INCREASING CARBON SEQUESTRATION IN SHADE-GROWN COFFEE PLANTATIONS

SECOND EDITION

Editors:
Gabina Sol Quintas
Jazmin Cobos Silva
Daniel Santos Cabrera
César Flores Ortiz
Isela Rodríguez-Arévalo
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CAPTURA DE CARBONO EN CAFETALES BAJO SOMBRA

Dedicated to the coffee producers of the municipalities of Chocamán, Coatepec, Huatusco, Ixhuatlán del Café, Teocelo, Totutla, and Xico, in the state of Veracruz, for their participation in the project.

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Second edition

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A project of

Royal Botanic Gardens Kew

Facultad de Estudios Superiores Iztacala

In collaboration with

pro natura veracruz, A.C.

INECOL Instituto de Ecología, A.C.

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1 «Incremento de la capacidad de secuestro de carbono y mejora de medios de vida en los cafetales de sombra del Estado de Veracruz, México.»

Preface

Sr. Jon Benjamin
British Ambassador to Mexico

In 2018, the UK and Mexico launched the Partnering for Accelerated Climate Transitions (UK PACT) Programme reflecting both countries' commitment to tackling climate change, the greatest global challenge of our generation. UK PACT works with partner countries to design and invest in initiatives that promote a sustainable and inclusive economy.

Within that larger programme, this particular project's two main priorities in Mexico are tackling deforestation, while accelerating carbon capture; and improving the livelihoods and quality of life of the communities that protect local forests. Three partners make this possible: Kew Royal Botanic Gardens, the Iztacala Higher Studies Faculty of Mexico's National Autonomous University, and Pronatura Veracruz. This partnership brings together strengths of each organisation in science, research and community engagement.

Shade-grown coffee offers a number of distinct advantages over traditional coffee production. It increases quality and reduces pest infestations, resulting in higher coffee prices and higher incomes for producers. The forestation element of the project involved a highly advanced selection of tree species, which this document describes in detail. The new trees, once planted, will optimise carbon capture and income generation by providing nuts, fruits, flavourings and ingredients for pharmaceutical and cosmetic products. Importantly, they will also counteract deforestation and enhance biodiversity.

For some time now, increased temperatures from climate change have negatively affected coffee production in the cloud forests of Veracruz. In fact, by one estimate, this area will lose 57% of its coffee production by 2040 due to high temperatures. Under pressure, producers are abandoning coffee and turning to monocultures such as sugar cane and citrus fruits or even selling their plots. Shade coffee offers a sustainable, economic and environmental alternative.

During the first phase of the project, I had the pleasure of visiting the communities of Huatusco, Teocelo, and Coatepec in a very beautiful part of Veracruz. I saw first-hand the striking difference between traditional and shade coffee growing methods and I began to appreciate the true value of these new agroforestry practices.

For this second phase of the project, and second edition of this report, I am pleased to see the updates offered by the implementing team, which include more detailed technical notes, images, and information on best practices, while making the operational differences between the sun coffee plantations and the shade coffee plantation much clearer. These updates are in high demand and are a direct response to the feedback received by producers during participatory workshops. I trust that this update provides all the relevant information needed to support subsequent phases of the project.

I want to conclude by thanking all those people from the communities, the implementing partners and the UK PACT Team for the time and dedication that they have invested in making this project such a success thus far. I am happy to report that the UK is currently considering a third phase of the Project in 2024-2025. More details on that will follow, but meanwhile the UK remains committed to supporting Mexico's climate change mitigation efforts through targeted local actions, such as the ones taken by those championing climate transition in the areas benefiting from this UK PACT Shade Coffee Project.

Sr. Jon Benjamin
British Ambassador to Mexico

Preface

Elisa Peresbarbosa Rojas
General Director of Pronatura Veracruz A. C.

We are in the second phase of the project "Enhancing carbon sequestration and improving livelihoods in shade-grown coffee plantations in the State of Veracruz, Mexico" and the second edition of this manual. There are three points that I would like to highlight: (i) the capacity producers gain through the exchange of experiences, (ii) the ongoing development of reforestation trials utilising the native tree species selected in the first phase of the project, and (iii) the endeavour to facilitate the links between key stakeholders in the production of shade-grown coffee. The latter aims to strengthen existing relationships and create new collaborations and alliances that allow the conservation, maintenance and consolidation of the productive system of shade-grown coffee, and its link to conservation and biodiversity in the mountainous regions of Mexico.

The strengthening of the producers' capacity has been carried out, in part, through workshops in which producers were able to share their traditional knowledge about the use of various species of native trees. I find this method highly enriching, since the exchange of practical knowledge on the use of native trees can contribute considerably to the improvement of farm management practices and their biodiversity. For example, orange trees, lemon trees and gourds help fix nitrogen; guava and soursop help with pest control; jinicuil provides leaves and nutrients to the soil; jonote attracts pollinators and produces a delicious edible mushroom; guava has a very strong root and helps combat gophers, and so on. The wealth of knowledge generated every day in the management of the farms is so vast and rich that these types of meetings should be promoted more frequently.

Additionally, initiating reforestation experiments on coffee farms, together with the owners and workers of the farm, appears to be an excellent mechanism to involve the producers in sharing the knowledge of the trees, their care and the generation of information on the behaviour of native species under diverse farm conditions. This approach creates a form of citizen science focused on trees.

I anticipate that the effort generated in this project will heighten awareness of many producers regarding the knowledge and care of native trees. I hope that they will be inspired to collect seeds, propagate native trees and continue the effort to enrich the coffee landscapes where their farms are situated. This, without a doubt, will allow for a much more resilient outlook better equipped to adapt to the challenges posed by climate change.

The links between key stakeholders is essential to continue promoting and strengthening shade-grown coffee farming. There are very few production systems in the world that offer economic alternatives to a wide variety of people and sectors while conserving biodiversity and environmental services, as shade coffee production does. This productive system deserves the continual effort and attention of various stakeholders to highlight its importance and to ensure that the hundreds of producers who take care of their farms every day receive a remuneration that enables them to continue maintaining it; without this support, the system faces the threat of a change in land use towards more the system faces the threat of a change in land use towards more profitable, less sustainable production systems.

We hope that the effort made through this project and this report will allow us to build a new network able to consolidate this production and conservation system.

Elisa Peresbarbosa Rojas
General director of Pronatura Veracruz A. C.

Abbreviations

DBH Diameter at Breast Height

BMM bosque mesófilo de montaña (mesophilic mountain forest, also known as a cloud forest)

C carbon

CO_2 carbon dioxide

CONABIO Comisión Nacional para el Conocimiento y Uso de la Biodiversidad

FESI-UNAM Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México

GHG greenhouse gases

GESI gender equality and social inclusion

ha hectare

ICO International Coffee Organization

INECOL Instituto de Ecología A. C.

INMECAFE Instituto Mexicano del Café

O oxygen

pH concentration of hydrogen ions in a solution, body, or area; measure indicating acidity or alkalinity.

REMIB Red Mundial de Información sobre la Biodiversidad

RESEM Reserva de Semillas [Seed Reserve], Pronatura Veracruz, A.C.

t tonne

UKPACT Partnering Accelerated Climate Transitions

INCREASING CARBON SEQUESTRATION IN SHADE-GROWN COFFEE PLANTATIONS

Introduction

Elizabeth Bell, Maraeva Gianella, Teresa Durand Mazza and Tiziana Ulian.

Context

The forests of the state of Veracruz are a key element in the biodiversity of Mesoamerica, and have been described as one of the major centres of arboreal diversity in Mexico. One important type of forest in the state is the cloud forest (also known as a mesophilic mountain forest). Cloud forests make up less than one percent of Mexico's territory, but they account for approximately 10% of the country's plant biodiversity and include a large number of endemic species (species found exclusively in Mexico).

The livelihood of the majority of families in the central region of Veracruz depends on coffee production, making it vital to the local economy to the local economy. Recent statistics indicate that 32% of women are self-employed, and seek to avoid abandoning their household labour; the remaining 68% have no gainful employment and thus no income. However, 74% of women administer their households and make decisions.

More than 700,000 ha of land is devoted to coffee cultivation in Mexico, distributed among 560,000 producers, the majority of them smallholder farmers with 5 ha or less. Shade-grown coffee accounts for 90% of the total, and 50% is exported. The state of Veracruz ranks second in coffee production in the country, with more than 145,210 ha.

Figure 1. Cloud forest landscape in Veracruz (November 2022). Photo: RBG Kew.

Figure 2. Coffee berries. Photo: RBG Kew.

Figure 3. Roasted coffee beans. Photo: RBG Kew.

The coffee region of Veracruz includes 842 communities, 82 municipalities, and approximately 86,000 producers, which include smallholder farmers or minifundistas (93.5% of coffee plantations are less than 3 ha in size). Smallholder farmers with 2-3 ha have traditionally represented more than 80% of the coffee producers in the region. The coffee land in this region is capable of hosting up to 85% of the species found in the cloud forest.

Climate change is altering the conditions of cultivation, and 50% of the cloud forest of Mexico has been affected by human activity such as urbanisation and deforestation for agriculture. The capacity of these forests to support the livelihoods of local communities, including their production of coffee, has thus been reduced.

This change is related to a reduction in the ability of the forest to mitigate the effects of climate change by eliminating carbon from the atmosphere. For this reason it is important to find innovative mitigation strategies. Adding native trees to the shade-grown coffee plantations, trees that have a high capacity for carbon sequestration and that are useful to local communities, would contribute to a reduction in the effects of climate change and at the same time improve people's livelihoods.

The Project

The objective of the project, "Enhancing Carbon Sequestration and Improving Livelihoods in Shade-Grown Coffee Plantations in the State of Veracruz, Mexico" ("Incremento de la capacidad de secuestro de carbono y mejora de medios de vida en los cafetales de sombra del estado de Veracruz, México"), is to strengthen the capacities of coffee producers, mitigate the effects of climate change, conserve biodiversity, and help improve their livelihoods by increasing the diversity of trees and their ecosystem services to shade-grown coffee plantations in parts of the cloud forest in Veracruz.

The specific objectives are: 1) to develop a methodology for the selection and agroecological management of species with a high potential for carbon sequestration in the cloud forest; 2) to support the conservation of native trees; and 3) to help improve the livelihood of smallholder farmers based on sustainable use of forestry goods and services on shade-grown coffee plantations.

The first phase of the project was carried out from the 15th of August 2022 to 31 March 2023, and the second phase, currently underway, will end on 31 March 2025.

Areas producing Veracruz coffee

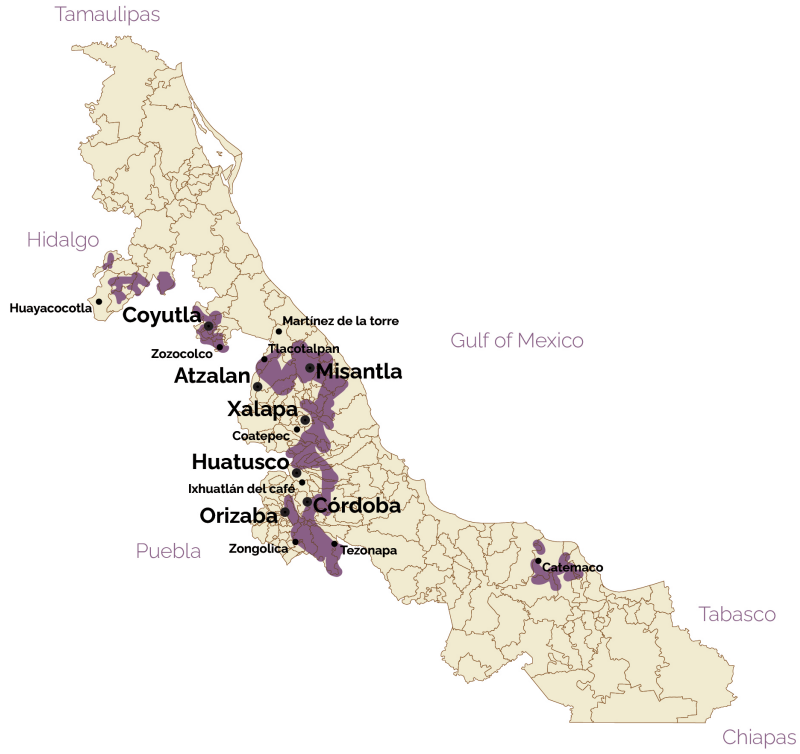


Figure 4. Areas producing coffee in Veracruz

Summary of the main results of the first phase:

- A methodology was developed, produced, and distributed for the selection and agroecological management of native tree species with a high potential for carbon sequestration and climate change resilience in the cloud forest (also known as the mesophilic mountain forest) of the state of Veracruz, producing and distributing informational materials.
- A list of 25 tree species was produced, i) applying an algorithm-based classification that considered the regional and local distribution, use, and carbon sequestration potential of the flora of the region, by means of ii) the implementation of participatory workshops to identify native tree species important to the local community (final classification), including human use and ecosystem services. This result was incorporated into the "Report on Analysis of the Selection of 25 Native Tree Species," a product of the first phase of the project.
- Based on the final list of native tree species, the seeds of 20 species were collected, processed, and placed in long-term storage in the seed bank of the FESI-UNAM. The first seven species were studied for carbon sequestration (field analysis of carbon) and climate change resilience (laboratory studies of germination).
- All of the results were distributed in the informational materials "Evaluation of Climate Resilience" and "Evaluation of Potential for Carbon Sequestration": a manual, videos (one short video and one long video in six parts), as well as technical fact sheets, postcards, blogs, and posters.
- The project was designed and implemented using principles of Gender Equality and Social Inclusion (GESI) in its activities.

The main objectives of the second phase are:

- To improve the abilities of smallholder coffee producers to mitigate the effects of climate change through training and pilot tests of reforestation using the native tree species selected in the first phase.
- To help develop ways for smallholder coffee producers to improve their livelihood by identifying commercial opportunities in shade-grown coffee plantations in Veracruz, based on a socioeconomic analysis and marketing strategy.
- To raise awareness about the methodology through the distribution of informational materials as global public goods.
- To strengthen and validate the methodology for selection and agroecological management of native tree species with a high potential for carbon sequestration and climate change resilience on shade-grown coffee plantations.
- To strengthen the existing network of small farmers and relevant stakeholders to mitigate the impact of climate change on shade-grown coffee plantations in Mexico.

The project includes elements of gender analysis of the effects of climate change on the design and implementation of the activities. This perspective helps the project staff to adapt strategies of participation and to address differences in the way men and women experience climate effects. The involvement of women and men in the project makes it possible to identify gender relations that sometimes limit the abilities of women, men, girls, and boys to adapt to the negative effects of climate change.

Figure 5. Community participation workshop on the Cielo Abierto plantation, Xalapa, Veracruz, September 2023. Photo: RBG Kew.

The project is led by the Royal Botanic Gardens, Kew (RBG Kew), in collaboration with the Seed Bank of the Facultad de Estudios Superiores Iztacala (FESI) of the Universidad Nacional Autónoma de México (UNAM), in alliance with Pronatura Veracruz, A .C. (2022-24) and Institute of Ecology, A.C. (INECOL). It includes the collaboration of coffee producers from the Veracruz municipalities of Chocamán, Coatepec, Huatusco, Ixhuatlán del Café, Teocelo, Totutla, and Xico, the main beneficiaries of the project.

The Manual

This manual is one of the major products of this project: it provides information on the effects of climate change on coffee plantations and the ability of different tree species to sequester carbon and mitigate its impact. It describes the methodology developed and the results obtained: the selection of native tree species, the collection and handling of seeds, Mexican conservation laws and regulations, best practices to mitigate the effects of climate change, and the propagation of native trees.

The selection of the species in this report was carried out following a method, developed by the project team, that identified native trees with a high potential for carbon sequestration and that could at the same time serve to improve the livelihood of local communities. This meant the inclusion of species that are useful for food, medicine, construction, and for providing shade for coffee plants.

Beginning with a list of tree species native to Mexico, a list was prepared of those native to the state of Veracruz. Scientific and social criteria were then used to propose a list of 50 species (Plant Physiology Laboratory, FESI-UNAM), which was evaluated in community workshops in order to rank 25 species of socioeconomic interest (Pronatura Veracruz, A.C.) into a final list of species with the greatest capacity for carbon sequestration and that would be useful to local communities.

Following the order of priority, seeds were collected from 15 species and preserved in the Seed Bank of the FESI-UNAM. The first seven species were analysed for their ability to sequester carbon in the field and for their climate change resilience in a study of seed germination (Laboratorio de Fisiología Vegetal, UBIPRO, FESI-UNAM).

This manual has been written for coffee producers, implementers of policy, researchers, and the general and technical publics, with the idea that this method of selecting tree species could help to strengthen the abilities of coffee producers to mitigate the effects of climate change, and at the same time increase the diversity of native tree species and their ecosystem services on shade-grown coffee plantations in parts of the cloud forest of Veracruz. We also hope it can be used for other coffee-growing regions in Mexico, in Latin America, and elsewhere in the world.

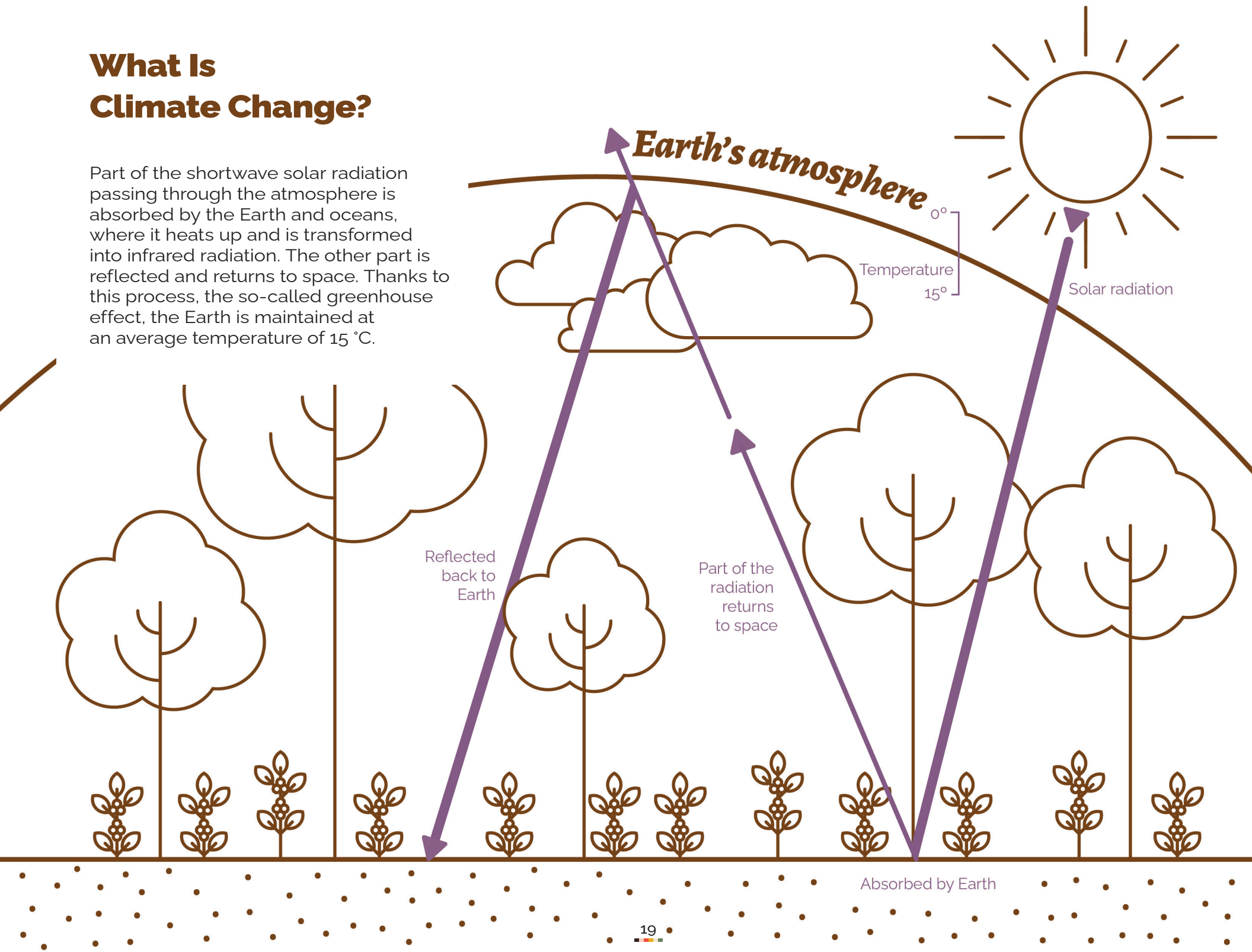
This is the second edition of this manual, which incorporates the comments of coffee producers from the Veracruz municipalities of Chocamán, Coatepec, Huatusco, Ixhuatlán del Café, Teocelo, Totutla, and Xico who participated in community workshops carried out in February and September 2023 to present the results of the project and receive feedback regarding the products of the first phase of the project, which included the first edition of the manual.

Ch. 1
Climate Change

Robert Hunter Manson and Teresa Durand

What Is Climate Change?

Part of the shortwave solar radiation passing through the atmosphere is absorbed by the Earth and oceans, where it heats up and is transformed into infrared radiation. The other part is reflected and returns to space. Thanks to this process, the so-called greenhouse effect, the Earth is maintained at an average temperature of 15 °C.



The concentration of greenhouse gases (GHG) in the atmosphere is increasing, resulting in more trapped infrared radiation, increasing the temperature of the Earth—the phenomenon known as global warming. The combined effects of this warming include an increase in temperature, a change in precipitation patterns, and a greater frequency and intensity of tropical storms, which is known as "climate change."
The production of the major GHG is shown below:

GHG

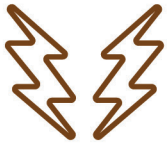
(Greenhouse gases)

The GHG are made up of:

76 % Carbon dioxide

16 % Methane

Distributed as follows

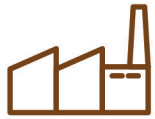


25 %

Electricity generation and heating

24 %

Agriculture and other soil changes

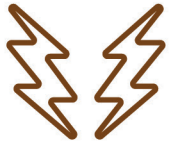


21 %

Industry

14 %

Transport



10 %

Other emissions

6 %

Domestic use

Source: European Environment Agency (EEA), 2019.

The increase in GHG is mainly from:

- The burning of coal, petroleum, and gas, which produces carbon dioxide (CO_2) and nitrous oxide.
- Deforestation. Trees help to regulate the climate by absorbing CO_2 from the atmosphere. When forests are cut down, this beneficial effect is lost, and the carbon stored in the trees is released into the atmosphere, which increases the greenhouse effect.
- Increase in livestock. Cattle and sheep produce large quantities of methane when they digest their food.
- Nitrogen fertilisers produce nitrous oxide emissions.
- Fluorinated gases are emitted by the products and devices that use them, such as aerosols and air conditioning. These emissions have an extreme heating effect, up to 23,000 times greater than that of CO_2.

The agricultural activities that emit large quantities of GHG are the excessive use of fertilisers and the processing and transportation of agricultural products through their value chain.

The cultivation of coffee has experienced the following specific effects from climate change:

- Alteration of the phenological cycles of the coffee plant
- Increase in the presence of disease
- Loss of fruits and flowers
- Hydric stress
- Decreased production and quality of coffee beans
- Greater price variation

Climate change directly affects the production of coffee, putting at risk the livelihoods of coffee producers and their families.

Figure 6. Young coffee plantation without shade. Photo: RBG Kew.

Figure 7. Coffee plantation with shade. Photo: RBG Kew.

Effects of Climate Change on Different Social Groups

Climate change disproportionately affects women, disabled people, older adults, migrants, refugees, and people who work in the informal sector. These groups tend to experience greater exclusion and vulnerability because of such factors as poverty, geographic location, and dependence on natural resources for survival.

According to the United Nations Food and Agriculture Organization (FAO), coffee is one of the most consumed agricultural products and beverages in the world. Its cultivation is one of the major sources of livelihood in Latin America, creating employment for millions of families in rural areas. The International Coffee Organization (ICO) calculates that as much as 70% of the worldwide labour force producing coffee is female, although it has historically been considered the labour of men.

Women participate in the field work, harvesting, and processing of coffee, while men work on maintenance of the plantation and the transportation and sale of the product. This division of labour in coffee production reduces women's access to the labour market and is a barrier to their economic independence.

Figure 8. Lucía Olvera García, coffee producer from Xico, Veracruz. Photo: RBG Kew.

This project includes elements of gender analysis of the effects of climate change on the design and implementation of the activities. This perspective helps the project staff to adapt strategies of participation and to address differences in the way men and women experience climate effects. The involvement of women and men in the project makes it possible to identify gender relations that sometimes limit the abilities of women, men, girls, and boys to adapt to the negative effects of climate change.

Figure 9. Coffee producers participating in the community workshop in Teocelo, Veracruz. Photo: RBG Kew.

Figure 10. Don Ramón Suarez Itza, coffee producer in Xico, Veracruz. Photo: RBG Kew.

Ch. II

Best Management Practices in Mitigating and Adapting to Climate Change

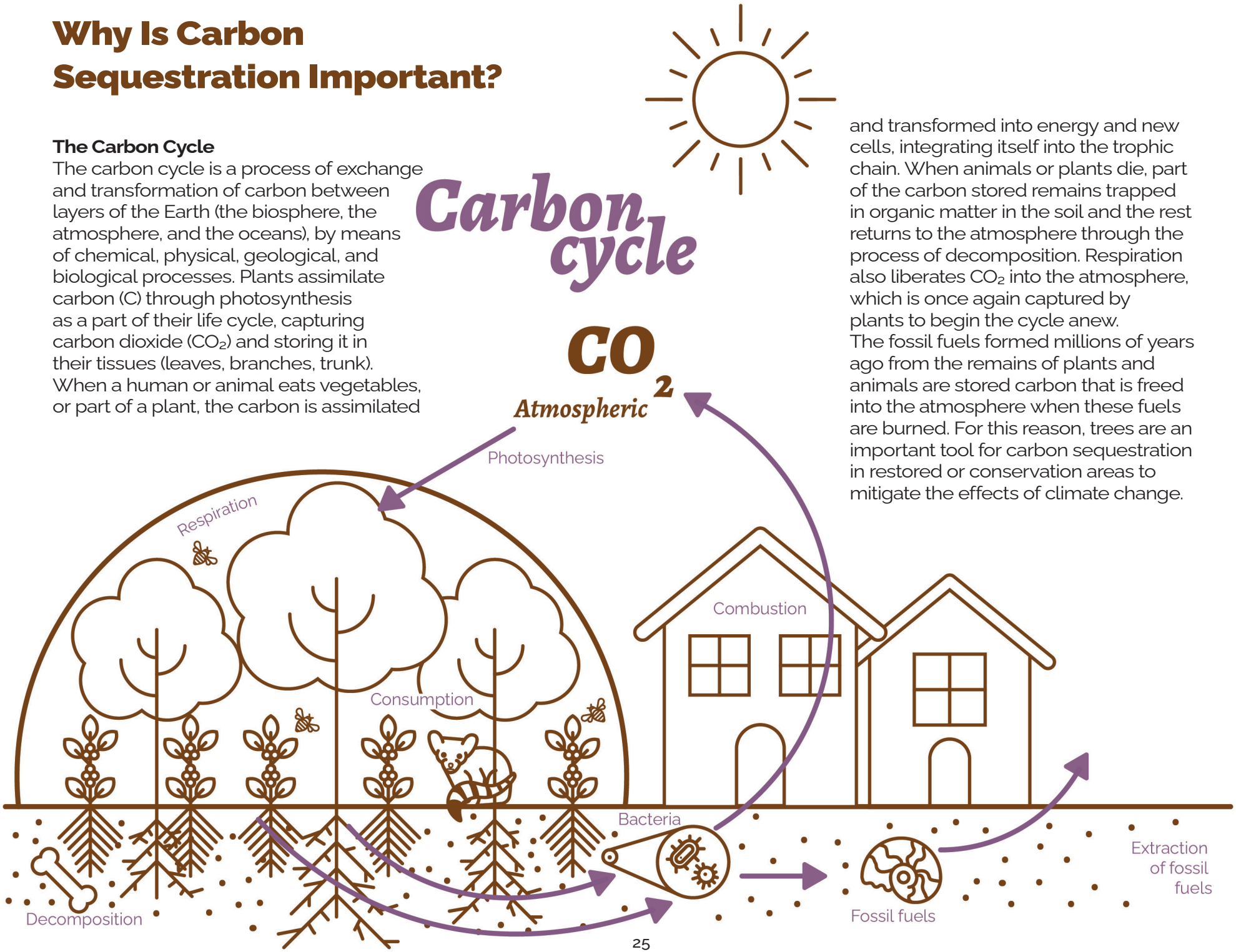
Daniel Jarvio Arellano, Gabina Quintas, Lucero García Miranda, Silvia Bacci, César Mateo Ortíz, Robert Manson Hunter y Daniel Cabrera Santos

Why Is Carbon Sequestration Important?

The Carbon Cycle

The carbon cycle is a process of exchange and transformation of carbon between layers of the Earth (the biosphere, the atmosphere, and the oceans), by means of chemical, physical, geological, and biological processes. Plants assimilate carbon (C) through photosynthesis as a part of their life cycle, capturing carbon dioxide (CO_2) and storing it in their tissues (leaves, branches, trunk). When a human or animal eats vegetables, or part of a plant, the carbon is assimilated and transformed into energy and new cells, integrating itself into the trophic chain. When animals or plants die, part of the carbon stored remains trapped in organic matter in the soil and the rest returns to the atmosphere through the process of decomposition. Respiration also liberates CO_2 into the atmosphere, which is once again captured by plants to begin the cycle anew.

The fossil fuels formed millions of years ago from the remains of plants and animals are stored carbon that is freed into the atmosphere when these fuels are burned. For this reason, trees are an important tool for carbon sequestration in restored or conservation areas to mitigate the effects of climate change.



Alliance of Native Plants for Carbon Sequestration

There are different plant characteristics that favour carbon sequestration and storage:

- Fast-growing trees: store a greater quantity of carbon during their first decades, which is often a tree's most productive period.
- Long-living trees: can keep carbon in storage for generations without freeing it.
- Large leaves and broad crowns: allow for maximum photosynthesis.
- Native species: thrive in their soil and provide better support for local wildlife.
- Low-maintenance species, resistant to disease: grow better without fertilisers or equipment that produces GHG, and have natural resistance to disease.

Further information about the native trees of Veracruz can be found in Chapter 4 and Appendix 1.

How Is Carbon Captured on Coffee Plantations?

Agroforestry systems, that is, agricultural systems in combination with native perennial tree species, enable the sequestration and storage of important quantities of CO_2 through soil and vegetation. They are therefore considered key to mitigating the effects of climate change.

The vegetation of shade-grown coffee plantations, with traditional rustic and traditional polyculture management are similar to secondary forests. In traditional rustic management, the original tree cover is maintained, under which the coffee plants are grown, while in traditional polyculture, coffee is produced with many other beneficial plant species on a shaded plantation. These agroecosystems managed with organic practices sequester greater quantities of carbon through the use of shade and coffee trees (194.7 t/ha) than non-organic polycultures (134.9 t/ha) and shade-grown coffee plantations with trees of the genus Inga, such as the jinicuil, chalahuite, or pámpano (154.3 t/ha).

The storage of carbon is also carried out through the decomposition and storage of organic matter in the soil. The rate of storage is higher with the trees on young plantations than with those on older plantations.

To mitigate GHG emissions and the effects of climate change, the actions are focused on:

- Avoiding the loss of carbon stored in agroecosystems as a result of deforestation or reversion of shade plantations to monoculture.
- Protecting carbon stored in the soil through practices to reduce its erosion.
- Regularly measuring the rate of carbon sequestration in biomass and soil in each hectare.

Reliable scientific evidence about the amount of sequestered carbon could be useful for obtaining economic stimuli such as carbon credits. Studies carried out in agroforestry systems in the tropics, including on shade plantations, show that these systems typically capture from 1.5 to 3 tonnes, and even up to 5.3 tonnes of carbon per hectare annually.

Best Practices on Coffee Plantations

Best practices are all of those management activities we should carry out on our plantations to improve productivity in a sustainable manner, ensuring the continuity of the plantations' environmental services.

The major management activities on a plantation are monitoring and control of pests and disease, fertilisation, pruning of trees, and elimination of weeds.

Pests, Disease, and Solutions

Pests and disease are one of the most serious threats to the crop, and they are among the most important factors limiting the productivity of agroforestry systems, since they can account for the loss of 30-50% of production.

In the coffee-producing region of Coatepec, the major threats are the following:

- Coffee leaf rust (CLR; *Hemileia vastatrix*) - fungus
- Coffee berry borer (*Hypothenemus hampei*) - beetle
- Nematodes (*Meloidogyne* sp. and *Pratylenchus* sp.)

Prevention with control of the proportion of shade, as well as with adequate ventilation of the plantation, are part of the first step toward maintaining a cooler microclimate that inhibits the propagation of pests and disease. Their constant monitoring helps to decide what actions to take and when, which allows for less expensive, more efficient preventive measures.

Coffee leaf rust (CLR) is a fungus that results in premature falling of leaves, reducing the photosynthetic capacity of the plants; it causes the death of branches and even the entire tree. Sun-grown coffee plantations are highly vulnerable to this fungus, since they facilitate the movement of spores. It is thus recommended that the plantation be diversified with other species of native trees, both wood and fruit trees, to provide a variety of sizes and types to the agroecosystem. Monoculture, with high temperatures and easy access for the fungal spores, is the type of plantation most vulnerable to CLR. It is important to ascertain the degree of infestation in neighbouring plots and encourage them to cooperate in the control and management of the fungus.

The coffee berry borer is a Curculionidae beetle that causes physical damage to coffee beans and their premature falling. It reduces the productivity of the plantations and affects the drink with ochratoxins. Ochratoxin A (OTA) is a neurotoxic mycotoxin that is an immune suppressor, genotoxic, carcinogenic, and teratogenic; it is a contaminant in foods for human consumption, mainly cereals and derivatives, alcoholic beverages, and milled products such as coffee and cocoa.

One of the main reasons the population of borer beetles has grown on coffee plantations is the temperature increase related to climate change, which has increased their reproductive rate. Coffee berries not cut from the plants are also an important source of adult beetles that can increase population growth. Among the main methods of biological pest control are the management of shade to ensure cooler microclimates, the collection and destruction of all of the berries that are not harvested, and the use of entomopathogenic fungi such as *Bauveria bassiana*, which attack insects and mites. These play an important role in biodiversity, as they produce biological products called bioinsecticides that are used to control insect pests that affect crops.

Another measure recommended to combat borer beetles are traps with lures consisting of mixtures of ethanol and methanol. The traps are hung on the plants, in the shade, at a height corresponding to three quarters of the height of the plant. At least 16 traps should be used per hectare, and they should be replaced regularly.

Nematodes, or roundworms, are thin, cylindrical, unsegmented unisexual worms with an epidermis. There are both free and parasitic forms. Parasitic nematodes are one of the major pathogens affecting the coffee crop: they reduce the yield by 15-60%. Numerous nematode species have been found in coffee plants, but *Pratylenchus filipjev* (yield reduction of 29-78%) and *Meloidogyne goeldison* (yield reduction of 10-100%) are the most widely distributed, and the ones that cause the greatest crop damage, thus being the most economically harmful. These nematodes feed by penetrating the cells of the plant's roots, and directly affect the roots' absorption. The damage begins when they enter and multiply: the roots turn a characteristic dark brown colour, caused by necrosis of the affected cells and the invasion of secondary pathogens such as fungi or bacteria, causing reduced growth of the roots and thus of the plants.

To avoid nematodes, it is important for producers to avoid buying coffee plants from nurseries with contaminated soil: they should establish their own nurseries to supply their plantations. Another strategy, grafting with robusta coffee roots, helps plantations to better withstand nematode attacks and hydric stress from drought. Producers should strictly avoid the use of Furadan, owing to its toxicological effects, in favour of nematicides with lesser residual toxicity. It is necessary to know the degree of

acidity or alkalinity of the soil (pH) and correct it with dolomite or agricultural lime, which permit the absorption of nutrients that are not otherwise available to the plants, as this is one of the main factors that limits plant development. This correction also regulates the activity of pathogenic microorganisms in the soil, so it can serve as a preventive measure to lessen the presence of fungi of the Phytophthora, Fusarium, and Rhizoctonia complex, the major causes of root drowning. This practice should enable a reduction in chemical fertilisers, since the plants will be able to absorb nutrients from the soil that were insoluble. This application of acidity regulators is recommended at least three or four times a year, especially in soils of volcanic origin such as those in the coffee-producing region in central Veracruz. For plantations on hills, the ideal is to construct individual terraces to facilitate the application of fertilisers or biological materials.

Pruning and Productivity

To ensure good coffee production, it is necessary for the coffee plant to have productive branches and new stems. There should be a program of pruning and removal of suckers (sprouts that are generally not productive, but that give the plant a nice appearance, which sometimes lead producers to remove more productive structures).

Producers should use the pruning process, which should be carried out every year during April and May, once the harvest season has ended, to note which plants will have to be replaced. The type of pruning will depend on the management of individual plantations; it might be selective, by row, or alternated. It should be carried out during months with the least rainfall to avoid propagating fungi as the plants are cut, and it should avoid the use of sealants or substances to promote healing, as these increase the cost of production. It is important to note that the benefits of pruning to maintain the productivity of coffee plants diminishes over time, and producers should consider replacing plants older than 20-25 years.

Fertilisation and Soil Conservation

There should be a series of fertilisations on coffee plantations according to the developmental stage of the plants. The supply of nutrients should match the requirements for the age of the plants and the type of soil. It should be emphasised that plants need more than the formulas or physical mixtures such as 17 17 17, 18 12 6, or others that were implemented during the time of the now-defunct INMECAFE, which producers continue to apply as part of their plantation management. In the case of new plants, fertilisation should be formulated with a greater quantity of major elements such as nitrogen, phosphorus, and potassium.

Best Practices for Reducing the Emission of GHG on Coffee Plantations

- Rational use of hydrocarbon-based fertilisers: if these are not rapidly absorbed, their gaseous derivatives, which have the greatest potential to cause a greenhouse effect, are emitted into the atmosphere. The use of foliage fertilisers, lower quantities at strategic times, and natural fertilisers can help to avoid emissions.
- Reduction in the use of trucks for transportation and of the distance to the facility for extraction of the seed, as well as the conversion of producers of coffee berries (cerezeros) to producers of beans (pergamineros), with the seed extraction carried out by the producers or their neighbours. This strategy has the additional benefit of generating greater added value and the opportunity to obtain higher prices for the product.
- Drying of coffee in the sun, a much more sustainable and inexpensive practice than the use of gas dryers. This too is a more practical strategy for producers, as they are processing their own coffee.
- Integration of native tree species for shade that are already adapted to local conditions and have the greatest capacity to

provide benefits to wildlife.

- Comprehensive management of pests and disease that recognizes the complexity of agroecosystems and uses biological mechanisms of control wherever possible.
- Maintenance of organic matter on the ground, avoiding bare ground and keeping leaf and plant matter. Avoiding planting in rows that are perpendicular to the contours of the land.

The Coffee Production Cycle

Presented below in general form are the different management activities carried out during the productive cycle on the coffee plantations of central Veracruz.

The harvest begins in October (at altitudes from 750 to 900 metres above sea level) and ends in March (altitudes over 1200 metres). After the harvest is finished, pruning continues, generally by hand. The purpose of pruning is to remove branches that were damaged during harvest, and also to identify the plants that should be replaced because of their age, low productivity, or the presence of pests or disease.

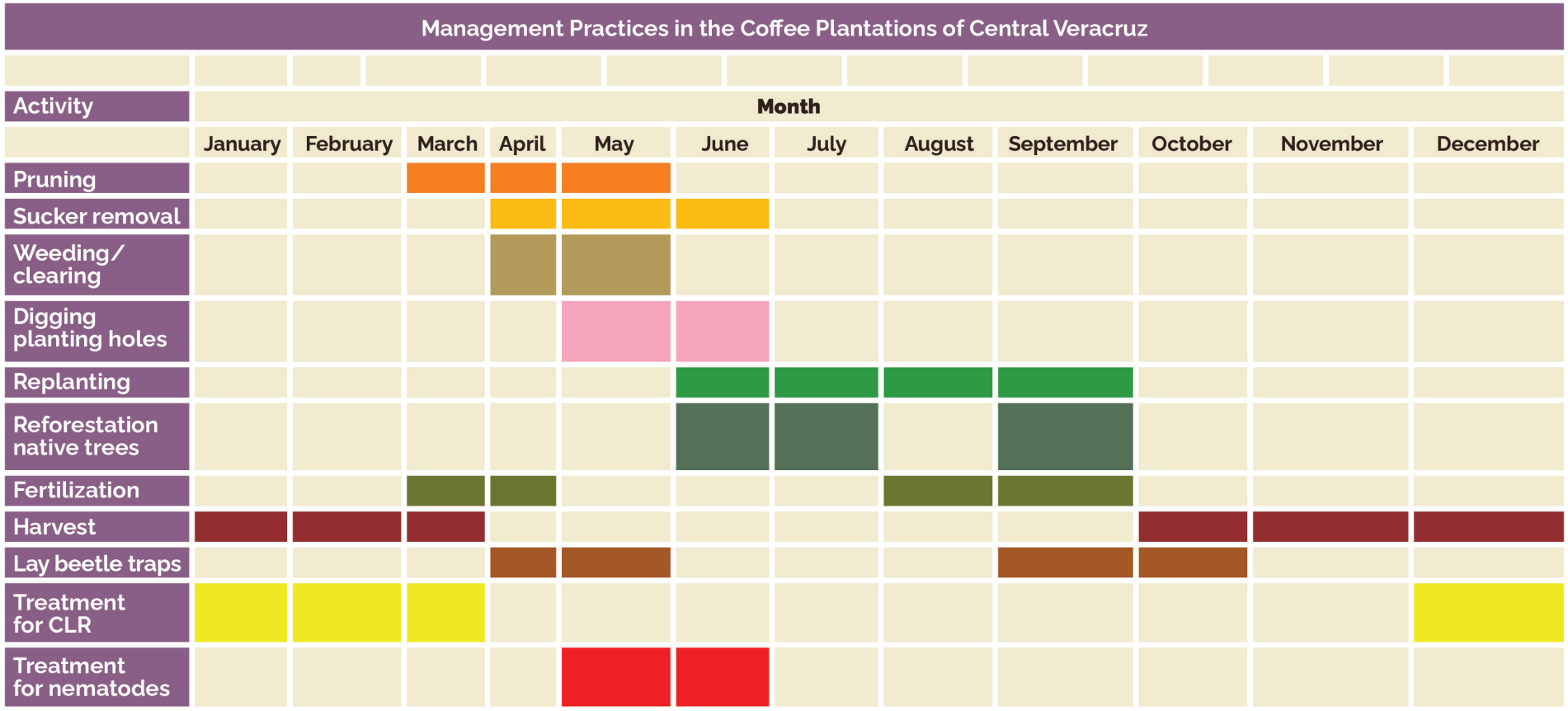


Figure 11. Management practices on the coffee plantations of central Veracruz.

The tasks of weeding and clearing, which are generally done by hand with a hoe or machete, should be carried out before the application of fertilisers, to avoid competition for nutrients.

It should be noted that pruning greatly stresses the plants, so they should be fertilised with nutrients to help them recover biomass and also induce flowering.

With the plants marked for replacement, holes are dug for new ones. The size of the holes depends on whether they are in tubes or a traditional bag; they can be as large as 60 cm in width by 30-40 cm deep. The holes should be left open for 30-40 days before the replacements are planted. They should be filled with the same soil that was removed; it can be enriched with an organic substrate such as vermicompost, compost, or sugarcane mill mud cake (i.e., an activated sludge-like byproduct from the clarifier of a raw sugar production factory used as fertiliser or bio-stimulant for the soil). The best moment for initiating important changes in the management of a coffee plantation to ensure it meets specific certification requirements is when coffee plants are replaced. This is also the moment for ensuring a certain proportion of shade trees according to agroforestry production guidelines. Afterwards, rapid-growth species, including banana trees, can be used to create more shade for the coffee trees and even to allow slower-growing species to become established.

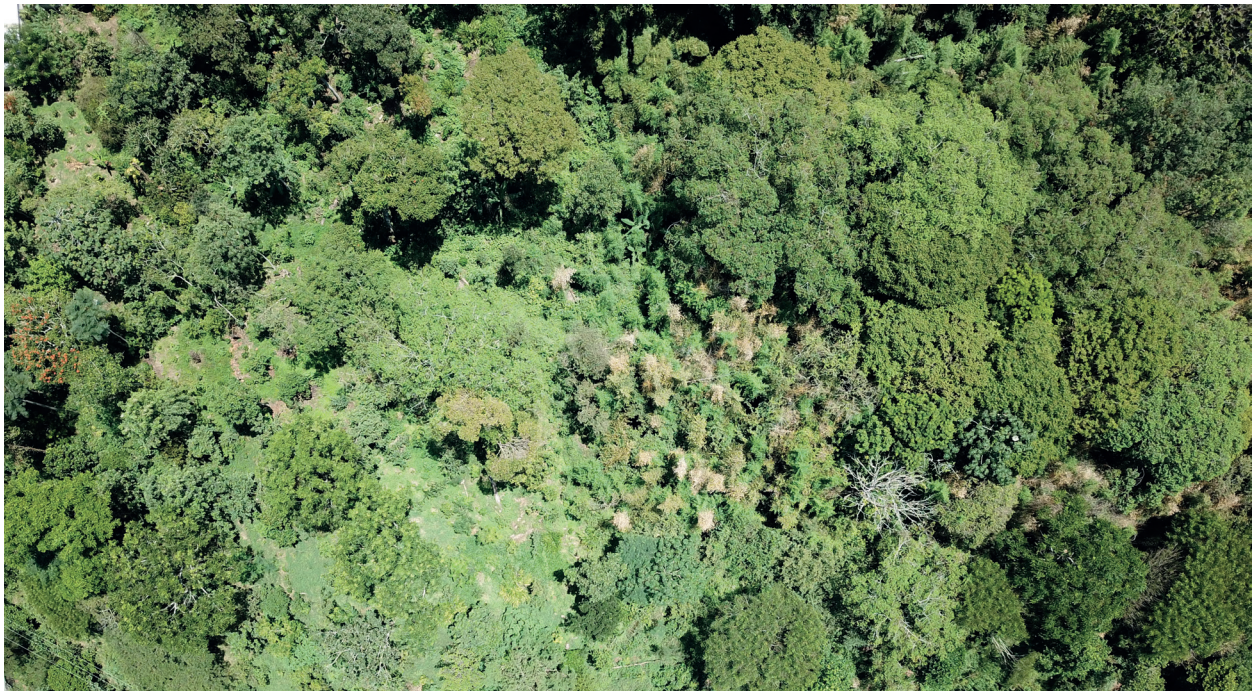


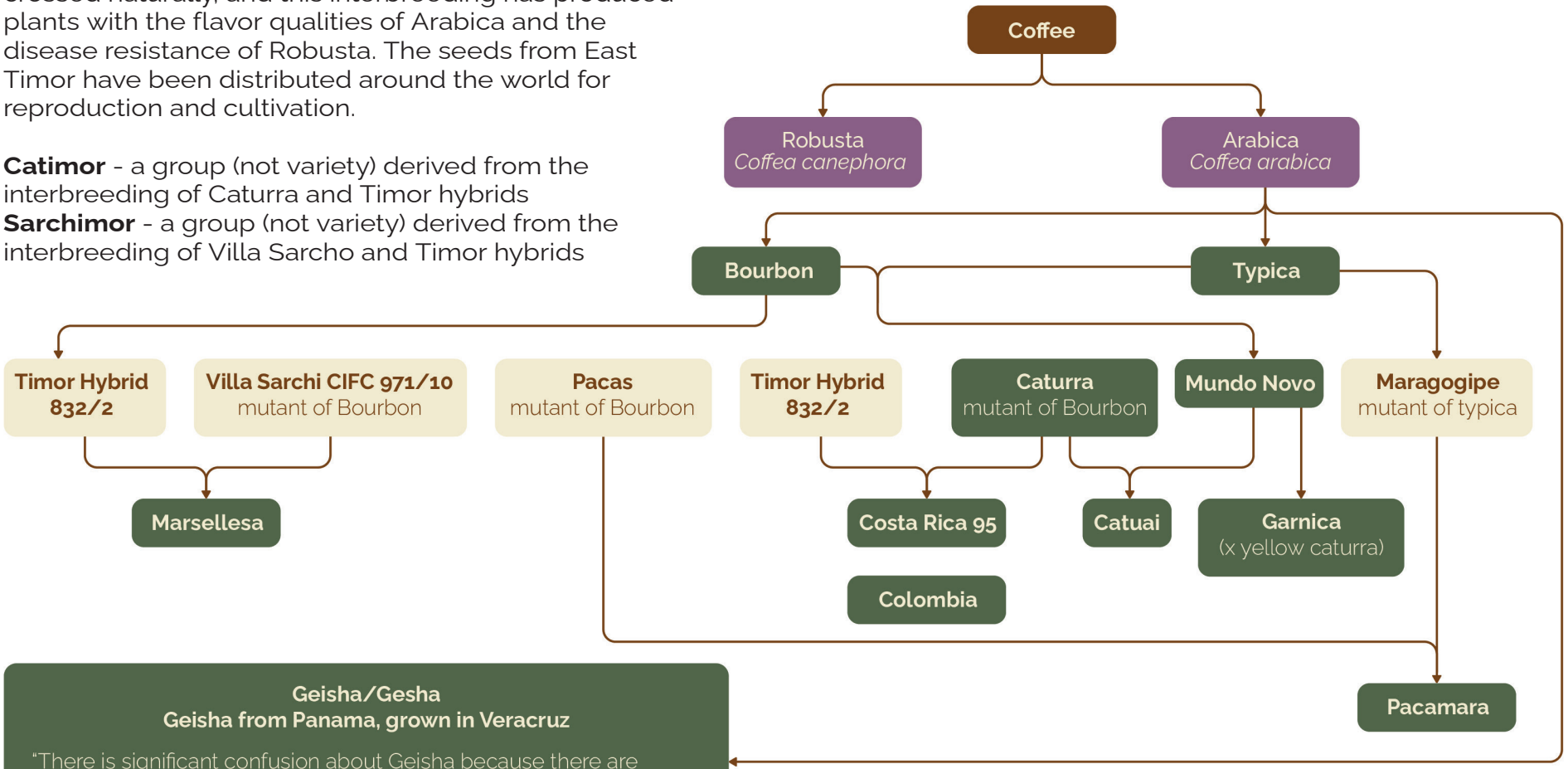
Figure 12. Los Barreales Plantation, Teocelo, Veracruz. Photo: RBG Kew.

Species and Varieties of Coffee in the State of Veracruz

The selection of varieties is one of the most important decisions in the establishment of a coffee plantation, since each variety responds differently to the range of temperatures and rainfall, to different levels of shade, and to the type of fertiliser used. There are also important differences in their capacity to produce a good quantity and quality of coffee. It is thus important for producers to investigate available sources of information and consult with neighbouring plantations to find out which varieties have the desired characteristics. Ninety-five percent of coffee production in Veracruz is C. arabica, and Robusta is grown mainly at lower altitudes. The most common varieties are Typica (22%), Bourbon, Caturra, and Garnica (19%), and Mundo Novo (21%), which together account for 62% of the area cultivated.

Timor Hybrids
In East Timor the Robusta and Arabica species have crossed naturally, and this interbreeding has produced plants with the flavor qualities of Arabica and the disease resistance of Robusta. The seeds from East Timor have been distributed around the world for reproduction and cultivation.

Catimor - a group (not variety) derived from the interbreeding of Caturra and Timor hybrids
Sarchimor - a group (not variety) derived from the interbreeding of Villa Sarcho and Timor hybrids



Geisha/Gesha
Geisha from Panama, grown in Veracruz

"There is significant confusion about Geisha because there are multiple genetically distinct plant types that have been referred to as Geisha, many of which share similar geographic origins in Ethiopia. Recent genetic diversity analyses conducted by World Coffee Research confirm that Panamanian Geisha descendent from T2722 is distinct and uniform. It is associated with extremely high cup quality when the plants are managed well at high altitude, and is known for its delicate floral, jasmine, and peach-like aromas."

—World Coffee Research

Varieties cultivated in Veracruz

For more information, see worldcoffeeresearch.org

Figure 13. Species and varieties of coffee cultivated in Veracruz.

Ch. III
Carbon Sequestration in the Project

César Mateo Flores Ortiz, Flor Gabriela Vázquez Corzas, and Daniel Cabrera Santos

How to Select Species that Favour Carbon Sequestration in a Coffee Agroforestry system

Figure 14: Social, ecological, and economic criteria considered in the participatory community workshops.

As part of the project, a prioritisation method was developed focused on the selection of species based on different attributes, with an emphasis on their capacity for carbon sequestration.

The method included the following stages:

1st stage: prioritisation
Based on the most complete and up-to-date list of the native trees of Mexico, and using algorithms, a selection was made of 50 species with the following attributes:

1. National distribution and endemism
2. State and regional biodiversity
3. Number of uses
4. Distribution in the cloud forest
5. Availability of seeds
6. Use in traditional rustic and traditional polyculture coffee production systems
7. Use as shade
8. Growth rate and nitrogen-fixation capacity

2nd stage: participatory workshops
The list of 50 species was validated by the coffee-growing communities of central Veracruz (Teocelo and Ixhuatlán del Café) in participatory workshops. Social, ecological, and economic criteria were taken into account. The first 25 species were ranked, based on the workshop results, and can be seen in Table 1.

3rd stage: studies of carbon sequestration
Physiological and morphometric data of the first seven species selected by the communities were evaluated to confirm their efficiency in carbon sequestration and the benefits they would provide to coffee cultivation.

Tree species	Common name	Teocelo (both sexes)	Ixhuatlán (women's group)	Ixhuatlán (men's group)	Average	Classification
Inga inicuil Schltdl. & Cham. ex G.Don	Jinicuil	6	4	4	5	1
Inga vera Willd.	Chalahuite/vainillo	5	4	4	4	2
Inga punctata Willd.	Pampano	5	4	4	4	3
Erythrina americana Mill.	Equimite/gasparito	6	3	3	4	4
Psidium guajava L.	Guava	3	5	4	4	5
Persea schiedeana Nees	Chinini	4	4	4	4	6
Heliocarpus appendiculatus Turcz.	Jonote	3	4	5	4	7
Beilschmiedia mexicana (Mez) Kosterm.	Aguacate oloroso	4	4	3	4	8
Bursera simaruba (L.) Sarg.	Mulato	5	4	0	3	9
Trema micranthum (L.) Blume	Ixpepe	1	3	5	3	10
Byrsonima crassifolia (L.) Kunth	Nanche	3	4	1	3	11
Cecropia obtusifolia Bertol.	Guarumbo	7	3	2	2	12
Heliocarpus donnellsmithii Rose	Jonote blanco	2	4	1	2	13
Juglans pyriformis Liebm.	Nogal	2	4	1	2	14
Perseo longipes (Schltd.) Meisn.	Aguacate	0	1	5	2	15

Table 1: First species of native trees (15) ranked in the participatory community workshops in the municipalities of Teocelo and Ixhuatlán del Café.

Ch. IV

Conservation, Management of Seeds, and Propagation of Plants

Isela Rodríguez Arévalo, Michael Way, Gabina Sol Quintas, Angela Viviana Rojas Rojas, Jazmin Cobos Silva, Silvia Bacci, and Lucero García Miranda

Seed conservation
The project's seed conservation is overseen by the Seed Bank of the FESI-UNAM and the Seed Reserve of Pronatura Veracruz, A.C. The activity has been focused on native and wild species, mainly those in a risk category (Seed Bank) or those that are useful to the communities (Seed Reserve).

The conservation is carried out in two phases.

- Collection of seeds and plant samples (field work)
- Processing and conservation of the samples (laboratory work)

Figure 16. Seed collection. Photo: RBG Kew.

Figure 15. Collection of plant samples in the field. Photo: RBG Kew.

Figure 17. Cut test to analyse seed quality. Photo: RBG Kew.

Collection of Seeds and Plant Samples

The collection of seeds is carried out according to the following considerations:

- Visits to collection sites should be planned in advance, based on the phenology and distribution of the species to be collected. The following databases should be consulted: Red Mundial de Información sobre la Biodiversidad (REMIB), EncicloVida - Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), taxonomic publications, and especially online herbaria.
- In the field, it is essential to verify that there are populations of at least 30 mature seeds. It is necessary to perform cut test on a sample of at least 20 seeds, in order to rule out infestation and immaturity. No more than 25-30% of the fruits or seeds should be taken from each plant.
- Collected fruits and seeds should be stored in paper bags or in cotton, and kept in the shade.
- Three duplicates of plant samples should be collected for each species, for purposes of taxonomic verification and donation to other herbaria in Mexico and in other countries

Processing and Conservation of Samples

This second phase has the following objectives:

- Short- and medium-term storage of seeds for diversification of community and local nurseries, enrichment of key spaces such as schools, and donation of material for education and research.
- Long-term conservation of seeds in the face of plant species disappearing from deterioration of their habitats, and for purposes of research.

Short- and Medium-Term Conservation

- Processing of fruits or seeds. All of the fruit or seed material collected is registered using a collection code with data recorded in the field. Recalcitrant species are prioritised and sent to nurseries for propagation. Orthodox species are maintained at 15 °C. and the seeds are later extracted from the fruits and processed.
- Seed extraction. Collected plant material is cleaned to avoid deterioration from moisture and fungi. Fleshy fruits such as guava (*Psidium guajava* L.) and avocado (*Persea americana* Mill.) are allowed to ripen or are washed with colanders and sieves to remove the seeds. The seeds are removed from dry fruits like colorín (*Erythrina americana* Mill.) or jonote (*Heliocarpus appendiculatus* Turcz.) by opening them with cutting tools, or in the case of some fruits, by leaving them for a few days until the seeds fall off.
- Germination tests. Once the seeds are extracted, the weight of the entire volume of seeds is recorded, and then 100 seeds are counted and weighed in order to estimate the total number of seeds. To obtain the percentage of viability, 100 seeds are placed in water for 24 hours, and the number that sink are then counted. Another test consists of planting 100 seeds in substrates of sand, peat moss, or tepezil, and counting the number of seeds that germinate.
- Storage. The dry seeds are vacuum-packed and labelled with the collection code, species, common name, and locality. Finally, the packets are stored in the refrigerator, freezer, or cold room, depending on the characteristics of the species.

Long-Term Conservation of Seeds

The seeds are processed to ensure that the material meets international standards for long-term storage. At the Seed Bank, the process of conservation begins with the arrival of samples in the laboratory,

Figure 18. Extraction of walnut seeds (J. pyriformis) in the Pronatura Veracruz A.C. cloud forest nursery. Photo: RBG Kew.

and includes the following steps:

- Initial dehydration. The seeds are kept at a temperature of 25-28 °C., with a relative humidity of 25-28%, for a week.
- Cleaning. Leaves and other plant matter are removed from the sample in order to have a clean collection. The fruits are opened to extract the seeds with the help of sieves, blowers (to separate the mature, healthy seeds from the empty ones), trays, knives, scalpels, pliers, needles, spatulas, and gloves. Fleshy and semi-fleshy fruits should be cleaned first.
- Main dehydration. The seeds are kept at a temperature of 15 °C., with a relative humidity of 14-15% for 4-6 weeks, to reduce their moisture content.
- Counting. Five subsamples of 50 seeds each are weighed in order to calculate the total number of seeds.
- Germination tests. Three subsamples of 20 seeds each are placed in Petri dishes with moist filter paper at 30 °C. for 20-30 days in darkness alternating with white light (12 h/12 h).
- Viability tests. When seeds do not germinate, the tetrazolium test is used. The seeds are first evaluated under a stereoscopic microscope; they are then immersed in 1% tetrazolium to determine the presence of live or dead tissue.
- Packing of samples. The seeds are packed in aluminium envelopes or tempered glass jars, hermetically sealed, and stored at -20 °C.
- Data management. The information collected throughout the process is entered and stored in databases.

Seeds processed in this way can be conserved up to hundreds of years.

Figure 19. Germination tests for evaluation of the quality of accessions from native trees. Photo: FESI-UNAM Seed Bank.

How to Obtain Seeds from the Pronatura Veracruz, A. C. Seed Reserve

The purpose of the Seed Reserve is to collect, process, store, and distribute seeds to different parties interested in the propagation of native species in the region. Seeds can be donated to individuals, academic or governmental institutions, or to non-profit organisations. Inquiries should be sent to reservasemillas@pronaturaveracruz.org. Availability will be checked and a form sent asking about the purpose of the request, the site where they will be propagated, and the volume or number of seeds required. The seeds will be delivered at the offices of Pronatura Veracruz, A .C., labelled with data about the species, common name, place of collection, and instructions for germination. A collection code will also be provided so that the results of the propagation can be monitored.

Propagation of Plants

The process of propagation in the project is made up of various steps:

Figure 20. Plant propagation at the BMM nursery, Pronatura Veracruz A. C. Photo: RBG Kew.

Extraction of Seeds

The seeds are removed from the pulp and other structures. Residual pulp may attract insects that can damage the seeds. Excess moisture should be removed before the seed is planted.

Planting of Seeds

Recommendations:

- Use a substrate that drains well to avoid an excess of moisture that can promote the growth of fungi (a mixture of 40% tepezil and 60% peat moss is recommended).
- Perform pre-germination tests, for example, a flotation test where the seed is submerged in water: if it floats, it is not viable.
- Place the seeds in germinators. The use of containers with multiple perforations is recommended. The depth of the container depends on the size of the seed. Small seeds should be broadcast (scattered along the length of the germinator).
- The germinator should be labelled with the seed information so that material can be traced: species name, date of planting, and collection code, if available. Masking tape is effective, as it resists moisture.
- Germinators should be placed in areas where humidity, temperature, and hours of sunlight can be controlled. The installation of seed houses increases the percentage of germination.

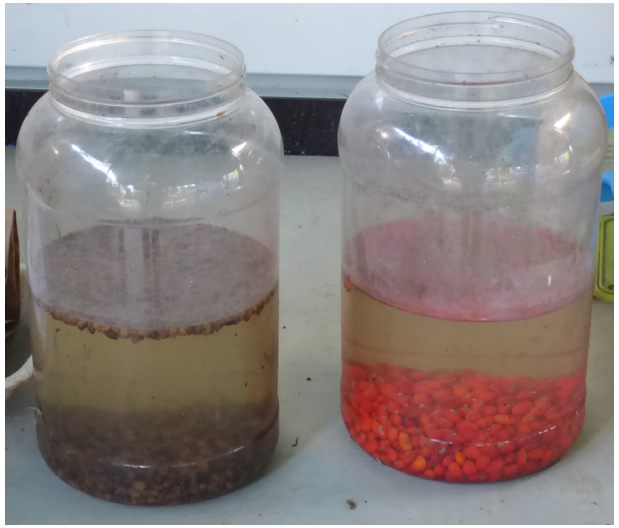


Figure 21. Float test at Pronatura Veracruz, A.C., used to separate viable seeds, which sink to the bottom, from non-viable seeds, which float. Photo: RBG Kew

Maintenance of the Plants

Once the seeds have germinated, it is necessary to wait for the appearance of true leaves before transplanting them to bags; it is then advisable to maintain them until they reach an appropriate size for transportation to planting sites. In the growth stage, plants

may be attacked by pests, disease, or predators. It is recommended that they be tagged with the species name and information about the seeds. Maintenance includes the following activities:

- Watering. Plants should be watered when the substrate is dry, avoiding excessive watering.
- Weeding. Weeds that grow in the bags should be removed, as they may rob the plant of nutrients.
- Fertilising. It is important to apply fertilisers that are appropriate to the age and nutritional needs of the plant species. When plants are close to leaving the nursery, they require slow-release fertilisers to ensure their successful establishment in the planting site. Preparation of organic fertilisers is recommended, using such ingredients as cattle manure, ashes, bone meal, and food waste.

Delivery of Plants to Recipients

Plants should be delivered during the rainy season, as this provides the ideal humidity for the trees' development.

Recommendations:

- Talk with the recipient to ensure the appropriateness of the species requested. Consider the space available for planting and its compatibility with the ecosystem.
- In the case of large donations, inform the recipient about proper conditions for transporting the plants.
- Record information about the recipients and the planting sites, so that there can be follow-up on the trees' development.

Figure 22. Delivery of plants to recipients in the cloud forest nursery of Pronatura Veracruz, A. C., Xalapa, Veracruz. Photo: RBG Kew.

Descriptions of these trees, including their phenology and habitat, the processing of their seeds, and their propagation, is provided below.

Native Trees As Allies to the Coffee Plantation: 15 Priority Species

Descriptions of these trees, including their phenology and habitat, the processing of their seeds, and their propagation, is provided below.

Beilschmiedia mexicana (Mez) Kosterm

Common names: Aretillo, Aguacate oloroso, Aguacate perulero.

Family: Lauraceae.

Classification: 8

Description: Evergreen bush or shrub, 8-10 m in height. Cylindrical twigs, green or reddish depending on age, bare or with scattered adpressed pubescence; terminal buds bare or with appressed pubescence; smooth, thin, reddish bark. The branches are approximately 1 cm in diameter; there are also records of Diameter at Breast Height (DBH) of up to 30 cm. Flowers are 1.5 mm in length, urceolate, greenish yellow; ovate tepals, 1.2-1.8 mm in length x 1.1-1.5 mm in width, the external ones slightly but clearly shorter than the internal ones, bare or lightly covered with simple, short trichomes. A key feature for identifying B. mexicana are the nine stamens. Ellipsoid fruit, around 3 cm in length x 1.5 cm in width. The fruits are green drupes, similar to the unripened fruits of P. americana. Ellipsoid grey-brown seeds, probably recalcitrant. No information about the management or storage of seeds.

Habitat: This species has been collected in the cloud forest, as well as in the adjacent oak and pine forests in northeast Querétaro. It thrives at an altitude of 600-1500 m.

Distribution: In Mexico it is found in Chiapas, Guerrero, Hidalgo, Oaxaca, Puebla, Querétaro, San Luis Potosí, and Veracruz.

Cultivation: Wild, cultivated. Phenology: In Veracruz, it flowers from March to May and it bears fruit from May to March.

Pests, disease, and care: Stenoma catenifer Walsingham, the "avocado moth," is one of the insect pests.

Bursera simaruba (L.) Sarg

Common names: Chaca, Cohuite, Indio desnudo, Mulato, Palo colorado, Palo mulato.

Figure 23. *B. simaruba* (tree). Photo: RBG Kew.

Family: Burseraceae.
Classification: 9
Description: Resinous, deciduous tree, 5-20 m (up to 35 m) in height, with an open, irregular crown and a DBH of 40-80 cm (up to 1 m). Flowers: inflorescences of 6-13 cm (up to 20-28 cm) in length, including the stem. Individual male flowers with 4-5 petals, pink, yellow-green, or white; female flowers with only 3 petals. Fruits: trivalvate capsule with a dehiscent exocarp, 10-15 mm in length, infructescence 4-9 cm (up to 15 cm) in length, globose or ovoid, 7-10 mm (up to 15 mm) in diameter, triangular, reddish brown, dehiscent. Remain several months on the tree with seeds; 1 or 2 seeds per fruit. Seeds 8-10 mm long x 7-8 mm wide x 5-6.5 mm thick , yellow, angular, triangular in cross-section, covered entirely by a red aril. Stored seeds are viable for 10 months.

Figure 24. *B. simaruba* bark. Photo: RBG Kew.

Figure 25. *B. simaruba* fruits and seeds. Photo: RBG Kew.

Habitat: This species thrives in soil derived from marine sedimentary rock and in calcareous soils, rich in organic matter, leptosol, vertisol, and oxisol. It grows on cultivated parcels, along the sides of roads, on the sides of ravines, and on the banks of estuaries and salt ponds. It grows in a very wide range of ecological conditions. It requires a tropical or subtropical climate, with an average annual precipitation of 500-1400 mm (3000 mm) and a temperature of 18-27 °C.

Distribution: From the Sierra of Tamaulipas and San Luis Potosí to

Yucatán and Quintana Roo in the Gulf watershed and from Sinaloa to the Central Depression of Chiapas in the Pacific watershed. Altitude: 0-1200 m (1800 m).

Cultivation: Wild, cultivated. Tolerated and protected.

Phenology: In Veracruz, it flowers from December to April; it bears fruit from October to March, from the age of 5 years.

Seed dispersal: The main seed dispersers are fruit-eating birds and bats, and sometimes small rodents, monkeys, and wild boars; 39 species of birds have been identified as eating the entire fruit. **Uses:[Environmental]** Used as live fencing and to provide shade in coffee plantations, pastures, and Totonaca family gardens in Veracruz; **[Fuel]** the wood is used as fuel; **[Fodder]** the leaves, fruits, and seeds are used as animal fodder, and the flowers attract many wild and domesticated bees; **[Material]** the resin is used as a glue substitute and as incense, and the wood is used in the manufacture of handicrafts and in construction; **[Medicinal]** the bark is used to treat fever and muscle pain; the fruits and flowers are used as antidiarrheals and to treat snake bites.

Management of seeds: A good-sized tree can produce up to 60,000 seeds in a harvest, but the average tree produces 600. The drupes (fruits) are collected when they change from a reddish colour to purple. They open when completely ripe, indicating that the seeds are ready for planting. The seeds are extracted by pounding the fruits and then they are transferred to germinators. Before planting, they can be subjected to a flotation test: those that float in water are not viable, therefore they are discarded. However, it is preferable not to wet them, as excessive moisture can cause them to rot. If they are flotation-tested, they must be drained and dried before planting. For long-term conservation, they must first be gradually dried in a well-ventilated area for at least 2-3 days, at temperatures around 25 °C. They maintain a high viability for 10 months without special requirements.

Germination: The seeds are soaked in water for 12 hours before planting. Planting is done directly in germinators or in beds of yellow sand (in very dry climates planting is done directly, without a flotation test), 1 cm apart, and covered with 0.5-1 cm of substrate. Germination is generally low, and seedlings emerge in approximately a month; this species is often thus planted simply with air layering, although this technique is preferable only when the plants are going to be used as living fences, because in that case it is not so important to maintain the high degree of genetic diversity that is guaranteed by sexual propagation with seeds. Germination begins at around 13 days and is complete at 55 days, and 40% of germination takes place within the first 20 days after planting.

Tolerance of desiccation: The seeds are orthodox.

Vegetative propagation: 1. Through shoots or seedlings. 2. Stakes (high rooting capacity). The stakes are collected from the tree in the dry season, when there are no leaves (January through May), and the plant material has to be managed quickly, kept far away from sunlight. The stakes should be 1-3 cm in width by 10-15 cm in length.

Growth and transplanting: The seedlings are transplanted with the help of a wooden stake (stake transplant), placing the roots in a hole in the substrate without damaging them. It is preferable to do the transplant very early in the morning or close to sunset, keeping the plants in the shade. This is a high-temperature species that grows better in warmer climates. The seedlings grow around 5-10 cm per month, reaching 10-20 cm in two months. In 4-5 months they reach 25-30 cm in height. The trees are ready for donation in 7-8 months, at 40-50 cm, the size at which they can be planted on the coffee plantations. It is a long-lived species of rapid establishment and growth, that tolerates cutting and pruning well, and that regenerates rapidly after cutting.

Pests, disease, and care: Exposure to full or near-full sunlight seems to be required for optimum growth. The plant is quite resistant to drought, occasional frost (adult trees), fire, and wind. It tolerates poor, saline, and compact soil. It is recommended to water plants every 2-3 days when there is no rain, although this species may be sensitive

to excessive moisture, both during germination and transplant. It should be weeded frequently and provided with organic fertiliser. In general, the resin of the bark is a natural insect repellent, so the species does not experience many problems with pests. During the rainy season, it is prone to the cercospora fungus *Mycosphaerella* sp. (a different cercospora than *Mycosphaerella coffeicola*, which affects coffee, although this one can also affect coffee plants). It is commonly called *tizón negro* because of the circular necroses that form on its leaves. Insect pests: [Isoptera] *Coptotermes crassus Snyder* and *Heterotermes aureus* Snyder; [Coleoptera] *Lagocheirus araneiformis* L.; *Xyleborus volvulus* F., *Xyleborus ferrugineus* F., and *Xylosandrus morigerus* Blandford.

Additional information: The average carbon storage observed in forest areas where *B. simaruba* is present is 144.45 mg of carbon per hectare, as compared with 75.95 mg of carbon per hectare in grassy areas. A contribution of 5.42 tonnes of biomass and a storage of 2.71 tonnes of carbon per hectare has also been observed.

Figure 26. *B. simaruba*, leaves and fruits. Credits: RBG Kew.

Byrsonima crassifolia (L.) Kunth

Common names: Arrayán, Nananche, Nance, Níspero

Figure 27. *B. crassifolia*. Photo: Reinaldo Aguilar CC BY-NC-SA 2.0 DEED

Family: Malpighiaceae.

Classification: 11

Description: Small twisted tree or evergreen bush (deciduous in dry forests), 3-7 m (up to 15 m) in height, irregular crown with rising branches, often branched from the ground and with a DBH up to 30 cm. Flowers in bunches or terminal narrow panicles 5-15 cm in length, pubescent; actinomorphic yellow-reddish flowers, 1.5 cm in diameter, green calyx, with 6-10 sessile glands; 5 petals, rounded. Fruits: Pendulous infructescences, 10-15 cm in length; globular drupes, 1.7-2 cm in diameter, yellowish to light orangish, with abundant bittersweet flesh surrounding a large, hard pit, only one each fruit. Ovoid seeds with a brownish, smooth and membranous seed coat. Lacking endosperm, with a white and spiralled embryo, proceeding from two unequal cotyledons.

Habitat: Found in highly degraded soils. It is adapted to seasonally flooded environments. It typically grows in abandoned fields. Soils: rocky, loamy (including yellow clay), volcanic lava, coffee rock, deep reddish limestone.

Distribution: Widely distributed throughout the tropical zone of Mexico at an altitude of 50-1000 m, from the south of Tamaulipas and east of San Luis Potosí to Yucatán and Quintana Roo in the Gulf watershed, and from Sinaloa to Chiapas in the Pacific watershed. In Veracruz it is found in Actopan, Alto Lucero, Catemaco, Comapa, Emiliano Zapata, José Azueta, Huatusco, Hueyapan de Ocampo, Jalcomulco, Misantla, Minatitlán, Puente Nacional, Paso de Ovejas, San Andrés Tuxtla, Soteapan, Tenampa, Tezonapa, Totutla, Vega de Alatorre, Xalapa, and Zentla. Cultivation: Native, wild. Semi-cultivated or protected in many parts of its area of distribution.

Phenology: In Veracruz, it blooms from April to July, with fructification from July to October, peaking in August and September.

Seed dispersal: Birds are the major dispersers of seeds.

Uses: [Food] The fruits are edible and used in many products, such as liquors, candies, jellies, or drinks, or eaten raw; **[Environmental]** they are used to attract birds, to enrich the soil with organic matter, to provide shade in pastures and coffee plantations, and as living fences; **[Fuel]** the wood is used as fuel; **[Fodder]** the leaves are used as animal fodder, and the flowers attract bees; [material] the skin of the fruit produces a light brown pigment that is used to dye cotton cloth, the wood is used in construction, and the tannin-rich bark is used in tanning; **[Medicinal]** the bark is the part used most for this purpose, and as an antidiarrheal, anti-inflammatory, and to heal wounds and snakebites.

Management of seeds: The fruits are collected by hand from the ground or off the tree by hitting branches to dislodge those that are ripe. The fruits are ripe when they are golden yellow and the pulp softens, facilitating the cleaning of the seeds. The seeds are removed from the pulp only when the fruits are ripe in order to ensure better germination. Before planting, the seeds are left in "sun water," which means they are left soaking in a container of water exposed to direct sunlight for up to 12 hours.

Germination: Germination without any pre-sowing treatments may be very low, because the seeds have physical dormancy, meaning that the very hard seed coat inhibits germination, as it

prevents imbibition. Some experiments proved that scarification (rupture of the seed coat) increases germination. Chemical scarification with sulfuric acid seems to be the most effective method, although mechanical scarification is also possible. Physiological dormancy may also be present, and it can be removed by first allowing the seeds to lose a little bit of moisture (a process known as "after-ripening") and then wetting them again with water and/or gibberellic acid. The seeds are planted in bags or germinators about 2 cm deep. In Mexico, germination generally occurs around 22 days after planting, in any case between 2 and 10 weeks, and the seeds germinate better if the planting medium is exposed to the sun.

Tolerance of desiccation: The seeds are recalcitrant, although those from semi-warm climates are more tolerant of desiccation than those from warm and humid climates.

Vegetative propagation: The plants are propagated with stakes, air layering, and grafts. Woody stakes of 20 cm are planted in autumn approximately 10 cm deep.

Growth and transplanting: The tree is heliophilic, with medium-slow growth. The species may experience problems during transplanting. The seedlings can be transplanted when they are approximately 5 cm high, and in 2 years they can grow to 40-60 cm. They can be planted in a field 6 m apart from one another (Correa, 2002).

Pests, disease, and care: The plants do not tolerate frost or floods, although they do tolerate pruning well. They require soil rich in organic matter. There are no particularly problematic pests, although the tree is host to several insects. Some of the most common pests are the caterpillar of a moth of the genus *Cryptophlebia* Walsingham, the dried fruit beetle (*Carpophilus* Stephens); the nanche spittlebug (*Clastoptera* sp.); the tree parakeet (*Membracis mexicana*); the green scale (*Coccus viridis* Green); and the citrus mealybug (*Planococcus citri* Risso).

Additional information: A gross annual carbon storage of approximately 5.5 kg per year has been reported for this species.

Cecropia obtusifolia Bertol

Common names: Guarumbo, Guarumo, Gusano, Manita de león, Trompeta.

Figure 28. *C. obtusifolia* (tree). Photo: RBG Kew.

Family: Urticaceae.

Classification: 12

Description: *C. obtusifolia* is an evergreen, myrmecophile tree, 20-25 m (up to 35 m) in height, with a straight, hollow trunk, very open, irregular and stratified crown made up of thin branches emerging horizontally from the trunk and with a DBH up to 50 cm. Flowers are grouped in grey-brown spikes, the male ones (12 to 15) 8-10 cm and the female ones (4 to 6) 13-20 cm in length. The fruits are achenes aggregated into yellowish-green sprigs, up to 20 cm in length; the achenes are very small, with one seed each and a flavour similar to ripe fig. There are 3000-5000 achenes per sprig. Mature populations produce an uninterrupted supply of abundant fruits that are sought by numerous bird and mammal species. The seeds are very small, 1-2.8 mm long and 0.8-1.3 mm wide, cylindrical, shiny brown. They have no endosperm and contain a massive embryo, straight and white, that fills the cavity.

Figure 29. Leaves of *C. obtusifolia*. Photo: FESI-UNAM.

Figure 30. Inflorescences of *C. obtusifolia*. Photo: FESI-UNAM.

Figure 31. *C. obtusifolia* fruits. Credits: RBG Kew.

Habitat: The tree grows in soils with different drainage levels, in volcanic, sedimentary, or metamorphic soils (shallow soils with volcanic rock, brown, reddish, and black loamy soils, Regosol, limestone, and karstic rock). It thrives close to streams, on river banks and in clearings. It is part of the early secondary vegetation of different types of forest, except for the deciduous and spiny lower forest. It colonises abandoned fields and pastures, old coffee plantations, edges of roads, and cleared land.

Distribution: The tree is originally from the humid and sub humid tropical regions of the Americas. It thrives from sea level to approximately 1200 m. Its geographic distribution is from Mexico and Central America to Colombia, Bolivia, and Ecuador. In Mexico it is widely distributed: from Tamaulipas and San Luis Potosí to Quintana Roo and Yucatán in the Gulf watershed, and from the south of Sinaloa

to Chiapas in the Pacific watershed. In Veracruz it is found near Coatepec, Xico, Teocelo, Acayucan, Catemaco, San Andrés Tuxtla, Minatitlán, Coatzacoalcos, Isla, Tezonapa, Pajapan, and other places.

Cultivation: Wild.

Phenology: Flowering and fructification take place throughout most of the year. In the Tuxtlas (Veracruz) it flowers from January to July, and there are two peaks of fructification, from April to May and from September to October.

Seed dispersal: The main seed dispersers are birds and mammals (e.g., raccoons, monkeys, bats, deer).

Figure 32. Seeds of *C. obtusifolia.* Photo: RBG Kew

Uses: [Food] The fruits are edible, with a flavour similar to figs; **[Environmental]** in the coffee plantation agroforestry systems of Veracruz it is used to provide shade for the coffee plants; **[Fuel]** the wood is used as fuel; **[Fodder]** leaves, stems, and fruits are used as livestock fodder; **[Material]** the fibres from the trunk and the wood are used for handicrafts, musical instruments, manufactured items (e.g., the fibres from the trunk are used to make matchsticks, ropes, and fishing nets), and the wood is also used in construction (e.g., of rafts, buoys, boxes, furniture, boards), while the hollow trunk can be used as a pipe; **[Medicinal]** there are more than 30 medicinal uses, for fever and ailments of the heart, nervous system, liver, and lungs; **[Social]** in Guatemala some of the fruit fibres are smoked.

Management of seeds: The seeds are collected directly from the mature fruit.

Germination: Germination is epigeal: the seeds require direct light to germinate, as it is a pioneer species that colonises clearings in the forest. The seeds do not germinate if they are covered with leaves (dormancy depends on light), and for germination to begin the seeds require long periods of direct light, with temperatures constant or fluctuating from 16 to 36 °C. Germination is rapid and high (90%) under favourable conditions. If germination is not stimulated by light, the seeds can remain viable in the ground, although their survival in the forest may be limited to an average of 7 days, due to different predators. In protected conditions, however, their longevity is more than 5 years.

Tolerance of desiccation: The seeds are orthodox: stored in distilled water (imbibition in water) and in absolute darkness, they can remain viable for five years; stored in paper bags at room temperature (22 ± 3 °C.) they are viable for 3 years.

Vegetative propagation: Cuttings and air layering. In general, the production of adventitious roots for this species is very easy, although air layering seems to be reported as more effective.

Growth and transplanting: Short-lived pioneer (it does not live more than 30 years), easy adaptation, and rapid growth (it can grow 3 m in height and 2 cm in diameter per year). Recently established seedlings (0.5 a 15 cm in height) grow at an average monthly rate of 1.5 cm.

Pests, disease, and care: This tree requires full sunlight for growth; it is intolerant to shade. It has been reported as sensitive to insect damage. It tolerates soil with little drainage or nutrients.

Additional information: This species has a mutualistic relationship with ants of the genus *Azteca* Forel, which protect it from harmful insects in exchange for nutrients in specific structures called Müllerian bodies. A carbon capture of 64517 tonnes per hectare has been observed.

Erythrina americana Mill.

Common names: Alcaparra, Colorín, Gasparito, Tzompantli.

Figure 33. *E. americana* (tree). Photo: RBG Kew.

Family: Fabaceae.

Classification: 4

Description: This tree reaches 10 m in height. Its bark is coarse, cork-like, yellowish, and protected with thorns. It has large leaves with three smooth, deltoid folioles, the central one larger than the others. The flowers are tubular and red, grouped in clusters, with pubescent pedicels. The fruits are leathery, blackish, pods approximately 15-20 cm in length, that open on ripening, with highly visible red seeds. The seeds are approximately 2-2.5 cm in length, resembling beans, but with an intense red colour and a dark brown hilum.

Figure 34. Flowers of *E. americana*. Photo:RBG Kew

Figure 35. *E. americana* leaves. Credits: RBG Kew.

Figure 36. Fruits and seeds of *E. americana*. Photo: RBG Kew.

Figure 37. Seeds of *E. americana*. Photo: RBG Kew.

Habitat: This tree is a pioneer species of the dry tropical forest that grows in clearings with an optimal temperature of 28 ˚C., in loamy, acidic soils, with poor drainage and with little organic matter. It requires moisture for its best development, although it also tolerates periods of drought.

Distribution: It is native to tropical and subtropical regions of Mexico, although its exact origin is uncertain, due to its wide prehispanic cultivation.

Cultivation: Wild and cultivated.

Phenology: In Mexico, the seeds are collected in December. In Veracruz, flowering occurs from March to May, and fructification from July to February.

Seed dispersal: The ripened fruits open, allowing the seeds to fall. The flowers are pollinated by hummingbirds.
Uses: [Food] The flowers are edible and popular in many Mexican recipes, especially in Veracruz; **[Environmental]** the tree is used as a living fence, to enrich the soil in nitrogen, and in coffee plantation agroforestry systems to provide shade for coffee plants; **[Fodder]** the leaves and a meal ground from the seeds are used as fodder, although the seeds are a little toxic, due to the presence of alkaloids; **[Material]** the seeds and the wood are used in the production of handicrafts, and the wood is used in construction; **[Medicinal]** the leaves are used in Veracruz to heal wounds, sores, and insect bites.

Management of seeds: The pods are ripe when they open naturally to release the seeds. As the seeds of this species are often attacked by beetles, it is advisable to perform a flotation test before planting to confirm their viability: if the seeds float in water, they have been attacked by beetles and can be discarded. During the flotation test, 5 ml of sodium hypochlorite can be added to each litre of water to sterilise the seeds and protect them from fungal attacks. This test can last from 10 minutes to one hour. Before planting, the seeds can be soaked in water (up to 24 hours) to stimulate germination. However, these seeds have a very hard seed coat that is usually difficult to soften solely by soaking. For this reason, it is advisable to scarify the seeds to enable imbibition.

Germination: Germination can normally take place in 8-15 days. According to literature, thermal scarification at 35 °C for 70 minutes seems to be the most effective treatment for removing physical dormancy, while control seeds (seeds with no pre-sowing treatments) germinate at a lower rate.

Tolerance of desiccation: The seeds are orthodox.

Vegetative propagation: Cuttings. The cuttings must be maintained in a greenhouse for at least four months before being transplanted to the field, which is done at the beginning of the rainy season.

Growth and transplanting: Rapid growth. The seedlings are usually transplanted once they reach 1.5 cm in height by means of the stakes technique, which consists of making a hole in the substrate with a stake to facilitate transplanting without damaging the roots. The seedlings reach a height of approximately 10-20 cm in a month. The trees are ready for donation in an average of 3-5 months.

Pests, disease, and care: This species is affected by a fly pest that causes deformities in the stems due to the larvae that dig into them. These pests, which affect the structure of the tree, allow other pathologies, such as fungi and bacteria, to opportunistically attack the tree and kill it. Another pest attacking the species is the beetle *Xyleborus volvulus* J.C. Fabricius, which also attacks many other tree species, damaging their wood. The seeds are eaten by *Specularius impressithorax.*

Figure 38. *E. americana* clean seeds. Credits: FESI-UNAM.

Heliocarpus appendiculatus Turcz.

Common names: Balsa, Corcho, Jonote, Jonote baboso, Jonote colorado, Jonote rojo.

Figure 39. *H. appendiculatus* (tree). Photo: RBG Kew.

Family: Malvaceae.

Classification: 7

Description: This tree can reach up to 14 m in height, with older branches dark brown in colour, furfuraceous, with simple and ramified trichomes, reddish, with white spots (lenticels) irregularly distributed on their surfaces. The leaves are alternating, ovate, sometimes almost three-lobed, up to 16 cm in length and 14 cm in width, pointed, with irregular serrate edges. The top of the leaf is dark green, with sparse tufts of ramified trichomes, while the bottom is whitish and abundantly covered with ramified trichomes. It has inflorescences up to 15 cm in length and 14 cm in width, ramified, with abundant flowers, generally located at the tips of branches, sometimes in the axillas of leaves. The stems have groups of three flowers. The main stems of the inflorescences are furfuraceous and covered with abundant reddish trichomes. The flowers are ovoid, bisexual, up to 6 mm in length, with four white petals and numerous stamens (approximately 30). The fruit is reddish-brown, dry, laterally flattened, more or less circular, approximately 5 mm in length and 4 mm in width, with trichomes that look like rays of the sun (hence the name Heliocarpus, which means "sun fruit"). There are 1-2 seeds per fruit, dark in colour, very small (2-3 mm in length), with ramified trichomes on their surface.

Figure 40. Flowers of *H. appendiculatus.* Photo: RBG Kew.

Figure 41. Fruits of *H. appendiculatus.* Photo: RBG Kew. Zamora Villalobos CC BY-NC 4.0 DEED.

Figure 42. *H. appendiculatus* seeds. Credits: FESI-UNAM.

Habitat: This is a pioneer tree found in altered tropical forests (high forest, low forest, cloud forest), along highways, and in pastures and coffee plantations. It has a preference for clearings with abundant available light, assimilating it into a greater carbon advantage. It prefers warm-humid climates, loamy soils, and

lutite rock (fine-grained loamy rock).

Distribution: Native to Mexico and Central America.

Cultivation: Wild and cultivated.

Phenology: In Mexico, flowering generally takes place from December to mid-March, and fructification from mid-March to mid-June. In Veracruz, flowering is from December to the beginning of April and fructification from March to June.

Seed dispersal: The entire unit of fruit and seeds is dispersed by the wind.

Uses: [Food] In Costa Rica, it is used as a flocculant in the processing of sugar cane; **[Material]** the wood is used to build houses, pigsties, corrals, and similar structures, and fibres from the trunk are used to make baskets, handicrafts, amate paper, and cord; **[Medicinal]** the bark and sap are used to treat skin conditions, the bark has antimalarial properties, and the hot leaves are used as a poultice to alleviate swelling and kidney or muscular pain.

Management of seeds: The fruits are collected by shaking the branches or by cutting the bunches of fruit. The fruit can be collected before it ripens, as it continues to mature after being cut from the tree, although it is better to collect it once ripened. There is no pre-planting treatment. The seeds are not separated from the fruit before planting: the dispersal units are planted whole, using the scattering method to distribute them randomly over the substrate in the germinators. The fruits do not entirely cover the substrate, or they cover it with a layer so thin as to allow the seedlings to emerge; as they are very small, they would not sprout if they were covered with substrate.

Germination: Temperature is the most influential factor in the germination of this species. The average daily temperature favouring germination is high (26-36 °C.), with a difference between night and day temperatures of 10 °C. This combination of temperatures increases the permeability of the seed pods, stimulating germination. After a year in storage, the seeds germinate in a wider range of temperatures. It has also been observed that germination increases if recently harvested seeds are submerged in hot water for up to a minute. The seeds can germinate with and without light.

Tolerance of desiccation: The seeds are orthodox.

Vegetative propagation: Stakes.

Growth and transplant: The plants grow rapidly and are transplanted once they develop true leaves, using a stake to make a hole in the substrate to facilitate transplanting without damage to the roots. The seedlings usually grow approximately 10-20 cm in a month. The recommended substrate is sand and sawdust.

Pests, disease, and care: Once the seedlings reach a height of 10-20 cm, a disease begins to appear on the underside of the leaves: they present a series of elevated, swollen spots, yellowish-green in colour. However, this disease does not kill the plants. Adult trees are affected by an edible worm: the jonote worm (*Arsenura armida* Cramer), which feeds on the leaves in its larval stage.

Heliocarpus donnellsmithii Rose.

Common names: Cajeta, Corcho, Jolocín, Jonote blanco, Majagua.

Figure 43. *H. donnellsmithii* tree. Credits: RBG Kew.

Figure 44. Flowers of *H. donnellsmithii*. Photo: RBG Kew

Family: Malvaceae.

Classification: 13

Description: This deciduous tree reaches up to 15 m in height, with a DBH of up to 40 cm. The trunk is often bifurcated or trifurcated; the crown is rounded and open. Both male and female inflorescences are up to 30 cm in length. The calyx is made up of four green linear sepals. The males have numerous yellowish stamens and a non-functional pistil; the females have a superior ovary that terminates in a bilobate stigma. The flowers are of a greenish cream colour with stellate trichomes and emerge from the junction of the stems and leaves; they are sessile and 3-3.5 mm in length. They are honey plants. The fruits are globular, 3 mm in diameter, slightly flattened, bordered with numerous filiform projections, dark brown in colour; the entire fruit is covered with abundant stellate trichomes, containing a rounded, flattened seed. The fruits are collected when they reach maturity and turn dark brown; they must be collected before the wind begins to disperse them. There are 1-2 seeds per fruit, dark in colour, and very small (2-3 mm in length and 1.5 mm in width).

Figure 45. Fruits of *H. donnellsmithii*. Photo: RBG Kew.

Habitat: This is a pioneer tree found in dry and humid tropical forests, especially in secondary forests deriving from high evergreen and medium sub-deciduous forests. It typically grows in forest clearings, scrubland, and abandoned pastures and fields at elevations up to 2300 m. It prefers moist soil, rich in organic matter, in completely open areas, and warm to temperate climates.

Distribution: The species is originally from the humid and sub humid tropical regions of the Americas. Its area of distribution runs from Mexico to Belize, Guatemala, El Salvador, Nicaragua, and Costa Rica. In Mexico it is found from the south of Tamaulipas to the south of Campeche and the centre of Quintana Roo. In the Pacific zone it is found from Sinaloa to Oaxaca. In Veracruz it grows near Cinco Palos, Xico, Teocelo, Coatepec, Xalapa, San Andrés Tuxtla, Atzalan, and other areas.

Cultivation: Wild, cultivated.

Phenology: In Veracruz, flowering is from October to February, and fructification from March until May or June.

Seed dispersal: The entire dispersal unit, fruit and seeds, is dispersed by the wind. Dispersion takes place from March to May.

Figure 46. Seeds of *H. donnellsmithii*. Photo: FESI-UNAM.

Uses: [Environmental] Used on coffee plantations to provide shade for coffee plants and as a living fence; **[Fodder]** the leaves are used as fodder and the flowers are very attractive to bees; **[Material]** fibres from the trunk are used in the production of amate paper and to make baskets, and the wood is used to build houses, pigsties, fences, and furniture; **[Medicinal]** the bark is used to heal wounds and as an antispasmodic.

Management of seeds: The fruits are collected by shaking the branches or by cutting the bunches of fruit. The fruit can be collected before it ripens, as it continues to mature after being cut from the tree, although it is better to collect it when it is ripe (dark brown-coloured). It is important to collect it before the wind begins to disperse it. There is no pre-planting treatment. The seeds are not separated from the fruit before planting: the dispersal units are planted whole, using the scattering method to distribute them randomly over the substrate in the germinators. The fruits do not entirely cover the substrate, or they cover it with a layer so thin as to allow the seedlings to emerge; as they are very small, they would not sprout if they were covered with substrate.

Germination: Germination is epigeal and very rapid: seedlings begin emerging 5-8 days after planting and normally finish in 18-20 days. As it is a pioneer species adapted to colonise forest clearings, germination requires exposure to daily temperatures around 30 °C. for several hours. Germination increases with a difference in temperature between night and day of at least 10 °C. This combination of temperatures increases the permeability of the seed pods, stimulating germination.

Tolerance of desiccation: The seeds are probably orthodox, but there is no documentation to date of their natural longevity and conservation under controlled conditions.

Vegetative propagation: Stakes.

Growth and transplanting: This species grows rapidly but is not very long-lived. Once seedlings reach 6 cm in height they can be placed in direct sunlight. transplanting is done by making a hole in the substrate with a stake to avoid damaging the roots. The seedlings are transplanted after the first true leaves are visible to avoid "stretching," the excessive development of the aerial part of the plant without a correctly balanced development of the roots.

Pests, disease, and care: The adult trees are affected by a pest, but it does not cause much damage; it is an edible worm: the jonote worm (*Arsenura armida* Cramer), which feeds on the leaves in its larval stage. More problematic is the rust that attacks the seedlings, a pathogenic fungus that damages but does not kill them.

Inga inicuil Schltdl. & Cham. ex G.Don

Figure 47. *I. inicuil*, tree. Photo: RBG Kew.

Common names: Algodoncillo, Cuajinicuil, Jinicuil, Vaina, Vainillo.

Family: Fabaceae.

Classification: 1

Description: Evergreen or deciduous tree, 12-15 m (up to 20 m) in height, 30-50 cm DBH. The bark is light grey and yellow when cut. The leaves are 8-20 cm in length and are made up of six lanceolate pinnas. The flowers are fragrant, 6 mm in length, light or yellowish green, white, or cream-coloured, and arranged in a colourful flower head. The fruits are oblong green pods, 15-20 cm in length, laterally flattened. Once ripe, the fruits turn greenish-yellow and open. Each contains 12-18 seeds. The pulp is white, cottony, pulpy, and sweet, and easily removed from the seeds. The seeds are oblong, laterally flattened, 24-32 mm in length, and 6-18 mm in width.

Figure 48. Fruit and branches of *I. inicuil.* Photo: RBG Kew.

Habitat: This species grows in cloud forests and gallery forests, alongside rivers. Like other Ingas, it has thick, deep roots and tolerates floods. It is found in these forests to an altitude of 1880 m.

Distribution: Found in tropical regions of Mexico, including the states of Puebla, Veracruz, Tabasco, Oaxaca, Guerrero, Michoacán, and Jalisco. It has been found from southern Mexico throughout both watersheds of Central America and as far as Peru.

Cultivation: Wild and cultivated.

Phenology: In Veracruz, flowers bloom from November to June, with fructification from March to December.

Seed dispersal: By gravity and occasionally by animals.

Uses: [Food] The fruit pulp is eaten raw and in preparations such as juices and ice creams; the seeds are boiled and eaten; **[Environmental]** the plant is used as a living fence in pastures and on coffee plantations; **[Fodder]** the flowers attract bees; **[Material]** the wood is used in rural construction; **[Medicinal]** the leaves and bark have anti-inflammatory and antibacterial properties.

Management of seeds: The seeds are processed rapidly because they do not survive desiccation. The pods (fruits) are opened, the white pulp around the seeds is removed to avoid excessive

moisture that would favour attacks by pathogenic fungi, the seeds are left to air, those that show damage from pests or disease are removed, and the others are planted. They are planted in bags; normally they are not planted in the field because no reliable method has been found.

Germination: The seeds are recalcitrant and often germinate while they are still in the fruit. They should be planted approximately 2 cm below the surface of the soil, and the substrate should be maintained in partial shade. Seedlings emerge in approximately eight days.

Tolerance of desiccation: The seeds are recalcitrant.

Vegetative propagation: Grafts (whip and side cleft). The rootstock must be at least two years old and measure 1.5 m in height and 1.5-2 cm in diameter. The scions must be approximately 20 cm in length, with 3-4 buds close to opening.

Growth and transplanting: The seedlings grow rapidly, reaching a height of 70 cm in a year. The seeds are thus planted directly in bags and grow an average of 10-20 cm in a year. Normally the seedlings are ready for donation and transplantation to the field in two months. Transplanting must take place no later than 5-6 months after planting, and not during the rainiest periods, as the species is sensitive to excessive moisture.

Pests, disease, and care: The seedlings should be watered regularly and the shade should be removed a month before transplanting. In the first two months after transplanting to the field they should be watered regularly, but they can then be watered less. However, before transplanting they should not be watered excessively, as the stems can rot and the seedlings can develop fungal infections from excessive moisture. For this reason it is advisable not to use irrigation that wets the leaves. The plant adapts well to pruning, which should be begun in the second year, removing low axillary branches or cutting the upper part of the main stem (Vargas-Simón and Pire, 2018). The biomass produced in pruning should be left on the ground to maintain soil fertility and preserve moisture in dry regions. The plant has a high tolerance for acid and low-fertility soils. It is affected by common pests, such as crickets, and it is a host to fruit flies (*Anastrepha distincta* Greene), but in general it is not susceptible to many pests or diseases.

Figure 49. *I. inicuil* seeds. Credits: FESI-UNAM.

Inga punctata Willd.

Common names: Acotope, Chalahuite Blanco, Chalahuite de cerro, Coajinicuil de rayo, Vainillo.

Figure 50. *I. punctata.* Photo: Reinaldo Aguilar CC BY-NC-SA 2.0 DEED.

Family: Fabaceae.

Classification: 3

Description: This tree is approximately 15 m in height, with leaves made of six lanceolate pinnas, 9-18 cm in length, and sprigs of 1-7 white or cream-coloured flowers. The fruits are oblong green pods, approximately 16 cm in length, flattened, straight or curved, transversely ribbed. The fruits open when ripe, and contain a sweet, white pulp that is easily separated from the seeds. The seeds are light or dark brown, with a smooth surface, approximately 1-1.5 cm in length and 0.6-0.8 cm in width.

Habitat: The species is common in humid forest environments from sea level to the pre-mountain level. It prefers loamy soil in clearings, on the edges of forests, streams, and highways, and in pastures. Like other Ingas, it has thick, deep roots and tolerates floods.

Distribution: Native to southern Mexico, Cuba, Central America, and the northern part of South America (Colombia, Venezuela, Ecuador, parts of northern Brazil, Bolivia, Perú, and French Guiana).

Cultivation: Wild and cultivated.

Phenology: In Veracruz, it flowers in September, with fructification in March and reports of fructification in July and August.

Seed dispersal: By gravity and occasionally by animals.

Uses: [Food] The fruit pulp is eaten raw and in preparations such as juices and ice creams; the seeds are boiled and eaten; **[Environmental]** the plant is used as a living fence in pastures and on coffee plantations, to enrich the soil in nitrogen, and to provide shade on coffee plantations; **[Fodder]** the leaves are used as livestock fodder and the flowers attract bees; **[Material]** the wood is used in rural construction to build floors and trunks; **[Medicinal]** no specific information is available.

Figure 51. Seeds of *I. punctata.* Photo: Reinaldo Aguilar CC BY-NC-SA 2.0 DEED.

Management of seeds: The seeds are processed rapidly because they do not survive desiccation. The pods (fruits) are opened, the white pulp around the seeds is removed to avoid excessive moisture that would favour attacks by pathogenic fungi, the seeds are left to air, those that show damage from pests or disease are removed, and the others are planted. Because they grow rapidly, they are planted in bags to avoid having to transplant them soon after planting.

Germination: The seeds germinate rapidly, with seedlings emerging approximately 10 days after planting.

Tolerance of desiccation: The seeds are recalcitrant.

Vegetative propagation: Cuttings.

Growth and transplanting: The growth of the seedlings is slow in comparison with other species of the genus Inga Mill. After emerging, they grow to approximately 10-20 cm.

Pests, disease, and care: In general, the seedlings are affected by common pests such as crickets, although a cochineal has been reported (*Dysmicoccus texensis Tinsley*) that feeds on the roots.

Inga vera Willd.

Common names: Acotope, Chalahuite, Chalahuite de vaina, Guama, Jinicuil, Vainillo.

Figure 52. *I. vera* (tree). Photo: RBG Kew

Family: Fabaceae.

Classification: 2

Description: This tree reaches a height of 30 m, with a DBH of 30 cm (sometimes up to 1 m). It has a wide, flattened, very extended crown, with sparse foliage, and a straight trunk. The branches are long; the bark is light grey with lenticels, more or less smooth, and pinkish to brown on the inside. There are 10-18 leaves, alternating, deriving from a vein, arranged in two diverging lines, 18-30 cm in length. Inflorescences: sprigs of several large whitish flowers that turn greenish-yellow a few hours after opening. Each flower has a kind of funnel approximately 1-2 cm in width. Fruit: Slightly curved brown cylindrical pod, straight or spiralled, 8-18 cm in length by 1.3-2.2 cm in width, with two wide longitudinal grooves. The fruit does not open on ripening, and contains a white pulp with few seeds.

Figure 53. Open fruit of *I. vera*, with seeds and pulp visible. Photo: RBG Kew.

Habitat: Found in the oak forest, gallery forest, deciduous, sub deciduous, and evergreen tropical forests, and xerophilous scrubland, from sea level to 1800 m. Grows well in a wide variety of soil types, and tolerates both floods (like other Ingas its roots are thick and deep) and dry soil. It is common on riverbanks and in hollows.

Distribution: Native of Mexico, Central America, the Caribbean, Colombia, Venezuela, Ecuador, and Bolivia.

Cultivation: Wild and cultivated.

Phenology: Generally flowers from January to June, with fructification from March to September. I. vera subsp. eriocarpa, another subspecies found only in Mexico, flowers at the end of the dry season (February to March) and the fruits can take a year to mature. In Veracruz, the flowering of I. vera is reported between September and November, and fructification in December-January and in August.

Seed dispersal: By gravity; occasionally by animals.

Figure 54: Seeds of *I. vera*. Photo: RBG Kew

Uses: [Food] The fruit pulp is eaten raw and in preparations such as juices and ice creams; the seeds are boiled and eaten; **[Environmental]** the plant is used

as a living fence in pastures and on coffee plantations, to enrich the soil in nitrogen, and to provide shade on coffee plantations; **[Fuel]** the wood is used to make charcoal; **[Fodder]** the leaves are used as livestock fodder and the flowers attract bees; **[Material]** the wood is used in carpentry and to make furniture; **[Medicinal]** the bark, shoots, and leaves have astringent, laxative, and antiseptic properties.

Management of seeds: The seeds are recalcitrant and sensitive to infections of pathogenic fungi, so it is important to process them quickly. Before planting, the seeds that are already visibly damaged by fungi or insects are discarded. The healthy seeds are separated from the pulp, quickly washed, and if possible disinfected with sodium hypochlorite for 10 minutes (5 ml of sodium hypochlorite per 1 L of water). They are allowed to dry before planting so as not to rot or become infected.

Germination: In general, it is preferable to plant directly in bags, given that transplanting can be delicate. Germination is rapid (3-5 days, with seedlings emerging within a week), but the growth of seedlings is slow compared to *Inga inicuil* Schltdl. & Cham. ex G.Don.

Tolerance of desiccation: The seeds are recalcitrant.

Vegetative propagation: Cuttings, shoots, and sprouts.

Growth and transplanting: transplanting is carried out after the seedlings emerge, in the second week after planting, unless planting is not done directly in bags. In the first phases of growth, the seedlings have a reddish colour and appear unwell even if they are healthy. The seedlings can reach 10-15 cm in a month. Compared with other Ingas, this species is usually slow in development, although it produces shade within three years.

Pests, disease, and care: This species tolerates drought and acidic soil; it is necessary to avoid excessive watering, as the stem rots easily. The major problem with the species is that the seeds are greatly affected by insect pests. Even if many pods are collected, many of the seeds will not propagate. The seedlings, however, are not attacked by specific pests, though they may be attacked by crickets and other insects such as the fruit fly *Anastrepha distincta*; the beetle *Diaprepes abbreviatus* L.; the cochineal *Maconellicoccus hirsutus* Green; and *Umbonia crassicornis* Amyot & Serville. It is also affected by the fungus *Rosellinia bunodes* (Berk. & Broome) Sacc.

Juglans pyriformis Liebm.

Common names: Michpa, Nogal, Nogal cimarrón, Nogalillo, Nuez.

Figure 55. *J. pyriformis* (tree). Photo: RBG Kew.

Family: Juglandaceae.

Classification: 14

Description: Deciduous tree, 10-25 m in height, straight trunk, dark brown bark, scaly or with longitudinal fissures. Its crown is wide and dispersed, with thick, rising branches, and a DBH up to 90 cm. A monoecious species, its female flowers are green, alternate, and arranged in groups of two or three on a terminal spike. The male flowers are yellowish green and small, 2-3 mm, arranged irregularly along a stem, forming amentiform bunches 9-23 cm in length with 38-78 flowers. The pollination is anemophilous (by means of the wind). The fruit is fleshy, with abundant light grey open warts and a small collar at the tip. They grow in bunches of 2, 3, or 4 fruits to a branch, and are greenish-yellow when ripe. The seed is a brown, woody, spherical nut, with longitudinal grooves, containing a depressed ovoid seed, laterally flattened, approximately 20 mm in length. The seed covering is brown, reticulated, and membranous. It has no endosperm, and the massive embryo has sinuous cotyledons.

Figure 56. Female inflorescences of *J. pyriformis*.
Photo: © Sarahí Díaz

Figure 57. Fruits of *J. pyriformis*. Photo: PNV

Habitat: This tree is part of the medium and high strata of the cloud and deciduous forests. It grows in a temperate climate with ample rain, and prefers deep or rocky well-drained soils. It thrives at an altitude of 1200-1500 m, in areas with an average annual temperature of 14-18 °C. and annual precipitation of 1500-2000 mm. It is found in pastures and cultivated fields that are protected by its shade. In Veracruz it is common in the coffee plantations along the old Xalapa-Coatepec highway and in the vicinity of Xico, Teocelo, Huatusco, Coscomatepec, Orizaba, Yecuatla, Plan de Las Hayas, and Juchique de Ferrer.

Distribution: This is an endemic species of walnut in Mexico. Its seeds have been collected only in the states of Hidalgo

and Veracruz (Alto Lucero, Calcahualco, Coatepec, Cuitláhuac, Coacoatzintla, Chiconquiaco, Huatusco, Huiloapan, Ixhuatlán del Café, Juchique de Ferrer, Nogales, Río Blanco, Texhuacán, and Yecuatla).

Cultivation: Wild, cultivated.

Phenology: In Veracruz, flowering takes place from February to March, and fructification from August to November. In Veracruz, flowering takes place from February to August; the female flowers are present for the entire period and the male flowers from February to April. Fructification in Veracruz takes place from September to November.

Figure 58. Nuts of *J. pyriformis*. Photo: RBG Kew.

Seed dispersal: Gravity. Dispersal takes place from August to October.

Uses: [Food] The nuts are eaten and used in a similar way as the common walnut (*Juglans regia* L.); **[Environmental]** the tree is planted in ecological reclamation sites for its ability to survive in adverse conditions, is used as a living fence, and is used to provide shade on coffee plantations and in pastures; **[Material]** the wood is of excellent quality and is used to make musical instruments, handicrafts, and furniture; **[Poison]** the leaves are ground and used to stun fish.

Management of seeds: Fruit collection can be carried out in September and October, and in seed years it is possible to collect it until the end of November. The fruits can be transported in raffia sacks, thick plastic bags, or plastic crates. Care must be taken in collecting the fruit, as it may be damaged by pathogenic fungi or animals, especially when it is collected from the ground. For this reason, it is advisable to collect fruits without visible damage, where the fleshy peel (exocarp) is yellowish-green, reddish-yellow, or black (although black fruits should be collected only if the pulp is firm). To process the seeds it is first necessary to clean the fruits and remove the pulp (fleshy exocarp). They should then be left to air out. The seeds are covered by a hard nut, the woody endocarp, that can be scarified to promote germination. Leaving the fruits in running water for seven days is also a treatment used to increase germination. The endocarp can also be mechanically scarified, but this is often not advisable, because it exposes the seeds too early, putting them at risk of being eaten by animals or attacked by pathogenic organisms.

Germination: Planting is carried out from October to February in double raised beds, 20-30 cm high, and the seeds are covered with 2-3 cm of substrate. Double beds are used because the species grows rapidly and has an extensive root system; to avoid the need to transplant shortly after planting, it is necessary to leave sufficient space for the roots to develop. Normally the seedlings emerge in a month or six weeks (40-55 days), so in 25-30 days there is germination. The seeds show resistance to germination: in fact, it may take 35-61 days to begin. The rate of germination can reach 70-83%.

Vegetative propagation: Mainly sexual propagation through seeds.

Growth and transplanting: Growth is rapid, and in a period of 6-7 months the plant reaches a height of 25-30 cm. Although planting is done in raised beds to avoid having to transplant right after planting, transplanting is necessary a month and a half after the seedlings emerge because by this time they can reach a height of 40 cm. It is important not to delay transplanting in order to avoid unequal development of the roots. The seedlings do not generally die with transplanting, but excessive moisture is a problem, so it is important to plant them in the field before the rainy season. The roots of seedlings that cannot be transplanted to the field are treated with the beneficial fungus Trichoderma sp. to defend them against pathogenic fungi.

Pests, disease, and care: It is advisable to apply an initial fertilisation to develop and strengthen the seedlings once they emerge, and they should be watered every 5-7 days depending

on the season and location. The seedlings develop best in soils rich in minerals, and that are deep and loose. The major diseases affecting the species are the Cercospora, better known as Tizón negro (black smut; *Phytophthora infestans* [Mont.] de Bary), which usually completely dehydrates the plant, beginning with the sprouts and eventually leaving it completely dried out (it is recognized by the dried, blackened leaves). Squirrels and ants also eat the seeds. To protect the seeds it is a good practice to enclose the planted areas with nets or fences.

Additional information: Protected endangered species (Mexican Official Norm: NOM-059-SEMAR- NAT-2001).

Persea longipes (Schltdl.) Meisn.

Common names: Aguacatillo, Laurus.

Family: Lauraceae.

Classification: 15

Description: Evergreen tree 8-15 m (up to 20 m) in height, with dark brown bark, deeply fissured to scaly and somewhat aromatic. The developing branches and leaves are always more or less pubescent, with straight adpressed trichomes. Reaches a DBH up to 60 cm. Flowers 5 mm in length; outer perianth segments 2-2.2 mm in length and 2-2.2 mm in width, ovate, with sharp points, with trichomes inside and bare outside, yellow to pale green. Infructescence contains several fruits, with the stem slightly thicker than in the inflorescence; pedicels 4 mm in length, swollen; reflected perianth, the points of the internal segments deciduous; fruits 6-7 mm in length, globular, green, with mucilage.

Habitat: Found in the cloud forest associated with *Oreopanax xalapensis*, *Quercus* sp. and *Croton draco*, it is a species that requires light. It has been collected at altitudes of 200-1500 m.

Distribution: This species is distributed along the slopes of the mountains in Veracruz to an altitude of 200 m. It has also been observed on the Honduran coast.

Cultivation: Wild, cultivated.
Phenology: In Veracruz, fructification is reported from May to September.

Management of seeds: The pulp is carefully removed from the fruits, and the seeds are processed quickly because they are recalcitrant. It is important to clean the pulp from the seeds, because although the seeds are not generally attacked, the remains of pulp could attract animals and insects.

Persea schiedeana Nees.

Common names: Aguacate de monte, Auacatillo, Chinine, Chinini, Pagua.

Figure 59. *P. schiedeana* (tree). Photo: RBG Kew.

Family: Lauraceae.

Classification: 6

Description: This tree is approximately 30 m in height, with an extensive crown. The leaves are elliptical, 8-35 cm in length and 4-25 cm in width. The tops of the leaves have no trichomes and show prominent secondary veins, while the undersides have trichomes and a reddish colour. The flowers are 6-10 mm in length, pubescent, yellowish-green with slightly reddish stems, and grouped in inflorescences. There are 1-2 fruits per branch, and are of different shapes: more elongated, oval, or nearly spherical, with a creamy, whitish pulp. Their colour is green, yellow, or black. The seeds are oval or almost spherical.

Figure 60. Flowers of *P. schiedeana*. Photo: RBG Kew.

Figure 61. Fruits of *P. schiedeana*. Photo: RBG Kew.

Habitat: Found at altitudes of 250-2500 m in cloud or pine forest environments, in humid climates.

Distribution: Throughout Mexico (except in the states of Sonora and Baja California), Guatemala, Honduras, El Salvador, Costa Rica, Panama, and Colombia.

Phenology: Flowers from January to March, with fructification from May to August.

Seed dispersal: The seeds can be dispersed by animals, such as monkeys, or through human activity.

Figure 62. Seeds of *P. schiedeana*. Photos: RBG Kew.

Uses: [Food] The fruit is eaten raw in various traditional dishes, such as guacamole, tacos, and soups, and are also the source of an edible oil; the unripe fruit is toxic; **[Environmental]** the tree is used for shade on coffee plantations; **[Fuel]** the wood from trees

that are no longer productive is used to make charcoal.

Management of seeds: The pulp is carefully removed from the fruits, and the seeds are processed quickly because they are recalcitrant. It is important to clean the pulp from the seeds, because although the seeds are not generally attacked, the remains of pulp could attract animals and insects.

Germination: Raised beds are used because the species grows rapidly and has an extensive root system; to avoid the need to transplant shortly after planting, it is necessary to leave sufficient space for the roots to develop. The seeds germinate in approximately one month, with emergence of seedlings in a month and a half.

Tolerance of desiccation: The seeds are recalcitrant.

Vegetative propagation: Various grafting techniques. Used as a rootstock for the *Persea americana* Mill. Avocado because it is resistant to the attacks of a pathogen (*Pytophthora cinnamomii*) that causes root rot.

Growth and transplanting: Seedling growth is rapid: in two months they can reach 20-30 cm, and in five to six months they are ready for transplanting to the field. transplanting is carried out after the emergence of seedlings, normally moving the seedlings to tubes filled with 2-3 kg of substrate at the moment of transplanting in order to avoid damage to the roots.

Pests, disease, and care: The large avocado pit weevil (*Heilipus lauri*) is one of the pests reported in Veracruz for this species. The adults lay their eggs on the fruits and the larvae attack the seeds. The avocado moth (*Stenoma catenifer* Walsingham) is another pest. The species is also susceptible to the Avocado Sunblotch Viroid.

Additional information: This avocado is typically found in cloud forests at altitudes of 250-2500 m.

Psidium guajava L.

Common names: Guayaba, Guayaba de venado, Guayaba dulce, Guayaba manzana, Guayaba perulera, Guayabilla.

Figure 63. *P. guayava.* Photo: Mauricio Mercadante CC BY-NC-SA 2.0 DEED.

Family: Myrtaceae.

Classification: 5

Description: This tree reaches a height up to 10 m and frequently has shoots at the base of the trunk. The bark varies between green and reddish-brown. It has opposing ellipse-shaped leaves, 5-15 cm in length and 5-7 cm in width. The flowers are single or in inflorescences, approximately 3 cm in diameter, with 4-5 white petals, 1-2 cm in length, and numerous yellowish stamens. The fruits are berries, 4-12 cm in length, with numerous yellowish seeds, hard, reniform, 3-5 mm in length, in a pinkish-white pulp.

Figure 64. Flowers of *P. guayava.* Photo: mauroguandi CC BY 2.0 DEED.

Figure 65. Fruits of *P. guayava.* Photo: Forest & Kim Starr CC BY 3.0 DEED.

Habitat: Grows well in humid and dry environments to an altitude of 1500 m (sometimes 2100 m). Harvests are best in regions with average daily temperatures of 20-30 °C. and annual precipitation of 1000-2000 mm.

Distribution: The original distribution is not clear; it was probably from southern Mexico to all of South America. Today it is cultivated in all tropical and subtropical regions.

Phenology: In Veracruz, flowering takes place from March to June, and fructification from July to October. Trees can flower in the first two years of life, with stable production of fruit in 5-8 years. They are not very long-lived: generally no longer than 40 years.

Seed dispersal: The seeds are dispersed by birds and mammals.

Uses: [Food] The fruits are eaten raw or cooked in a variety of preparations, including jellies, ice cream, juice, and tamales; **[Environmental]** attracts fauna and is planted on coffee plantations for shade; **[Fodder]** the flowers attract bees; **[Material]** the wood is very durable and is used in carpentry, while the leaves are used for dye and tanning; **[Medicinal]** the leaves are used as an antidiarrheal.

Management of seeds: The seeds are removed from the fruits with a spoon and washed to remove pulp. They must be aired before planting. They can be soaked in water to favour germination. Scarification in acid for 12 hours stimulates germination by removing physical dormancy.

Germination: Germination takes place in 10-20 days, and in general the species

germinates very well. The seeds can germinate in the dark with alternated temperatures, which appears to be important to germination.

Tolerance of desiccation: The seeds are orthodox.

Vegetative propagation: Grafting. There are other guava species (e.g., *Psidium guineense* Sw.) used as rootstock that are resistant to the bacterial wilting caused by *Gliocladium vermoeseni* (Biourge) Thom and the root nematode *Meloidogyne incognita* (Kofoid & White).

Growth and transplanting: The seedlings do not grow very rapidly: in a month they reach 5-10 cm and in six months they can be transplanted to the field. The seedlings are resistant to transplanting; they are usually sensitive to excessive moisture, so it is necessary to water them with caution.

Pests, disease, and care: In general, *P. guajava* is a resistant species that adapts to many different conditions of growth. It grows at altitudes from sea level to 1500 m, at temperatures of 15-45 °C. The optimal temperatures for growth are 23-28 °C. It is resistant to light frosts, and depending on the cultivar, three and a half months of temperatures above 16 °C. are sufficient for fructification. In general, in the first two years it is a good practice to apply 110-225 g of fertiliser three or four times per year. It is generally affected by various diseases. Guava canker, a disease that produces rot, decay, and brown spots on the leaves and fruits, is caused by fungi of the genera *Colletotrichum* and *Gloeosporium* sp. Algal leaf spot, which results in decay and necrosis in leaves and fruits, is caused by various organisms, such as the microalga *Cephaleuros virescens* Kunze ex E.M.Fries. Fruit rot is caused by pathogenic fungi of the genus *Guignardia* sp. Guava wilt is caused by fungi such as *Gliocladium vermoeseni* (Biourge) Thom and *Fusarium oxysporum* Schlecht. emend. Snyder & Hansen. Guava rust is caused by the fungus *Austropuccinia psidii* (G. Winter) Beenken. Fungi of the genus *Mucor* sp., such as *Mucor hiemalis* Wehmer, also cause rot. These fungi often attack the plants at wounds caused by the oviposition of pathogenic insects such as the guava fly (*Bactrocera correcta* Bezzi). Apical rotting owing to calcium deficiency causes the complete wilting of the fruit. Root rot is caused by fungi of the genus *Phytophthora* sp., although there are resistant rootstocks. The pathogenic insects are mainly the guava fruit fly and the Mexican fruit fly (*Anastrepha ludens* Loew). Best practices against attacks of pathogenic fungi include disinfection of the soil with ecological fungicides prior to planting, good soil drainages, removal of weeds and damaged plant matter, especially fallen fruit, every 2-4 days, rolling the soil, avoiding wetting the leaves during watering, avoiding monoculture, and disinfecting pruning tools.

Trema micranthum (L.) Blume.

Common names: Capulincillo, Capulincillo cimarrón, Capulín, Chaca, Ixpepe, Majagua.

Figure 66. *T. micranthum.* Photo: FESI-UNAM.

Figure 67. *T. micranthum* leaves. Credits: RBG Kew.

Family: Cannabaceae.

Classification: 10

Description: This evergreen tree reached 5-13 m (up to 30 m) in height, with an umbrella-shaped crown, open and irregular, and a DBH of 6-20 cm (up to 70 cm). The flowers are actinomorphic and appear in axillary inflorescences. The male inflorescences measure up to 3 cm in length and are pubescent, with sessile male flowers or with very short pedicels, 5 mm in diameter. The female flowers are 3 mm in length, with pedicels of 1-2 mm and a marked construction just below the calyx. The fruits are fleshy drupes, ellipsoid or spherical, 1.5-3 mm in diameter, green at first and brilliant red to orangish when ripe, bare, with persistent sepals, and a pit containing a single seed. The seeds are black and small, with the weight of an endocarp between 1.38 (±0.13) and 3.83 (±0.22) mg, and can survive in the seed bank for at least a year. The endocarp is 1.5-2 mm long by 1.2-1.4 mm wide, pale grey or greyish white, without endosperm. The small seeds are orthodox and remain viable at low temperatures.

Figure 68. Fruits of *T. micranthum.* Photo: FESI-UNAM.

Figure 69. *T. micranthum* seeds. Credits: FESI-UNAM.

Habitat: This species has no particular requirements as to type of soil. It grows in poor, eroded, or fallow soils, and in loamy or rocky soil. It is found in ravines, near streams, in pastures, in open places, clearings, stands of trees along highways, and the edges of forests and agricultural lands. It grows in different types of climates, from warm and subhumid to semi-warm and temperate, with rain in the summer, summers influenced by monsoons, or evenly distributed rainfall.

Distribution: Found in Morelos, Estado de México, and Hidalgo. Along the Gulf it grows from Tamaulipas to the Yucatán peninsula, and along the Pacific from Sonora to Chiapas. It is also found from Belize to Panama, and in the Caribbean (Puerto Rico). It is associated with the secondary vegetation of the forests.

Cultivation: Wild, cultivated.

Phenology: In Veracruz, flowering is from March/April to August, and fructification from April to July, although it has also been reported as year-round.

Seed dispersal: The seeds are dispersed by migratory birds who feed on the fruit.

Uses: [Environmental] improvement of habitat for native and migratory birds, with potential in restoration; **[Fuel]** the wood is used to make charcoal; **[Fodder]** the leaves and branches are used as livestock fodder; **[Material]** the wood is used in rural construction to make chairs and mills, and the bark is used to make a type of amate paper and also cord; **[Medicinal]** the leaves and bark are used as a remedy for measles.

Management of seeds: Collecting seeds by hand is difficult, as there is only one seed per fruit, and the fruit is taken by birds as soon as it is ripe. If the seeds can be collected, they should be cleaned as soon as they have an orange colour. To remove excess pulp, they can be softened by soaking and washed with a sieve, although care must be taken because of their small size. Before planting, the seeds can be placed in water for 24 hours to stimulate germination, or they can be kept at 2 °C. for 3-4 months.

Germination: As with other pioneer species, the seeds require intense light in order to germinate. Fresh seeds germinate in approximately 10-20 days, although they may take as long as 50 days, depending on their physiological dormancy.

Tolerance of desiccation: The seeds are orthodox.

Vegetative propagation: Shoots, sprouts, woody parts treated with rooting products.

Growth and transplanting: Once they germinate, the seedlings grow approximately 5-15 cm in a month, depending on the substrate, the amount of sunlight, and the maturity of the seed. The species grows rapidly, reaching up to 7 m in a year, although it is a short-lived tree that lives no longer than 30 years.

Appendices

Appendix 1: Other Native Tree Species Ranked in Participatory Workshops

Common name	Scientific Name	Uses
Sangregado	*Croton draco* Schltdl. & Cham.	animal fodder, environmental uses, fuel, materials, medicines
Encino roble	*Quercus xalapensis* Bonpl.	environmental uses, fuel, materials
Palo gusano	*Lippia myriocephala* Schltdl. & Cham.	environmental uses, fuel, materials
Encino roble	*Quercus germana* Schltdl. & Cham.	materials
Guaje	*Leucaena leucocephala* (Lam.) de Wit	animal fodder, environmental uses, fuel, human food, food for invertebrates, materials, medicines, poisons, social uses
Higuera	*Ficus cotinifolia* Kunth	animal fodder, environmental uses, human food, materials, medicines, poisons
Jobo	*Spondias mombin* L.	animal fodder, environmental uses, human food, food for invertebrates, materials, medicines, poisons, social uses
Huele de noche	*Cestrum nocturnum* L.	environmental uses, human food, food for invertebrates, materials, medicines, poisons
Haya	*Platanus mexicana* Torr.	materials
Aguacatillo	*Ocotea psychotrioides* Kunth	n/a
Bienvenido, cacao de monta	*Tapirira mexicana* Marchand	fuel, human food, materials
Cucharo	*Dendropanax arboreus* (L.) Decne. & Planch.	animal fodder, human food, materials, medicines
Cedro rojo	*Cedrela odorata* L.	environmental uses, human food, materials, medicines

Common name	Scientific Name	Uses
Palo de corcho negro	*Cordia alliodora* (Ruiz & Pav.) Oken	animal fodder, environmental uses, fuel, food for invertebrates, materials, medicines, social uses
Capulin	*Prunus serotina* Ehrh.	animal fodder, environmental uses, fuel, human food, materials, medicines, poisons y social uses
Mala mujer	*Cnidoscolus multilobus* (Pax) I.M. Johnst.	animal fodder, medicines
Flor de cera	*Palicourea padifolia* (Willd. ex Schult.) C.M.Taylor & Lorence	n/a
Cocuite	*Gliricidia sepium* (Jacq.) Kunth	animal fodder, environmental uses, fuel, human food, food for invertebrates, materials, medicines, poisons
Coralillo	*Cojoba arborea* (L.) Britton & Rose	environmental uses, fuel, materials
Nacaxtle	*Enterolobium cyclocarpum* (Jacq.) Griseb.	animal fodder, environmental uses, fuel, human food, food for invertebrates, materials, medicines, poisons
Habin	*Lonchocarpus guatemalensis* Benth.	human food, materials, poisons
Higuera	*Ficus obtusifolia* Kunth	medicines
Amate	*Ficus pertusa* L.f.	environmental uses, human food, materials, medicines
Ramoncillo	*Trophis racemosa* (L.) Urb.	animal fodder, human food, materials, medicines
Anón	*Annona squamosa* L.	animal fodder, environmental uses, fuel, human food, materials, medicines, poisons y social uses
Algodoncillo	*Wimmeria concolour* Schltdl. & Cham.	fuel. materials
Hule	*Ficus yoponensis* Desv.	animal fodder, environmental uses, materials, medicines
Palo de hacha	*Chrysophyllum mexicanum* Brandegee	n/a

Common name	Scientific Name	Uses
Palo blanco	*Meliosma alba* (Schltdl.) Walp.	n/a
Limoncillo	*Symplocos coccinea* Bonpl.	n/a
Estrellita	*Trophis mexicana* (Liebm.) Bureau	human food, materials, poisons
Hediondilla	*Cestrum dumetorum* SchltdL	environmental uses, medicines, social uses
Quiebracha	*Cupania dentata* Moc. & Sessé ex D.C.	animal fodder, fuel, materials, medicines
Carne de caballo, malhombrillo	*Alchornea latifolia* Sw.	environmental uses, materials

Appendix 2: Integration of Gender Equality and Social Inclusion in Climate Change Adaptation Projects in the Coffee Sector.

Teresa Durand

How Does Climate Change Affect Women?

As a result of gender norms, women are often more affected by climate change than men. For example, women face more institutional barriers to access funding for technological and ecological innovation.

Women are also in large part the ones in charge of collecting and processing food, carrying water, and obtaining fuel for heating homes. These tasks have become increasingly complex with climate change: for example, it is necessary to travel greater distances to find water or firewood.

There are different factors that prevent women, and other vulnerable groups, from fully carrying out their role in the struggle against climate change. Among these factors are limited employment opportunities and rights to land and other goods; the lack of access to financial services, training, and technology; and limited ability to make decisions in the home and community.

What Is the Social Impact of Climate Change on Coffee Production?

In Mexico, primary agricultural activities are the economically productive activities of rural men; rural women usually focus on domestic tasks and caretaking. But women also carry out productive labour in backyards and small plots, work as day labourers or in small business, or have responsibilities in the community or in social organisations. The workday of rural women is a combination of domestic, agricultural, wage, and organisational tasks.

In Latin America, the cultivation of coffee is one of the major sources of livelihood; it employs millions of families in rural areas. Climate change threatens this source of livelihood, and the income of coffee producers and their families, by affecting the production cycles of their plantations.

Finally, the income of migrant farm workers, paid by the volume or weight of the coffee beans collected, is particularly important in areas potentially affected by climate change, where there are few opportunities for diversification.

Adaptation to Climate Change with Social Impact on Coffee Plantations

When it promotes diversification and lessens the risks of monoculture, shade-grown coffee production contributes to the conservation of ecosystems and improves the livelihood of the producers. This sector is thus a key actor in the response to climate change, although it also becomes vulnerable to its effects. Measures to prepare coffee-producing communities against the potential negative impact of climate change include diversification of income, both within and outside the plantation; improving access to financial services for women; training coffee producers to use adaptation strategies; improving producers' access to weather forecasting; and motivating men and women to work together to address the challenges.

Adaptation to climate change is defined as adjustment in natural or human systems in response to present or anticipated climate threats and their effects, in order to mitigate damage and take advantage of beneficial opportunities. Gender dynamics inform the differing abilities of men and women to adapt to these changes. An understanding of such factors as gender, age, ethnicity, and disability in different contexts is key to successful adaptation.

Gender Equality and Social Inclusion in the Project

Activities for adaptation on coffee plantations should, for example, take into account whether they will require additional time and effort on the part of women, recognizing their "triple shift" of domestic/family, productive, and community labour. Adaptation should strengthen both men's and women's control of the livelihood of their household, improve women's working conditions and economic autonomy, and avoid negative effects on other agricultural activities carried out by women and vulnerable groups in the community.

UK PACT, in accordance with current British legislation, requires projects selected for funding to improve gender equality and social inclusion (GESI) in beneficiaries. It is thus necessary to include women and other vulnerable groups in initiatives to reduce GHG emissions.

To comply with this legal requirement, the project developed an Action Plan for Gender Equality and Social Inclusion that proposed a three-fold strategy:

- Technical activities focused on conservation of seeds for native cloud forest tree species that combine scientific research with the traditional knowledge of the selected communities.
- Interaction with beneficiaries to expand the knowledge of small farmers regarding species selection, contributing to forest conservation and improvements in local livelihoods.
- Educational materials for the general public regarding a replicable method of carbon sequestration and conservation of the biodiversity of native trees. This is presented as a strategy of adaptation to climate change with a perspective of gender equality and social inclusion for shade-grown coffee plantations.

Figure 70. Conversation with female coffee producers, Monte Blanco, Teocelo.

Mexican Conservation Law and Regulations Related to the Use of Seeds and Coffee Plantations

Daniel Jarvio

This section is a brief introduction to Mexican laws and regulations related to coffee cultivation in Veracruz, Mexico.

Various reforms to the **Act for the Promotion, Sustainable Development, Production, Distribution, and Commercialization of Veracruz Coffee** were published in the *Gaceta Legislativa del Congreso del Estado de Veracruz LXV Legislatura.* Año III. Número 155 (19 October 2021).

Article 3 (section XIII) provides a definition of shade-grown coffee plantation: "Agricultural land that uses a system of land management for the cultivation of coffee under a canopy of other plant species, typically trees."

Article 30 recognizes the importance of shade-grown coffee plantations in Veracruz as providers of environmental services and as habitats for the conservation of biodiversity, recognizing under Veracruz law the importance of considering the coffee plantations to be key natural spaces for conservation, in the form of productive ecological reserves.

The Sustainable Rural Development Act, published in the *Diario Oficial de la Federación* (7 December 2021), includes the following:

- **Art. 5**, Section IV, "Promoting Conservation of Biodiversity and Improvement of the Quality of Natural Resources Through Sustainable Use."
- **Art. 5**, Section V, "Evaluating the Economic, Environmental, Social, and Cultural Functions of Different Types of Mexican Agriculture."
- **Art. 7**, "To promote sustainable rural development, the federal government will promote capitalization of the sector through basic and productive infrastructure projects to meet the six objectives defined in this article."
- **Arts. 178 and 179**, "On Food Sovereignty and Safety," in which coffee is considered a basic strategic product.

Mexican Norm NMX-F-597-SCFI-2016. GREEN COFFEE - SPECIFICATIONS, PREPARATIONS, AND SENSORY ANALYSIS (SUPERSEDES NMX-F-551-SCFI-2008)

This Mexican Norm establishes the definitions, descriptions, and specifications commonly used to evaluate the quality of whole green coffee, as well as the types of preparations used for its sensory analysis. The norm applies to green coffee beans produced or commercialised throughout the country, independent of the method of their production or seed extraction and independent of the commercial market for which they are produced.

For the correct application of this norm, the following current norms, or those that supersede them, should also be considered:

- NMX-F-107-SCFI-2008, "Green Coffee in Sacks - Sampling." *Diario Oficial de la Federación*, 1 July 2008.
- NMX-F-129-SCFI-2008, "Green Coffee - Preparation of Samples for Sensory Analysis." *Diario Oficial de la Federación*, 1 July 2008.
- NMX-F-158-SCFI-2008. "Green Coffee - Olfactory and Visual Inspection - Determination of Defects and Foreign Matter." *Diario Oficial de la Federación*, 1 July 2008.
- NMX-F-162-SCFI-2008. "Green Coffee - Reference Table of Defects." *Diario Oficial de la Federación*, 1 July 2008.
- NMX-F-176-SCFI-2008. "Green Coffee - Determination of Loss of Mass at 105 °C. - Testing Method." *Diario Oficial de la Federación*, 2 September 2008.
- NMX-F-191-SCFI-2013. "Green and Raw Coffee - Size Analysis - Manual and Automated Sieves." *Diario Oficial de la Federación*, 25 February 2014.
- NMX-F-192-SCFI-2014. "Green Coffee - Determination of Moisture Content - Basic Reference Method." *Diario Oficial de la Federación*, 21 January 2015.

NOM-149-SCFI-2001. Coffee producers who are interested in obtaining a certification of origin for their coffee must adhere to this norm,

whose major criterion is the altitude at which the coffee is grown.

NOM-037-FITO-1995. Establishes specifications for the production and processing of organic agricultural products. Published in the Diario Oficial de la Federación, 23 April 1997.

NOM082-SGA-FITO/SSA-2017. Establishes the technical guidelines and procedures for the authorization of maximum limits of chemical pesticides for agricultural use, their registration, and their use.

NMX-F-013-SCFI-2000. Establishes specifications and testing methods for pure roasted coffee, whole bean or ground, including decaffeinated coffee. Published in the Diario Oficial de la Federación, 28 August 2000.

NMX-F-083-SCFI-1996. "Food - Moisture Determination in Food Products." Published in the Diario Oficial de la Federación, 14 July 1986.

NMX-B-231-1990. "Sieves for the Classification of Granular Materials." Published in the Diario Oficial de la Federación, 9 January 1991.

NMX-F-551-SCFI-1996. "Green Coffee - Specifications and Testing Methods." Published in the Diario Oficial de la Federación, 11 April 1997.

NMX-Z-012/1,2,3-1987. "Sampling for Attribute Inspection." Published in the Diario Oficial de la Federación, 28 October 1987.

There are at least two Mexican norms focused on the management and control of the coffee berry borer beetle (Hypothenemus hampei), one published in 1995 and the other in 2001. These are:

1. NOM-002-FITO-1995, which establishes the mandatory quarantine and eradication of centres of infestation.
2. NOM-002-FITO-2000, which establishes all of the measures previously mentioned, to maintain infestations under the economic threshold (< 3%).

Glossary

Agroforestry systems. Agroforestry is a fundamental part of the comprehensive process of conservation and soil improvement. It is a strategy whose objective is to establish and reinforce sustainability in agriculture through the promotion of such practices as productive diversity and training in the management of stratified systems; the improvement and maintenance of all types of agriculture; and an increase in organic matter in the soil, the fixation of atmospheric nitrogen, the recycling of nutrients, the modification of the microclimate in the field, and the optimization of productivity through sustainable production. An agroforestry system is a specific example of a local practice characterised by its surrounding environment, plant species, their arrangements (acting and interacting as components), and the products and materials it generates and uses.

Barochory. The dispersion of fruits and seeds by gravity.

Carbon cycle. Term used to describe the flow of carbon in various forms (e.g., carbon dioxide) through the atmosphere, oceans, terrestrial biosphere, and lithosphere.

Climate change. Important statistical variation in the average state or variability of the climate during a prolonged period (normally decades or more). It may arise from internal natural processes or from external forces, or from persistent anthropogenic changes in the composition of the atmosphere or land use. It should be noted that the United Nations Framework Convention on Climate Change (UNFCCC), Article 1, defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC distinguishes between climate change attributed to human activities that alter atmospheric composition and climate variability attributed to natural causes.

Climatic resilience. Resilience is the ability of a system to absorb perturbations or the rapidity with which it can recover from climatic disturbances. Social resilience is the ability of communities to maintain their social structure in the face of external shocks.

Global warming. Increase in the temperature of the planet as a consequence of human actions, in particular, the emission of greenhouse gases.

Greenhouse effect. Greenhouse gases absorb infrared radiation emitted by the Earth's surface, by the atmosphere itself because of such gases, and by clouds. Atmospheric radiation is emitted in every direction, including toward the Earth's surface. These phenomena are referred to as the "natural greenhouse effect." Atmospheric radiation is linked in large part to the temperature at the level at which it is emitted. In the troposphere, the temperature generally falls with increasing altitude. Infrared radiation emitted into space originates at an altitude with an average temperature of -19 ˚C., in equilibrium with the net entering solar radiation, while the Earth's surface has a much higher average temperature of approximately +14 ˚C. An increase in the concentration of greenhouse gases produces an increase in the infrared opacity of the atmosphere, and thus an effective radiation in space from a higher altitude at a lower temperature. This causes a radiating force, an imbalance that can only be offset with an increase in the temperature of the tropospheric surface system. This is called the "enhanced greenhouse effect."

Greenhouse gases. Gases in the atmosphere, of natural or anthropogenic origin, that absorb and emit radiation at specific wavelengths of the infrared radiation spectrum emitted by the Earth's surface, the atmosphere, and clouds. This phenomenon causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the main greenhouse gases in Earth's atmosphere. There are also a series of greenhouse gases produced entirely by human activity, such as halocarbons and other substances that contain chlorine and bromine, that are addressed in the Montreal Protocol. The Kyoto Protocol, in addition to CO_2, N_2O, and CH_4, addresses greenhouse gases such as sulphur hexafluoride (SF6), hydrofluorocarbons (HFC), and perfluorocarbons (PFC).

Heliophile. Describes plants or other organisms that require direct sunlight for their development.

Myrmecophile. Describes plants or other organisms that live in association with ants.

Orthodox (seed). Seeds that can be dried to a low moisture content, around 5% by weight, and be stored at low temperatures or below 0 °C. for long periods.

Photosynthesis. The process by which plants absorb carbon dioxide (CO_2) from the air (or bicarbonate from water) to produce carbohydrates, emitting oxygen (O_2) in the process. There are various paths of photosynthesis with differing responses to the atmospheric concentrations of CO_2.

Recalcitrant (seed). Seeds that cannot survive below a relatively high moisture content (often defined as 20-50% by weight), and that do not tolerate long-term storage.

Seed house. A structure that allows for greater control of temperature, humidity, and light. It can be constructed with available materials and covered with greenhouse-type plastic or shade netting.

Trichome. Trichomes or plant hairs are appendages of the epidermis of plants. The functions they perform are varied: water absorption, temperature regulation, dispersion of seeds and fruits, protection against abrasive agents and perception of stimuli. Glandular trichomes also eliminate sticky compounds that trap insects or toxic substances that irritate, kill or modify their behaviour.

Zoochory. Distribution of seeds or spores by animals.

References

Acosta-Hernández, C. C., & Ortiz-Muñoz, E. Biología y silvicultura del cedro-nogal (*Juglans pyriformis*) para su conservación en México.

Betemariyam, M., Negash, M., & Worku, A. (2020). Comparative analysis of carbon stocks in home garden and adjacent coffee based agroforestry systems in Ethiopia. Small-Scale Forestry, 19, 319-334. https://doi.org/10.1007/s11842-020-09439-4

Black, M., & Pritchard, H. W. (2002). Desiccation and survival in plants drying without dying. Cabi.

Bonjovani, M. R., & Barbedo, C. J. (2014). Induction of tolerance to desiccation and to subzero temperatures in embryos of recalcitrant seeds of *inga*. Journal of Seed Science, 36, 419-426.

Castañeda-Vildózola, A., Del Angel-Coronel, O. A., Cruz-Castillo, J. G., & Váldez-Carrasco, J. (2009) *Persea schiedeana* (Lauraceae), nuevo Hospedero de Heilipus lauri Boheman (Coleoptera: Curculionidae) en Veracruz, México. Neotropical Entomology, 38(6), 871-872. https://doi.org/10.1590/S1519-566X2009000600024

Castellanos-Castro, C., & Bonfil, C. (2013). Propagation of three *Bursera* species from cuttings. Botanical Sciences, 91(2), 217-224.

Centro Agronómico Tropical de Investigación y Enseñanza [CATIE]. (2015). Informe técnico final del proyecto Sensibilidad y adaptación del café al cambio climático en Centroamérica: CafAdapt. Fondo Regional de Tecnología Agropecuaria (FONTAGRO), CATIE-Costa Rica, CIAT- Colombia, UNA-Nicaragua, ICAFE-Costa Rica. https://www.fontagro.org/wp-content/uploads/2010/01/1027-_-INFOTEC-FINAL.pdf

Chaves-Salinas, S. L., & Hurtado-Imbachí, L. M. (2019). Fichas de especies nativas Jardín Botánico de Popayán. http://repositorio.unicauca.edu.co:8080/bitstream/handle/123456789/1592/FICHAS%20DE%20ESPECIES%20NATIVAS%20JBP%20%282%29. pdf?sequence=2&isAllowed=y

Cordero, J., & Boshier, D. (2004). Árboles de Centroamérica: un Manual Para Extensionistas. Editorial CATIE. https://repositorio.catie.ac.cr/handle/11554/9730

Comisión Económica para América Latina y el Caribe [CEPAL] & Consejo Agropecuario Centroamericano del Sistema de la Integración Centroamericano [CAC/SICA]. (2014). Impactos potenciales del cambio climático sobre el café en Centroamérica (LC/MEX/L.1169). CEPAL-ONU. https://repositorio.cepal.org/bitstream/handle/11362/37456/1/S1421045_es.pdf

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad [CONABIO]. http://www.conabio.gob.mx/conocimiento/info_especies/arboles/

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. 2023. EncicloVida. CONABIO. México, consultado en octubre de 2023. https://enciclovida.mx/

Conabio, *Bursera simaruba* (L.) Sarg. (1890), Garden & Forest 3: 260. 1890

Conabio, *Byrsonima crassifolia* (L.) Kunth. (1822), Nova Genera et Species Plantarum 5: 149. 1822

Conabio, *Cecropia obtusifolia* Bertol. (1840), Novi Commentarii Academiae Scientiarum Instituti Bononiensis 4: 439. 1840.

Conafor, *Bursera simaruba* (L.) Sarg., SIRE-Paquetes tecnológicos. http://www.conafor.gob.mx:8080/documentos/docs/13/894Bursera%20simaruba.pdf

Cortés Gabaudan, F. (2009). Dicciomed: diccionario médico-biológico, histórico y etimológico. Revista de Medicina, Lenguaje y Traducción, 10(29), 88-92.

Cruz-Castillo, J. G., Ángel-Coronel, O. A. D., Cruz-Medina, J. D. L., & Joaquín-Martínez, M. C. (2007). Características morfológicas y bioquímicas del chinene (*Persea schiedeana* Nees.) Revista Chapingo Serie Horticultura, 13(2), 141-147. https://www.redalyc.org/pdf/609/60913280005.pdf

Cruz Márquez, U., López Binnqüist, C., & Negreros Castillo, P. (2011). Una especie multiusos del trópico mexicano *Trema micrantha* (L.) Blume. Ciencias, 101(101). https://www.revistas.unam.mx/index.php/cns/article/view/26579

Cunill, J., Ramírez, D., Reyes-Trejo, B., Zuleta-Prada, H., Villa-Garcia, M., Salcido, G., & Escobar, I. (2016). Capacidad antioxidante de las hojas de Jonote (*Heliocarpus appendiculatus* Turcz) dentro de su función como forraje alternativo en un sistema agroforestal. En F. Rérez, E. Figueroa, L. Godínez, J. Quiroz & R. García (Eds.), Química, Biología y Agronomía (pp. 1-6). ECORFAN. https:// www.ecorfan.org/handbooks/Handbook_Quimica_Biologia_y_Agronomia_T1V1/Particiones/1.pdf

Cunill-Flores, J. M., & Guerra-Ramírez, D. (2014). Presencia, Ecología y Gestión del Jonote (*Heliocarpus appendiculatus* Turcz) dentro de Sistemas Agroforestales en Ecatlán, Municipio de Jonotla, Puebla, México. Tropical and Subtropical Agroecosystems, 17: Summaries XLI AMPA-VII SASYP, Mérida, Yucatán, México.

Economic Botany Data Standard, Board of Trustees of the Royal Botanic Gardens, Kew.

Espinoza-Domínguez, W., Krishnamurthy, L., Vázquez-Alarcón, A., & Torres-Rivera, A. (2012). Almacén de carbono en sistemas agroforestales con café. Revista Chapingo serie ciencias forestales y del ambiente, 18(1), 5 7-70. https://doi.org/10.5154/r.rchscfa.2011.04.030

Estrada, A., Coates-Estrada, R., & Vazquez-Yanes, C. (1984). Observations on fruiting and dispersers of *Cecropia obtusifolia* at Los Tuxtlas, Mexico. Biotropica, 16(4), 315-318.

Farfán, F. F. (2014). Agroforestería y Sistemas Agroforestales con Café. FNC-Cenicafé. https://www.cenicafe.org/es/publications/Agroforester%C3%ADa_y_sistemas_agroforestales_con_caf%C3%A9.pdf

Fehling-Fraser, T. C., & Ceccon, E. (2015). Macropropagation of *Erythrina americana* in a greenhouse: a potential tool for

seasonally dry tropical forest restoration. Revista Chapingo serie ciencias forestales y del ambiente, 21(1), 5-16.
Fischersworring, B., Schmidt, G., Linne K., Pringle, P., & Baker, P. (2016). La adaptación al cambio climático en la producción de café. Una guía paso a paso para apoyar a los productores de café en la adaptación al cambio climático. Iniciativa café y clima. https://toolbox.coffeeandclimate.org/wp-content/uploads/cc-step-by-step-guide-for-climate-change-adaptation-in-coffee-production_SPANISH.pd

Forero, E., & Romero, C. (Eds.). (2005). Estudios en leguminosas colombianas. Academia Colombiana de Ciencias exactas, físicas y naturales https://www.accefyn.com/PubliAcad/Leguminosas/LEGUMINOSAS%201.pdf

Francis, J. K. (2000). *Bursera simaruba* (L.) Sarg. Almácigo, gumbo limbo. Bioecologıa de árboles nativos y exóticos de Puerto Rico y las Indias Occidentales. General Technical Report IITF-115. USDA Forest Service International Institute of Tropical Forestry, Rıo Piedras, PR, 91-95.

Gallegos-García, A. J., Lobato-García, C. E., González-Cortazar, M., Herrera-Ruiz, M., Zamilpa, A., Álvarez-Fitz, P., ... & Gómez-Rivera, A. (2022). Preliminary Phytochemical Profile and Bioactivity of *Inga jinicuil* Schltdl & Cham. ex G. Don. Plants, 11(6), 794

García, J. M. P., & Islas, C. G. R. (Eds.). (2018). Recursos arbóreos y arbustivos tropicales para una ganadería bovina sustentable. Universidad de Colima.

García-Mateos, R., Soto-Hernández, M., & Vibrans, H. (2001). *Erythrina americana* Miller ("Colorín"; Fabaceae), a versatile resource from Mexico: a review. Economic Botany, 55, 391-400. https://doi.org/10.1007/BF0286656

Gil, P. D. J. P., Vásquez, G. E., Cruz, C. Y. L., Nápoles, J. R., & Arce-Cervantes, O. (2023). Daño en semillas de *Erythrina americana* Mill., (Leguminosae: Faboideae: Erythrininae) por el brúquido Specularius impressithorax (Pic, 1932) (Coleoptera: Bruchidae) y su efecto en la germinación. Acta zoológica mexicana, 39, 3.

Gobierno del estado de Veracruz de Ignacio de la Llave. (2005). Programa Veracruzano de las mujeres 2005-2010. http://www.veracruz.gob.mx/wp-content/uploads/sites/2/2012/01/tf07-pe-pvd-mujeres.pdf

Gold, K., & Hay, F. (2008). Identifying desiccation-sensitive seeds. Technical information sheet, 10.

Gómez, R., Fermán, R. E., Hernández, L., & Sermeño, J. M. (2008). Guía ilustrada de insectos asociados al árbol de nance (*Byrsonima crassifolia* L.) en los Municipios de La Palma, Departamento de Chalatenango y Quezaltepeque, Departamento de La Libertad, El Salvador, CA.

González-Espinosa, M., Meave, J., Marcial, N., Toledo-Aceves, T., Lorea-Hernández, F., & Ibarra-Manríquez, G. (2012). Los bosques de niebla de México: Conservación y restauración de su componente arbóreo. Ecosistemas, 21 (1-2), 36-54. https://www.revistae- cosistemas.net/index.php/ecosistemas/article/view/26

Guadarrama, H. A. R., Trejo, J. F. G., Cruz, R. G., & Pérez, A. A. F. (2019). Efecto del método de escarificación sobre el porcentaje de germinación en semillas (*Erythrina americana* Miller). Perspectivas de la Ciencia y la Tecnología, 2(3), 12-21.

Gutiérrez Uribe, A. M. (2003). Propagación del burío (*Heliocarpus appendiculatus* Turcz.) por semillas, estacas y acodos.
Henao-Londoño, A. I. (2022). Identificación de especies arbóreas para la remoción de contaminantes y la captura de carbono en el Valle de Aburrá. [Trabajo de grado para optar al título de Ingenieras Ambientales]. Universidad EIA Ingeniería ambiental Envigado.

Hermida Rosales, C. H. (23 de octubre de 2018). Café de Veracruz, el de mayor calidad en el país. Universo, sistema de noticias de la UV. https://www.uv.mx/prensa/%20reportaje/cafe-de-veracruz-el-de-mayor-calidad-en-el-pais/#:~:text=Caf%C3%A9%20en%20Veracruz&text=Aroma%20de%20la%20biodiversida-%20d%2C%20de,etnias%20n%C3-%A1huatl%2C%20totonaca%20y%20popoluca

Hernández-López, A., Cruz-Hernández, M., Guerra-Ramírez, D., Cunill, J. M., Guerra-Ramírez, P., Cabrera, F. R., ... & Avila-Alejandre, A. X. (2019). Estudio de la actividad antioxidante, antimicrobiana y toxicidad de tres extractos de *Heliocarpus appendiculatus* Turcz (malvaceae). Acta Agrícola y Pecuaria, 5(1).

Hernández-Rodríguez, Z. G., Castro-Moreno, M., González-Esquinca, A. R., & de-la-Cruz-Chacón, I. (2021). Fenología de *Bursera simaruba* y *Bursera tomentosa* en un bosque tropical seco de Chiapas, México. Madera y bosques, 27(3).

Hernández Vásquez, E., Campos Ángeles, G. V., Enríquez del Valle, J. R., Rodríguez-Ortiz, G., & Velasco Velasco, V. A. (2012). Captura de carbono por *Inga jinicuil* Schltdl: En un sistema agroforestal de café bajo sombra. Revista mexicana de ciencias forestales, 3(9), 11-21.

Jaimes Albíter, C., García de los Santos, G., Carballo Carballo, A., Calderón Zavala, G., Jaimes Albíter, F., & Cuevas Sánchez, J. A. (2014). Tolerancia a la desecación en semillas de nanche (*Byrsonima crassifolia* L.) Kunth. Revista mexicana de ciencias agrícolas, 5(5), 819-831.

Kopp, L. E. (1966). A taxonomic revision of the genus Persea in the Western Hemisphere (Perseae-Lauraceae). Mem. New York Bot. Gard., 14: 1-117.

Koptur, S. (1983). Flowering phenology and floral biology of Inga (Fabaceae: Mimosoideae). Systematic Botany, 354-368.

LaPierre, L. M. (2001). Vegetative propagation of *Cecropia obtusifolia* (Cecropiaceae). Revista de Biología Tropical, 49(3-4), 973-976

Lascurain, M., Avendaño, S., del Amo S., & Niembro, A. (2010). Guía de frutos silvestres comestibles en Veracruz. Fondo Sectorial para la Investigación, el Desarrollo y la Innovación Tecnológica Forestal, Conafor-Conacyt. http://www1.inecol.edu.mx/inecol/ documentos/frutos_silvestres_comestibles.pdf

Maldonado Peralta, M. D. L. Á., Garcia De Los Santos, G., García Nava, J. R., & Rojas García, A. R. (2017). Propagación vegetativa de nanche *Malpighia mexicana* y *Byrsonima crassifolia*. Revista mexicana de ciencias agrícolas, 8(3), 611-619.

Mahecha-Vega, G. E., Ovalle-Escobar, A., Camelo-Salamanca, D., Rozo-Fernández, A., & Barrero-Barrero, D. (2012). Vegetación del territorio CAR: 450 especies de sus llanuras y montañas (2da. ed.). Corporación Autónoma Regional de Cundinamarca-CAR.

Manson, R. H., Mehltreter, K., Gallina, S., & Hernández, V. (Eds). (2008). Agroecosistemas cafetaleros de Veracruz: biodiversidad, manejo y conservación. INE-INECOL. https://inecol.repositorioinstitucional.mx/jspui/bitstream/1005/162/1/1245_2008-10121.pdf

Martínez-Gauna, C. (2021). Estimación del contenido de carbono en la selva mediana perennifolia en Tízimin, Yucatán, México. [Tesis de maestría en ciencias forestales]. Universidad autónoma de Nuevo León, Facultad de ciencias forestales.

Martínez Orea, Y., Castillo Argüero, S., & Guadarrama Chávez, P. (2009). La dispersión de frutos y semillas y la dinámica de comunidades. Ciencias, 96, 38-41. https://www.revistacienciasunam.com/pt/97-revistas/revista-ciencias-96/532-la-dispersion-de-frutos-y-semillas-y-la-dinamica-de-comunidades.html

Medina-Torres, R., Juárez-López, P., Salazar-García, S., & Valdivia-Bernal, R. (2013). Estudio de las principales plagas del nanche [*Byrsonima crassifolia* (L.) HBK] en Nayarit, México. Revista mexicana de ciencias agrícolas, 4(3), 423-433.

Nestel, D. (1995). Coffee in Mexico: international market, agricultural landscape and ecology. Ecological Economics, 15(2), 165-178. https://doi.org/10.1016/0921-8009(95)00041-0

Niembro Rocas, A., Vázquez Torres, M., & Sánchez Sánchez, O. (2010). Árboles de Veracruz: 100 especies para la reforestación estratégica. Comisión Organizadora del Estado de Veracruz de Ignacio de la Llave. https://www.sev.gob.mx/servicios/publicaciones/colec_veracruzsigloXXI/ArbolesVeracruz100especies.pdf

NYBG Steere herbarium. (3 de octubre 2023). *Persea longipes* (Schltdl.) Meisn. https://sweetgum.nybg.org/science/world-flora/monographs-details/?irn=26901

Ortiz Muñoz, E., Acosta Hernández, C. C., Linares Márquez, P., Morales Romero, Z., & Rebolledo Camacho, V. (2016). *Juglans pyriformis* Liebm. seed tree selection in natural populations of Coatepec and Coacoatzintla, Veracruz. Revista mexicana de ciencias forestales, 7(38), 43-58.

Orwa C, A Mutua, Kindt R, Jamnadass R, S Anthony. 2009 Agroforestree Database: a tree reference and selection guide version 4.0 http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp.

Palma-García, J. M., & González-Rebeles, C. (Comp.). (2018). Recursos arbóreos y arbustivos tropicales para una ganadería bovina sustentable. Universidad de Colima. http://ww.ucol.mx/content/publicacionesenlinea/adjuntos/Recursos-arboreos-y-arbustivos-tropicales_462.pdf

Paz Paredes, L. (2018). Mujeres del cafetal en la región central de Veracruz. Argumentos. Estudios Críticos De La Sociedad, (86), 229-252. https://argumentos.xoc.uam.mx/index.php/argumentos/article/view/12

Peeters, L. Y., Soto-Pinto, L., Perales, H., Montoya, G., & Ishiki, M. (2003). Coffee production, timber, and firewood in traditional and Inga-shaded plantations in Southern Mexico. Agriculture, ecosystems & environment, 95(2-3), 481-493.

Pennington, T. D. (1997). The genus Inga Botany. Royal Botanic Gardens, Kew. Pennington, T. D., & Fernandes E. C. M. (Eds.). (1998). The genus *Inga* Utilization. Royal Botanic Gardens, Kew.

Pennington, T. D., & Fernandes E. C. M. (Eds.). (1998). The genus *Inga* Utilization. Royal Botanic Gardens, Kew.
Peralta, M. D. L. Á., Nava, J. R. G., Santos, G. G. D. L., García, A. R. R., & Salado, N. T. (2017). Reguladores del crecimiento y sustratos en la propagación vegetativa de Nanche (*Malpighia mexicana* A. Juss. y *Byrsonima crassifolia* (L) HBK). Revista Brasileira de Fruticultura, 39, e-700.

Pereira, L. C., Mayrinck, R. C., Zambon, C. R., José, A.C., & Faria, J. M. (2020). Storage of short-lived seeds of *Inga vera* subsp. affinis in osmotic medium. Seed Science Research, 30(2), 156-160.

Pérez-Calix, E. (2009). Fascículo 160: Tiliaceae. En J. Rzedowski & G. Calderón de Rzedowski (Eds.), Flora del Bajío y de Regiones Adyacentes. Instituto de Ecología, A.C. Centro Regional del Bajío Pátzcuaro, Michoacán. http://inecolbajio.inecol.mx/floradelbajio/documentos/fasciculos/ordinarios/Tiliaceae%20160.pdf

Pozos, A. M. G., Cruz, E. C., & Cordova, C. A. M. (2013). Germinación de semillas de *Byrsonima crassifolia* (L.) Kunth. Revista Mexicana de Ciencias Forestales, 4(20), 82-89.

Pritchard, H. W., Haye, A. J., Wright, W. J., & Steadman, K. J. (1995). A comparative study of seed viability in Inga species: desiccation tolerance in relation to the physical characteristics and chemical composition of the embryo. Seed Science and Technology, 23(1), 85-100.

Real Academia Española. (s.f.). Calentamiento global. En Diccionario panhispánico del español jurídico. Recuperado el 16 de marzo de 2023, de https://dpej.rae.es/lema/calentamiento-Global

Red de herbarios del noroeste de México. (octubre 2023). *Beilschmiedia mexicana* (Mez) Kosterm. https://www.herbanwmex.net/portal/collections/list.php?usethes=1&taxa=127128

Renaud-Basso, O. (8 de marzo de 2021). Why gender has to be at the heart of the agenda for green. European bank for reconstruction and development. https://www.ebrd.com/news/2021/why-gender-has-to-be-at-the-heart-of-the-agenda-for-green.html

Rojas-Sandoval J. (2018), *Heliocarpus donnellsmithii* Rose, CABI Compendium, https://doi.org/10.1079/cabicompendium.26615.
Romero, C. (2005). Revisión de las especies colombianas de *Inga* sección Pseudinga. En E. Forero & C. Romero (Eds.), Estudios en Leguminosas colombianas (pp. 175-414). Editorial Guadalupe.

Ruiz-Montoyal, L., López-López, M. Z., Lorenzo, C., García-Bautista, M., & Ramírez-Marcial, N. (2021). Variación genética de cuatro especies de árboles tropicales de la Reserva de la Biosfera Selva El Ocote, Chiapas, México. Acta botánica mexicana, (128), e1847. https://doi.org/10.21829/abm128.2021.1847

Santiago-Vera, T. D. J., García-Millán, M. A., & Michael-Rosset, P. (2018). Enfoques de la resiliencia ante el cambio climático. Agricultura, sociedad y desarrollo, 15(4), 531-539. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1870-54722018000400531&lng=es&tlng=es

SEINet. (3 de octubre 2023). *Persea longipes* (*Laurus longipes*) Meisn. https://swbiodiversity.org/seinet/collections/list.php?usethes=1&taxa=132028

Singh, G., Sahare, H., & Deep, M. (2019). Recent Trends in Guava Propagation-A Review. Biosciences Biotechnology Research Asia, 16(1), 143-154.

Sriram, V. (2018). Achieving Gender Equality and Women's Empowerment in Smallholder Adaptation: Lessons from IFAD's Adaptation in Smallholder Agriculture Programme. CCAFS Info Note. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://cgspace.cgiar.org/bitstream/handle/10568/91537/InfoNote_GenderS- mallholderAdaptation.pdf

Soto-Pinto, L., & Aguirre-Dávila, C. M. (2015). Carbon stocks in Organic Coffee Systems in Chiapas, Mexico. Journal of Agricultural Science, 7(1): 117-128. https://doi.org/10.5539/jas.v7n1p117

Sousa, S. M. (1993). El género Inga (Leguminosae: Mimosoideae) del sur de México y Centroamérica, estudio previo para la flora Mesoamericana. Annals of the Missouri Botanical Garden, 80(1), 223-269. https://doi.org/10.2307/2399826

Téllez-Valdés, O., Mattana, E., Diazgranados, M., Kühn, N., Castillo Lorenzo, E., Lira, R., Montes-Leyva, L., Rodríguez, I., Flores-Ortiz, C., Way, M., Dávila, P., & Ulian, T. (2020). Native trees of Mexico: diversity, distribution, uses and conservation. PeerJ, 8, e9898. https://doi.org/10.7717/peerj.9898

Torres, L. J. (2003). Tratamientos para acelerar la germinacion del nance (*Byrsonima crassifolia* L.) en vivero (Doctoral dissertation, Zamorano: Escuela Agricola Panamericana, 2016).

Valera, V. & Carvaja, N. (2014). Valoración económica del secuestro de carbono en un sector del Parque Nacional Waraira Repano (Caracas, Venezuela). Anales de la Universidad Metropolitana, 14 (2): 241-264.

Van der Werff, H. & Lorea, F. (1997) Fascículo 56: Laureceae en Rzedowski, J. (Ed.), Flora del Bajío y de Regiones Adyacentes. Instituto de Ecología, Pátzcuaro, Michoacán. México.

Vargas Simón, G. (2018). *Inga jinicuil* Schild. Árbol Multiuso. DOI: 10.19136/book.13

Vázquez Torres, M., Campos Jiménez, J., & Juárez Fragoso, M. (2017). Árboles tropicales de Veracruz. Universidad Veracruzana. https://libros.uv.mx/index.php/UV/catalog/view/QC016/324/851-1

Van der Werff, H. & Lorea, F. (1997) Fascículo 56: Laureceae en Rzedowski, J. (Ed.), Flora del Bajío y de Regiones Adyacentes. Instituto de Ecología, Pátzcuaro, Michoacán. México.

Vázquez-Yanes, C., & Orozco-Segovia, A. (1982). Seed germination of a tropical rain forest pioneer tree (*Heliocarpus donnell-smithii*) in response to diurnal fluctuation of temperature. Physiologia plantarum, 56(3), 295-298.

Watson, R. T. (Ed.). (2003). Cambio climático 2001: Informe de síntesis. Grupo Intergubernamental de Expertos sobre el Cambio Climático, OMM-PNUMA. https://www.ipcc.ch/site/assets/uploads/2018/08/TAR_syrfull_es.pdf

Willan, R. (1991). Guía para la manipulación de semillas forestales con especial referencia a los trópicos. FAO. http://www.fao.org/docrep/006/ad232s/ad232s00.htm

Zaro, G. C., Caramori, P. H., Yada Junior, G. M., Sanquetta, C. R., Androcioli Filho, A., Nunes, A. L. P., Prete, C. E. C., & Voroney, P. (2020). Carbon sequestration in an agroforestry system of coffee with rubber trees compared to open-grown coffee in southern Brazil. Agroforestry Systems, 94, 799-809. https://doi.org/10.1016/S0065-2113(10)08005-3

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