquired sufficient size and resistance for transplanting into the final ground.[1]

Reforestation ideally is carried out in places where latex is collected and where families grow subsistence crops. We reforest using an agroforestry system and plant each seedling in a 5 x 5-meter space (a total of 400 trees per hectare). We learned from our 30 years of experience that reforestation in secondary forests and open-field agroforestry systems works well. We recommend reforesting in relatively humid soils with good organic matter content. In degraded soils, it is necessary to use at least 25 grams of natural fertilizer (e.g., phosphoric rock or island guano). It is important to prune other trees and remove other fast-growing plants at least twice during the first two years of growth of the *C. lechleri* trees, as this species requires adequate sunlight and is susceptible to competition from the surrounding vegetation. We also replace seedlings that have not survived in the first six months after planting. Finally, a general thinning of the reforestation site is undertaken at the end of the first two years to remove trees that are not growing well, which allows for the healthiest trees to flourish.

In the Pichis valley, we have been conducting reforestation since 2009 with the financial support of Jaguar Health, Napo Pharmaceuticals Inc., and the critical contributions of 140 families from Yánesha and Asháninka indigenous communities and local communities. The collaborating families are 85% indigenous and 15% local non-indigenous. To date, we have planted approximately 118,230 *C. lechleri* trees on about 230 hectares. The reforestation work has been undertaken on secondary forest lands, as well as on soils that were used to cultivate cassava (*Manihot esculenta*, Euphorbiaceae), bananas (*Musa* spp., Musaceae), cacao (*Theobroma cacao*, Malvaceae), maize (*Zea mays*, Poaceae), rice (*Oryza sativa*, Poaceae), and other daily food products. Currently, 90% of the reforestation is well-developed; the trees planted in 2011 have a maximum diameter of 30 cm and an average height of 15 meters. In this area, we have set a goal of replanting up to five trees for each gallon of latex collected.

In 2019, we replanted approximately 5,600 *C. lechleri* trees. We currently have a list of local families who will

Enrique Perez, member of Ashaninka indigenous peoples, examining growth of a portion of the 1600 Croton trees that he has planted in 2011 on 4 hectares of his land in near the community of Nuevo Progresso-Kirishari utilizing seedlings provided by CORFA SAC. The latex from these reforested trees will be sold in the next 12 months for income for his family.
Photo ©2020 Steven King

receive seedlings produced by our nursery. During the reforestation process, it was important to coordinate actions with the indigenous organizations UNAY and ANAP and the local communities, and to select families who were serious and committed to taking on the reforestation work. In some cases, we established collaboration efforts with the Association of Cocoa Producers promoted by DEVIDA. We have found that women are and continue to be key in the management of plants, weed control, and silviculture as the trees grow.

Reforestation in Collaboration with Cocoa Producers

In September 2017, we established agreements with DEVIDA and the Association of Cocoa Producers to supply cocoa producers with *C. lechleri* seedlings to create windbreak curtains and enable the producers to sell the latex and wood of *C. lechleri* trees. Tree windbreak curtains can help reduce damage caused by strong winds, reduce wind erosion, minimize sudden changes in soil temperature, protect cacao pods when ripening, and establish a microclimate conducive to development and production of better-quality cacao fruits. The *C. lechleri* trees are being reforested in association with tornillo (*Cedrelinga cateniformis*, Fabaceae), bolaina (*Guazuma crinita*, Malvaceae), mahogany (*Swietenia macrophylla*, Meliaceae), capirona (*Calycophyllum spruceanum*, Rubiaceae), and other commercial timber species.

According to DEVIDA, in the Constitución district in central Peru, more than 970 families have cocoa plantations distributed in 39 communities, and they are members of the Association of Agricultural Producers of the Pichis Valley. These producers receive support and technical assistance from DEVIDA. The aim is to incorporate a minimum of 100 seedlings of *C. lechleri* per hectare of cocoa cultivation in a windbreak curtain formation, with a distance of 5 x 5 meters between each plant; in the case of reforestation in "open-field" agroforestry systems, we suggest a distance of 5 x 5 meters, or 400 trees per hectare. However, we leave this to the discretion of each farmer and work only with cocoa producers committed to diversifying their crops through the implementation of windbreak curtains and agroforestry systems.

Over a period of two years, our goal was to distribute 10,000 *C. lechleri* plants to more than 100 families (100 plants per family) of cocoa producers in the Constitución district. In this program, we managed to meet only about 30% of our goal and distributed 3,000 plants to approximately 30 families. The remaining 7,000 plants were distributed and reforested in alliance with indigenous

Organic Certification of *Croton lechleri* with the Yánesha and Asháninka

Organic certification for *C. lechleri* latex in indigenous communities of the Pichis valley was facilitated by the company Corporación Forestal Amazónico (CORFA), with the economic support of Jaguar Health. The certification was audited by IMOcert, an accredited entity for a variety of certification programs and with expertise in the socio-environmental context of the Central Rainforest region of Peru. The collectors and people who reforest *C. lechleri* do not use pesticides, insecticides, or chemical fertilizers. There is no need or advantage in doing so, and these external inputs cost money. The latex of *C. lechleri* also is quite bitter and acts as a natural deterrent to insects and pests. The latex periodically is tested after leaving Peru for the presence of synthetic chemicals, and, to date, none have been detected using standard analytical methods. This certification process was a useful exercise for both local families and CORFA SAC.

At the beginning of this new certification process, we had to make sure that certain fundamental principles of ecological production and conservation were being followed. We also had to be sure that producers were able to adopt sustainable management standards, which include compliance with environmental and social laws, a commitment to follow a detailed management plan, limited use of organic agrochemicals, prevention of commercial hunting and sale of bushmeat, respecting the proper use of soils, and implementation of safety practices.

Once these basic principles were reviewed with the producers, we informed IMOcert that we were ready to start the formal process. We then completed an organic certification class. The first task was to identify potential producers, locate them on a map, and contact them to provide information and training related to the certification process. After the training, we scheduled a technical visit to assess production centers and areas where *C. lechleri* was both regenerating naturally and planted manually. Once the field supervision work was completed, we carried out an evaluation and established a follow-up plan with the producers or latex collectors. We intensified this fieldwork process during the peak latex collection months in this area (i.e., from October to May). At the latex collection center, we prepared for the inspections, and adapted and organized the product reception documents (e.g., producer identification, origin, volume, quality control mechanism, latex packaging, and registration information) in accordance with the requirements of IMOcert

The First Organic Certification of Croton lechleri

The certified organic production of *C. lechleri* latex required a sustainable production system with optimal management of natural resources without contamination of chemical synthesis products. This helps maintain soil fertility and biological diversity, and it provides assurance of a synthetic chemical-free natural product. It also indicates a respect for traditional forms of land use and enhances the use of traditional agricultural crops, which generally do not require synthetic pesticides or fertilizers.

In the Peruvian Amazon, very few NTFPs have organic certification. We are aware of two other NTFPs in Peru that have achieved this: aguaje (*Mauritia flexuosa*, Arecaceae) oil and camu camu (*Myrciaria dubia*, Myrtaceae) pulp. We are proud to be the first certified organic producers of *C. lechleri* latex, which was accomplished with Yánesha and Asháninka indigenous peoples. We started this process in January 2016, and by 2018 we had 52 latex-producing families who were providing certified organic latex. During this two-year period, we learned that to ensure that indigenous communities comply with organic requirements, the participation of a permanent local facilitating institution is required because certification is relatively complex. The collection center is required to assure careful handling of technical documents, reception of latex, quality control, and appropriate packaging and labeling of the product.

communities (4,500 plants), Fondo Verde (1,000 plants), and owners of individual plots (1,500 plants), benefitting another 15 families in the valleys of Pichis and Palcazú, Selva. We learned that alliances and good institutional relationships can help create synergistic collaborations to recover degraded areas, reduce damage to biodiversity, and minimize illegal coca crops.

Reforestation with EDMAR

In 2000, the NGO Eco-Development, Environment and Reforestation (EDMAR) initiated a large reforestation project based on the market we have been creating in this region, planting 110,000 *C. lechleri* trees. These trees were planted in agroforestry systems and in seven native communities of the Pichis valley (El Milagro, Puerto Davis, Sargento Lores, Belén, Divisoria, Dinamarca, and La Paz de Getarina). This project was approved and funded by the International Tropical Timber Organization (ITTO). Technical support for this project was provided in part by Elza Meza, an expert on the sustainable management of *C. lechleri* who has worked with Napo Pharmaceuticals in several regions of Peru.

The Napo River Region in the Department of Loreto

In this section, we present information on the reforestation and sustainable management of *C. lechleri* in the areas of the Napo River, Mazán and Alto Nanay which are near the large city of Iquitos, Peru. The most frequently used modes of transport are by river with some limited roads out of Iquitos. Large areas close to rivers and streams have been cultivated, and timber species have been harvested from primary and secondary forests for more than 100 years. There are areas of primary forest in reserves and protected areas, especially between the Napo River and Putumayo River. The population of these areas, excluding the city of Iquitos, is approximately 57,750 people. The indigenous communities in this area are Kichwa, Orejone, Arabela, Huitoto, and Yagua, as well as a large number of non-indigenous mixed-descent Spanish-speaking communities.

Maintenance of Open-field Reforestation and Enrichment Planting

Between 2009 and 2011, reforestation was carried out on 232 hectares near the village of Llachapa using the open-field reforestation system. Seedlings were planted in lines 100 meters wide, with a variable length from 600 to 1,000 meters depending on the physiography of the land. *Croton lechleri* plots were situated next to equal-sized areas of untouched forest in a checker-board pattern to maximize the conservation of biological diversity. The distribution of seedlings was mostly random, with an approximate planting distance of 4.5 meters, and about 450 trees per hectare. Approximately 104,000 trees were reforested in this process.

The most recent silvicultural treatment was performed in May 2019 and consisted of removing the fast-growing

Feliciano Sevillano in one of multiple reforestation sites near the village of Llachapa on the Napo River in Peru, where Feliciano has supervised and planted approximately 104,000 Croton trees since 1997, developing innovative low impact methods for collecting seedlings, planting and maintaining plants for maximum growth. Photo ©2020 Steven King

trees, especially cetico (*Cecropia* spp., Urticaceae) and palo balsa (*Ochroma* spp., Malvaceae), followed by thinning and cutting of lianas. This reforestation maintenance was effective as the *C. lechleri* trees are now growing successfully, occupying the upper canopy, and have good ramification branches. On average, the elite trees have DBHs of 32 centimeters and stem heights of 15 meters. It is evident that silvicultural treatments can significantly enhance *C. lechleri* tree growth.

We also have implemented natural-regeneration forest management on the 30 hectares where we collected latex in May 2018. Ten months after collecting latex from the trees, we carried out a general evaluation of the entire harvested area. We found the area mainly covered by secondary forest plant species. When exploring the interior of this thick vegetation, we found small stands with a large number of *C. lechleri* seedlings, with heights ranging from 10 cm to 1.5 meters, trying to compete with shrubs, lianas, and other fast-growing species.

In places with *C. lechleri* seedlings, we observed the spatial distribution, development, and phytosanitary condition of the seedlings. Then, in circular plots with a radius of about three meters, we carried out the silvicultural work to promote the seedlings' growth. We cleared other fast-growing vegetation to create spaces with appropriate sunlight and then selected *C. lechleri* seedlings by pruning the branches and removing the small, weak, or unhealthy trees.

In areas where *C. lechleri* trees were harvested and were not regenerating naturally, we replicated the natural clearings that occur in tropical forests by creating artificial clearings in nearby places or around the stumps of harvested *C. lechleri* trees. The area of these clearings varied from approximately 10 to 12 square meters. The aim of creating these open spaces is to increase sunlight and soil temperature, to offer favorable conditions for germination of *C. lechleri* seeds that are still dormant in the soil.

We will continue with silvicultural treatment in the 30-hectare area every six months. The goal is to achieve a harvestable population of 270 to 330 quality trees per hectare.

Natural regeneration of Croton, seedling in secondary forest with near village of Llachapa on Napo River of Peru. Hundreds of seedlings grow in and around gardens, reforestations sites and natural clearings or gaps in secondary forests. Photo ©2020 Steven King

A portion of 10,000 Croton seedlings in nursery of CORFA SAC that where collected from wild " mother trees" being prepared for distribution to families, communities and non profits who are part of the sustainable harvesting of this species in the area of Lorencilo, Peru. Photo ©2020 Steven King

Relationships with Neighboring Communities in Napo River Area

The policy of Jaguar Health and Napo Pharmaceuticals Inc. is to conduct operations in a harmonious manner, to build a relationship of healthy coexistence with indigenous peoples and local residents, to respect the laws of indigenous communities and civil society in general, and to provide up-front benefits to the communities with which we work. As examples, we describe two cases:

In August 2017, the Llachapa Village requested that Jaguar Health donate a plot of land to expand the infrastructure of the high school educational center and areas for agricultural research. After evaluating the proposal, Jaguar Health accepted the request. The company donated 27 hectares of forest land that will be used solely by students and teachers according to the plan developed by the principals of the integrated alternative high school: the Yarina Isla-Llachapa Rural Center for Alternative Training No. 60303 (Centro Rural de Formación en Alternancia Yarina Isla-Llachapa).

A donation was made to the Orejones Native Community, who requested equipment to improve the community's water supply and economic resources to improve administrative activities in the city of Iquitos. To provide support to this neighboring community, Jaguar Health donated a Honda motor pump to complete a project that the community had already invested in, which will supply clean well water for more than 40 families.

Reforestation and Sustainable Management in Departments of Amazonas and Loreto

In this section, we present a summary on the reforestation and sustainable management of *C. lechleri* in the departments of Amazonas and Loreto as well as the provinces of Datem del Marañón, San Martín, and Condorcanqui by the organization PROBOS-L&CH. The climate in this area is also tropical and humid, with temperatures ranging from 23°C to 36°C (73°F to 97°F). The approximate population of the area described is 450,000 people and the land area is 88,000 square kilometers. The indigenous communities that have collaborated with us are Kichwa, Awajún, and Kandozi peoples, though a number of other indigenous groups are in this large region. The primary mode of transportation is by river, and this area has a large amount of primary tropical forest that also has been used to extract hardwood timber species, and it is a region that produces oil in various locations. The region has a high level of poverty with limited opportunities for families to generate income for basic necessities that cannot be grown or produced in the communities.

In this region, we have replanted 236,000 *C. lechleri* trees since 2006 in collaboration with indigenous and local communities. The primary method we have used in these reforestation sites is opening gaps in lines in secondary forests where *C. lechleri* commonly is found. With this approach, we clear enough vegetation so that the trees have enough light to grow and reach the lower canopy within the secondary forest. After three to four years, it is difficult to notice that trees have been planted if the secondary forest is viewed from above the canopy. In this system, as in the majority of reforested areas with *C. lechleri*, the secondary forest rapidly re-absorbs the trunks of felled trees, returning all of the nutrients contained in the trees to the forest floor through the rapid action of fungi and other organisms.

We have undertaken this process in five distinct locations where we have been collecting latex of *C. lechleri*. We have spread this work out over eight years and will continue to work with communities that are interested in the sale of latex as well as reforestation. The process by which we collaborate in this region is similar to the process undertaken in the central rainforest area of the Pichis valley. We also are making monthly visits to communities, providing technical information on the most efficient process for reforestation and collection of *C. lechleri*. Most recently, we have entered into a collaboration agreement with a regional government agency to enhance our outreach and effectiveness in this region.

Three of the people who have been working on sustainable harvest and management of Croton in the Pichis River Valley, Richard Fonseca, Steven King and Manuel Lazaro Martin, with reforested Croton trees.
Photo ©2020 Steven King

PROBOS-L&CH collaboration with regional government agency PEDAMAALC

Datem del Marañón – Alto Amazonas – Loreto and Condorcanqui (PEDAMAALC) is a special project attached to the Ministry of Agriculture and Irrigation (MINAGRI) of Peru. Its purpose is to identify, promote, formulate, and execute projects that include forestry and reforestation. PEDAMAALC is especially focused on families with reduced access to national assistance or support. Its objective is to increase the agricultural capacities of local communities with an emphasis on women and families. It promotes the exchange of knowledge on adding value and diversifying sources of income through the enhanced production and commercialization of a diverse set of agricultural and forest resources, including *C. lechleri*. PEDAMAALC recently signed an agreement with PROBOS-L&CH to collaborate on the long-term sustainable management of *C. lechleri*. In this collaboration, PROBOS-L&CH will provide expertise on how to produce, plant, prune, maintain, and effectively harvest *C. lechleri* in diverse locations where PEDAMAALC is active.

Conclusion

Over the past 30 years, we have been learning about the most effective methods of reforestation of *C. lechleri*, as part of our commitment to the long-term sustainable management of this species in the tropical rainforest of several Western Amazon basin countries. Our approach to the sustainable harvest and management of *C. lechleri* combines wild harvesting and reforestation/cultivation in numerous locations using a low-density agroforestry approach. We also have focused on using distinct regional approaches to reforestation and natural regeneration management, as learned from and practiced by local peoples and our collaborating expert colleagues, many of whom have devoted more than 25 years to learning how to manage this species in a way that is both ecologically sustainable and of economic and social benefit to local forest-dwelling communities.

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Mature 8 year old reforested Croton trees in secondary forest in village of Llachapa on Napo River of Peru. Photo ©2020 Steven King

communities of Peru for five years, and with the Field Museum of Natural History in Chicago as part of the rapid ecological survey teams that conducted ecological and community inventories in 10 locations in Peru over an 11-year period.

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